The Pediatric Mechanical Ventilation in Canada (PeMViC) Study: A Delphi Survey of Pediatric Mechanical Ventilation Practices by Canadian Respiratory Therapists

By

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An oral defense of this thesis took place on April 7 2021 in front of the following examining committee:

Examining Committee:

Chair of Examining Committee	Manon Lemonde
Research Supervisor	Mika Nonoyama
Examining Committee Member	Carolyn McGregor
Examining Committee Member	Efrosini Papaconstantinou
Thesis Examiner	Brian Walsh, Liberty University

The above committee determined that the thesis is acceptable in form and content and that a satisfactory knowledge of the field covered by the thesis was demonstrated by the candidate during an oral examination. A signed copy of the Certificate of Approval is available from the School of Graduate and Postdoctoral Studies.

Abstract

The Pediatric Mechanical Ventilation in Canada (PeMViC) Study: A Delphi Survey of Pediatric Mechanical Ventilation Practices by Canadian Respiratory Therapists

Chairperson of the Supervisory Committee: Dr. Mika L. Nonoyama
Faculty of Health Sciences

The gap in knowledge for pediatric mechanical ventilation (MV) management makes practice standardization difficult. The European Society for Pediatric and Neonatal Intensive Care (ESPNIC) was the first to establish consensus recommendations on pediatric MV management. In Canada, respiratory therapists (RTs) have a large role in MV management, but do not exist in Europe. The purpose was to determine Canadian RTs' recommendations on common pediatric MV management.

An e-Delphi study included n=56 participants from 15 Canadian pediatric facilities. All statements achieved consensus and this guideline consists of 59 recommendations, organized into 10 subsections: *Non-invasive ventilation*; *tidal volumes and inspiratory pressures*; *respiratory rate and inspiratory time*; *PEEP and FiO_2*; *Advanced Mechanical Ventilation; Weaning*; *Physiologic Targets; Monitoring*; *General MV practice* and *Equipment adjuncts*.

These commonly practiced pediatric MV techniques by RTs may be used as a standard for future clinical practice and studies to understand their clinical impact in critically ill children.

Keywords: Pediatric mechanical ventilation; pediatric intensive care; respiratory therapists; respiratory therapy; consensus guideline

Author's Declaration

I hereby declare that this thesis consists of original work of which I have authored. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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The research work in this thesis that was performed in compliance with the regulations of Research Ethics Board/Animal Care Committee under **REB # 1000064842 (Hospital of Sick Children's)** and **File # 15636 (Ontario Tech University)**.

_____ Shirley Quach

Statement of Contributions

I, Shirley Quach, hereby certify that I am the sole author of this thesis and that no part of this thesis has been published or submitted for publication as of this date. I have used standard referencing practices to acknowledge ideas, research techniques, or other materials that belong to others. Furthermore, I hereby certify that I am the sole source of the creative works and/or inventive knowledge described in this thesis.

Part of the work described in Chapter 4 will be submitted for journal publication. I performed the majority of the data synthesis and summarized as described. I will assume the lead responsibility of writing the manuscript.

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List of Abbreviations

AAP	American Academy of Pediatrics
AE	Adverse events
ALI	Acute lung injury
APRV	Airway pressure release ventilation
ARDS	Acute respiratory distress syndrome
ARDSNet	Acute respiratory distress syndrome Network (National Heart, Lung and Blood Institute)
CF	Cystic Fibrosis
CI	Confidence interval
CIHI	Canadian Institute of Health and Information
cmH_2O	Centimeter of water
CO_2	Carbon dioxide
CPAP	Continuous positive airway pressure
CPS	Canadian Pediatric Society
CSRT	Canadian Society of Respiratory therapists
CV	Coefficient of variation
ECMO	Extracorporeal Membrane oxygenation
ECLS	Extracorporeal Life Support
ESPNIC	European Society of Pediatric and Neonatal Intensive Care
FiO_2	Fractional inspired oxygen
He	Helium
HFJV	High frequency jet ventilation
HFNC	High flow nasal cannula
HFOV	High frequency oscillatory ventilation
IBW	Ideal body weight
ICU	Intensive care unit
IMCU	Intermediate care unit
iNO	inhaled Nitric oxide
IQR	Interquartile range

KWT	Kruskal Wallis test
LOS	Length of stay
LPMV	Lung protective mechanical ventilation
mmHg	Millimeters of mercury
MV	Mechanical ventilation
mWCAS	modified Wood clinical Asthma score
NAVA	Neurally Adjusted Ventilatory Assist
NGT	Nominal Group technique
NICU	Neonatal intensive care unit
NIV	Non-invasive ventilation
NIV-NAVA	Non-invasive neurally adjusted ventilatory assistance
OR	Odd ratio
$PaCO_2$	Partial pressure of carbon dioxide
PALICC	Pediatric Acute Lung Injury Consensus Conference
PALS	Pediatric advanced Life Support
PaO_2	Partial pressure of oxygen
PARDS	Pediatric acute respiratory distress syndrome
PAV	Proportional Assist ventilation
PC	Pressure control
PEEP	Positive End expiratory pressure
PICU	Pediatric intensive care unit
PIP	Peak inspiratory pressure
Pplat	Peak plateau pressure
PRVC	Pressure regulated volume control
PS	Pressure support
RCT	Randomized controlled trial
REDCap	Research Electronic Data Capture
RT	Registered respiratory therapist
SBT	Spontaneous breathing trial
SD	Standard deviation
SIMV	Synchronized Intermittent mandatory ventilation

SpO_2	oxygen saturation
SvO_2	Central venous/ mixed venous oxygen saturation
VAP	Ventilator acquired pneumonia
VC	Volume Control
VILI	Ventilator induced lung injury
VS	Volume support
Vt	Tidal volume
WSRT	Wilcoxon Signed rank test (Mann-Whitney U test)

Chapter 1 – Introduction

1.0 Introduction to Thesis

1.1 Overview of Pediatric Mechanical Ventilation

Mechanical ventilation (MV) is a life-sustaining treatment, used to assist critically ill patients when they are in respiratory failure and unable to breathe on their own (1-3). Respiratory failure is a common cause for pediatric intensive care until (PICU) admission and is associated with increased mortality in the pediatric population (2, 4, 5). Children with difficulty or failure to sustain adequate spontaneous breathing require MV (1, 4). MV may be provided non-invasively (e.g. mask, nasal prongs) and invasively (e.g. endotracheal tube) (2, 4, 6) and can further be classified by the mode and settings delivered by different devices for different ranges of diseases (4, 6-8). MV management is quite sophisticated and dynamic; appropriate knowledge and skills are required to safely, efficiently and continuously treat patients using MV (9, 10).

Inconsistent use of MV may lead to negative consequences including ventilator associated pneumonia, ventilator induced lung injury, sedation complications, longer hospital stay and increased mortality (1, 3, 11, 12). Therefore, it is crucial that MV therapy is managed effectively using standardized approaches across patients, to improve safety and efficiency (2, 3). Standardization of practices is difficult because of the many components of pediatric MV management. In addition, there is limited evidence to determine the best pediatric MV practices as children vary in size, maturity and underlying conditions (6, 7, 13, 14). Though limited, a few systematic reviews, meta-analyses and clinical trials have suggested that standardized pediatric MV practices may improve clinical outcomes (1, 9, 15).

1.2 Statement of problem

Currently, there is an evidence gap for pediatric MV management, making standardized practices difficult (6, 16). Often common clinical practices for pediatric MV management are adopted from clinical experience and evidence from neonates and adults (2, 4, 17). The European Society for Pediatric and Neonatal Intensive Care (ESPNIC)(6) is one of the first groups to establish consensus recommendations on many aspects of pediatric MV management. However, there are minimal studies to support the use of protocolized MV management in critically ill children and their associated outcomes. There are a few studies that report clinical outcomes on the different subtopics of MV, in different diseases (1, 7, 15, 18-22). Although protocols and guidelines are available, they vary across different centers and not integrated within the practice

culture (11, 23, 24). Potential barriers to successful implementation may include: not considering the social and cultural work environment, the intensivists' level of acceptability to the protocol, and lack of large multicenter data to support the practice (11, 21, 23-25). This inconsistency of MV practices make it difficult to determine which method is best, and which are associated with adverse events. Therefore, minimizing practice variability may improve patients' safety, treatment efficiency and clinical outcomes (9, 15, 18, 25).

In Canada, RTs are considered one of the experts in MV management, whereas in Europe, they do not exist. The ESPNIC recommendations are from the perspectives of European physicians only. It would be of significance for Canadian RTs to compare their perspectives with ESPNIC's to determine specific approaches to expedite the knowledge and standardization in pediatric MV practices in Canada.

1.2 Purpose

The purpose of this study was to determine Canadian RTs recommendations on common pediatric MV management, based on the European (ESPNIC) (6) consensus guidelines. It is anticipated this information will guide future research to facilitate the standardization of MV management practices.

1.3 Research Question

What are Canadian RTs consensus recommendations on pediatric MV practice and management in critical care?

1.4 Research Hypothesis

It was hypothesized that by the end of Round 2 (26, 27), Canadian RTs would reach consensus (≥75% agreement) on pediatric MV recommendations.

1.5 Impact and Significance

This study highlights Canadian RTs' perspectives on pediatric MV management, based on the consensus recommendations from Europe. These common practices can be used to inform standardized protocols, used in future studies to measure their efficacy and clinical impacts in pediatric critical care environments.

1.6 Methodology

Not all questions can be answered by conventional quantitative research methods, and many times, limited conflicting data make it difficult to understand and guide practices (28, 29). Expert consensus group methods such as the Delphi technique is considered an appropriate and accepted approach to compile available information to address clinical problems and management in health sciences (28-30). There are several different versions of the Delphi techniques, with the Classical and Modified Delphi techniques as the most popular (27, 31-34). Any form of the Delphi study delivered in an electronic format is called an electronic Delphi (e-Delphi) (27, 35).

The Delphi technique is a well-recognized method used to identify solutions and priorities in medical and nursing research since the 1970s (27, 34). It is used as a tool to identify, understand and establish guidelines and priorities in speciality practices (e.g. mental health, palliative care, critical care), predict disease patterns, direct nursing education, and standardize practices and policies (27, 34, 36). It is based on the principle that combined intelligence is superior and reliable, compared to anecdotal experiences (26, 37, 38). The structured system for participant feedback specifically minimizes the effect of noise and bias by maintaining anonymity amongst participants (26, 39). In contrast, other consensus gathering methods, such as focus groups or committees, are prone to bias and influence from dominating figures at meetings (40). Using a Delphi technique is time efficient, cost-effective and convenient when participants are geographically dispersed (27, 34, 38, 41, 42).

The Delphi technique utilizes a series of surveys, referred to as Rounds, to gather controlled feedback (opinions and feedback) from a group of participants, identified as experts in the field (43). This technique enables discussions, and guides future approaches in areas with unknown or not well supported evidence (30, 40, 44); it combines existing information and experiences to address the lack of knowledge in a particular area (26, 27, 35, 42). The number of Round iterations vary across studies, but it is suggested that further Rounds are terminated once consensus is achieved or after a predetermined number of Rounds is met (26, 27, 39).

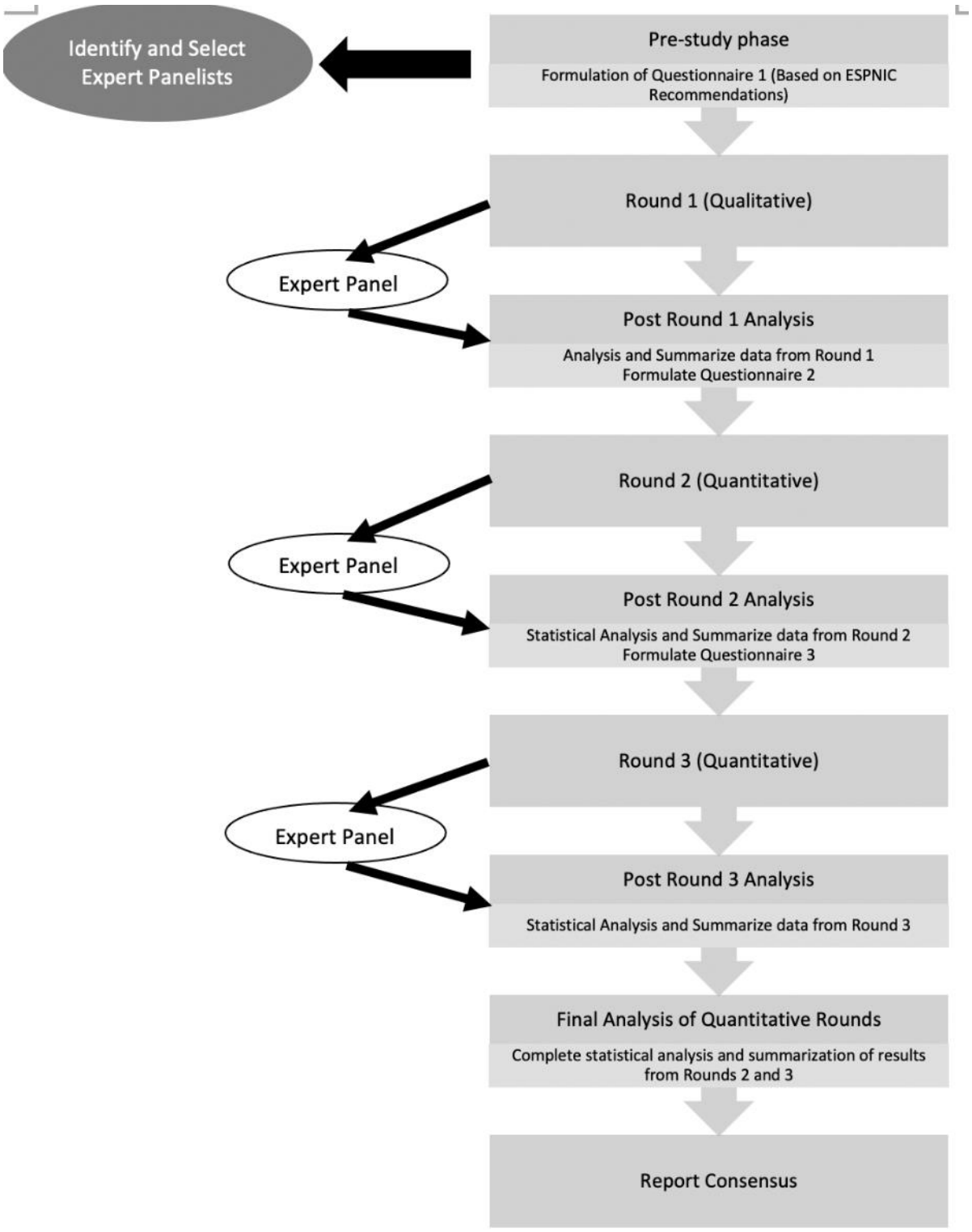
A 3 Round Modified e-Delphi technique was used in this study (Figure 1). The ideas and topics for the Modified Delphi were derived from the literature (27) and existing ESPNIC consensus guideline. Round 1 used a qualitative approach, where participants were asked to provide open-text feedback on survey topics, in order to form the contents for the subsequent

Rounds (26, 35). Subsequent Rounds were quantitative in nature; participants were asked to rate their level of agreement or disagreement using a 5-point Likert scale (26, 27, 35). At the end of Round 2 and Round 3, descriptive statistics, measures of central tendencies and consensus for each item were reported. Items in Round 2 that did not receive consensus (≥75% agreement) were revised and included for Round 3 (33, 35, 39). Statements that achieved consensus in Round 2 were removed from Round 3 to minimize the length of the survey (27, 45). The study was terminated after completion of Round 3 as consensus was achieved across all survey items. An overview of the study was presented in a video presentation and the finalized recommendations and their consensus distributions were summarized in a report for participants to review for additional comments or remarks.

1.7 Outline of Thesis

This thesis provides an overview of the existing pediatric MV management literature, and the rationale and importance for undertaking the Modified e-Delphi study to establish Canadian pediatric MV management guidelines from the RT perspective. Chapter 2 highlights the existing knowledge gap in pediatric MV management, the known effects of protocolized MV interventions, clinicians' engagement in providing protocolized MV and an overview of the role of RTs in MV practices. Chapter 3 elaborates on the Modified e-Delphi methodology, and Chapter 4 (4.2 Methods) describes its appropriateness to fulfill the purposes of this study. Additionally, Chapter 4 presents the details of this research project, including an in-depth discussion of the results and the implications of the Canadian RT-consensus MV management guideline. A finalized manuscript version of Chapter 4 will be revised and submitted to the Respiratory Care Journal and/or the Canadian Journal of Respiratory Therapists. Chapter 5, the final chapter provides an overview summary of this thesis. Chapters 6 to 8 provide the finalized guideline, supplementary data and study documents.

Figure 1: Delphi study process.



Process derived from Hsu and Sandford, 2007 (26); Keeney, Hasson and McKenna, 2011 (27); and Shariff, 2015 (38).

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Chapter 2 – Literature Review

2.1 Introduction and Search strategy

Defining the Key terms for literature search:

Mechanical ventilation (MV) is an intensive life supportive treatment for patients who are critically ill and unable to sustain spontaneous breathing required for life (1-4). MV can be provided non-invasively or invasively, through different devices, modes, and settings (2, 3, 5). Invasive MV modes (delivered through an endotracheal tube) include, but are not limited to, high frequency oscillatory/ jet ventilation (HFOV/ HFJV), pressure control (PC)/ support (PS), volume control (VC), pressure regulated volume control (PRVC), synchronized intermittent mandatory ventilation (SIMV), proportional assist ventilation (PAV), airway pressure release ventilation (APRV), or neurally adjusted ventilatory assist (NAVA). Non-invasive MV (delivered through nasal or facial interfaces) includes interventions such as high-flow nasal cannula oxygen therapy (HFNC), bi-level positive pressure ventilation (PPV), continuous positive airway pressure (CPAP) or non-invasive NAVA. The term "MV management" includes management of all of these different components.

The *pediatric population* is a group of children from infancy (greater than 28 days after birth) to 18 years of age (6, 7). Though the age limit of the pediatric population varies across studies, many studies use 18 years old as the higher limit (2, 8). However, this upper limit is arbitrary and may extend past 18, up to 21 years or older if a child requires special health needs from a pediatrician (as defined by the Canadian Pediatric Society and American Academy of Pediatrics) (7, 9).

Standardized practices are harmonized approaches to ensure consistent treatment and management in specific medical conditions (2). To enforce standardized practices, protocols and guidelines may be developed through expert consensus, and using current evidence to inform care in specific patient populations (10).

Search approach:

The following approach was used to search and obtain relevant articles pertaining to the key terms defined previously. The first search was run on October 27 2019 and updated on January 16 2021.

Key terms used:

Combinations of key terms were used to search for articles in a variety of databases. Search terms included controlled vocabulary e.g. Medical Subject Heading (MeSH) and keywords related to standardized pediatric mechanical ventilation. The following key terms were used:

- Pediatrics, paediatrics, children (in critical care, intensive care)
- Mechanical ventilation, mechanical respiration, artificial ventilation
- Standardized guidelines, protocols, recommendations, consensus

Databases:

Articles were searched and selected from the following databases:

- PubMed
- Embase Classic and Embase (1947 to 2021)
- Ovid MEDLINE
- Cochrane library (Reviews and Trials)
- Cumulative Index to Nursing and Allied Health Literature (CINAHL)

Eligibility Criteria:

Search results were screened manually via titles and abstracts. Articles were primary or secondary in nature, but only articles that satisfied the criteria outlined in below were included. Similarly, additional resources were screened for and selected through the references lists of eligible articles.

Types of participants

Only articles that identified children (of any age) receiving MV care in the PICU were included. Studies identifying neonates or newborns (birth to 28 days of age) as their primary population of interest were excluded as their MV management differs to older children (1). Children receiving MV care outside the PICU, such as for transport and long-term care were excluded.

Types of interventions

The intervention of interest was protocolized/ standardized MV management, including computer-driven protocols. Since MV includes many forms and settings delivered by different devices, studies that investigated any protocolized MV technique (e.g. mode, settings, strategies) were included (2, 3, 5, 8). Medical treatments that were not a form of MV were excluded, such medications, nutrition, and physiotherapy.

Type of Comparisons

Protocolized MV management were compared to non-protocolized invasive or non-invasive MV management, which includes but were not limited to, physician-driven care or non-protocol directed MV management.

Types of outcome measures

Trials were included if they evaluated clinical outcomes of standardized pediatric MV therapies and management e.g. number of adverse events, duration of MV, length of PICU stay, length of hospital stay, quality indicators, mortality etc.

Study Designs

Eligible articles were retrospective or prospective in design, interventional or observational, including systematic reviews, meta-analyses, randomized controlled trials, interventional trials, cohorts, case report, control and cross-sectional studies. Reviews and documents from working groups or conferences, consensus guidelines/ recommendations, or protocols on any aspect of pediatric MV management were acceptable. Articles of the commentary, editorial and newsletter nature were not included.

Other requirements of eligibility

Articles were in English, from peer-reviewed journals and published within the last 20 years, 2000 until present day (to identify recent practices and research). The details of the inclusion and exclusion criteria for the articles included for this literature review are summarized in Supplementary Table 1A.

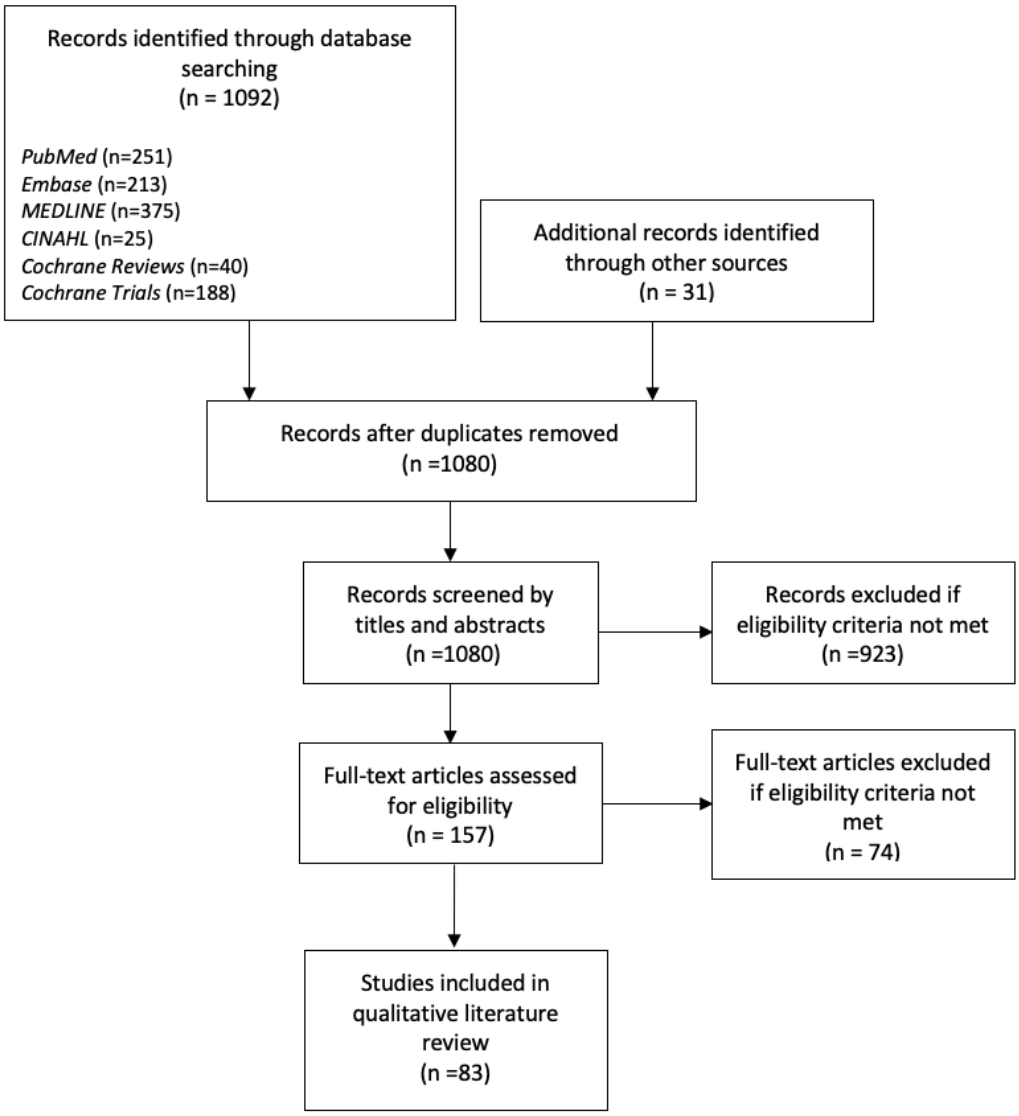
Additional resources

To further identify relevant articles or studies, reference lists of screened and accepted articles were reviewed for eligibility.

2.2 Search Results:

The search generated a total of 1092 articles from the databases and 31 articles from other sources. Included articles (n=83) consisted of five systematic reviews (two with a meta-analysis), five randomized controlled trial (RCTs), nine interventional (including pilot) studies, three observational studies, two retrospective analyses, 37 literature reviews (one with case studies), 13 survey studies, one thesis manuscript and eight consensus guidelines for different MV therapies of pediatric MV management in specific diseases. This information is displayed in Figure 2 and Supplementary table 1B.

Figure 2: Flow diagram of literature search



2.3 Literature review:

This section will provide background information and statistics for the topics of: 1) critically ill children, along with the challenges associated with their inclusion in research; 2) the indications and concepts of pediatric MV; 3) pediatric MV management and their associated health outcomes divided into subsections: (a) available modes and settings; (b) weaning; (c) management in specific disease groups, including pediatric acute respiratory distress syndrome (PARDS), bronchiolitis, and asthma; 4) clinician engagement and perceptions on the use of protocolized MV management; and 5) the role of respiratory therapists (RT) in MV management.

2.3.1 Topic 1 - Critically Ill Children

The Canadian Pediatric Society (CPS) reports that children are traditionally an underserved population in health research (6). Children are considered a vulnerable population, and usually have additional safeguards that limit their participation in clinical studies, compared to adults (11, 12). Participants of research must have the cognitive capacity to make informed decisions to provide consent or assent(6, 12, 13). This raises ethical concerns, as children may not have the competence to make informed decisions and be at risk for coercion because they are cognitively undeveloped (13, 14). Therefore, consent or assent from children are usually taken with the agreement of their legal guardian (11, 12). Complications occur when a child has the cognitive ability to make a decision, but provincial laws prevent this by defining the minimum age required for children to make legal decisions without parental consent (11).

Critically ill children are severely sick children who require PICU admission and complex care (12, 15). Although the overall PICU mortality has declined in recent decades, there are higher incidences of morbidity after PICU discharge (16-18). The Canadian Institute for Health Information (CIHI) reported that 171,786 children, under the age of 17, were hospitalized across Canada in 2018 (19). The CIHI estimates that around 12,000 children were readmitted for complications related to respiratory diseases, surgical interventions and newborn conditions. This data does not specify the number of children who require critical care attention; epidemiology of critically ill children is not well reported (18). A longitudinal study conducted by the Mayo Clinic Children's Hospital reported that children under the age of one have the highest incidence of PICU admission compared to other ages, and a mortality of 3% (18). In the five year period at the Mayo Clinic Children's Hospital, respiratory problems were the most common reason for PICU admission (2003-2007). Even after hospital discharge, children who were previously critically ill are at risk of developing complications. A cohort study by the National Institute of Child Health and Human Development Collaborative Pediatric Critical Care Research Network (CPCCRN) described the contributing factors to the morbidity and mortality of critically ill children (16). Out of the 292 children included in their cohort, 117 (40.1%) died, with 175 (59.9%) presenting with new morbidities by discharge. The pathophysiological contributors in the cohort were low cardiac output, cardiac arrests and inflammatory complications from sepsis, respiratory failure, acute respiratory distress syndrome or multiple organ dysfunction.

Research with critically ill children presents many challenges (11, 13, 14). The critical

care environment makes it difficult for researchers to approach family and guardians due to the extreme stress and lack of time (11, 17). These challenges are demonstrated in a RCT aimed at measuring the effect of protocol-directed weaning in infants (20). Only eight infants (age 2 to 8 weeks) were successfully enrolled and randomized into the protocol-directed (n=3) or physician directed (n=4, with n=1 died) interventional groups. Although RCT is a gold-standard research design, the authors suggested that the restrictive eligibility criteria, ethical constraints and parental refusal were several potential barriers to successful recruitment in their study. Parents of the critically ill infants could not be approached until 24 hours after PICU admission, and this waiting period was enforced by the facility's ethical committee to allow parents to become accustomed to the stressful PICU environment and to their child's illness. However, the waiting period led to the loss of several potential participants and limited the opportunity for the researchers to build a positive relationship with the parents. This may have led to a lack of trust the parents had for the researchers who were not their child's physician, but study consent obtained by the physician poses several ethical concerns. Therefore, poor patient enrollment and small sample size prevented the authors from reporting any study outcomes. They suggested future studies were needed to evaluate the best research approach to ensure successful recruitment to measure the effectiveness of protocolized weaning or any MV intervention.

Because of these challenges presented above, many of the treatment options for sick children are not evidence based (17). Many of the practices in place are based on the extrapolation of animal or adult data, which is inappropriate as children do not share the same physiological maturity as adults (17, 21). Furthermore, children vary greatly in size, maturity and underlying conditions across a large age range, making it difficult to recommend the best treatments for all critically ill children (6, 14). Therefore, it is necessary to continue to research in critically ill children to improve the quality of data and enhance treatments (17).

2.3.2 Topic 2- Pediatric MV

Respiratory failure is a common cause of PICU admission and mortality in the pediatric population (4, 5, 18). In comparison to adults, children have a higher risk of developing respiratory failure, as they are physiologically immature (3, 4, 22). Children presenting with breathing difficulties or impending failure require MV (1, 5), and about 30% (3)of children admitted into the PICU require it to manage respiratory distress and resolve pulmonary disorders

(3, 4, 22, 23).

MV can be described as a respiratory life-support therapy, used to provide patients with adequate gas exchange for the function of vital organs, and to alleviate respiratory distress for different respiratory etiologies (4, 22). MV is an umbrella term to describe a variety of respiratory support treatments, settings and modes that are provided across different devices and ventilator models (2, 5, 8, 24). Children may be provided non-invasive and/or invasive options to resolve their underlying respiratory issue during their PICU care (25) (see also Section 2.3.3c Topic 3c - MV in Specific Diseases).

MV use and management are sophisticated and dynamic; appropriate and standardized knowledge and skills are required to safely, efficiently and continuously treat patients without generating complications (26, 27). Over the last few decades, the optimal risk and benefits associated with using MV are better understood, but there continues to be minimal or conflicting data on their use and impact in the pediatric population (3-5, 22, 26). A widely accepted guideline detailing all the available modes and settings to treat and support critically ill children is not available (2, 5, 28). Therefore, uncertainties exist about the best MV practices for their management, and variabilities exist across centers due to adopting practices from adult data or clinicians' experiences (3-5, 29-31).

Inconsistencies in pediatric MV management can be explained by several factors. First, the vulnerable nature of this population; they are usually protected and excluded from studies due to the difficulty in obtaining consent (see 2.3.1 Topic 1 - Critically Ill Children) (17, 21). Children also vary greatly in size, maturity, anatomy, physiology and underlying conditions at a given age, limiting the applicability of study interventions (2, 7, 9, 14, 32). Secondly, there is a broad variety of devices, settings and mode options available for a wide spectrum of pediatric diseases (4). The choice of MV therapy to manage a child will also differ across critical care teams (3, 4, 8, 33, 34). Even when facilities have protocols and guidelines in place, they may not be integrated within the practice culture, resulting in variation in practice (29, 35, 36). Despite these limiting factors, more research is required to understand the optimal MV management techniques and their outcomes to standardize practices (2, 3, 25).

2.3.3 Topic 3- Pediatric MV management and Patient Outcomes

The different types of pediatric MV management techniques (across various disease groups) are mainly presented in narrative literature reviews, surveys and case studies (29, 32, 33, 37-46). These only offer a broad summary of different MV treatments, settings and modes for all children and do not provide clear practice recommendations (5, 23, 40, 47, 48). There are recommendation guidelines available, but they are limited in numbers and for specific diseases (24, 49-51). Guidelines for specific practices such as managing particular modes or settings (e.g. indications, initiation time, level of support, weaning time) are required across all critically ill children (29, 32, 40, 42, 52).

The following subtopics sections will describe studies for different components of pediatric MV management including different modes, settings and adjunct therapies (e.g. NIV, HFNC), weaning techniques and MV management in specific pediatric diseases.

2.3.3a Topic 3a- MV Modes and Settings

A systematic review and meta-analysis published in 2011 (421 critically ill children, five clinical trials) evaluated the impact of different MV mode on the length of stay, oxygenation, ventilation duration and mortality (8). Six specific ventilation modes were used across these studies, which were high frequency ventilation modes (HFOV, volume diffusive respirator) and four conventional ventilation modes (PC, PS, VS and bilevel positive airway pressure). Participants included in these studies ranged from 0 to 23 years of age, and were diagnosed with air leak syndrome, acute hypoxemic respiratory failure, inhalation injury and/or weaning failure. There were no significant differences between the high frequency ventilation and conventional ventilation modes on mortality (three studies, odds ratio [OR] 0.7, 95% confidence interval [CI] = 0.33 to 1.47). Conventional ventilation was found to have significantly lower length of ventilation compared to HFOV (four studies, weight mean difference -2.3 days, 95% CI= -3.63 to -1.04). HFOV was associated with improved oxygenation after 72 hours compared to other methods of ventilation, but heterogeneity between the three studies limit definitive conclusions. Limited evidence prevented a recommendation on the best MV mode in critically ill children immediately after the newborn period. They suggest future studies should investigate the best ventilation strategies for age specific ranges and disease pathologies, measuring the same outcomes.

In a pre and post intervention study by Smith et al (53), a NIV protocol for children

presenting with respiratory failure in the intermediate care unit (IMCU) was created to help with clinical decision making and optimize patient outcomes. It included 207 children with an average age 8.3 years (range 2.4 to 14.5), with the most common diagnosis of pneumonia. Data for the study was collected for 4.5 years following NIV guideline implementation, and was compared to the data 3.25 years before guideline introduction. There was a decrease in overall hospital stay (-49.52 days, p=0.03), and a decrease in intubation rates (3 vs. 0 patients, p=0.035) post-intervention. Although the study showed a NIV protocol improved patient outcomes, it may not be applicable in the PICU as it took place in an IMCU where traditionally MV is not initiated. The purpose of their guideline was meant to guide NIV use in the IMCU to reduce PICU resource and bed use. Nonetheless, Smith et al (53) demonstrated that the use of a NIV protocol was safe, and provided positive health outcomes with reduced resource use.

In a retrospective study, a total of 848 children (age range 4.1-4.8 years) presenting with respiratory failure in 2006 to 2009 were separated into three cohort groups: cohort 1- prior to HFNC availability, cohort 2- pre-HFNC guidelines and cohort 3- after HFNC guideline implantation (54). The cohort groups were compared to determine whether HFNC *plus* the use of a HFNC guideline made a difference to health outcomes. There was an 83% decrease in intubation rates in cohort 3 compared to cohort 1 (OR 0.17, 95% CI=0.06 to 0.5, p<0.001). There were no significant changes in the health outcomes between cohort 2 and cohort 1 (OR 0.98, 95% CI= 0.39 to 2.45, p=0.97). When comparing the intubation rate across different respiratory illnesses, there were decreases in cohort 3 compared to cohort 1 in patients with asthma (0.6% vs. 5%, p=0.03) and bronchiolitis (10% vs. 21%, p=0.05). In addition, there was a decrease in the ventilator-utilization ratio (proportion of ventilator days to total patient days) after HFNC guideline implementation, seen in the difference between cohort 1 (0.41) and cohort 3 (0.21, p<0.001). Although the results did not show changes in the length of stay or mortality, guideline implementation showed promising effects on intubation rates in certain disease groups.

There are a large number of narrative literature reviews, surveys and case studies on pediatric MV. A guideline from the Japanese Respiratory Society (49) detailed the indications and settings of NIV across various clinical conditions and diseases for adults and children; however, there were only a few sections dedicated to its use in children. Another guideline described prevention and treatment options for skin lesions caused by NIV interfaces, but did not focus on MV management (55). A narrative review (plus case report) on NIV provided an

overview of the indications (pathophysiology) for NIV, along with different modalities to consider for MV management (42). Other NIV narrative reviews have provided overviews of current evidence, and information on the contraindications, indications, interfaces, monitoring parameters and modalities available for children across various diseases (4, 23, 47, 48, 56-61). Several others present details about the goals, and mechanism of action of NIV therapy and the different interfaces (55, 58, 59, 61). Like NIV, there are various case studies and literature reviews describing different invasive MV modalities (4, 22, 23, 46). Several of these narrative reviews provide suggestions for MV techniques including monitoring equipment, weaning options, lung protective strategies, lung recruitment, or modalities such as PC, PS, NAVA, HFJV, HFOV, and APRV (4, 25, 44, 62, 63). Two topic-specific narrative reviews looked at MV protective lung strategies to minimize lung injury in children (62, 63). These reviews and case reports all provide valuable overviews, but verifying the impact of different MV therapies with larger clinical studies is needed (4, 25). Descriptions for all the articles discussed in this subtopic are found in the table below (Table 1).

Table 1: Articles and reviews discussed in Chapter 2, Subtopic 3a - MV modes

Authors	Study type (or article type)	Participant characteristics	Intervention	Results
NIV				
Duyndam et al, 2011 (8)	Systematic review	421 children across 5 trials (0-23 years old)	Comparisons between HFOV, PC, PS, VS, VDR, NIV	• no difference in the length of stay, mortality or survival rate associated with any particular MV mode • pool analysis for the mortality rate between HFOV vs. conventional MV (3 studies) OR 0.7 (95% CI=0.33-1.47) • Conventional MV vs. HFOV for length of stay (4 studies) for weight mean difference -2.3 days (95% CI=-3.63 to -1.04) • HFOV may have provided improvements in oxygenation, but heterogeneity in the studies made the conclusions inconclusive • there was limited evidence to suggest which MV mode was the best to minimize mortality, survival rates and length of stay
Smith et al, 2019 (53)	Pre/ post interventional study (2009-2016)	207 children (8.3 years, range 2.4 to 14.5)	Pre/post NIV protocol implementation	• a NIV protocol was introduced to guide clinical decisions and optimize patient outcomes in children presenting with respiratory failure in intermediate care unit • data from 3.25 years prior and 4.5 years following the NIV protocol implementation were collected • overall decrease in hospital stay (49.52 days, p=0.03), and intubation rates (3 vs. 0 patients, p=0.035) • this study suggested that a NIV protocol to guide clinical decisions may provide

				positive health outcomes and reduce resource use • one limitation was that the protocol was trialed in an intermediate care unit, where NIV is not traditionally used
Wing et al, 2012 (54)	Retrospective study (2006-2009)	848 children (4.1-4.8years)	Analysis of 3 cohort groups: 1) prior to HFNC availability; 2) pre-HFNC guideline; 3) after HFNC guideline implementation	• children presenting with respiratory failure were separated into 3 cohort groups to compare their effects on health outcomes • improved health outcomes in cohort 2 and 3 (when HFNC was available) • 83% decrease in intubation rates in cohort 3 compared to 1 OR 0.17 (95% CI=0.06 to 0.5), p<0.001 • no differences between cohort 1 and 2, OR 0.98 (95% CI=0.39 to 2.45), p=0.97 • decreased intubation rates in children with asthma (6% vs 5%, p=0.03) and bronchiolitis (10% vs. 21%, p=0.05) in cohort 3 compared to 1 • decreased in ventilator days/ total patients day in cohort 3 (0.21) vs. cohort 1 (0.41), p<0.001 • no significant changes in mortality or median PICU stay
Akashiba et al, 2017 (49)	Guideline	-	-	• 24 recommendations of NIV use in adults and children, supported by existing evidence • recommendations for children in acute respiratory failure and neuromuscular diseases
Raurell-Torredà et al, 2017 (55)	Guideline	-	-	• Recommendation guide on prevention and treatment of skin lesions for patients using NIV • not specifically written for children, but the principles outlined may be applied • overview of the pathophysiology involved in skin damage from NIV interfaces, preventative measures, interface selection and treatment
Haut, 2015 (42)	Case report and review	15-day old infant	-	• a case report of an infant (day 15 of life) that presented with nasal congestion, cough and apnea; the infant was treated with HFNC • described the pathophysiology involved in acute respiratory illnesses in children and infants, NIV, their initial settings and complication prevention • author elaborated on the potential treatments, which were NIV (i.e. CPAP, bilevel) and HFNC • evidence and review of the literature on the use of NIV and HFNC were discussed • literature review revealed these forms of NIV can be used in children with asthma, bronchiolitis, pneumonia, PARDS, respiratory failure, post-operatively and in neuromuscular diseases, with varying levels of evidence • emphasis on the interprofessional management required to successfully monitor any children on NIV therapies • recommendations on the initial settings could not be made

Vitaliti et al, 2013 (60)	Literature Review and experience report	-	-	• presented the views and efficacy on NIV use in children with respiratory failure due to different conditions • based on the reviewers' experience, NIV use depended on the physician, disease severity, risk of PARDS, oxygen requirements, comorbidities and NIV response • NIV may be provided in the early stages of respiratory failure to avoid intubation
Teague, 2006 (47)	Literature Review	-	-	• evaluated the use of NIV in children with respiratory failure, cystic fibrosis, sleep apnea, upper airway obstruction, and chronic respiratory distress • important factors to consider are the indications for NIV, monitoring parameters, interface selection, initiation settings, ventilator/ mode selection and humidification • for initial settings, bilevel pressures should be set to offload respiratory muscles yet optimize comfort (2-4 cmH_2O above PEEP) • NIV in children is a promising therapy, but lacks high quality clinical data to support its safety, effectiveness and limitations
Turner and Arnold, 2007 (48)	Literature Review	-	-	• assessed pediatric MV publications and adult studies that may be applied in children • NIV may be used for children with appropriate level of consciousness • lower tidal volumes (lung protective) were used in adults, but their protective effects were not confirmed in children • lung recruitment maneuvers were adjuncts to lung protective strategies, and may provide benefits in certain clinical situations • HFOV should be considered a rescue therapy for patients who continue to fail conventional MV • APRV is relatively new and more studies are required to understand their benefits • MV weaning protocols may reduce MV time (adult studies) compared to physician directed weaning but there were minimal randomized controlled trials to demonstrate their effects in children
Bourguignon da Silva, Foronda, and Troster, 2003 (56)	Literature Review	-	-	• provided the details of NIV objectives, indications, contraindications, advantages, interface selection, management and failure • described the available types of NIV modes (i.e. CPAP, bilevel, spontaneous assisted, controlled assisted, controlled mechanical), but did not indicate which is best • the authors provided suggestions for initial setting parameters, but they must be individually tailored
Deis et al, 2008 (59)	Literature Review	-	-	• summary of NIV including the description, mechanism of action, interface selection, goals of therapy, benefits over invasive MV, and an overview of the available modes • comparison between CPAP vs. bilevel use, their indications, and initial settings • NIV may reduce work of breathing, improve

				cardiac output, increase functional residual capacity, reverse hypoventilation and maintain airway patency
Fedor 2017 (57)	Literature Review	-	-	• review on the use of NIV in infants and children and different indications for NIV, including asthma, bronchiolitis, PARDS, cystic fibrosis, obstructive sleep apnea, neuromuscular disorders, cardiac diseases • other factors to consider when initiating NIV were interfaces, delivery devices and challenges with comfort and adherence • description of monitoring, NIV management and alternatives to ensure safe use
Hidalgo et al, 2015 (58)	Literature Review	-	-	• describe the use of NIV from RT perspective • indications (signs and symptoms) in children with respiratory failure • highlighted the key features to consider when selecting interfaces (e.g. nasal vs. mask, skin integrity, comfort) • signs and symptoms of NIV failure
Al-Mukhaini and Al-Rahbi, 2018 (61)	Literature Review	-	-	• discussed the applications and advantages between conventional NIV (i.e. CPAP, bilevel) compared to HFNC in children with acute respiratory failure • elaborative discussion on the mechanism of action, clinical indications, interface choices, monitoring and their benefits in conventional NIV (and HFNC therapy • NIV and HFNC may have similar effects on patients' work of breathing and are safe • HFNC may be reserved for children with milder forms of respiratory distress compared to conventional NIV. • greater use of NIV may reduce the number of PICU admissions
Schibler 2016 (64)	Literature Review	-	-	• overview of NIV and HFNC to provide respiratory support children with acute respiratory distress • with the introduction of HFNC therapy, there had been an increase in their use and as an alternative to CPAP • indications and management of NIV and HFNC were briefly summarized, along with failure criteria to warrant invasive MV
HFNC-focused Reviews and studies are summarized in Table 4: Articles and reviews discussed in Chapter 2, Topic 3b Bronchiolitis				
NIV and Invasive MV				
Cheifetz 2003 (23)	Literature Review	-	-	• overall summary of the different types of invasive and non-invasive MV modes, and specific settings to optimize MV management (i.e. low tidal volumes, inspiratory flow patterns, patient-ventilator interactions, weaning to extubation) • either invasive or non-invasive MV are indicated when children are unable to breathe on their own; the primary objective for either is to improve gas exchange, work of breathing and comfort • provided a comparison between NIV and invasive MV (indications and epidemiology)

				• discussed the available literature and potential of using protocolized MV weaning; adult data shows benefits but their effects are unknown in children • regardless of the settings, it is most important to monitor and optimize patient-ventilator interactions to minimize the likelihood of adverse events
Invasive MV				
Pacheco, Mendelson and Gaspers, 2018 (46)	Clinical cases and literature review	3 individual cases: 7 year old girl, 4 year old girl, 3 year old boy	-	• presented 3 different cases and described the MV management for each • the approaches for each clinical case differed in the diagnostic tests and MV modes • there were multiple factors to consider when initiating any form of MV and clinicians should follow an algorithm to determine the next steps when providing MV
Marraro et al, 2003 (25)	Literature Review	-	-	• described the available MV modes and supportive treatments in children • a combination of strategies should be used, including recruitment maneuvers, low-tidal volumes, and higher PEEP • modes such as HFOV, PRVC, PS, and VS are several potential modes to use • other adjunctive therapies/ solutions such as permissive hypercapnia, prone positioning, surfactant and nitric oxide may be important in certain pathologies • much of the data were from case studies and pilot studies
Williams and Cheifetz, 2019 (4)	Literature Review	-	-	• summarized the pathophysiology of PARDS, initial MV settings, review of the therapies and other rescue treatment options • discussed about target tidal volume, driving pressure and oxygen concentration • data for alternative support modes including NAVA or PAV were sparse and the authors were unable to comment on their use • reviewed adjunct therapies including prone positioning and ECMO; these may be considered, but there is limited data • there was an overall improvement in children's mortalities over the years; however, more studies are necessary
Jauncey-Cooke, East and Bogossian, 2015 (62)	Literature Review	-	-	• reviewed the evidence of the different lung recruit maneuvers for children • provided background information, indications and purposes of lung recruitment • heterogeneity of the studies prohibited pooled analyses • evidence did not suggest the best method to perform lung recruitment
Jauncey-Cooke et al, 2010 (63)	Literature Review	-	-	• overview of the pathophysiology of VALI and the lung protective strategies to minimize the risk • lung protective strategies included lower tidal volumes of 6-8ml/kg, PEEP of 8-12cmH_2O, lung recruitment maneuvers, prone positioning and permissive hypercapnia

				• alternative strategies such as HFOV, NIV, early MV weaning, and biological variable ventilation may reduce the risk of VALI • though there is minimal data available, clinicians should consider the use of lung protective strategies when ventilating children, to minimize the risk of VALI
Conti and Piastra, 2016 (5)	Literature Review	-	-	• assessed the data on MV practices in PARDS and the overall literature on the optimal management of NIV and invasive MV in children • discussed the PALICC recommendations, ARDSNet considerations, conventional MV, HFOV and nitric oxide use in PARDS • elaborated on the role of NIV in children, the indications, interface selection and other settings to consider to maximize comfort • descriptive analysis and overview of patient-ventilator synchrony in different modes (e.g., HFOV, NAVA, PC/ PS) • despite the improvement in treating respiratory failure in children, more studies are required to determine the best methods for pediatric MV management
Mallory and Cheifetz, 2020 (44)	Literature Review	-	-	• overview of APRV, its indications, perceived benefits and complications • available studies on APRV and its associated outcomes demonstrated variable results; thus more research is required
Smallwood and Davis, 2018 (22)	Literature Review	-	-	• summarized pediatric MV studies published June 2017 to December 2018 • contrasted the pathophysiologic similarities between adults and children with PARDS • described the different MV strategies including PEEP titration, target tidal volumes using ideal body weight, nitric oxide therapy, NAVA, weaning and MV for other populations (e.g. post-cardiac surgery) • discussed RT driven weaning protocols, and the lack of significant improvements in outcomes; but this may be explained by poor protocol adherence • knowledge gaps in the use of certain modes, adjunctive therapies and RT driven protocols still exist
Jouvet, Hernert and Wysocki, 2011(26)	Literature Review	-	-	• due to variable effects and poor compliance with written protocols, this review suggested the use of computerized protocols for MV management • overview of computer-based protocols, how they are designed and the available ones • closed-loop systems were available in the market with some preliminary data to suggest their benefits i.e. decreased MV time

Abbreviations: *APRV-airway pressure release ventilation; CI-confidence interval; CPAP-continuous positive airway pressure; ECMO-extracorporeal membrane oxygenation; HFJV-high frequency jet ventilation; HFNC-high flow nasal cannula; HFOV-high frequency oscillary ventilation; MV-mechanical ventilation; NAVA-neurally adjusted ventilatory assist; NIV-non invasive ventilation; OR-odds ratio; PALICC-Pediatric Acute Lung Injury Consensus Conference group; PARDS- pediatric acute respiratory distress syndrome; PAV-proportional assist ventilation; PC- pressure control; PEEP-positive end expiratory pressure; PICU-pediatric intensive care unit; PRVC-pressure regulated volume control; PS- pressure support; RT- respiratory therapist; VALI-ventilatory associated lung injury; VDR- volume diffuse respiration; VS- volume support*

2.3.3b Topic 3b- MV Weaning

A component of MV management is the process of weaning MV to liberate children from life support (65, 66). Weaning children off of MV as early as possible is essential as it has beneficial effects for their functionality and quality of life, but little evidence exists to suggest the best weaning method (66-71). A Cochrane systematic review published in 2013 (1) included three clinical trials with 321 children, and assessed the effects of protocolized compared to non-protocolized weaning. The authors defined protocolized weaning as the use of an algorithm to direct weaning while non-protocolized weaning was defined as usual care or clinician-led care. The largest trial (n=260 children) included in the systematic review found protocolized weaning (daily screening and spontaneous breathing test [SBT]) significantly reduced MV time by 32 hours (95% CI= 8 to 56 hours, p=0.01). Similarly, protocolized weaning significantly reduced the weaning time in the two smaller trials (n=61 children) by 106 hours (95% CI= 28 to 184 hours, p=0.007) and 21 hours (95% CI= 9 to 32 hours, 0<0.001). However, reduced weaning time in these two trials did not significantly decrease total MV time, PICU or hospital stay. The majority of the studies (2 of the 3) in that systematic review had small sample sizes and the weaning protocols differed across studies, thus the evidence can only cautiously suggest that protocolized weaning may reduce MV duration. Overall, the authors concluded that larger multi-center, interventional studies are necessary to understand the effects of protocolized weaning and determine whether they are associated with reduced MV time.

The systematic review performed by Rose et al (65) compared automated weaning systems with weaning protocols executed by clinicians (both attempt to standardize the weaning process across patients). Within that review, automated weaning was defined as computerized systems that were capable of weaning without the presence of clinicians. It included 21 studies totaling 1,676 participants, of which 48 were children from two studies. They found that automated weaning systems reduced ICU stay by 8% (0% to 15% reduction in geometric mean; -0.08 mean log days, 95% CI= -0.16 to 0.0, p=0.05) and MV duration by 10% (3% to 16% reduction in geometric mean; mean hours log hours -0.11, 95% CI= -0.18 to -0.03, p=0.005). Duration of hospital stay, incidence of adverse events, and mortality were not significantly different between the weaning groups. The results of that systematic review may have limited generalizability in the pediatric population, as a very small proportion of children were included in the overall analysis.

There are several RCT and interventional studies that compared the differences in outcome measures between protocol-directed versus traditional, non-protocolized weaning. Two RCTs showed that a protocolized weaning method, extubation readiness evaluations, and SBT, may have reduced MV duration and PICU length of stay, and increased extubation success (72, 73). In one RCT, 294 children (range 28 days to 15 years old) were randomized into the standard weaning practice (no protocol, n=139) or SBT group (n=155) (72). In their SBT group, children were evaluated daily for their readiness for extubation, and were trialed on PS (10cmH_2O) with positive expiratory end pressure (PEEP) (5cmH_2O) for two hours. The control group received physician-directed weaning on any of the following MV modes: PS, PC or SIMV. The SBT group had a significantly lower average MV duration of 3.5 days (95% CI= 3.0 to 4.0) compared to the control group of 4.7 days (95% CI= 4.1 to 5.3) (p=0.0127). In a 2019 RCT conducted in Brazil (73), the recruited children (average age of 8 months) received the same SBT parameters outlined in the RCT by Foronda et al (72). Their control group performed weaning using PC, SIMV with PS, or PS alone, directed by the physician. The results demonstrated that the SBT group (n=56) had shorter PICU length of stay and greater extubation success compared to the control group (n=54) (85 vs. 367 hours, $p<0.01$; 83% vs. 68%, p=0.02, respectively). There were no significant differences in the hospital length of stay, ventilator-associated pneumonia or mortality. Although both RCTs used the same SBT intervention, there were differences in their outcomes, indicating that larger interventional studies are required to verify whether the outlined SBT parameters are beneficial (72, 73).

In a RCT by Schultz et al (74), 223 children were randomized into either protocol-directed weaning (n=107; average ± standard deviation [SD] age, 5.1 ±5.71 years) or physician directed weaning groups (n=116; 4.19±5.4 years). The protocol-directed weaning group outlined the eligibility criteria the children must meet before weaning to SIMV with PS. There was a significant decrease in the average weaning time (5.9 vs. 25.2 hours, $p<0.001$) and extubation time (16.2 vs. 30.1 hours, $p<0.004$) in the protocol group compared to the control group. However, there were no significant differences in MV duration, reintubation rates, or adverse events such as pneumonia, new onset of tracheitis or subglottic stenosis.

In a RCT across 10 pediatric hospitals in North America from 1999 to 2001, 182 children under the age of 18 years old on invasive MV over 24 hours and had failed an extubation readiness test, were recruited to study the effect of two different types of MV weaning protocols

(10). The children were randomized into three groups: PS protocol (n=62), VS protocol (n=60) or no protocol (n=60). The primary outcome measures were the duration of MV and extubation success. Across the three groups, there was no significant difference in extubation failure (PS 15%, VS 24%, no protocol 17%, p=0.44) or median weaning duration (PS 1.6 days, VS 1.8 days, no protocol 2 days, p=0.75). The compliance to these protocols was 66% in both the PS and VS groups, and its poor adherence may have been the reason there were no significant differences in the outcomes.

Other smaller interventional studies suggested protocolized weaning may improve clinical outcomes (68, 70, 75). A quasi-experimental time series over two years compared MV duration, length of stay and quality indicators before and after a weaning guideline implementation in 220 patients aged 0 to 16 years old (n=107 pre-, n=113 post implementation) (70). There were no significant differences in the MV duration (median difference -15.8 hours, $p<0.067$), length of stay (-23.75 hours, $p<0.089$), or quality indicators (weaning failures 12% vs. 7.9%, p=0.371; reintubation 6% vs. 3.5%, p=0.743) after the weaning guideline was implemented. In two pilot studies, computer-driven protocols were evaluated for their effectiveness in weaning children off of MV (68, 75). The first pilot study compared 20 children (aged 1 to 17 years old) using a computerized PS mode (68), with a historic cohort of 20 children weaned by clinicians. There was no significant change in MV duration in the computerized weaning group (mean±SD; 5.1±4.2 days) compared to the clinician-directed group (6.7 ±11.5 days) (p=0.33). In the other pilot study (75), 30 children (aged 2 to 17 years) were randomized to receive a computer driven protocol (n=15) compared to weaning techniques directed by physicians (n=15). The computerized weaning group in that RCT had a significantly lower weaning time (time from weaning initiation to extubation) at 21 hours (range 3 to 142 hours), compared to the control group at 90 hours (range 4 to 552 hours) (p=0.007).

A recent guideline by the German Respiratory Society outlined the physiology, importance, and techniques to wean children and adult patients off MV (50). That guideline summarized the rationale, evidence, indications, MV modalities and techniques for maximizing weaning success. As weaning studies were heterogenous, direct comparisons between weaning techniques across centers were difficult. As a result, that guideline was informed by various health care professionals, including intensivists, pediatricians, anaesthesiologists, surgeons, cardiologists, neurologists, respirologists, intensive care/chronic care nurses, respiratory

therapists, physiotherapists, speech therapists and ventilator manufacturers. These consensus-based recommendations aimed to provide MV weaning approaches and strategies in acute medicine and chronic MV in adults and children.

In summary, the literature on protocolized MV weaning in critically ill children may be associated with positive outcomes, such as decreased MV time, weaning time, PICU stay, hospital stay, and improved extubation success (43, 66, 67, 70) (Table 2). However, the results may not be generalizable because studies were heterogeneous, including their patient population (ages, characteristics, underlying conditions), design and delivery of the interventions (some studies used computerized protocols (68, 75), while others used practitioner directed protocols) and the specified weaning settings (different studies used different modes) (10, 70, 72-74). Although the results from the presented studies are promising, conclusions cannot be drawn from the limited data as more high-quality studies in investigating the clinical outcomes of standardized pediatric MV weaning is necessary (1, 43, 65).

Table 2: Articles and reviews discussed in Chapter 2, Topic 3b- MV weaning

Authors	**Study type (or article type)**	**Participant characteristics**	**Intervention**	**Results**
Blackwood et al, 2013 (1)	Systematic review	321 children (3 studies)	Protocolized weaning compared to usual care (physician directed)	• largest trial included in the systematic review (n=260 children) showed reduced MV time by 32 hours (95% CI= 8 to 56 hours, p=0.01) • in the 2 small studies, there was decreased weaning time (n=61 children) by 106 hours (95% CI 28 to 184 hours, p=0.007) and 21 hours (95% CI 9 to 32 hours, 0<0.001) • there was heterogeneity across the trials where protocols differ, small sample sizes • more clinical trials were necessary to evaluate whether protocolized weaning was associated with reduced MV time
Rose et al, 2015 (65)	Systematic review	48 children (2 studies)	Automated weaning systems compared to weaning protocols on their effect on health outcomes	• compared the effects of automated weaning (computerized systems) and protocolized weaning • 21 studies included, 2 on children (48 children/ 1,676 patients) • automated weaning reduced ICU stay by 8% (95% CI= 0% to 15%; -0.08 mean log days, 95% CI=-0.16 to 0.0, p=0.05) and MV duration by 10% (95% CI= 3% to 16%; -0.11 mean hours, 95% CI= -0.18 to -0.03, p=0.005) • reduced weaning only in mixed medical ICU patients (42%, 95% CI= 10% to 63%) • hospital stay, incidence of adverse events, and mortality not significantly different between weaning groups • limited applicability of the data in children

				since the analyses included adult data
Foronda et al, 2011 (72)	RCT	294 children (age 28 days to 15 years old)	SBT compared to standard weaning practice groups	• 294 children in the SBT protocol group (n=155) or standard care (n=139) • SBT protocol included an assessment (readiness for extubation) and PS trial (10cmH_2O) with PEEP of 5 cmH_2O for two hours • significant decrease in the average MV duration of 3.5 days (95% CI= 3.0 to 4.0) in SBT protocol compared to the control group of 4.7 days (95% CI=4.1 to 5.3), p=0.0127 • SBT group had non-significant decrease in the risk of post-extubation NIV, reintubation, ventilator associated pneumonia and accidental extubation
Ferreira et al, 2019 (73)	RCT	110 children (median age 8 months)	SBT compared to standard weaning practice groups	• 110 children in the SBT group (n=56) or control group (n=54) • SBT protocol entailed PS trial (10cmH_2O) with PEEP of 5 cmH_2O, oxygen ≤ 0.5 for two hours • no-protocol group received MV weaning based on clinical judgement • significant decrease in PICU stay in the protocol vs non-protocol groups, 85 vs. 367 hours, p<0.01; and greater extubation success 83% vs. 68%, p=0.02 • no significant differences in the length of stay, ventilator-associated pneumonia or mortality
Randolph et al, 2002 (10)	RCT	182 children (under 18 years), 10 pediatric hospitals in North America	PS, VS compared to protocol groups	• 182 children in PS protocol (n=62), VS protocol (n=60) or no protocol (n=60) • no significant differences between the 3 groups in extubation failure (PS 15%, VS 24%, no protocol 17%, p=0.44) or median weaning duration (PS 1.6 days, VS 1.8 days, no protocol 2 days, p=0.75) • protocol compliance was 66% in both protocol groups
Schultz et al, 2001 (74)	RCT	233 children	Protocol directed weaning compared to physician directed weaning	• 233 children enrolled; n=107 in the protocol-directed weaning (average ± SD age 5.1 ±5.71 years) or n=116 in the physician directed weaning groups (4.19±5.4 years) • in the protocol group, patients met a list of eligibility criteria before receiving the weaning settings (SIMV with PS) • decreased average weaning time (5.9 vs. 25.2 hours, p<0.001) and extubation time (16.2 vs. 30.1 hours, p<0.004) in the protocol group • no differences in MV duration, reintubation rates or adverse events between groups
Rushford 2004 (20)	RCT	8 infants (age 2 to 8 weeks)	Protocol directed compared to physician directed weaning groups	• 8 infants, n=3 in protocol group and n=4 in physician directed group • No differences between the two groups • true effects are unknown due to the limited recruitment, strict eligibility criteria, ethical constraints and barriers to parental participation

Keogh, Courtney and Coyer, 2003 (70)	Pre/ post (quasi-experimental time series)	220 patients	Weaning protocol implementation	• pre-intervention n=107 and post intervention n=113 • no significant differences in the MV duration (median difference -15.8 hours, p<0.067), length of stay (-23.75 hours, p<0.089), or quality indicators (weaning failures 12% vs. 7.9%, p=0.371; reintubation 6% vs. 3.5%, p=0.743)
Jouvet et al, 2007 (68)	Pilot	40 children (1 to 17 years old)	Closed loop computer system protocol compared to physician driven	• n=20 in each interventional group • closed loop system (protocol) decreased PS in 16 children; n=14 were extubated with no adverse events • no significant change in mean MV duration in the closed loop system group (5.1±4.2 days) compared to the physician-directed group (6.7 ±11.5 days), p=0.33 • no difference between reintubation or NIV post-extubation
Jouvet et al, 2013 (75)	Pilot	30 children (age 2 to 17 years old)	Computer driven protocol (Smartcare/PS, Drager Medical) compared to usual care	• n=15 in the protocol group and n=15 in non-protocol group • significant decrease in MV weaning in the protocol group, 21 hours (range 3-142 hours) compared to non-protocol group, 90 hours (4-552 hours), p=0.007 • reintubation in 2/15 in the protocol group and 1/15 in the non-protocol group; NIV post-extubation was 2/15 in both groups • computer-driven protocols for children younger than 2 years may be beneficial in reducing MV weaning time
Schonhofer et al, 2020 (50)	Guidelines (German Respiratory Society)	-	-	• not specific to children • elaborated on the definitions, epidemiology and pathophysiology to weaning and weaning failure • reviewed the different weaning strategies including NIV, HFNC, PS, SIMV, NAVA, PAV, automated weaning and controlled ventilation
O'Brien et al, 2006 (67)	Literature Review and consensus report	-	-	• detailed the approaches to weaning children from MV in a post-acute setting • Described strategies to wean children in post-acute setting were different from PICU as most children in a post-acute setting have tracheostomies from failed weaning • the Weaning Severity Index can be used to assess the severity of ventilatory requirements and whether they are ready to be weaned • an algorithm may aid pediatric weaning in post-acute care (i.e. SBT, CPAP)
Newth, Hotz and Khemani, 2020 (66)	Literature Review	-	-	• overview of MV assessment, weaning techniques, extubation readiness tests and post-extubation management • two common predictive indexes for weaning described: rapid shallow breathing index (RSBI), Compliance, resistance, oxygenation, pressure (CROP) • weaning modes include SIMV or PS, but there was no universal mode of choice • the leak test, negative inspiratory force, and

				SBTs were common tests to assess for extubation readiness • ventilator liberation in children has improved but there is limited evidence on the best weaning process in children
Valenzuela, Araneda and Cruces, 2014 (43)	Literature Review	-	-	• summary of weaning techniques, protocols, indications of weaning failure and the use of NIV for weaning purposes • most common weaning mode was SIMV • SBT may be used to assess and test for weaning and extubation success • daily assessment of clinical and functional parameters with SBT may identify patients ready for MV weaning
Newth et al, 2009 (71)	Literature Review	-	-	• described weaning recommendations to achieve extubation success in adults and children including factors that impact weaning, predictive tests and modes • SBT, ERT and criteria for readiness for extubation were common assessment tools • protocolized weaning was safe and lead to earlier and faster weaning in adults • the best predictive test to indicate successful extubation was unknown • t-piece or PS trials for extubation assessment were effective in adults, though it is inconclusive for children

Abbreviations: *CPAP-continuous positive airway pressure; ERT- extubation readiness test; HFNC-high flow nasal cannula; MV-mechanical ventilation; NAVA-neurally adjusted ventilatory assist; NIV-non invasive ventilation; PAV-proportional assist ventilation; PC- pressure control; PEEP-positive end expiratory pressure; PICU-pediatric intensive care unit; PRVC-pressure regulated volume control; PS- pressure support; RCT- randomized controlled trial; SBT-spontaneous breathing test; SIMV-synchronic intermittent mandatory ventilation; VS- volume support*

2.3.3c Topic 3c - MV in Specific Diseases

Pediatric acute respiratory distress syndrome (PARDS)

PARDS is described as an acute onset (within seven days) of parenchymal lung disease seen on chest radiographs, and presenting with pulmonary edema (not explained by cardiac failure or fluid overload) (22, 76). PARDS' severity is classified by the oxygenation index (OI), a formula used to calculate the usage of inspired oxygen concentration in the body (4, 51, 76-78). Prior to guidelines by the Pediatric Acute Lung Injury Consensus Conference Group (PALICC) in 2015, PARDS was described using the adult diagnostic criteria (acute lung injury [ALI] with ARDS) (78). The definition and management of ARDS in adults was extrapolated to children, due to the lack of high-quality studies in children with ALI/ARDS (77, 79). For example, the National Heart, Lung, and Blood Institute's (NHLBI) ARDSNet protocol included a lung protective MV (LPMV) strategy that demonstrated decreases in mortality in adult studies (35, 80). Experts followed the same adult guidelines for children with ALI/ARDS, because pediatric-specific standards had not been developed (34, 76). This subsection will describe three stages of evidence on the MV management for PARDS. First, studies published prior to the development of PALICC guidelines. Second, a broad description of the PALICC guidelines will be provided. Finally, studies published after will be described.

An observational study from 2011 to 2012 that included 120 PICU patients (aged 17 days to 18 years) with PARDS, assessed whether a pediatric MV protocol, adapted from the LPMV strategies from the ARDSNet protocol, would reduce variability in MV management (35). Several types of MV modes were used, including PC (60%), VC (19%), PRVC (18%) and HFOV (3%). Despite its wide acceptance, changes in settings were rarely done in accordance with the protocol (followed 29% of the time), with decisions in MV management varying considerably. The findings suggest that a collaboratively created, well accepted protocol was required to successfully implement into the practice culture.

The LPMV strategies in the ARDSNet protocol includes lower tidal volumes and higher PEEP to minimize atelectrauma, and lung injury caused from opening and closing of the alveoli (81, 82). A retrospective analysis evaluated whether children were managed according to the ARDSNet recommendations and measured its effect on mortality (82). Data was collected from four time periods from 2000 to 2016 across multiple hospitals, on 1,134 children with PARDS (average age 46.6 months [IQR 13.2 -137.6]). It was observed that children receiving lower PEEP compared to protocol-directed (higher) PEEP, demonstrated higher overall mortality by

18.6% ($p<0.001$), even after adjusting for hypoxemia, inotrope use, comorbidities, severity of illness, ventilator settings, and nitric oxide (OR 2.05; 95% CI= 1.32-3.17). The authors suggested that LPMV may reduce mortality in this pediatric population. Similarly, in a separate study, a secondary analysis of four multi-center studies from 2000 to 2010 included 315 children with PARDS (median age 3.3 years, [IQR 0.4-10.8]) and reported poor adherence to maintaining low tidal volumes of ≤6-8ml/kg ideal body weight (81). The authors found that 58-60% of children on MV received tidal volumes ≤8ml/kg, indicating a large proportion of children were still receiving tidal volumes greater than recommended (>8ml/kg). However, the study did not assess or address the impact of poor protocol adherence and its influence on the measured health outcomes. Both analyses emphasized a need for clinical studies focussing on LPMV strategies in children with PARDS, and their associated outcomes (81, 82).

An adjunct to MV therapy is inhaled nitric oxide (iNO) therapy, a potent vasodilator to treat refractory pulmonary hypoxemia common in PARDS (25, 79). A quality improvement project evaluated whether implementing an iNO therapy protocol would minimize practice variability, iNO utilization and impact health outcomes (83). The project included a total of 63 children separated into two groups, n=30 (median age 2 years [IQR 0.79-12.5]) in the pre-guideline group, and n=33 (median age 4 years [IQR 0.96-14]) in the post-guideline implementation group. Significant changes between pre- and post-guideline occurred in the total median MV hours from 359 (IQR 283-846) hours to 304 (IQR 141-551) hours, $p=0.03$; mortality 15% to 7%, $p=0.02$; and iNO therapy duration of 62 (IQR 87-290) to 76 (IQR 48-124) hours, $p=0.0004$, with a median iNO cost savings of $4600 (USD). Unfortunately, there were no significant differences in the median PICU length of stay (pre 443 [IQR 324-895] vs. post 477 [IQR 181-761] hours, $p=0.08$) or hospital length of stay (pre 726 [IQR 447-1114] vs. post 592 [IQR 310-1203] hours, $p=0.25$). However, the data suggests that implementation of a protocol may improve health outcomes and iNO utilization in children with PARDS. Therefore, more clinical trials will help verify the beneficial effect of an iNO guideline by clarifying the role of iNO as an adjunctive therapy.

A 2008 PARDS case scenario survey distributed across American and European PICUs (12 countries) assessed and provided different MV management strategies (34). The authors found that even though many respondents endorsed the widely accepted ARDS guidelines in adults, and understood their associated benefits, these strategies were rarely translated into

clinical practice for critically ill children with PARDS. The data revealed that large tidal volumes (>10ml/kg) were used to ventilate over 25% of pediatric patients, possibly from the lack of strict MV protocols. In contrast, a 2012 questionnaire about MV strategies for children (one month to six years of age) was sent to 21 Nordic ICUs that treated children with PARDS (84). That survey revealed that 44% of the ICUs (three PICUs, five mixed ICUs) had written protocols, and the majority (n=18) had similar MV management (89% of units used PC setting) for children with PARDS. Though each survey demonstrated different practice patterns in different geographical locations, both authors concluded that an international MV guideline for PARDS would be beneficial to emphasize LPMV strategies to optimize compliance and limit variabilities (34, 84).

A few narrative literature reviews have focused on the characteristics and management options for children with PARDS (25, 48, 63, 85). For example, an evidence-based review used a series of Delphi surveys, conference meetings and subgroup meetings to formulate recommendations on the use of specific MV options including NIV, LPMV strategies, APRV, iNO therapy, proning, and weaning protocols in sepsis induced PARDS (79). Another review discussed LPMV strategies (e.g. the control of tidal volumes, PEEP, lung recruitment), weaning, monitoring targets and alternative MV strategies to reduce risk for ventilator induced lung injuries (VILI) in PARDS (63). Some reviews did not explicitly focus on PARDS, but PARDS was mentioned as an indicator for MV strategies or techniques (23, 85). This included an overview of various MV techniques and adjunctive therapies with clinical experience summaries (many of these techniques mentioned were for PARDS). Indications, mechanisms and clinical data were described for different techniques, which included NIV, pressure-limited MV, high frequency ventilation, heliox, and extracorporeal membrane oxygenation (85). Similarly, two other reviews provided a summary of different MV options (e.g. PRVC, PS, VC, HFOV, iNO, LPMV strategies) to minimize the risk of VILI in PARDS and children in general (25, 48).

In 2015, PALICC created three consensus recommendation documents on MV strategies and management of PARDS that included the characteristics, diagnostic criteria and overall management (51, 78, 86). The first consensus recommendation document provided an overview of PARDS and listed possible pediatric-specific MV management options (78). The second focused on the use of NIV and HFNC, and described the indications, contraindications, mode selection, duration of therapy, and ideal interfaces (86). The third focused on the use of invasive MV, including the indications, contraindications, initiation, mode selection and lung protective

strategies (51). PALICC strongly encouraged clinicians to use the recommendations as a guide to direct medical discussions and decisions. These practice guidelines were re-iterated by several review articles that provided an overview of the pathophysiology, potential strategies and MV management for PARDS (4, 22, 62, 77, 87). There were very few studies investigating specific components of the recommendations, and their impact on patient outcomes.

In a before-after pilot by Wong et al (88), the PALICC PARDS consensus guideline was used to qualify children with diagnosed PARDS into their study. Data was collected from 2016 to 2019 and in 2018, a PARDS LPMV protocol approved by the medical and nursing staff, was implemented for their 16 bed PICU. A total of 132 children (median age 2.4 years [IQR 0.5-0.77]) were included, n=69 in the no-protocol (prior to protocol implementation; median age 1.8 years [IQR 0.4-7.7]) and n=63 in the protocol groups (median age 2.8 years [IQR 0.59-9.6]). The PARDS LPMV protocol had 5 essential target components: 1) peak inspiratory pressures <28cmH_2O, 2) tidal volumes 3-6ml/kg, 3) an incremental PEEP to FiO_2 table, 4) permissive hypercapnia for moderate/ severe PARDS and 5) permissive hypoxemia (mild PARDS pulse oximetry 92-97%, moderate/ severe 88-92%). After implementing the LPMV protocol, there were no significant differences in mortality (15% vs. 26.1%, p=0.152), ventilator-free days (16.0 vs. 19.0, p=0.679) or PICU-free days (13.0 vs. 16.0, p=0.233). After adjusting for severity of PARDS and illness, there was a significant decrease in mortality risk (adjusted hazard ratio = 0.37; 95% CI= 0.16-0.88) in the protocolized LPMV group. After protocol implementation, authors observed a significant decrease in median tidal volumes (pre 6.4ml/kg [5.4-7.8] vs. post 6.0ml/kg [5.1-7.6], p=0.005), higher PEEP levels (pre 8cmH_2O [7-9] vs. post 8cmH_2O [8-10], p=0.002), higher acceptable arterial carbon dioxide ($PaCO_2$) (pre 44.9mmHg [38.8-53.1] vs. post 46.4mmHg [39.4-56.7], p=0.033), lower acceptable arterial oxygenation levels (PaO_2) (pre 78.1mmHg [67-94.6] vs. post 74.5mmHg [59.2-91.1], p=0.001) and oxygen saturation (SpO_2) (pre 97% [95-99] vs. 96% [94-98], p=0.007). When categorized into PARDS severity, at-risk / mild PARDS did not have significant improvements in their median tidal volumes (pre 6.4 ml/kg [5.5-7.8] vs. post 6.1 ml/kg [5.1-7.6], p=0.153), PEEP (pre 8cmH_2O [7-9] vs. post 8 cmH_2O [7-9], p=129), PaO_2 (85.9 mmHg [74.5-103.5] vs. post 83.5 mmHg [69.7-98.7], p=0.072) or SpO_2 (98% [96-100] vs. post 98% [95-98], p=0.273) even after protocol implementation. Although each of the five elements in the LPMV protocol had non-significant improvements in compliance, when SpO_2 targets were separated into PARDS severity, there was a significant

improvement in clinicians complying to a SpO_2 target of 88-92% in moderate to severe PARDS (pre 17.4% vs. post 29.3%, p=0.031). The pilot study suggests a PARDS protocol may improve compliance to LPMV strategies and potentially reduce mortality. Larger trials on LPMV strategies are needed to understand their impact on clinical outcomes, including the association of protocol compliance and PARDS severity (88).

In summary, MV management for PARDS is complex and involves various MV modalities, strategies and adjunct therapies. Table 3 summaries all the articles reviewed in this section). LPMV strategies appear to be common in managing PARDS, though different studies report different outcomes including mortality, MV duration and length of stay (81, 82, 88). In the small number of studies, children varied greatly in their age, and protocol adherence was not high (81, 88). Larger high-quality clinical trials are needed to validate the effects of various PARDS and MV management strategies (e.g. LPMV), rather than literature reviews and summaries.

Table 3: Articles and reviews discussed in Chapter 2, Topic 3c - Pediatric Acute Respiratory Distress Syndrome

Authors	**Study type (Article type)**	**Participant characteristics**	**Intervention**	**Results**
Newth et al, 2018	Prospective observational study	120 children (age range 17 to 18 years old) with PARDS from 8 tertiary PICU in USA (2011 to 2012)	-	• assessed MV changes on blood gases, pulse oximetry, and end-tidal CO_2 • PARDS MV protocol based on the ARDSNet protocol and data from the Pediatric Acute Lung Injury and Sepsis Investigators and the Collaborative Pediatric Critical Care Research Network • MV modes were either PC (60%), VC (19%) PRVC (18%) or HFOV (3%) • PEEP settings 10cmH_2O • overall MV management varied considerably across different sites even when a protocol was available
Karsies et al, 2017 (83)	Quality improvement (pre/post) study	63 children (2010 to 2013)	Implementation of iNO protocol	• iNO is an expensive therapy and this study aimed to see if a guideline would decrease practice variability, utilization and costs • 63 children into two groups, n=30 (median age 2 [IQR 0.79-12.5)) in the pre-guideline group, and n=33 (median age 4 [IQR 0.96-14]) in the post-guideline implementation group • Significant changes between pre- and post-guideline in total MV hours from 359 (IQR 283-846) to 304 (IQR 141-551) hours, p=0.03; mortality 15% to 7%, p=0.02; and iNO therapy duration from 62 (IQR 87-290) to 76 (IQR 48-124) hours, p=0.0004, with a

				median iNO cost savings of $4600 (USD) • no significant differences in PICU length of stay • implementing an iNO protocol may reduce the cost, MV duration and mortality in this population of children
Jensen et al, 2015 (84)	Survey study	21 Nordic units that treated pediatric patients (Norway, Denmark, Finland, Sweden)	-	• explored MV strategies for PARDS and how it differed from international guidelines • a survey for children 1 months to 6 years • 18/21 (86%) units participated, 50% PICU • MV was mostly achieved by PC (89%) compared to VC (11%); NAVA was only used in some units (44%) • only 44% of the units had a protocol in place for MV management, 44% had ECMO, 94% had nitric oxide therapy and HFOV available • 67% used low tidal volumes, 72% used PEEP between 10-15 cmH_2O, 89% used prone positioning and 50% used cuffed ETT • MV practices across the countries were similar and follow international guidelines
Kissoon, Rimensberger and Bohn, 2008 (85)	Literature Review	-	-	• overview of the indications, mechanisms and clinical experience for HFOV, NIV, nitric oxide, heliox, and ECMO • no single approach was appropriate and therefore, therapies should be given when warranted and appropriately monitored
Sevransky, Levy and Marini, 2004 (79)	Literature Review	-	-	• question-directed recommendations, and an overview of existing evidence on the MV management in sepsis-induced PARDS • described recommendations for the indications for NIV, invasive MV, and MV strategies such as low tidal volume (<6ml/kg with plateau pressures <30 cmH_2O), APRV, HFOV prone positioning, and weaning protocols/ SBT
Jauncey-Cooke et al, 2010 (63)	Literature Review	-	-	Described in Table 1: Articles and reviews discussed in Chapter 2, Subtopic 3a - MV modes.
Jauncey-Cooke, East and Bogossian, 2015 (62)	Literature Review	-	-	
Turner and Arnold, 2007 (48)	Literature Review	-	-	
Haut, 2015 (42)	Literature review	-	-	
Vitaliti et al, 2013 (60)	Literature review	-	-	
PALICC consensus guidelines in 2015				
PALICC, 2015 (78)	Guideline	27 experts	-	• Consensus conference to evaluate and create 151 recommendations on the practices in acute lung injury/ PARDS • included 1) definitions, prevalence, epidemiology; 2) pathophysiology, comorbidities, and severity; 3) ventilatory support; 4) pulmonary-specific ancillary treatment; 5) non-pulmonary treatment; 6) monitoring; 7) NIV support and ventilation; 8) ECMO support; 9) morbidity and long

				term outcomes • recommendations took 2 years to finalize and were intended to optimize and standardize the care of children with PARDS
Essouri and Carroll (PALICC group) (86)	Guideline	-	-	• Total of 11 recommendations on the NIV management in children with PARDS • NIV may be most beneficial in children with milder forms of PARDS • choice of interface, environment, and available clinicians were important in the success of using NIV
Rimensbnerger and Cheifetz (PALICC Group) (51)	Guideline	-	-	• Total of 27 recommendations on the MV management in children with PARDS • 17 recommendations reached strong agreement and 10 reached weak agreement • guideline should be used to encourage discussions when managing the care of children with PARDS
After PALICC consensus guidelines were available				
Wong et al 2020 (88)	Pilot study	132 patients (median years 2.4, IQR 0.4-8.3)	Lung protective MV protocol (includes direction in peak pressures, tidal volumes, PEEP, oxygen, permissive hypercapnia and hypoxemia)	• assessed whether a lung protective MV protocol is associated with improved health outcomes in the PICU • n=69 in non-protocol group (usual care) compared to n=63 protocol group (lung protective MV protocol) • decrease in median tidal volume after protocol implementation, pre-6.4ml/ kg (5.4-7.8ml/kg) vs. post- 6.0 ml/kg (4.8-7.3ml/kg), p=0.005; PaO_2 pre- 78.1 mmHg (67-94.6) vs. 74.5mmHg (59.2-91.1mmHg), p=0.001 and SpO_2 pre 97% (95-99) vs. post 96% (94-98), p=0.007 • increase in PEEP settings in the protocol group, pre- 8cmH_2O (7-9) vs. 8 (8-10), p=0.002; permissive hypercapnia PCO_2 44.9 mmHg (38.8-53.1) vs. post- 46.4mmHg (39.4-56.7), p=0.033, • no differences in mortality, ventilator free days or PICU-free days • the protocol group was associated with decreased mortality (adjusted hazard ratio, 0.37 (95% CI 0.16-0.88) (when adjusted for disease severity, organ dysfunction and OI)
Khemani et al, 2018 (82)	Retrospective analysis	1134 children (median age 46.6 months, IQR13.2-137.6)	-	• determined whether children are managed with the appropriate PEEP level as suggested by the ARDSNet • 26.6% of the 1134 children were managed with lower PEEP than suggested, p<0.001, and was associated with increased mortality (OR 2.05; CI=1.32-3.17) • after covariate adjustment, lower PEEP still associated with increased mortality
Ward et al, 2016 (81)	Post hoc analysis	315 PARDS patients from 26 PICU (median age 3.3 years, IQR 0.4-10.8)		• evaluated the use of low tidal volumes in children with PARDS, and suggested methods to improve compliance to this practice • patients were included in this study if there was data to calculate the IBW • 2 thresholds for low tidal volumes were assessed: ≤6.5ml/kg IBW and ≤8ml/kg

				• with threshold ≤6ml/kg, the adherence rate was 32%, with ≤8ml/kg, adherence was 56% • overweight children were less likely to receive low-tidal weight practices (≤6ml/kg at 11% and ≤8ml/kg at 38%) • low-tidal volume practices were underused and did not improve over time
Santschi, Randolph, Rimensberger and Jouvet, 2013 (34)	Survey	54 pediatric intensivists, from 47 PICU in 12 North American and European countries	Survey with 3 case scenarios to assess MV strategies	• assessed pediatric intensivists' knowledge and MV practices in children with PARDS • most (88-96%) intensivists used target tidal volumes 5-8ml/kg, upper pressure threshold of 35 cmH_2O, and permissive hypercapnia/ mild hypoxemia • additional therapies such as nitric oxide, prone positioning, ECMO, or medications were considered if patient's condition worsened • participants reported compliance and agreement to using lower tidal volumes and pressure limits, but over 25% of centers actually tolerate higher tidal volumes and pressure limits • a comprehensive decision support tool or protocol was necessary to enhance compliance to these recommendation goals
Orloff, Turner, Rehder, 2019 (77)	Literature Review	-	-	• described PARDS and its epidemiology, mortality and standards of care (which were consistent with ARDS network protocol) • emphasized using lung protective strategies, with reference to the PALICC guidelines • other adjunctive therapies were reviewed, such as HFOV, recruitment maneuvers, prone positioning, nitric oxide and ECMO
Matthay et al, 2019 (87)	Literature Review	-	-	• summary of PARDS pathophysiology, and available diagnostic tests and treatments (not MV focused) • MV management of PARDS is complex, and respiratory support may be provided as NIV or invasive ventilation • was a particular focus on using protective lung strategies in lower tidal volumes, higher PEEP, and prone positioning • other considerations for PARDS management included fluid management, ECMO, steroids, and vasodilators
Newth, Khemani, Jouvet and Sward, 2017 (35)	Literature Review	-	-	• review of MV protocol and the advantages of computer-based protocols • computer-based protocols may improve medical care and patient outcomes • described the process in developing, initiating and managing a computer-based protocol, along with challenges in implementation • even though decision support tools are shown to be beneficial, MV management differed across centers and clinicians
Cheifetz 2017 (76)	Literature Review	-	-	• review of PARDS and the available MV therapies, adjunctive treatments, and weaning options

				• PALICC guidelines for MV management were recommended for lower tidal volumes, limited peak inspiratory pressures, higher PEEP and recruitment maneuvers
Williams and Cheifetz, 2019 (4)	Literature Review	-	-	• summarized the pathophysiology of PARDS, initial MV settings, review of the therapies and other rescue treatment options • discussed target tidal volume, driving pressures and oxygen concentration • alternative support modes included NAVA or PAV, with limited use in children • review of other therapies included prone positioning, HFOV, and ECMO; these may be considered, but there was limited data • an overall improvement in children's mortalities over the years
Goh and Jacobe, 2016 (37)	Literature Review	-	-	• overview of MV strategies for children with lung inhalational injuries • causes, pathophysiology and diagnosis of lung inhalational injuries were explained in depth, including the grade classification of lung injuries • MV strategies covered in this review included Conventional MV Lung protective strategies, HFOV, HFPV, APRV, NIV and HFNC • since lung inhalation injury may involve complications such as airway edema, and bronchoconstriction, PC mode may be the most beneficial in avoiding more damage • HFPV and HFOV may provide improved ventilatory and gas exchanges, but there is limited evidence • there is limited evidence to support the use of APRV, especially in children with lung inhalation injuries • limited data on NIV use, as it is problematic to apply any interface on facial burns • no HFNC studies were found in children with lung inhalational injuries
Schibler 2016 (64)	Literature Review	-	-	Described in Table 1: Articles and reviews discussed in Chapter 2, Subtopic 3a - MV modes
Conti and Piastra, 2016 (5)	Literature review	-	-	
Smallwood and Davis, 2018 (22)	Literature Review	-	-	

Abbreviations: *APRV-airway pressure release ventilation; CO_2- carbon dioxide; CPAP-continuous positive airway pressure; ECMO-extracorporeal membrane oxygenation; ETT-endotracheal tube; HFJV-high frequency jet ventilation; HFNC-high flow nasal cannula; HFOV-high frequency oscillary ventilation; HFPV-high frequency percussive ventilation; MV-mechanical ventilation; NAVA-neurally adjusted ventilatory assist; NIV-non invasive ventilation; OI-oxygenation index; PARDS- pediatric acute respiratory distress syndrome; PAV-proportional assist ventilation; PC- pressure control; PEEP-positive end expiratory pressure; PICU-pediatric intensive care unit; PRVC-pressure regulated volume control; PS- pressure support; RT- respiratory therapist; VALI-ventilatory associated lung injury; VDR- volume diffuse respiration; VS- volume support*

Bronchiolitis

Bronchiolitis is a respiratory infection common among younger children and can be treated with CPAP, and/or with HFNC oxygen therapy (24, 89). HFNC is of particular interest, as it is relatively new and may be a preferred option to CPAP in children (24, 90).

A 2011 systematic review evaluated the use of CPAP and its effect on the clinical outcomes of children with acute viral bronchiolitis (89). A total of eight studies (five CPAP and three CPAP-Heliox (He) studies) were included, with a total of 221 children (under 2 years old). In the five CPAP studies, four were before-after designs and one a RCT-crossover. CPAP levels from 4 to 8cmH_2O, and the impact on $PaCO_2$ and work of breathing was investigated. One of the RCTs using CPAP levels of 5-6cmH_2O showed a decrease in $PaCO_2$ by 6.9mmHg compared to standard oxygen therapy (nasal prongs/ mask) at 0.3mmHg ($p<0.015$). In two of the CPAP before-after trials, $PaCO_2$ decreased from a range of 7mmHg to 11.7mmHg ($p<0.001$) after 2 hours of 4-8cmH_2O CPAP. In the quasi-RCT crossover with 1-2 month old infants, 5-12cmH_2O CPAP was delivered with or without heliox (a mixture of helium-oxygen,70%/30%). There was a greater decrease in $PaCO_2$ in the CPAP-He group by 9.7 mmHg compared to the CPAP group, 5.4mmHg ($p<0.001$) after 30 minutes (similar to two before-after studies that demonstrated a decrease of PaCO2 9.7mmHg in the CPAP-He group after 1 hour of use, $p<0.05$). One before-after trial with children under 3 months old (n=12), noted a decrease in respiratory distress (measured by the modified Wood clinical Asthma score [mWCAS]), by 2.2 points after 1 hour of 6cmH_2O CPAP ($p<0.01$). Two other before-after studies with children 0 to 2 years old (n=75), showed a significant decrease in the respiratory rate by 12-16 breaths/min ($p<0.01$), after 2 hours on 5-8cmH_2O CPAP. In comparison, the quasi-RCT CPAP-He trial with 12 children (1-2 years old) showed a decrease in nWCAS by 2.12 in the 5-12cmH_2O CPAP-He compared to the 5-12cmH_2O CPAP only group, 1.08 ($p<0.001$) (89). The other two before-after trials of CPAP-He with 23 children (0-2 years old) showed a decrease in respiratory rate by 8 to 13.7 breaths/min after 1 hour of ≥5cmH_2O CPAP-He use ($p<0.05$). The overall evidence to support the use of CPAP at any pressure level, with or without heliox, for children with bronchiolitis, included studies using CPAP at various levels and measured different outcomes. Variability across studies make it difficult to provide a definitive conclusion, thus stronger evidence is required before recommendations can be made on the best CPAP pressure levels, in conjunction with heliox.

A prospective physiologic study from 2011 evaluated the different levels of nasal CPAP

(nCPAP) to treat acute bronchiolitis in 10 infants (27 to 94 days old) (91). The infants' respiratory pattern and gas exchange were recorded during spontaneous oxygen therapy (nasal prongs), 4cmH_2O nCPAP, 7cmH_2O nCPAP and 10cmH_2O nCPAP. In all infants, the greatest reduction in respiratory rate and transcutaneous CO_2 (compared to spontaneous oxygen therapy) occurred at 7cmH_2O nCPAP: average (range) 78 (41-96) vs. 56 (39-108) breaths/min, $p<0.05$; 61.5 (50-78) vs. 49 (35-65) mmHg, $p<0.05$ (respectively) (91). It is suggested that nCPAP of 7cmH_2O may be sufficient in unloading respiratory distress and improve breathing patterns in infants with bronchiolitis.

In a protocol implementation study by Riese et al (36), a pre and post intervention study investigated the use of HFNC in children with bronchiolitis outside the PICU (general floors) and their associated health outcomes. In the period of 2010 to 2014, there were a total of 1937 patients, 936 children (median 4 months [IQR 1.75-10]) in the pre-protocol phase and 1001 children (median 5 months [IQR 2-11]) in the post-protocol phase. Overall, there was an increase of HFNC use in children with bronchiolitis from 23.9% to 35.2% ($p<0.001$). However, after using an interrupted time series analysis, there were no statistical differences in total hospital stay (0.48), PICU length of stay (0.06), PICU transfer ($p=0.97$), intubation ($p=0.7$) or 30 day readmission ($p=0.37$). Overall, the possible explanation for increase HFNC use in bronchiolitis may be because of its ease of use and tolerance in children. Though the protocol was not implemented in the PICU, the associated benefits demonstrated may still apply. Therefore, more research is required to determine the relationship between a HFNC protocol in and outside of the PICU and their associated benefits.

A retrospective observational study described the care received by children with bronchiolitis in a PICU, during two separate time periods, 2014 to 2015 and 2015 and 2016 (92). A hundred and thirty-eight children were included, 75 children (median age 1.49 months) in the first time period, and 63 children (median age 1.89 months) in the second. NIV modalities (CPAP and Bilevel) were less frequently used in the second period (38% vs. 56%, $p=0.036$), while HFNC use increased, especially in children less than 1 month (25% vs. 63%, $p=.035$) and less than 1 year old (32% vs. 53%, $p=0.021$). This study demonstrated a shift from NIV to HFNC practices, warranting the necessity of clear guidelines on its use and outcomes.

A survey from 2017 to 2018 in France collected information on the use of HFNC in infants with bronchiolitis outside PICU (93). A total of 217 pediatricians from 135 hospitals

responded, providing details on the characteristics to initiate, wean and discontinue HFNC. HFNC practices were not standardized across centers, and clinical outcomes were not reported. The authors highlighted the urgency to establish comprehensive guidelines on HFNC for children with bronchiolitis, especially given its increase in popularity.

In a retrospective cohort study evaluated the effectiveness of using HFNC outside the PICU in 80 children (median 4.6 months [IQR 2.0-10.4]) with bronchiolitis from 2013 to 2015 (94). Children that required HFNC received a median minimum flow of 3 (IQR 3-5) L/min with the median maximum flow of 8 (IQR 6-8) L/min; the maximum flow was 10 L/min with median maximum oxygen FiO_2 0.4 (0.3-0.5). Children who stayed on the general floors received a median maximum flow of 7 (IQR 6-8) L/min and children who were transferred to PICU received a median maximum flow of 8 (8-10) L/min, which was shown to be significantly different ($p<0.001$). A total of 33 children (41%) were transferred to PICU, and 58% of these children required higher respiratory support options. None of the children recruited required intubation, or experienced any complications such as aspiration, pneumothoraces or death. These results indicate the safe use of HFNC as a respiratory support for children with bronchiolitis outside the PICU using this wide flow range. However, it was observed that children who required HFNC on the floors were commonly admitted to the PICU (41%) within 24 hours, which indicated that HFNC use still requires close monitoring.

There are a few guidelines for bronchiolitis management, but they are limited in scope. The American Academy of Pediatrics (AAP) guideline focuses on diagnostic and pharmaceutical management, with minimal suggestions on respiratory support therapies for children with bronchiolitis (95). Similarly, the CPS (96) clinical practice position statement describes the background information, indications, safety concerns and brief suggestions for the initiation and management of HFNC. Milési et al (24) presented a HFNC recommendation guideline but it was not bronchiolitis-focused (though it did mention bronchiolitis as a strong indicator for this form of respiratory therapy). Other literature reviews only highlighted the potential of HFNC for children with bronchiolitis, including the indications, mechanism of action and suggested settings (39, 90). These studies and reviews are summarized in Table 4.

Table 4: Articles and reviews discussed in Chapter 2, Topic 3b Bronchiolitis

Authors	Study type (or article type)	Participant characteristics	Intervention	Results
Donlan et al, 2011 (89)	Systematic review	221 children (under 2 years) from 8 studies	CPAP compared to CPAP-heliox	• eight studies (five CPAP and three CPAP-Heliox (He) studies) were included • one RCT using CPAP levels of 5-6cmH_2O showed a decrease in $PaCO_2$ by 6.9mmHg compared to standard oxygen therapy (nasal prongs/ mask) at 0.3mmHg ($p<0.015$) • in two CPAP before-after trials, $PaCO_2$ decreased from a range of 7mmHg to 11.7mmHg ($p<0.001$) after 2 hours of 4-8cmH_2O CPAP • one quasi-RCT crossover with 1-2 month old infants, compared 5-12cmH_2O CPAP with or without heliox; greater decrease in $PaCO_2$ in the CPAP-He group by 9.7 mmHg compared to the CPAP group, 5.4mmHg ($p<0.001$) after 30 minutes • Definitive conclusions cannot be made from the available data as further research is required to understand the benefits of CPAP and CPAP-He
Riese et al, 2017 (36)	Retrospective, pre/post study	1937 children	HFNC protocol	• assessed the implementation a HFNC protocol outside the PICU and impact on health outcomes • 936 were in the pre- (median age 4 [1.75-10]) and 1001 were in the post (median age 5 [2-11]) groups • increase in HFNC use for bronchiolitis from 23.9% to 35.2%, $p<0.001$ • significant decrease in HFNC therapy time, average 2.5 days ± 1.5 in pre and 2.0 ± 1.4 in the post implementation, $p<0.001$; and PICU stay, with median 2.3 days (1.5-3.4) before compared to after 1.7 days (1.0-2.6), $p<0.001$ (significance lost after an interrupted time-series analysis) • no significant differences in hospital length of stay, rate of PICU transfer, intubation rate or readmission
Essouri et al, 2011 (91)	Prospective physiologic study	10 infants with bronchiolitis (27 to 94 days old)	Nasal CPAP at 4, 7 and 10 cmH_2O	• a significant reduction in respiratory rates with nasal CPAP 7cmH_2O, average (range) 78 (41-96) vs. 56 (39-108) breaths/min, $p<0.05$; and transcutaneous CO_2 measurements 61.5 (50-78) vs. 49 (35-65) mmHg, $p<0.05$ • nasal CPAP at 7 cmH_2O may be sufficient in offloading respiratory muscles and improving breathing patterns
Marcos-Morales et al, 2020 (92)	Retrospective/ prospective observational study	138 children (Median age 1.8 months, IQR 1.1 to 3.6)	American Academy of Pediatrics (AAP) bronchiolitis guideline publication (2014-2015 compare with 2015-2016)	• no changes in management between the two periods except for an increase use of HFNC in 2nd time period ($p=0.036$) • the PICU did not follow the AAP guideline but followed routine clinical care • non-recommended treatments were familiar to the primary physician, and the staff were not extensively educated on the AAP guideline nor was it enforced

Dadlez et al, 2019 (94)	Retrospective cohort study	80 children (Median age 4.6 months, IQR 2.0 to 10.4)	HFNC 3 to 10L/min	• examined the safety in HFNC use outside PICU after protocol implementation • median minimum flow of 3 (IQR 3-5) L/min with the median maximum flow of 8 (IQR 6-8) L/min; the maximum flow was 10 L/min • median maximum oxygen FiO_2 0.4 (0.3-0.5) children on the general floors received a median maximum flow of 7 (IQR 6-8) L/min vs. children transferred to PICU received a median maximum flow of 8 (8-10) L/min, ($p<0.001$) • 33 (41%) children required transfer to PICU, 19 (24%) required higher respiratory support therapies, no incidences of intubation, pneumothoraces, aspiration or death
Bradshaw et al, 2018 (40)	Survey study	57 PICU physicians from 13 PICUs in Canada	-	• assessed practices in treating bronchiolitis across Canadian PICU • survey contained 2 case studies • the response rate was 55% (57/ 103 invited physicians, 13/15 PICU) • in patients that required MV, HFNC was the most common respiratory support therapy (57%) compared to CPAP (29%) • NIV was a standard of care for children with bronchiolitis in Canada, despite the lack of robust data to support its use • pediatric intensivists did not follow North American guidelines for bronchiolitis; as data for all the therapies were lacking • unique considerations in different cases were necessary; guidelines did not address the management of severe bronchiolitis
Panciatici et al, 2019 (93)	Survey study	135 hospitals with 217 pediatricians in France	-	• assessed practices in HFNC in the emergency department and general floors • 135/ 217 (81%) responded (96 general hospitals, 39 university hospitals) • HFNC was commonly used in acute bronchiolitis outside the PICU (59.4% general hospitals vs. 38.5% in university hospitals) • HFNC initiation, settings and withdrawal were not standardized
Milési et al, 2014 (24)	Guideline/ review	-	-	• review on the use, indications and management of HFNC in children • an overview of the machinery, mechanism of action and settings • descriptions on the use of HFNC in certain clinical conditions, including bronchiolitis, asthma and withdrawal of care • much of the information were drawn from evidence in infants • HFNC therapy should be initiated in the emergency rooms and PICU early to evaluate the severity of disease/ respiratory failure and the need to escalate respiratory support treatments
Hutchings, Hilliard, and Davis, 2015 (39)	Literature Review	-	-	• described the mechanism of action in HFNC therapy and its role in treating respiratory distress (especially bronchiolitis), including its advantages, limitations and complications

				• provided suggestions for initial settings, signs of failure and escalation in settings • HFNC therapy may reduce work of breathing and reduce the risk of children requiring NIV and invasive ventilation
Mikalsen, Davis and Øymar, 2016 (90)	Literature Review	-	-	• described HFNC use in children, including mechanism of action, clinical effects and indications in children after the newborn period (particularly bronchiolitis) • HFNC was a safe, well tolerated and feasible intervention and may reduce work of breathing • other benefits may the potential to reduce the need of CPAP and invasive MV • though there are no international guidelines on how to use HFNC, flow rates may be set up to or even greater than 10L/min
Kline, Kalburgi and Halley, 2018 (45)	Literature Review	-	-	• reviewed the knowledge, evidence and use of HFNC in children with bronchiolitis in the emergency department and acute floors • a summary of the HFNC initiation settings from different hospitals in USA • HFNC in children and infants may be safe, and more centers were using HFNC as an initial therapy for bronchiolitis

Abbreviations: *CPAP-continuous positive airway pressure; HFNC-high flow nasal cannula; MV-mechanical ventilation; NIV-non invasive ventilation; PICU-pediatric intensive care unit*

Asthma

Children presenting to the hospital with severe asthma exacerbation may require respiratory support (41, 42, 97). NIV options, such as BiPAP, CPAP and HFNC, are the most common (41). A methodological review with case scenarios highlighted one case of a 3-year old child presenting in the emergency room in severe respiratory distress, as a result of status asthmaticus, complicated with pneumonia (46). The article provided a general review of pediatric respiratory physiology, and the possible MV modes (e.g. PC, VC, PRVC) and initial settings (e.g. inspiratory time, respiratory rates, PEEP, PIP, tidal volumes). The child was initiated on HFNC for his respiratory distress but required imminent intubation for invasive MV due to impending respiratory failure. Once intubated, the child was started on SIMV PRVC settings, and shortly after the ventilator alarmed for high peak pressures. The review created and described an algorithm to troubleshoot this clinical situation.

Other literature reviews also provide descriptions on the pathophysiology, diagnosis, medications and respiratory options to treat children with asthma (41, 97). This includes HFNC, NIV BIPAP, and if necessary, invasive modes of MV (41, 97). Jones et al., aimed to provide additional evaluation and management options for pediatric acute asthma exacerbations, not outlined in the guideline by the National Asthma Education and Prevention Program (NAEPP)

(97). The authors acknowledged there was limited evidence to provide recommendations on when or which MV option should be used, but HFNC, BiPAP and/or intubation should be considered. If a child requires invasive MV, no specific MV mode is considered superior to another, but clinicians must be careful to minimize risk of VILI and air trapping. There are generic HFNC recommendation guidelines available, but they do not explicitly review and comment on the use in children with asthma (24). Collectively, these only provide potential guides in MV management for children with asthma (Table 5). Therefore, more studies are required to inform evidence-based guidelines.

Table 5: Articles and reviews discussed in Chapter 2, Topic 3c- Asthma

Authors	**Study type (or article type)**	**Participant characteristics**	**Intervention**	**Results**
Batabyal and O'connell, 2018 (41)	Review	-	-	• review on asthma management, including medications, HFNC, NIV and heliox • NIV indications included significant work of breathing, hypercapnia or hypoxemia • NIV mode should be selected based on the support required, either Bilevel or CPAP • a brief summary of HFNC was provided, and suggested that it may be used but there are limited studies to support its use
Jones et al, 2016 (97)	Review	-	-	• overview of the available treatment options in acute asthma exacerbation in children • compared to National Asthma Education and Prevention Program guidelines
Milési et al, 2014 (24)	Guideline/ review	-	-	See Table 4: Articles and reviews discussed in Chapter 2, Topic 3b Bronchiolitis
Pacheco, Mendelson and Gaspers, 2018 (46)	Clinical cases and review	-	-	See Table 1: Articles and reviews discussed in Chapter 2, Subtopic 3a - MV modes

Abbreviations: *CPAP-continuous positive airway pressure; HFNC-high flow nasal cannula; NIV-non invasive ventilation; PEEP-positive end expiratory pressure; PICU-pediatric intensive care unit*

2.3.4 Topic 4- Clinician Engagement in Protocolized MV

Use and management of different MV options are often based on clinicians' experience, due to the lack of national or international guidelines and protocols (33). Clinicians support the use of protocols (to limit variability in MV management), however, they acknowledge there are several barriers to successful implementation of protocols from recommended guidelines (3, 40). There are a few surveys and studies that explored the consistency of MV management across different centers and how protocol compliance may be improved.

A systematic review evaluated 11 studies (with 267 participants) to understand the barriers and facilitators in the use of MV weaning protocols (98). Only one of the included studies was performed in the PICU, which the authors acknowledged is a different clinical environment compared to adult ICU. This systematic review showed protocols are generally accepted, but must take the social and cultural environment into account. To facilitate implementation, providers must be involved in the protocol development, and be familiar with the protocol (98).

In a protocol implementation study by Duyndam and colleagues (28), an invasive MV management algorithm (targeted towards two different groups: with and without lung disease) assessed physicians' adherence before protocol implementation, and after at two different time periods (t_1=May to November 2009 and t_2=May to November 2010). Prior to protocol implementation, 178 children (median age 4 months [IQR 0-211]) were included for the comparison and were divided into two groups, children with (n=67) and without lung disease (n=62). The compliance to the protocol for each were 79% in the lung disease group and 66% in non-lung disease group before the implementation. The protocol was designed by a multidisciplinary team, and included elements of LPMV strategies, with a specific MV mode for each group (lung disease group, PC vs. non-lung disease group, PRVC). The protocol was implemented in October 2008, and children thereafter were either included into the protocol group with lung disease (t_1 n=51; t_2 n=46) or without lung disease (t_1 n=79; t_2 n=85). In the first time period, t_1, after protocol implementation, there were a total of 173 children (median age 8 months [IQR 0-233]) and the reported compliance was 71% in the lung disease group and 78% in the non-lung disease. In the second time period, t_2, a year after protocol implementation (n=156; median age 4.5 months [0-21]), there were noted improvements in protocol adherence (84% in both lung and non-lung disease group). Between the two groups, only the non-lung

disease group showed a significant increase in compliance (pre 66% vs. t_1 78% vs. t_2 84%, p=0.015). For successful protocol implementation, the authors gained staff approval, provided reminders, continuous education and safety reports. Furthermore, a well-organized implementation plan addressing the potential barriers and facilitators may have influenced the success of protocol adherence. Overall, with the proper education, resources and support, protocol adherence can be sustained and may translate to positive clinical outcomes.

In a cross-sectional survey across Europe, 101 facilities from 23 countries responded to a survey that gathered information on the diverse use of NIV (30). The study revealed that NIV was initiated across different diseases and clinical circumstances. About 99% of the PICUs used NIV as a respiratory support therapy immediately after extubation, 77.5% for palliative care; and for respiratory failure caused by bronchiolitis (95%), pneumonia (97%), pulmonary edema (84%), upper airway obstruction (76%) and ARDS (91% in mild, 53% in moderate, 5% in severe) (30). Only 48% of the respondents had NIV protocols in place, suggesting variable NIV practices across Europe . Though this study did not provide clinical outcome measures, it demonstrated that NIV can be used for various applications, but availability of protocols were limited.

With the increase in HFNC use as a NIV option for children in critical care, Hosheh and colleagues (33) used a cross-sectional survey to describe the current practices of HFNC use on the general floors and high dependency units (HDU). A total of 218 pediatricians from 81 hospitals participated; 75 (91%) of the hospitals provided HFNC and 47 (58%) hospitals had HDU. The pediatricians were responsible for HFNC management 75% of the time, and responses for flow rates varied in different diseases and scenarios. One hundred and eighty-seven pediatricians (85%) supported the idea of developing national HFNC guideline for children on the general floors. And HFNC failure and HFNC length of use were identified as the most important outcome measures to include for future research. The results from this survey indicates that more research to is required to provide guidance in developing a national guideline.

A survey collecting information on the airway management of children in burn units across North America, reported differences in MV practices (38). A total of 25 burn centers completed the survey, nine large centers (>50 ventilated patients in 5 year period) and 16 small burn units (<50 ventilated patients in 5 year period). There were no differences in the MV mode of choice, ranging from PC, SIMV, HFOV, or combination of settings. It did appear that HFJV

was used the least ($p<0.05$) compared to the others. Larger centers used SIMV more frequently compared to smaller centers ($p<0.05$). Therfore, MV management varied across centers and future studies should identify the benefits and limitations for each MV mode for burn patients.

There are no guidelines for the use of NIV in cystic fibrosis (CF), a genetic disease, that is characterized by respiratory complications including airway obstructions, mucus plugging, inflammation and destruction of the parenchyma (99). A nationwide survey in France evaluated the NIV practices in CF patients, including their indications, MV modes, settings and interface options to develop a guideline (99). Thirty-six centers (15 pediatric, 13 adult, 8 adult and pediatric centers) for a total of 4,416 CF patients, were involved in the study. There were multiple indications for NIV reported across all centers, including CF exacerbations, lung function, sleep disturbances, insufficient long-term oxygen therapy, or lung transplantation. Bilevel pressure targeted ventilation was the preferred mode of MV compared to VC ($p=0.18$) or CPAP ($p=0.9$). Furthermore, the respondents provided a list of the perceived NIV benefits, but many were not backed up by evidence. This survey included NIV practices for both adults and children with CF (children were not separated out). The study concluded that NIV practices appear to be relatively similar across centers, but further studies are required to investigate the benefits of NIV in CF patients.

Extracorporeal membrane oxygen (ECMO) is a life-support treatment specifically for supporting the heart and lungs in critically ill patients who are also intubated (29). The Extracorporeal Life Support Organization (ELSO) provides broad guidelines on the use of ECMO and MV. MV practices may vary across centers because there are no specific recommendations offered (29). A hundred and forty-four responded (34.2%) out of the 421 centers invited, with representation from North America, Europe, Latin America, Asian-Pacific and Southwestern Asia/ Africa (29). Centers provided ECMO to children or adults, or both, with 37.2% of respondents from pediatric-exclusive facilities, and 17.6% from mixed facilities. The MV strategy at the pediatric centers varied in regard to the mode of choice, with PC (74.5%) setting as the most common, compared to the others (e.g. PRVC 10.9%, VC 1.8%, HFOV 9.1%, NAVA 1.8% and Bilevel 1.8%). Additionally, indications for bronchoscopy, when to initiate MV weaning, lung recruitment techniques, tracheostomy and when to extubate, differed across pediatric sites. The authors noted an increasing trend in bronchoscopy use, tracheostomy and extubation across the adults and pediatric centers, but concluded that the change in respiratory

care and MV practices required further research to determine if this change translates to improved outcomes.

A prospective postal survey in the United Kingdom aimed to describe the responsibilities involved with pediatric MV weaning in the PICU (100). Seventeen out of the invited 28 PICUs (61%) responded. Only 35% of the units had MV protocols, including specific topics such as weaning and NIV. Decision criteria in MV and weaning were collaboratively decided between nurses and doctors. The authors suggested that other health care provider directed protocols and automated weaning systems may minimize delays in MV weaning. Similarly, a European cross-sectional survey with 65 participating facilities, from 19 countries aimed to determine the responsible personnel for MV management and the use of protocols in the PICUs (101). The most responsible person for MV management was usually the physician (>75% of facilities), and protocols for MV (31%), weaning (22%) and NIV (33%) were uncommon.

An online questionnaire evaluated the acceptability of using a MV management protocol in a PICU for children with PARDS (31). A hundred and twenty-two physicians assessed the MV recommendations for 50 clinical case scenarios, with 80% of those recommendations deemed acceptable. In general, the recommendations for different MV modes were accepted, with HFOV at 83%, PRVC at 82% and PC at 75% ($p=0.002$). With respect to recommendations for specific parameter changes, all were widely accepted, including FiO_2 86%, PIP 88%, HFOV frequency 74%, HFOV Amplitude 78%. PEEP changes was the least accepted at 66% ($p<0.001$). When physicians were asked about their MV management practices, there was variability in some decision criteria. This included when children should be re-evaluated for weaning, whether the actual weight or ideal body weight for target tidal volumes should be used, the OI threshold to consider HFOV, or if VC should be used as the primary MV mode. Although many recommendations were accepted, this survey demonstrated that MV practices still varied greatly across centers. Therefore, MV management protocols may be necessary to reduce variability, and future research should evaluate the effects on patient outcomes.

A multi-phase study explored the necessity and impact of MV weaning guidelines in an Australian PICU (69). In phase 1, a national survey revealed that SIMV with PEEP and PC or PS was the most popular MV weaning mode in PICU. For phase 2, a guideline with a descriptive algorithm was developed and evaluated by medical staff for its validity and safety. The MV weaning guideline was piloted on 10 patients for one month prior to implementation in Phase 3.

Phase 3 used a quasi-experimental time series design to measure the impact of the guideline on 113 patients (historical control group before guideline implementation included 107 children) over two years at a tertiary PICU. There were no significant changes to the length of stay, but quality measures were slightly improved and a reduction in fluctuation of outcome variables, suggesting improved adherence to the guideline. In the final phase, a qualitative methodology (survey and interviews) was executed to understand the medical staffs' perceptions on using the proposed guideline. Overall, staff perceived that the guideline implementation improved patient outcomes as it provided a framework and improved interdisciplinary collaboration for their weaning practice. However, several barriers in guideline use included resistance to practice change and the concern of withholding their clinical judgement. In summary, staff feedback on the use of a MV weaning guideline was positive and the barriers identified were associated clinicians' autonomy and comfort. Though the author emphasized that the weaning guideline should not replace clinical judgement.

Overall, it is important to include clinicians to not only develop optimal MV management protocols for different pediatric diseases, but to also help facilitate its implementation in practice (31, 33-35). This is especially important given MV practice varies across centers (32, 33, 100, 101). Much of the current available information are overviews and broad guidelines for NIV and HFNC (2, 24, 50), or specific diseases, such as PARDS, asthma or bronchiolitis (76, 89, 91, 102) (summarized in Table 6). However, these only describe a few types of MV delivery mechanisms for certain diseases out of the many that require MV management.

Table 6: Summary of articles discussing clinician engagement in protocolized MV management described in Chapter 2, Topic 4

Authors	Study type (article type)	Patients' characteristics	Intervention	Results
Jordon, Rose, Dainty, Noyes and Blackwood, 2016 (98)	Systematic review (Qualitative)	11 studies involving 267 participants	-	• evaluated the barriers and facilitators of using protocolized weaning • one study was conducted in the PICU • protocols were generally accepted, but must take into account for social and cultural environment • broadening the understanding and the application of the protocol may improve their use
Duyndam et al, 2014 (28)	Pre/post protocol implementation;	507 children (median age 5 months, 0-50)	MV protocol for children with or without lung disease	• assessed physicians' adherence to MV protocol prior (before October 2008) and after implement (measured in 2 time periods; t_1 =May – November 2009; t_2 = May – November 2010) • for children with lung disease, there

				was a slight increase in adherence; pre 79%, post t_1 at 71% and post t_2 at 84%, p=0.092 • for children without lung disease, there was an improvement from pre 66% and post t_1 78% and post t_2 84%, p=0.015 • education, reminders, and protocolized nursing care, may improve MV protocol adherence
Authors	**Participants' characteristics**	**Region/ Countries**	**Survey's objective**	**Results**
Mayordomo-Colunga et al, 2018 (30)	101 units from 23 countries	Northern (n=19), Central (n=40) and Southern Europe (n=52)	To describe NIV use in Europe	• 99% of the countries used NIV as a respiratory support post extubation (95.5% prophylactically, 99.1% therapeutically) • 77.5% used it for palliative care • NIV was used 15.5% on the floors, 20% in the emergency department, and 36.4% during transport • indications for NIV included 97.4% for pneumonia, 94.6% bronchiolitis, 75.2% bronchospasm, 84% for pulmonary edema, 76.1% for upper airway obstruction and 91% for PARDS • NIV was given using oronasal mask (44.4%) and CPAP using nasal cannula (39.8%) • bilevel mode of preference is PS (62.3% in infants, 74.5% in older children) • authors concluded that NIV use varied across Europe
Hosheh, Edwards and Ramnarayan, 2020 (33)	218 pediatricians from 81 hospitals	United Kingdom	To describe HFNC use, weaning practices, and ideal outcome measures (for future research)	• 93% of the hospitals used HFNC • 75% of the decision to initiate HFNC was the responsibility of the physician • about 68% of the physicians used HFNC instead of CPAP (HFNC was seen more effective with less complications) • failure rate and length of HFNC therapy were deemed as the most important outcome to measure • pediatricians supported the development of national HFNC guideline
Silver et al, 2004 (38)	25 pediatric burn centers	North America	To examine the patterns of pediatric airway management	• North American pediatric burn centers listed by the American Burn Association were invited • no specific MV mode used; PC, SIMV, HFOV, HJFV or combination of different modes were used • large centers used SIMV more than small ($p<0.05$) • large centers usually used cuffed endotracheal tubes compared to small centers
Faroux et al, 2008 (99)	36 centers	France	To determine NIV practices for treating cystic fibrosis	• a total of 36 centers (15 pediatric, 13 adult, 8 mixed) • NIV was used for various purposes, including cystic fibrosis exacerbations,

				lung function, sleep disturbances, insufficient long-term oxygen therapy, or lung transplantation • bilevel was the most preferred mode and nasal masks to deliver therapy
Jenks et al, 2017 (29)	144 centers (neonatal, pediatric and adult ECMO centers)	International; Europe, Southwestern Asia, Africa, Latin America, Northern America, and Asian Pacific	Descriptive cross-sectional 22 item survey	• Described changes in MV strategies, use of tracheostomy, bronchoscopy practices at ECMO centers • Increased extubation at all ECMO centers (27% pediatric, 41% mixed, 52% adult); increase use of bilevel for lung recruitment, bronchoscopy and tracheostomies • MV modes varied across centers, with PC as the most common (95% for all centers, 74.5% in pediatric, 50% in mixed centers) • other MV modes included VC, PRVC, bilevel, CPAP, HFOV, VDR, NAVA and assist control • weaning MV modes varied, with PC as the most common (34% for all centers) followed by bilevel, PRVC, HFOV and manual ventilation • significant variation in ECMO MV modes internationally (even though PC is the most commonly reported) • other MV considerations such as PEEP, rate, initiation of weaning and lung recruitment modes differed =
Blackwood et al, 2013 (100)	One nurse manager from each of the 17 PICU	United Kingdom	To describe clinicians responsible for MV weaning, protocol use and education on MV	• reported the characteristics of clinicians responsible for MV weaning, the use of protocols and automated weaning options and perception on MV management education • 17/28 PICU invited (14 PICU, 3 mixed) • weaning initiation, method, management and assessment were the collaborative responsibility of physicians' and nurses' responsibilities • 35% of the units had MV protocols in place, 18% for weaning, 35% for NIV • 18% used closed loop systems • protocol-directed and close looped systems may reduce weaning time
Tume, Kneyber, Blackwood and Rose, 2017 (101)	65 centers across 19 European countries	Austria, Belgium, Croatia, Cyprus, Estonia, France, Greece, Ireland, Israel, Italy, Netherlands, Poland, Spain, Slovenia, Sweden, Switzerland, Turkey, United Kingdom	To evaluate MV and weaning practices in Europe	• this study described: 1) the responsibility for MV management and weaning; 2) use of protocols, SBT, NIV, HFNC, automated systems; 3) nurse-to-patient staffing ratios and their autonomy and influence in making MV decisions • 65 out of 102 centers responded • >75% physicians and fellows had key responsibility for MV management • guidelines/ protocols were available but uncommon for respiratory management; for MV (31%), weaning (22%), and NIV (33%) • HFNC (53%) and NIV (52%) were

				used often to avoid intubation • SBT were used in 44% of the PICUs • large variability in the interprofessional team involvement and MV management responsibility across the centers
Sward et al, 2017 (31)	122 PICU physicians from 8 PICU	Collaborative Pediatric Critical Care Research network, USA	Survey with 50 clinical scenarios with suggested MV strategies	• assessed the acceptability of the MV strategies outlined in clinical scenarios • about 80% of the scenario recommendations were accepted • acceptance varied by the MV mode: 83% in HFOV, 75% in PC and 82% in PRVC (p=0.002) • PEEP recommendations were the least accepted (69%) • lack of consensus in MV practices demonstrated that a protocol may be necessary for lung protective strategies • though many of the recommendations were accepted, it did not translate to successful implementation/ adherence
Keogh, 2004 (69)	PICU	Australia	Identify weaning practices and staff perceptions to weaning protocol	• This thesis manuscript described a multi-phase study: 1) national survey on the practices of pediatric MV weaning methods; 2) protocol development and pilot study; 3) pre/post protocol interventional study; 4) qualitative study on the staff's perceptions and feedback of guideline use • phase 1: the most common method for pediatric weaning was SIMV with PEEP and PS/ PC • phase 2 and 3: the protocol was trialled, with no significant improvements in outcome measures including length of stay and ventilation time (70) • phase 4: staff responded positively to the protocol as it provided them with a framework and guide to collaboratively wean patients and may have improved clinical outcomes • barriers were clinicians' discomfort and restrictions on their clinical judgement • use of a protocol is meant to guide practices, not to replace clinical judgement

Abbreviations: *APRV-airway pressure release ventilation; CPAP-continuous positive airway pressure; ECMO-extracorporeal membrane oxygenation; HFJV-high frequency jet ventilation; HFNC-high flow nasal cannula; HFOV-high frequency oscillary ventilation; MV-mechanical ventilation; NAVA-neurally adjusted ventilatory assist; NIV-non invasive ventilation; PARDS-pediatric acute respiratory distress syndrome; PAV-proportional assist ventilation; PC- pressure control; PEEP-positive end expiratory pressure; PICU-pediatric intensive care unit; PRVC-pressure regulated volume control; PS- pressure support; RT-respiratory therapist; SBT- spontaneous breathing triarl; VDR- volume diffuse respiration; VS- volume support*

2.3.5 Topic 5- Respiratory Therapists

RTs are health care professionals who assess and provide therapies to support people's breathing, across all age groups, in a variety of practice settings, and in an assortment of diseases (58, 103-105). They are specially trained to provide care in acute and long-term MV, airway management, cardiopulmonary resuscitation, diagnostics, oxygen therapies, and pulmonary rehabilitation (PR) (105-107). Specialized RT driven protocols in acute care have been shown to reduce direct and indirect costs in healthcare (58, 108). Currently, RTs are known to practice in Canada, Qatar, United States of America (USA), Taiwan, China, Philippines, India, Saudi Arabia, Singapore, Liberia, Ghana, Yemen, Puerto Rico, Kuwait and United Arab Emirates (https://twitter.com/MikaRT/status/1298664147010359297?s=20).

When RTs are most responsible for identifying and treating patients on MV (through the use of standardized protocols), patient outcomes improve (109), evidence-based practice and standardization of care is enhanced, and compliance to best-practices and interprofessional teamwork is improved (27, 110-112). RT-driven evidence-based and standardized protocols on MV management have been shown to be feasible and associated with positive patient outcomes (27, 103, 109, 111, 112). RT-driven protocols have been associated with decreases in mean MV duration by 58 hours ($p<0.001$) and hospital length of stay by 1.77 days, compared to historical physician-directed protocols (113). Similarly, Wood et al (114) demonstrated a shorter median MV duration when RTs weaned patients from MV, compared to physicians. This included weaning patients after stable elective and emergency coronary artery bypass surgery, 16.8 vs.18.6 hours ($p=0.02$); and with the addition of patients on intra-aortic balloon pumps, with prior history of cardiac surgery, and cardiac valve surgery: 17.8 vs. 19.7 hours ($p=0.04$), respectively (114). A prospective cohort study with 271 adult patients were weaned by respiratory care practitioners using a weaning protocol, which decreased the median time to wean from 29 days to 17 days ($p<0.001$) (115).

Health professional/allied health directed protocols, particularly by RTs, can decrease duration of MV, length of stay and optimally wean patients from MV (110, 112, 113). Furthermore, RT specialized care through protocols, may reduce direct and indirect healthcare costs and resource allocation by providing specialized care, protocol-directed interventions and decision making (58, 108). Though RT-driven MV protocols have shown success, the majority were performed in the adult population (103, 114, 115). The outcomes of RT-driven protocols

for pediatric MV management is scarce, and one study from the Penn State Children's hospital (219 children, median age 33.7 [IQR 3.5-157.7]) indicated there were no changes in SBT initiation, MV duration, hospital or PICU stay (109). That pre and post protocol implementation study developed a RT-driven protocol to guide SBT screening, initiation and initial PS level. However, although implementation was successful, RTs screened 56.4% of the eligible patients, 30.7% completed the screening within the protocol's timeline and only 42.1% set the PS level as indicated in the protocol. The authors acknowledged that there were difficulties in maintaining compliance over time and poor protocol compliance may have been the reason their RT-directed protocol yielded minimal benefits. Overall, more research is required to understand the impact RT-driven protocols have on pediatric MV management.

2.4 Summary and Conclusions

There is sparse literature informing the best approaches for *standardized and comprehensive* pediatric MV management (17). Much of the evidence was based on adult, neonatal and/or practitioner personal experiences (1, 2). Many trials were small, and described pediatric MV management for single diseases, or smalls component of MV management such as weaning. When protocols were available, compliance was usually low across studies (31, 34, 40, 88). Many of the included studies in literature review were not conducted in Canada. Only two surveys (34, 40), one study in a systematic review (98) and one pilot study (75) were found. Therefore, adherence and impact of protocolized MV in Canadian PICUs less known. Larger clinical studies in the Canadian context are required to understand the impact of standardized pediatric MV management on patient outcomes (8, 34, 40, 75, 98, 102).

In response to the overall lack of standardized and comprehensive pediatric MV practices, the ESPNIC (2) organized a consensus conference for European physicians with expertise in pediatric MV management. The premise of this conference was to collectively determine the best approaches to pediatric MV management for clinical practice and future research. ESPNIC outlined 142 recommendations, which detailed many aspects of pediatric MV management including MV modes, monitoring, targets of oxygenation and ventilation, weaning and extubation (termination of MV) readiness in children with various diseases. ESPNIC were the first group to establish consensus recommendations on the many components of pediatric MV management, across different disease groups. The consensus conference found insufficient

to no evidence on all aspects of MV weaning and extubation processes for critically ill children. This led the group to challenge healthcare providers to "embark on local or global initiatives to fill this huge knowledge gap" (2). Additionally, the authors repeatedly mentioned the need to minimize variability in practice to facilitate the understanding of their impact on clinical outcomes. Standardized protocols for overall pediatric MV management across a wide range of diseases would support this cause.

ESPNIC were the first to outline comprehensive recommendations for many aspects of pediatric MV management across many disease states. These were based only on European physician expertise. Reinforcing the recommendations outlined by ESPNIC with Canadian RT expertise, may expedite the standardization of pediatric MV practices in Canada. This may enhance clinical practice by minimizing interventional variability and help inform future studies to understand their impact on patient outcomes.

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Chapter 3- Delphi Methodology

3.1 Introduction to the Delphi technique in Health Sciences

The Delphi technique was originally developed in the 1940s, and has been modified over the years to satisfy the unique goals of different disciplines, but its overall purpose remains the same (1-4). In health sciences, this technique is used to identify, discuss and guide future health approaches in the areas with unknown or not well supported evidence (5-8). It is important to use empirical evidence to guide medical practices and education but not all questions can be answered by conventional quantitative research methods (2, 9). The Delphi can be used to understand and establish guidelines and priorities in speciality practices (e.g. mental health, palliative care, critical care), predict disease patterns, direct nursing education, and standardize practices and policies (2, 7, 10, 11). Other applications of the Delphi technique include diagnostic criteria development, indicators for medical quality, assessment for medical interventions, and establishment of research agendas (12).

The Delphi technique utilizes a series of surveys, referred to a Round, to gather controlled feedback from a group of participants, identified as experts in the field (13). The process generates ideas and seeks consensus from these experts to resolve problems or clarify information (1, 2, 14). Details of the process is outlined in Sections 3.4 Preparing for a Delphi Survey and 3.5 Sequential steps of the Delphi survey. This chapter aims to provide the background information about the Delphi survey technique; the specific application of this technique to the outlined study are described in Chapter 4– The Pediatric Mechanical Ventilation in Canada (PeMViC) Study: A Delphi Survey of Pediatric Mechanical Ventilation Practices by Canadian Respiratory Therapists.

3.2 Other Consensus Methods

The consensus conference, nominal group technique, and the Research ANd Development (RAND) / University of California, Los Angeles (UCLA) appropriateness method are several other consensus methods that aim to generate new ideas, problem solve or collaboratively form solutions in topics lacking sufficient data (15, 16). Each technique builds consensus differently, yet they share fundamental features including some level of anonymity, systemic controlled feedback, and statistical group responses (15).

However, these consensus groups have several disadvantages compared to the Delphi technique such as requiring their participants to meet face-to-face to discuss ideas, risking the influence from dominating individuals on the final consensus (5, 15, 16). These methods have a

similar challenge in organizing real-time meetings, which require extensive resources to be executed properly (8, 12). In contrast, the Delphi technique allows non-synchronous consensus building process, which is convenient and require minimal resources (2, 9, 10, 14, 15, 17). Participants in a Delphi are anonymous to each other, which also minimizes the risk of influence from other members during the consensus building process (1, 18, 19).

3.3 Types of Delphi surveys

The Delphi technique has been modified to improve its applicability to different disciplines and to satisfy different research goals (2, 3). The various types of Delphi techniques are Classical, Modified, Decision, Real-time, Policy and Argument Delphi surveys (1, 2, 5, 20). Two common Delphi methods in health sciences are the Classical and Modified Delphi technique, which differ by the structure of their Round 1 (2, 17, 21).

3.3.1 Classical method

Round 1 in the traditional Classical Delphi method is unstructured and seeks feedback using open-ended questions (6, 21). The purpose and open-ended questions must be clear to help participants provide targeted information, and avoid vague, broad responses (1). Participants are invited to freely provide their ideas and opinions drawn from their knowledge and personal experiences (2, 10, 17). Unfortunately, this approach can be time consuming because it usually produces a large amount of unstructured raw data for review and analyses (1, 14).

3.3.2 Modified method

In a modified Delphi, Round 1 does not follow the same open-format as the Classical method (3, 7, 14, 22). Instead, the research team specifically identifies the issues or topics to include in the survey prior to asking the experts to review and comment (2, 14, 17). The data collected is qualitative, focused, and minimizes large volumes of data (compared to the Classical method) (1, 2, 18). The content of the survey may be generated in any of the following ways (1, 14):

- From existing literature or documents
- Focus groups, or
- One-to-one structured interviews

Unlike the Classical method, this approach helps experts orientate to the available data and researchers to analyze and interpret reasonable volumes of raw data (1, 21). Although this minimizes the volume of data, researchers must be aware that this method may limit response options and introduce researchers' bias (1, 6).

3.4 Preparing for a Delphi Survey

An official guideline to prepare and run a Delphi survey do not exist, but there are several notable factors to consider when preparing for one (2, 17).

3.4.1 Outlining the Purpose of the Delphi technique

One must evaluate whether the Delphi technique will answer or fulfill the intended research objectives (2, 17, 23). A Delphi survey may be considered over other consensus methods when there are geographical constraints and resource limitations (10, 24). The Delphi technique should be considered when the purpose(s) includes any of the following: 1) to explore or generate information about a topic; 2) to seek information and establish consensus; 3) to expose and educate diverse views of participants; and/or 4) to generate expert opinions or recommendations on a topic with limited empirical data (1, 2, 6, 11, 14, 17, 22, 25). The Delphi technique is recommended and commonly used for the development of practice guidelines, especially in healthcare, when evidence for standards of practice are limited (16).

3.4.2 Resources for Delphi survey

The resources required to smoothly run a Delphi study will depend on the sample size, the participants' characteristics, the complexity of the Rounds, and the research team's skills (2, 18). Access to appropriate, qualified participants is necessary in a Delphi study. Depending on the purpose of the Delphi survey, the participants involved may be individuals who have extensive background knowledge or personal experience on a topic, or are from the general public (1, 13). Researchers must explicitly outline the desirable characteristics prior to recruitment and ensure participants understand the purpose of the study (1, 2, 14, 24). To identify and recruit the most suitable participants, see Chapter 3.4.3 Target sampling/ Panelists.

An individual acquainted with the process usually maximizes the study's success because they provide valuable insight, and can address any complications that may arise (2, 17). However, regardless of how experienced a researcher may be, improper management or analysis

of the data will threaten the success and integrity of the study (13, 17). Therefore, it is crucial to establish a detailed monitoring system to oversee the communication, responses, and data analysis of the study (2, 13).

The time required to run a Delphi survey, is usually underestimated, but with the popular use of electronic platforms, distributing Delphi surveys are easier (2, 10, 24). Technology and online resources facilitate quick communication, and saves time and costs (10, 14). Participants need adequate amounts of time for each step of the Delphi study to ensure quality results and good response rates (1). Timing required during a Delphi survey is further discussed in Chapter 3.6.2 Limitations.

3.4.3 Target sampling/ Panelists

One of the unique features of the Delphi technique is the panel of experts. The term *expert* is liberally used, as it is defined as any individual with the understanding, knowledge, experience and skills related to the topic being investigated (1, 24). Because the literature does not provide an absolute definition of an expert, researchers should identify their target participants by outlining a list of eligibility characteristics prior to the start of the study (2, 6, 10, 14). The literature suggests recruiting individuals with an assortment of characteristics and experience to maximize heterogeneity within the panel to yield high quality results (1, 6, 11, 21). Credible experts with variable backgrounds will generate a wide range of information compared to homogenous panels, and less credible experts will raise concerns on the validity of the consensus (2, 6, 13, 22). In clinical science, there should be considerations of the individual's scientific credibility, work experience, knowledge and influence in the field of study (6, 24). Therefore the expert panel must be purposefully sampled, using a variety of techniques such as non-random sampling and snowballing technique (2). The size of the expert panel varies greatly across studies, ranging from as little as five, up to a few hundred (1, 14). The literature does not provide an ideal number of participants to include, but suggest over 30 may be excessive (2, 18, 24). Larger sample sizes may increase the heterogeneity but are hard to manage and likely to experience higher attrition rate (16, 18). In comparison, small sample sizes may be easier to manage but may not be representative of the discipline's collective judgements if recruitment is restrictive (14, 22). It is recommended that researchers recruit 15 to 30 participants from the same discipline or include 5 to 10 participants from each discipline when considering a

multidisciplinary panel (16, 18, 22).

In summary, the researchers are responsible for defining the characteristics of their expert panel and how many should be included to satisfy the purposes of their Delphi study (12, 14). Emphasis should be placed on the quality of the experts (to enhance group representativeness) instead of focusing on the sample size (6, 11). Additional factors such as the study's aims and resources should be considered when deciding the number of experts to include (7, 10, 16). It is best to recruit a manageable size of well-informed individuals to ensure feedback quality, while minimizing attrition (6, 10, 13).

3.4.4 Defining Consensus and Stability

The fundamental objective of using a Delphi study is to determine the level of agreement on a topic or problem, amongst experts in a field (4, 14). Currently, a universally accepted definition of consensus does not exist and are measured differently across studies (21, 26). Some studies do not explicitly state what constitutes consensus, and leave it to the readers' interpretation (6). However, it is recommended that prior to survey initiation, the definition of consensus is distinctly defined (2, 17, 20). This is done by statistically analyzing the convergence of opinions from the Likert responses in the quantitative Rounds of the Delphi study (22).

Although the definition of consensus is not always reported in studies, the percentage threshold is the most common method (6, 14, 27). The percentage threshold will rely on the importance of the research question (21). Many studies use percentages with thresholds ranging from 50% to 100%, with 70 to 75% agreement as most common (1, 22, 27). For example, when using a 70% cut-off, consensus is achieved when greater than 70% of the participants vote on a particular rating on the Likert scale (2, 14). A consensus level of approximately 70% is reasonable and is usually within one standard deviation of the mean of all responses (21, 24).

For other studies, a percentage level may not be sufficient (14, 28). Measures of central tendencies and dispersion are the next commonly reported measures of consensus, and showcase the distribution of scores collected (2, 3, 14, 22, 26). The mean represents the participants' collective stance on the Likert scale score, and a small standard deviation (minimal dispersion around the mean), supports the certainty of consensus (18, 27). The combination of the median and interquartile range is just as popular in Delphi studies; they are considered rigorous and objective, and are not skewed by outliers (26).

Additional statistical analyses may be performed to determine the responses' confidence and stability as measurements for reporting consensus (14). Group stability occurs when there are no significant differences between responses across the Delphi Rounds (14, 26), and can be measured using parametric or non-parametric statistics (26, 28-30). In surveys with over 30 participants and normally distributed data, parametric measurements such as the coefficient of variation, F-ratios, Pearson's correlation coefficient or paired t-tests across two consecutive rounds may be measured (28, 29). When data is collected from less than 30 participants or is skewed, non-parametric tests such as McNemar change test, Spearman's rank correlation coefficient, Wilcoxon paired signed ranks t-test (Mann-Whitney U test), could be considered to analzye categorical and ordinal data (23, 28). The use of these categorical analyses may provide relevant information about the differences in subgroup opinions (18).

There is no preferred method to determine consensus, and various measurements are reported across different studies (1, 2, 14, 27, 28). Given the flexibility of the Delphi technique, it is possible for investigators to consider a combination of statistical analyses when exploring their data, in order to thoroughly assess for possible patterns or explanations (1, 18). The Delphi technique is utilized for a broad range of topics and disciplines; therefore, a widely accepted consensus definition is not possible. Regardless of which statistical analyses are used, it is recommended the method used to measure consensus, is decided prior to initiating the study and suits the research question (1, 14, 21).

3.4.5 Administration and Informing the Panel

Delphi surveys may be distributed through the post, or preferably, using an electronic platform (10, 22, 24). Once the participants are identified, a formal information sheet detailing the research objectives, time commitment, instructions for each Round and the value of their opinions, is recommended (2, 10, 17). Informing participants is an important step as it will help them understand the goals of the study and build a rapport to enhance response rates (17). The key is to maintain constant communication with the participants, as participant retention is crucial in the Delphi technique (10, 17).

3.5 Sequential steps of the Delphi survey

3.5.1 The Pilot Test and Round 1

The type of Delphi method used will determine the contents of the survey nature of Round 1's format. Whichever type is used, the contents of the survey for Round 1 should be piloted in a smaller group of experts (2). A pilot test is optional, and are not consistently reported in studies or performed. (2, 24) However this step is essential as it trials the potential survey and identify ambiguities in the process. This allows researchers to improve on its feasibility and clarify the questions to decrease the risk of study problems, and improve content and face validity (2, 6, 11, 24).

Once the survey contents are finalized for Round 1, it may be distributed to the expert panel for review and feedback. It is important to engage with the participants to ensure they understand the importance, purpose and timeline of the study (10). Regardless of the type of Delphi used, the intention of this Round is to collect open response feedback that will inform the contents of the subsequent Rounds (2, 14, 16, 17).

3.5.2 Round 1 and analysis

The amount of data produced from Round 1 can be large, especially when using the Classical Delphi approach (21). Ideas and feedback are reviewed, categorized, condensed and cross-referenced based on key terms and recurring ideas (10, 14, 17, 22). Reviewing and summarising the information is crucial; avoiding this step will lead to an excessive number of statements (21). The content analysis can be performed manually by designated members of the research team, or with software such as NVivo, Ethnograph or Nud*ist (10, 17). Round 1 results will highlight the important ideas from the panel, and will guide the construction of the questionnaire for subsequent Rounds (1, 6).

3.5.3 Round 2

Rounds following Round 1 are specifically structured to collect quantitative data by using a ranked scale, usually a Likert scale (2, 10). The purpose of this Round is to confirm the accuracy of the results obtained from Round 1 (1, 10). To ensure participants understand, they receive an information sheet for Round 2, detailing the purpose and process (2). Participants are asked to rate their level of agreement or disagreement using the rating scale for each item on the survey (2, 21).

Round 2 Analysis

The statistical analyses for Round 2 will depend on the research question and methods chosen. For example, ratings from Round 2 can be inputted into a statistical software for data analysis (2). Each item is evaluated for convergence of responses, and other statistical information including frequencies, measures of central tendency and dispersions (22, 24, 26, 28). Consensus for an item is reached once it reaches the decided threshold (Section 3.4.4 Defining Consensus and Stability) (1, 3, 14).

For the statements that have reached consensus, the researchers may choose to either remove or keep the statements for subsequent Rounds (1, 2, 24). Clear criteria on omitting and combining items across Rounds must be outlined before initiation and well-documented throughout the study (2). Maintaining all items for future surveys, may help all items gain the highest possible level of consensus (2). However, eliminating items when consensus is reached shortens the survey for subsequent Rounds, and minimizes participants' fatigue (2, 24).

3.5.4 Round 3 to n Rounds

Rounds subsequent to Round 2 follow the same format (2, 14). The purpose of Round 3 is for participants to review opinions from the previous Round (based on a summary of the statistical results) (2, 10, 14, 24), and to keep or reconsider their answers (14). This is an opportunity for participants to clarify information and explain why their responses may have fallen outside the consensus range (14, 22). The data analysis for Round 3 (and the Rounds following) is identical to Round 2 (2, 14).

The total number of Rounds for the Delphi survey is based on the main research objective, and the degree of consensus desired as early termination may yield meaningless results (2, 14, 17). Often it is terminated when all questionnaire items reach consensus; however, this may not be feasible due to limited resources, time and increase participants' fatigue and attrition (2, 7, 10, 25). Traditionally, the Delphi technique consisted of 3 to 4 Rounds, but over the years, 2 to 3 Rounds were deemed sufficient (17). To minimize fatigue, many studies have opted to terminate the study after 2 to 3 Rounds, even if consensus is not reached on all items (7, 10).

3.5.5 Completing the Delphi study

There may be items in a Delphi survey that do not gain consensus. Different statistical analyses and thoughtful review should be considered to evaluate and understand the reasons why (14, 27). If consensus is achieved on all items, it does not mean the results are the final solutions to the original research question or issue; a Delphi survey does not replace scientific studies (21). The results from Delphi studies are the sum of the available evidence and research data, aimed to direct future research and discussions (7, 17, 21, 22).

3.6 Benefits and limitations of using Delphi

3.6.1 Benefits

There are several advantages associated with using a Delphi technique. This technique is a flexible and cost-effective way to generate information from a group of experts for the unique purposes of each study (3, 10, 18, 22). The Delphi can also be time-efficient, since most questionnaires are now distributed and managed with electronic tools, which facilitates data collection and communication (2, 10, 14).

The Delphi technique minimizes biases and group think as participants respond anonymously, and have considerable amounts of freedom to express their opinions and explore new ideas without embarrassment or scrutiny from their colleagues (3, 7, 10, 14). Though anonymous to each other, the Delphi technique as a whole is quasi-anonymous because the researchers are able to see all responses from all participants (13). This feature ensures accountability and scientific merit because it allows researchers the opportunity to follow up with participants to clarify responses or gather more data if necessary (6, 22, 31). However, it is crucial to remember that the consensus derived from a Delphi survey is specific to that specific group of experts during that period of time (13).

3.6.2 Limitations

Lack of universal guidelines

While the Delphi technique can be modified to meet unique purposes, this feature is considered a weakness as well (21, 24). The lack of scientific or universally accepted methods threatens the technique's methodological rigor and validity, especially when poorly managed (3, 10, 20, 24). Variations can occur during participant selection, when consensus definitions are established, in the number of Rounds, and during reporting. To address this issue researchers can

utilize methods journals or logbooks to monitor and manage the study, and to preserve its integrity (4, 6).

Participants

The definition of expert is often ambiguous; the criteria for experts can be broad or specific. As a result, researchers' bias can influence the panel selection, affecting who and how many participants are recruited (2, 7, 12, 17, 21). This limitation has led to several debates on the validity of professional opinions (6, 17).

Another disparity across studies is the size of the panel. Some have suggested a minimum of 10 participants is ideal, but some studies have included up to a few hundred (1, 14). Including over 30 participants may not improve results, as larger groups are harder to manage and may result in higher attrition rates (1, 10). Sample size should be dependent on the characteristics of the involved participants, as the goal is to include participants that are not only qualified, but representative of the larger population (31).

Lack of complete anonymity

The Delphi technique is quasi-anonymous, which may increase the risks for participant and researcher bias (13, 21). Since the recruitment is selective, participants may refer acquaintances to participate in the study, making it difficult to maintain anonymity amongst the participants (17). Thus, true anonymity is not guaranteed and may potentially influence participant responses to conform with the group majority (21).

Participants are also identifiable to the researchers, allowing them to follow-up with participants to enhance response rate, and clarify any ambiguities (2, 14). However, researchers are in an influential and powerful position, which may cause participants to feel pressured into completing the surveys (13, 24). And the quasi-anonymous feature may be a concern and risk for participant's privacy and confidentiality.

Achieving Consensus

Consensus is not universally defined, and it is the researchers' responsibility to decide which method is the most appropriate for their objectives (14, 21, 24). It is recommended that the consensus threshold is defined *prior* to data collection, and clearly reported in publications, though this is not exercised in all studies (6, 27).

The Delphi survey has been criticized for "forcing consensus" or "molding of opinions" (7, 14). The Delphi survey reduces opportunities for participants to discuss their ideas, which may lead them to rely on group results to inform their opinions (17). Some experts may actually change their responses to conform with consensus instead of conveying different and valid issues (22, 24).

Resources

Organization, time and resources are required to efficiently and properly execute Delphi studies, but descriptions on the time and dedication required to run them is underreported and underestimated (2, 17, 22). Although electronic platforms minimize many of the traditional costs such as paper copies and postage fees, virtual subscriptions and other expenses may be required to ensure smooth administration (2, 13). Furthermore, ongoing attention and time commitments from both the participants and researchers are required (1, 3). It is recommended that a minimum of 45 days is set aside to complete the Delphi survey, with two weeks in between Rounds (14, 22). If there are large quantities of statements, it will increase the time required to revise and analyze. More time may be required to follow up with non-respondents and to adequately analyze the data in between Rounds (13). Increasing the time required to complete the Delphi survey, may affect participants' motivation and response rates (14, 24). In addition, the continuous repetitiveness and isolation from other participants may induce frustration (1, 24). Thus, it is important that the required time commitment, purposes, and study protocol are explicitly explained to participants prior to study initiation (2).

Response Rates

There are several factors that may increase the risk for low response rates (14). This includes the complexity and number of Delphi Rounds, prolonged turn-around times between Rounds, or large groups of participants (causing attrition) (10, 22). Response rates for Delphi surveys have ranged widely between 8% to 100% (1). Low response rates are undesirable and will jeopardize the quality of the results; therefore, striving for the highest possible response rate will support the survey's validity (10, 14). It is suggested that at a minimum 70% response rate is required to safeguard content validity (20). Section 3.7 Addressing Attrition describes important ways to maximize response rates.

3.7 Addressing Attrition

The Delphi technique may have issues with attrition if the process is time consuming, causing participants to fatigue and withdraw from the study (3, 24). This will introduce non-response bias into the data (31). There are several factors that can be incorporated to minimize attrition, summarized in Table 7.

3.7.1 Factors to Consider When Designing the Delphi study

As described in Section 3.4.3 Target sampling/ Panelists, large numbers of participants can be difficult to manage and are prone to high levels of attrition (7, 11, 24). Researchers should personally engage with a small group of 15 to 30 participants (18). A manageable panel size will also allow researchers to personally convey information and instructions, and to emphasize the goals and importance of the study (10, 17).

Running a Delphi survey can take substantial amounts of time, especially if there are many statements in the survey for participants to review (14). Participants should be made aware of the expected time requirement, and the importance of their involvement (10). Researchers must also be considerate of work and personal schedules by allowing flexibility on how and when participants complete Rounds (2). To decrease the length of the questionnaires, and the amount of time required to complete them (14), researchers may consider removing items (that have received consensus in prior Rounds) in subsequent Rounds (1, 24). Researchers can compensate participants for their time with a small token (e.g. gift card) and/or participation certificate (2).

Another consideration when designing the Delphi study is the type of data-collecting and analysis tools (10). Electronic tools are recommended, as they efficiently collect data and distribute data to minimize delays (1, 10, 14). Online survey platforms can quickly deliver and gather data from participants, and statistical software can facilitate quick data analysis (10).

3.7.2 Factors to Consider During the Delphi study

Throughout the study, researchers should continuously engage with the participants to maintain their interest and provide encouragement (2). Time limits should be enforced during and between Rounds, to prevent unnecessary delays (20). It is important that participants do not feel pressured, to avoid introducing involuntary biases (2, 13). Table 7 lists several strategies to support the participants and minimize non-response.

Table 7: Methods to minimize attrition.

Strategies to minimize attrition (2, 10, 14)**:**
• Limited the number of Rounds, 2 to 3 is sufficient and will minimize fatigue • Provide clear explanations of the Delphi process, describing the expectations of commitment and feedback process • Obtain written consent or intent to commit • Develop personal rapport with participants • Respond to questions or concerns • Ongoing communication, incentives and continual reminders • Quick turnaround times for data collection to maintain interest • Conduct study around participants' work and holiday schedules • Communicate the importance of individual's contribution to the research results • Clearly indicate the time commitment and the expected deadlines • Motivate and acknowledge participation with incentives/ compensation

3.8 Conclusion

The Delphi technique is a widely used consensus method to establish priorities, and define and clarify practices and information when there is limited knowledge on a topic (1, 7, 18, 19, 22). Distinguishing features of the Delphi technique include the use of a diverse expert panel, anonymity between the participants, cost-effectiveness, flexibility, and convenience (14). Limitations associated with its use include, lack of universal guidelines for the methods and panel sizes, and varied "expert" and consensus definitions (2, 14). It is the researchers' responsibility to ensure all precautions are in place to enhance validity, reliability, credibility, dependability, transferability, confirmability and ethics (13, 20). The Delphi survey provides valuable knowledge and ideas to inform future practice and research in health sciences and medicine, especially when rigorous techniques are applied (17).

3.9 References

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Chapter 4– The Pediatric Mechanical Ventilation in Canada (PeMViC) Study: A Delphi Survey of Pediatric Mechanical Ventilation Practices by Canadian Respiratory Therapists

4.0 Abstract:

Background

Currently, there is a gap in knowledge for pediatric mechanical ventilation (MV) management due to the ethical liabilities, variability in size, maturity and underlying conditions in children. Standardization of pediatric MV management is difficult because practices are often adopted from clinical experience and/or data from the neonatal and adult populations. Although protocols and guidelines are available, they vary across centers and are not always integrated into the practice culture. Inconsistent MV management may be associated with adverse events.

The European Society for Pediatric and Neonatal Intensive Care (ESPNIC) established consensus recommendations on many aspects of pediatric MV management from the perspectives of European physicians. In Canada, respiratory therapists (RTs) are considered to be one of the experts in MV management, and they do not exist in Europe.

Research objective

The purpose of this study was to determine Canadian RTs' recommendations on common pediatric MV management, based on the European (ESPNIC) consensus guidelines.

Method

A Modified e-Delphi Survey Technique was used. The contents of this Delphi study were based on the published ESPNIC recommendations. The 142 recommendations that reached *strong agreement* were individually reviewed by three research team members, including a pediatric RT content expert. Recommendations that were relevant to Canadian RT practices, specifically to acute MV therapy management, were included for the survey. Statements that did not provide practice recommendations were excluded, and the subsections of chronic MV/ congenital diseases and lung hypoplasia syndromes were omitted. The included recommendations were reviewed, regrouped and revised into 10 different subtopics for the Delphi survey.

The expert panel consisted of RTs with ≥5 years, working at pediatric acute care facilities or centers with dedicated pediatric beds across Canada (recruited from national and provincial registries and by snowball sampling). Research Electronic Data Capture (REDCap) was used to collect demographic information and data from participants.

Prior to Round 1, a pilot trial was conducted with three expert RTs to review and finalize the contents of the survey. For Round 1, participants provided open-text feedback for each of the statements in the survey. The feedback from Round 1 were reviewed and incorporated into the statements for Round 2. In Round 2, participants ranked their level of agreement or disagreement using a 5-point Likert scale. Statements that received significant feedback on its content or *did not* receive consensus in Round 2 were reviewed and rephrased for Round 3. The remaining statements that achieved consensus were not included for Round 3. In Round 3, participants reassessed and ranked their level of agreement using the 5-point Likert scale on the 11 statements.

Data Analysis

Three study personnel discussed and revised the statements to reflect participants' feedback prior to finalizing the survey for Round 2. The Likert scale responses from Round 2 and Round 3 were categorized into three groups: disagree, no opinion, and agree. Raw scores with ≥75% of participants in a categorized group were considered as consensus and verified using the coefficient of variation (CV). The Wilcoxon Signed Rank test and CV difference were performed to measure the differences between Round 2 and 3. Descriptive statistics was completed using IBM® SPSS Statistics and Microsoft Excel.

Results

N=56 (41 females/ 14 males, 1 unreported) participants from 15 different Canadian pediatric acute care facilities or hospitals with dedicated pediatric beds were enrolled into the study. RT participants had an average of 15 years of PICU experience, and were in various positions including: clinical supervisor, practice/ team leaders, clinical educators, core PICU staff, rotating clinical staff, transporters and ECMO specialists. After the pre-Round 1 and pilot work, Round 1 survey had 53 statements. After Round 1, some statements were modified and five were added. The finalized Round 2 survey had 58 statements. After Round 2, three statements did not reach consensus and were modified. Significant feedback for seven statements were identified and revised, and one additional statement was added. All 11 modified statements in Round 3 reached consensus.

Conclusion

This guideline consists of 10 sections, 1) *Non-invasive ventilation*, 2) *tidal volumes and inspiratory pressures*, 3) *respiratory rate and inspiratory time*, 4) *PEEP and FiO_2*, 5) *Advanced Mechanical Ventilation*, 6) *Weaning*, 7) *Physiologic Targets*, 8) *Monitoring*, 9) *General MV practice* and 10) *Equipment adjuncts*, for a total of 59 recommendation statements. These commonly practiced pediatric MV techniques were based on the perspectives of Canadian pediatric RT experts and reached consensus by Round 3. These recommendations can be used as a foundation for other pediatric MV health care providers, and to inform standardized protocols to help minimize interventional variabilities in future studies. This may reinforce our understanding of the clinical impacts of MV in critically ill children.

4.1 Introduction

MV is a life-sustaining therapy used to assist children's breathing when they are unable to (1-5). However, prolonged MV is associated with adverse events (AEs), including ventilator-induced injury, pneumonia, and sedation complications (1, 3). Research in critically ill children is scarce and is complicated by the fact they vary greatly in size, maturity and underlying conditions (6, 7). Collectively, these factors make it challenging for pediatric clinical studies to thrive, which leads to knowledge gaps, and decreased external validity. The European Society of Pediatric and Neonatal Intensive Care (ESPNIC) reported that there is insufficient to no evidence available on all aspects of MV weaning and extubation processes for critically ill children, with most clinical practice based on personal experience or adult data (8). This group challenged "everybody involved in paediatric mechanical ventilation to embark on local or global initiatives to fill this huge knowledge gap" (8).

Clinical practice guidelines or protocolized procedures are generally evidence-based and allow for systematic application of various health interventions, thereby reducing variability, and delays in care (9-15). A systematic review and meta-analysis of MV weaning (two of 16 trials included children), reported a decrease in MV duration and intensive care unit (ICU) length of stay (LOS) when there was a protocol in place to minimize practice variation and emphasize objective decision-making (9). Similarly, another systematic review reported that protocolized weaning may decrease MV duration, PICU LOS, mortality and adverse events (1). Several other studies on MV report reduced AEs and improved clinical outcomes when standardized protocols or guidelines were implemented (9, 16, 17). Unfortunately, much of the evidence describes only *one* aspect of MV management (e.g. weaning, non-invasive ventilation, or high flow oxygen therapy) (1, 9, 16, 18), or include children with one disease or disorder (e.g. acute respiratory distress syndrome) (4, 19-25). The variability of MV practices, and limited trials with children, make it difficult for researchers and health care providers to determine which methods are best practice (6-8). A standardized guide or protocol for overall MV pediatric management across a wide range of diseases may help minimize practice variability, improve safety, and have a positive impact on clinical outcomes (1, 8).

To address the knowledge gaps and help inform standard practice, the ESPNIC developed consensus recommendations for pediatric MV (8). It detailed all aspects of pediatric MV including ventilation modalities, monitoring, targets of oxygenation and ventilation,

weaning and extubation readiness in children with various diseases. These recommendations were developed and scored by a panel of 15 European physician experts and may have limited applicability in the Canadian practice setting. Furthermore, RTs have a large clinical role in MV management in Canada, but they do not exist in Europe. RTs (75% working in critical or acute care) are rigorously trained in all aspects of respiratory care, especially MV management (26-29). Studies have shown that RT-driven MV weaning protocols have significantly reduced duration of MV and ICU LOS compared to physician directed MV weaning (12, 13, 30, 31). This knowledge gap in RT specific pediatric MV management can be explored with the use of a Delphi study, using the ESPNIC consensus recommendations as the content foundation. The expert panel would consist of RTs (instead of physicians) in institutions where they have a significant role in pediatric MV management. Their feedback will further increase the scientific merit of the recommendations and may identify differences in Canadian practices.

This study will be the first step in the development of standardized pediatric MV practices in Canada. It will develop pediatric MV consensus recommendations from the perspectives of Canadian RTs with expertise in pediatric critical care. These recommendations can then be used as a foundation in all Canadian pediatric critical care centres by incorporating the perspectives of each centre's unique culture, including other members of the clinical team, and patients and caregivers.

4.2 Methods

4.2.1 The Delphi Technique

A Delphi survey is a systematic consensus method that collects experts' opinions on a particular topic when there is limited data or knowledge (32-34). There are several different types of Delphi, with the Classical and Modified as the most common in health sciences (32, 35). These two differ by how the contents for Round 1 are finalized; the Classical Delphi uses a series of broad questions about a topic in Round 1 to collect responses to inform the subsequent Rounds, whereas the Modified Delphi uses existing literature, focus groups or interviews to develop statements in Round 1 to minimize large volumes of qualitative data (34, 36, 37). This study adopted the Modified format, as the ideas explored in the subsequent Rounds were based on ESPNIC recommendations.

Experts are individuals with the understanding, knowledge, experience, credibility, and

skills related to the topic being investigated (32, 34, 36-39). Experts are chosen based on specific criteria outlined by the research team, and by considering the research objectives and topics of interest (36, 38). The quality of the results relies on the traits of the experts, as less credible experts will impact the validity of the consensus and collected data (34, 40).

The Delph Technique is based on the impression and belief that combined intelligence is superior and reliable, compared to individual, anecdotal experiences (33, 39, 41). It utilizes a series of surveys, referred to a Rounds, to gather controlled feedback from a group of participants, identified as experts in the field (42). The process generates ideas and seeks consensus from these experts to resolve problems or clarify information (32-34). It is cost-effective, especially when there are geographical constraints (33, 43), and it is administered electronically (electronic Delphi [e-Delphi]) (34). Participants are anonymous to other participants, which limits the influence or judgement of their peers (33, 39, 44).

There are gaps and inconsistencies in pediatric MV management evidence, making the Delphi method an appropriate consensus approach for this study (33, 39). As RTs are one of the experts in MV management, RTs working at pediatric facilities would provide valuable feedback and information for the topic of interest. In addition, the wide geographical distribution of centres across Canada makes an e-Delphi survey cost-effective and ideal way to manage the data collection (33, 34, 43).

4.2.2 Study Design

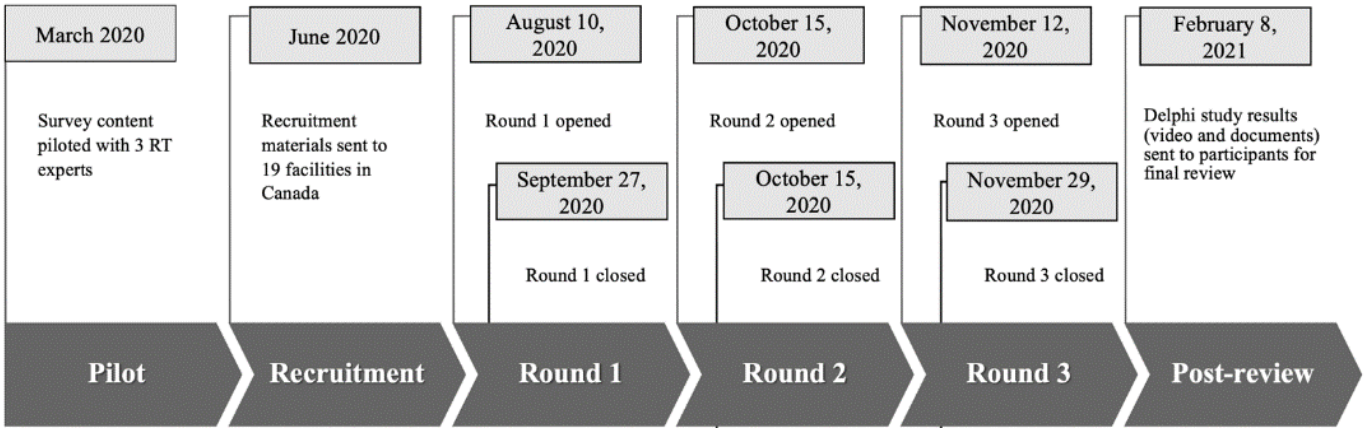
A three-Round Modified e-Delphi survey was performed (33, 34, 39). For all Delphi survey Rounds, Research Electronic Data Capture (REDCap, licensed by the Hospital of Sick Children [SickKids]) was used to collect the results for each round (45). REDCap provided participants the option to return to their survey using a "return code", if they were not able to complete it during one sitting. It also recorded where in the survey a participant stopped, and when it was completed. These features made it possible for partially completed surveys to be included in the analyses. Other employed methods to maximize response rates in this study included open communication, participant engagement, and individualized email reminders (32, 34, 37, 42, 43). This study was approved by the SickKids and Ontario Tech University research ethics boards (#1000064842 and #15636 respectively).

Expert Participants

The experts in this study were pediatric RTs, working in Canada. For this Delphi study, an *expert* was defined as an individual who fulfilled the eligibility criteria for inclusion. The inclusion criteria was any RT who: 1) was a registered RT with a regulatory body in Canada; 2) had at least 5 years of pediatric critical care experience; 3) worked at a facility with either a stand-alone pediatric unit or dedicated beds; 4) had experience in leadership, either as staff involved in leadership activities (e.g. involved in policy/ procedure reviews, orientating new staff) and/ or are in leadership positions, including but not limited to practice leaders, clinical educators, supervisors, managers, or senior staff; 5) provided written consent; 6) was fluent in English (reading and writing). The exclusion criteria were anyone who were: 1) a student or graduate RT; 2) primarily working in adult or neonatal critical care; 3) primarily working in non-critical care units or facilities, e.g., long term care, diagnostics, sleep, rehabilitation. Pediatric critical care was defined as the practice of providing specialized intensive care treatments, including MV to manage acutely ill children with life-threatening conditions or diseases (3, 46, 47).

In Canada, there are 15 pediatric hospitals with stand-alone pediatric critical care units and seven hospitals with dedicated pediatric care beds (48). The goal was to recruit one RT-expert from each pediatric hospital for a minimum of 15 participants (34, 49). With the assistance of the Canadian Society of Respiratory Therapy (CSRT), a list of RTs in leadership positions from across these different facilities, and their contact information, was used as our sampling frame. All individuals on the list provided consent to the CSRT for release of this information. Additional names were obtained from publicly available hospital registries. We were able to get the contacts from 19 out of the 22 facilities (see Supplementary table 2 for full list of centers). All RT leadership teams who were contacted, responded to our request, and forwarded the recruitment poster and consent form (Chapter 8.3- Recruitment materials) to their respective RT department. The recruitment poster and study information were also posted on the CSRT members' professional practice forum. Recruitment began in July 2020 and officially closed once Round 2 ended on November 3, 2020 (for the study timeline, please see Figure 3).

Figure 3: Study timeline, from the Pilot to Post-Delphi review phase.



Participants were compensated for their time and dedication to the study with a gift card and CSRT continuing education/ continual professional development credits.

4.2.3 Delphi Survey Content

The contents of this survey were derived from the ESPNIC consensus guidelines (8). These guidelines included 152 recommendations on various topics, with 142 receiving *strong agreement* from their expert panel. We reviewed, re-grouped and condensed (amalgamated similar items and topics) these 142 recommendations. Statements of clinical importance and relevance within Canada and RT practices were included (as determined by study team). Statements that did not provide practice recommendations, and/or address MV management for children not acutely ill were excluded e.g. chronic diseases such as lung hypoplasia or neuromuscular diseases. A total of 53 recommendations remained for the Delphi survey.

4.2.4 Pilot survey

The research team finalized a draft for Round 1 in March 2020. This was pilot tested by three pediatric RT experts, with over 5 years of critical care experience at SickKids. Feedback from this pilot Round was used to amend the content and wording of the recommendation items before finalizing the survey for Round 1 (8.6- Round 1 survey).

4.2.5 Round 1

Expert participants reviewed and reflected on all 53 recommendation statements based on their personal practice and experiences, using free-text comments and feedback. They did this for statements they felt could be improved, or they disagreed with. If the participant agreed with the recommendation statement, no feedback was required.

Participants also completed a demographics questionnaire that included details of their personal characteristics (e.g. age, gender, education), individual practice (e.g. years of practice in pediatric critical care), and practice location (8.5 - Demographic Information survey). Round 1 data collection started on August 10, 2020 and remained open for seven weeks (closed September 27, 2020). Participants were initially given four weeks to complete the survey; however, due to lower than anticipated response rate (<50%), the deadline was extended. Reminder emails were sent to non-respondents every week and on the day before the deadline. Non-respondents were still eligible for Round 2 if they did not complete Round 1.

4.2.6 Round 1 Analysis

Completed surveys were tabulated into Microsoft Excel. Partially completed surveys were also included for analysis, but only the sections with feedback. Initial assessment of the raw text feedback was performed by one researcher (SQ), before review by the whole research team. Key words, terms, ideas and phrases in the text feedback were highlighted, tabulated and summarized for each recommendation statement. Feedback that did not explicitly address the recommendation statements were not considered when revising the contents for the next Round. Similarly, any comments that were irrelevant or not applicable to RT practices in Canada were omitted. Grammatical and content suggestions were incorporated. The draft for the Round 2 survey was reviewed and revised by each research team member separately until a final draft was collectively agreed upon.

4.2.7 Round 2 and Round 3

In Round 2 and Round 3, participants were instructed to rank their level of agreement or disagreement using a 5-point Likert scale for each of the recommendations (Figure 4). If the recommendation statement was not practiced at their work location, participants were instructed to choose “0 No comment”.

Figure 4: 5 point Likert scale.

1	2	3	4	5	0
Strongly disagree	Disagree	Neutral	Agree	Strongly agree	No comment

At the end of each section, participants had the opportunity to provide open-text feedback if they strongly disagreed or disagreed (Likert score 1 or 2) with any of the recommendation statements or had additional concepts or feedback to provide.

Invitations for Round 2 were sent to participants on October 15, 2020 and was open until November 3, 2020. Participants who failed to complete Round 2 by the deadline were considered lost to follow up and were not invited for Round 3. The remainder were invited for Round 3 on November 12, 2020 and given 16 days to complete (Round 3 ended November 29, 2020). Email reminders were sent to non-respondents weekly and the day before the deadline for both Round 2 and Round 3. Participants were considered lost to follow up if they did not respond by end date.

4.2.8 Round 2 and Round 3 Analysis

Descriptive statistics of the quantitative data from Rounds 2 and 3 included measures of central tendencies, response frequencies, dispersion, consensus (defined as ≥75% threshold), and additional statistics (see below). All statistical analyses were performed using Microsoft Excel and IBM® SPSS Statistics, with a p-value <0.05 considered significant.

The five Likert ranks were grouped into three categories to determine whether consensus for a particular statement was achieved. For each statement, the responses with rank 0 were eliminated from the tabulation, and the remainder were categorized into three separate ranking groups: Group 1 (disagree) included 1- strongly disagree and 2- disagree; Group 2 (neutral) included 3- neutral; Group 3 (agree) included 4- agree and 5- strongly agree. Consensus was achieved when ≥75% of participants' responses fell within one particular ranking group. The proportion (%) of participants (consensus) in each ranking group was calculated by dividing the number of participant responses in a ranking group by the number of total responses.

The open-text feedback for each section were analyzed similar to Round 1 analysis.

Round 2 statements that did not reach consensus and/or reached consensus but received significant feedback were revised for Round 3's re-evaluation. Statements that reached

consensus in Round 2 and/or did not have significant feedback, were not included in Round 3 to decrease the length of the survey in order to minimize participant fatigue and attrition (32, 37). The percentage consensus data for each recommendation statement was summarized and distributed to each participant for viewing at the beginning of Round 3 and at the end of the study.

Three additional statistics were performed to strengthen the validity of the Delphi data (44). First, the Coefficient of Variation (CV) for each statement was calculated to report the ratio of the standard deviation of the responses, to its respective mean. Statements with CV ≤0.5 suggest minimal variations in the responses, supporting ceasing of further Rounds (44, 50). Second, the stability between the statements in Round 2 and 3 were assessed by comparing the CV difference in Likert responses. CV differences close to zero (statistically similar results) indicate consensus stability in responses across the two Rounds, supporting ceasing of further Rounds (44, 50, 51). Since the response data was skewed, the Wilcoxon Signed-Rank test (WSRT) was used to compare the CV differences between Round 2 and 3 (44, 50). Finally, for exploratory purposes we performed the Kruskal Wallis test (KWT) for subgroup analyses of Likert responses between participants with different years of PICU experience (>15 years versus ≤15 years).

4.2.9 Post Delphi Review

All the finalized consensus recommendation statements, some with clinical remarks, were provided as a written report (8.10- Post-Delphi summary for participants). The clinical remarks were derived from the open text responses received throughout each Round. They were created because it was not possible to incorporate all the suggested concepts into each recommendation statement. The clinical remarks elaborated on unique and special circumstances not captured in the general statement recommendation e.g. those that require further discussions with the interprofessional team.

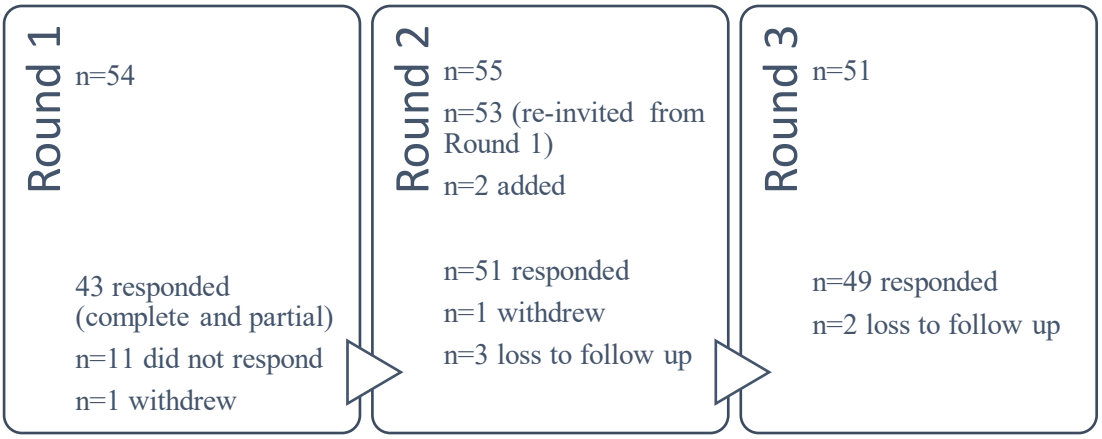
In addition to the recommendation statements (plus clinical remarks), summaries of the original written feedback and statistical results from all Rounds were provided. A total of three documents and a video presentation of the study results were available for participants to review between February 8 to March 5, 2021. Participants were invited to review and provide, if any, additional comments or feedback.

4.3 Results

4.3.1 Participants

A total of 56 participants (41 females, 14 males, 1 non-respondent) from 15 facilities, across nine provinces were included in the study (see Figure 6). Two regional hospitals with dedicated pediatric beds reported they were rarely used; therefore, participants were not recruited from these centers. One participant consented into the study but did not complete any Rounds or the demographic survey. Three participants completed the demographic information survey but did not complete any Rounds. Figure 5 provides a detailed overview of the number of participants involved in each Round of the Delphi study.

Figure 5: Number of participants across the Delphi Rounds.



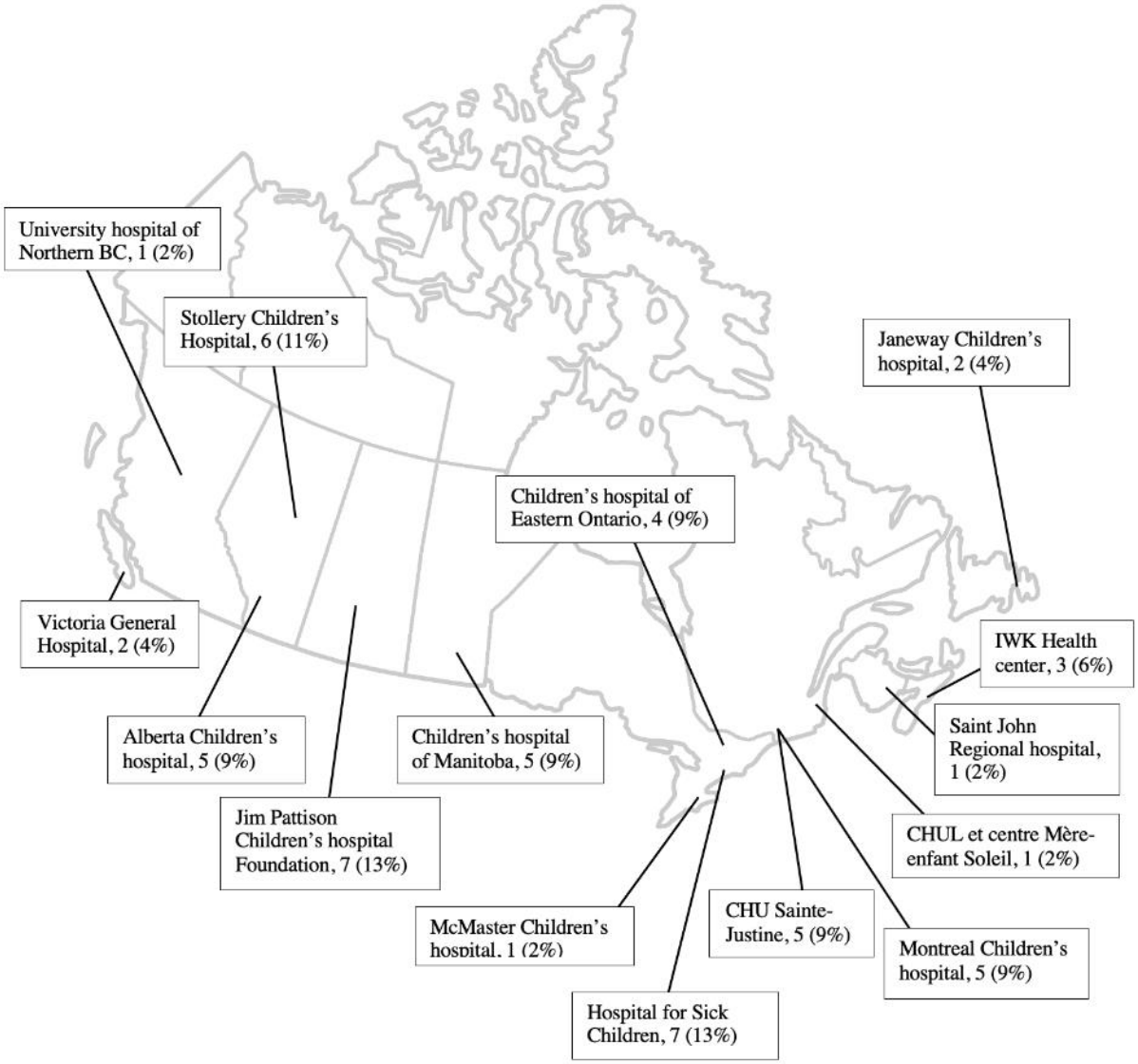
The majority of the participants in this study were from Alberta (n=11, 1 male), Ontario (n=12, 2 males) and Quebec (n=11, 3 males). The Atlantic Provinces were represented by six participants (2 males) across three facilities. All participants graduated from a Canadian respiratory therapy program. The average ± standard deviation (SD) years of pediatric RT experience in the expert panel was 15.04 ± 8.33 years, and 72± 27.78% of their practice time were in the PICU (Table 8). The expert panels consisted of RTs in multiple roles including charge supervisors, practice leaders, team leaders, clinical educators, ECMO specialists, transport RTs, pediatric core and rotating staff. All RT participants had work experience in the PICU, with 80% also experienced in the neonatal ICU and 20% in the adult ICU (Table 8). RT participants partook in different professional development activities for various reasons, as shown in Table 8.

*Table 8: Characteristics of Expert Participants, N=55**

Variable	**N (%) or Mean ±SD**
Female	41 (74.5)
Age, years	40.64 ± 8.81
Education	
Bachelor's degree	26 (47.3)
Additional credentials	2 (3.6)
Practice experience	
# of years as RT	16.37 ± 8.82
# of years in PICU	15.04 ± 8.33
Hours of clinical work / week	38.06 ± 12.14
% of clinical work in PICU	72 ± 27.78
Clinical role **	
Charge supervisor	14 (25)
Practice Lead	9 (16)
Team Lead	14 (25)
Clinical Educator	14 (25)
Core Staff	27 (49)
Rotating Staff	11 (20)
Transport	5 (9)
ECMO specialist	2 (4)
Other***	12 (22)
Additional practice areas	
Neonatal	44 (80)
Adults	13 (24)
Professional activities	
Reading research and medical literature	50 (91)
Presentations	51 (93)
Conferences	19 (35)
Courses, Workshops	38 (69)
Simulation Labs	53 (96)
Other†	5 (9)
Reasons for attending professional activities	
Challenging clinical case(s)	27 (49)
Supervisor/ colleagues highlighting opportunities	36 (65)
Mandatory Staff Education	33 (60)
Identified area of improvement through self-reflections and/ or performance reviews	37 (67)
Personal interest	6 (11)
Continuing Education	3 (5)

ECMO: Extracorporeal membrane oxygenation; N: total sample size; PICU: pediatric intensive care unit; RT: respiratory therapist; SD: standard deviation; *Includes n=3 who did not complete any Rounds; ** Respondents may have chosen more than one role; ***Other: clinical practice coordinator, clinical educator for interprofessional committees, simulation lab facilitator, preceptor; †Other: research, teaching, interprofessional training, certifications.

Figure 6: Graphical representation of the Canadian expert panel.



N=55; Center, n (%); Includes n=3 who did not respond to any Rounds. Information is also presented in text summary (Supplementary table 3).

4.3.2 Pilot Round results

The initial draft of the Delphi survey from the ESPNIC recommendations included 53 statements. This draft was reviewed by three individual SickKids' RTs for its relevance, clarity and applicability. Based on their feedback, several statements were reworded and modified to be more applicable to Canadian practices.

4.3.3 Round 1 results

After review of the original ESPNIC recommendations and pilot testing, 53 statements were included for Round 1. The statements were separated into 10 different sections: 1) *Non-invasive ventilation*, 2) *Tidal volume and inspiratory pressures*, 3) *Respiratory rate and inspiratory time*, 4) *PEEP and FiO_2*, 5) *Advanced modes of ventilation*, 6) *Weaning*, 7) *Physiologic targets*, 8) *Monitoring*, 9) *Other General MV practice* and 10) *Equipment Adjuncts*.

A total of 43 out of 54 participants responded (80% response rate), one withdrew, and 11 did not respond. Of the 43 who responded, two participants partially completed Round 1. Given the nature of Round 1, we received a large volume of written open-text feedback which was tabulated in Microsoft Excel. Review of this feedback played a significant role in its revision for Round 2 (4.2.6 Round 1 Analysis). Participants reported several statements were too wordy and/or consisted of too many concepts. Therefore, several statements were broken into two statements. Additionally, participants suggested the addition of new concepts, because of their relevance and importance in pediatric MV practices. Feedback led to the introduction of several MV recommendation statements that were not originally included: use of high-flow nasal cannula oxygen therapy, high-frequency jet ventilation, guidelines from various health associations (e.g. Heart and Stroke Foundation's Pediatric advanced Life support, Extracorporeal Life Support Organization, etc.) and ventilator acquired pneumonia prevention practices. See Supplementary Table 4 for the open text feedback from Round 1.

The Round 2 draft was reviewed and revised by each research team separately, and collaboratively, until a final draft was agreed upon. The 53 recommendations statements from the Round 1 survey were modified to 58 recommendations statements for Round 2. A comparison between Round 1 and 2 are available in Supplementary Table 5. The finalized Round 2 survey is in Chapter 8- Appendix.

4.3.3 Round 2 Results

A total of 51 out of 55 participants (91% response rate) completed Round 2. Three participants did not respond, and 1 withdrew. Fifty-five out of the 58 statements (95% of the survey) reached consensus: one statement between 75% to 80% (1.7% of survey), 16 statements between 81% to 90% (28% of survey) and 38 between 91% to 100% (66% of survey). Three statements did not reach consensus (5% of survey). Six reached consensuses but had considerable open-text feedback (10% of survey). One recommendation was added, resulting in a total of 11 recommendation statements for Round 3. The CV indicated stability in the participants' responses, as values for each of the 58 statements were less than 0.5, ranging from 0.09 to 0.31.

The three statements that did not reach 75% consensus came from each of the following sections: 2) *Tidal volumes and inspiratory pressures*, 5) *Advanced modes of ventilation* and 10) *Equipment adjuncts*. In section 2, the statement: *"For specific congenital cardiac patients requiring optimal venous return, higher tidal volumes of >8ml/kg may be used to if peak pressures are <25cmH2O*" had 60% consensus (CV 0.21). Participants noted these children could be ventilated with target tidal volumes less than 8ml/kg, and at times, with higher peak inspiratory pressures up to 28 to 30cmH_2O (depending on the underlying lung condition). In section 5, one recommendation explicitly described high frequency jet ventilation (HFJV), and had 57% consensus (highest CV 0.31). Many participants commented that children were not commonly placed onto HFJV, as this practice is seen more in the NICU, and in specific pathologies. Lastly, a recommendation in section 10 described proximal flow sensor use in the PICU and gained a consensus of 71% (CV 0.26). Some participants noted it had limited use in the PICU, and was more common in the NICU, where smaller tidal volume measurements are required. Generally, children under a specific weight may have tidal volumes monitored with a proximal flow sensor, but the reported thresholds varied across centers. Table 9 describes the changes of the statements that did not achieve consensus from Round 2 to Round 3.

Seven statements received consensus but were still included for Round 3 (Table 9). The research team believed the open text-feedback would strengthen the practice recommendation. One statement in section 1 "*Consider the use of high flow nasal cannula oxygen therapy (form of oxygen therapy) prior to NIV, to alleviate work of breathing*" gained 76% consensus (CV 0.25). Many participants believed NIV and HFNC may be considered in parallel instead of one before

another, and NIV should not be delayed if indicated. The remaining six statements did achieve at least 80% consensus, but were revised to include: a broader range of numerical thresholds, practice exceptions and/ or grammatical and content reorganization. One additional statement was added into Section 9- *General MV practice* recommendations, which emphasized the necessity of interprofessional collaboration. Though it was not explicitly about MV management, it was a reoccurring theme amongst the open response feedback.

The consensus and revised statements from Round 2 to Round 3 are summarized in Table 9. Supplementary table 6 presents consensus and descriptive statistics for each recommendation statement. A summary of the Round 2 results was made available to the participants to view prior to starting Round 3.

Table 9: Round 2 statements that were revised for Round 3.

Section	R2 statement (consensus %, CV)	Revised for R3
1	Consider the use of high flow nasal cannula oxygen therapy (form of oxygen therapy) prior to NIV, to alleviate work of breathing. (76%, 0.26)	Consider the use of HFNC prior to NIV, to alleviate any work of breathing. However, the use of HFNC is not a substitute for NIV and should not delay or replace the use of NIV, if NIV is more appropriate.
2	Target tidal volumes in the physiologic range (5-8ml/kg ideal body weight) for pediatric patients >10kg with healthy lungs. Target tidal volumes 5-8ml/kg measured weight for pediatric patients ≤10kg with healthy lungs. (92%, 0.15)	In pediatric patients >10kg, target tidal volumes in the physiologic range (5-8ml/kg ideal body weight). In pediatric patients ≤10kg, target tidal volumes 5-8ml/kg measured weight.
2	For all pediatric patients on pressure-limited modes, aim to achieve optimal tidal volume in the physiological range (5-8ml/kg ideal body weight) with minimal delta pressure (PIP-PEEP). (94%, 0.18)	For pediatric patients on pressure-limited modes, aim to achieve optimal tidal volume in the physiological range (5-8ml/kg ideal body weight) with minimal driving pressure (PIP-PEEP).
2	In absence of transpulmonary pressure measurements, limit the inspiratory plateau pressure to 30cmH_2O in all pediatric patients. (82%, 0.21)	In absence of transpulmonary pressure measurements, the inspiratory plateau pressure should be limited to 30cmH_2O in pediatric patients. Site specific limits should be within 28 to 32 cmH_2O.
2	For specific congenital cardiac patients requiring optimal venous return, higher tidal volumes (>8ml/kg ideal body weight) may be used if peak pressures	If unable to achieve physiologic tidal volumes (5-8ml/kg) within pressure limits (30cmH2O), targeting ranges outside these limits should be discussed

	are within safe range (< 25cmH_2O). This would allow a lower set respiratory rate to minimize mean airway pressure. (60%, 0.21)	with the interprofessional team. For example, congenital lesions, congenital hypoplastic lung, severe PARDS. Similarly, there may be circumstances where tidal volumes >8ml/kg may be cautiously used, but should not be routinely used.
5	When conventional mechanical ventilation has failed, consider high frequency jet ventilation (HFJV) in pediatric patients with restrictive or mixed diseases and severe oxygenation and/or ventilation failure. (57%, 0.31)	When conventional mechanical ventilation and/or HFOV has failed for pediatric patients, consider the use of other advanced modes, acknowledging that each has unique benefits and / or limitations. These modes include high frequency jet ventilation (HFJV) and Airway Pressure Release Ventilation (APRV). These advanced modes should not substitute or delay inevitable ECLS, if appropriate.
5	Consider the use of other advanced ventilation techniques to optimize patient-ventilator interactions, acknowledging that each has unique benefits and/or limitations. These modes include Airway Pressure Release Ventilation (APRV), Neurally Adjusted Ventilatory Assist (NAVA), Proportional Assist Ventilation (PAV), high frequency jet ventilation (HFJV), automated weaning etc. (83%, 0.21)	Other advanced ventilation techniques may optimize patient-ventilator interactions. Consider their use while acknowledging that each has unique benefits and/or limitations. These modes include Neurally Adjusted Ventilatory Assist (NAVA), Proportional Assist Ventilation (PAV), automated weaning etc.
5	Strongly consider Extracorporeal life support (ECLS) such as NovaLung, or extracorporeal membrane oxygenation. Use ECLS in pediatric patients with reversible diseases, if available within the facility, not contraindicated, and/or when conventional and/or high frequency oscillatory ventilation has failed. Follow guidelines (e.g. extracorporeal life support organizations) for specific criteria. Early consultation with an ECLS center should be considered if this therapy is not available within the facility (81%, 0.2)	When conventional mechanical ventilation and/ or HFOV has failed, consider the use of Extracorporeal life support (ECLS) in pediatric patients with reversible diseases, if available within the facility and not contraindicated. Follow guidelines (e.g. ECLS organizations) for more specific criteria. Consider early consultation with an ECLS center when ECLS is not available within the facility.
10	Use a proximal flow sensor for accurate tidal volume measurements in small patients (<10kg) or patients with small	Proximal flow sensors are not routinely used for pediatric patients. Follow the specific ventilator's recommendations on

	tidal volumes (<10mL). Follow the specific ventilator's recommendations on its use. (71%, 0.26)	proximal flow sensor use. In the absence of specific ventilator recommendations, use a proximal flow sensor for small tidal volumes (<10mL)
10	Avoid routine use of manual hand-ventilation to minimize frequent circuit disconnects. If manual hand-ventilation is required, pressure manometers, pressure relief valves and PEEP valves should be used on self-inflating and flow-inflating bag. (84%, 0.22)	Minimize routine use of manual ventilation to avoid circuit disconnects. Manual ventilation may be used to augment pulmonary hygiene as part of chest physiotherapy. Manual resuscitation devices should be capable of maintaining PEEP, limiting and monitoring pressures
9	Additional statement	Mechanical ventilation management and anticipated plans should be discussed as an interprofessional (IP) team at minimum on a daily basis. Any changes in the patients' trajectory or mechanical ventilation needs should be communicated between all members of the IP team.

4.3.4 Round 3 Results

Of the total 51 participants who completed Round 2, 49 completed Round 3 (97% response rate). Two participants were lost to follow up. All 11 statements received consensus; three statements achieved consensus within 81-89% and eight statements over 90%. The CV indicated stability in the participants' responses, as values for each of the 11 statements were less than 0.5, ranging from 0.12 to 0.24 (Table 10).

Nine of the 10 statements revised from Round 2, obtained greater consensus in Round 3, increasing between 1% to 38%. The respective CV values also decreased, between 0.005 to 0.14. One statement (finalized statement #2.1) decreased consensus from 92% to 81%, with an increase of CV from 0.15 to 0.24. The newly added statement for Round 3 (Statement 9.7) achieved 100% consensus (CV 0.10). When the rank responses were compared across Rounds 2 and 3 (WSRT), there were four statements with significant differences ($p<0.05$). These were the four statements that had the greatest increased change in consensus percentage. Further details can be viewed in Supplementary Table 7. Open text feedback for Round 2 and 3 are collectively summarized in Supplementary table 9.

Table 10: comparison between the consensus for the statements included in Round 3, compared to their prior version in Round 2.

Finalized Statement *	Round 2 consensus %	Round 3 consensus %	% Change	Round 2 CV	Round 3 CV	CV difference	Wilcoxon Signed Rank test (p-values)
1.6	76%	92%	+16%	0.25	0.19	-0.07	<0.01
2.1	92%	81%	-9%	0.15	0.24	+0.09	0.23
2.2	60%	98%	+38%	0.21	0.12	-0.09	<0.01
2.3	94%	96%	+2%	0.18	0.18	-0.005	0.79
2.4	82%	93%	+11%	0.21	0.15	-0.07	0.13
5.3	57%	90%	+33%	0.31	0.17	-0.14	<0.01
5.4	83%	84%	+1%	0.21	0.19	-0.02	0.44
5.5	81%	96%	+15%	0.20	0.15	-0.05	0.03
10.4	71%	84%	+13%	0.26	0.21	-0.05	0.89
10.5	84%	94%	+10%	0.22	0.15	-0.07	0.44

**refer to the Finalized Consensus Statements with clinical remarks (*Chapter 6- Finalized Canadian Pediatric MV management Consensus Guideline*). CV=coefficient of variation.

The evolution (revisions and comparisons) of the statements, consensus percentage, Likert score, and CVs from Round 1 to 3 are summarized in Table 11.

Table 11: Evolution of the statements from Round 1 to 3.

Section 2: ***Tidal volumes and inspiratory pressures***			
Round	**Consensus % CV**	**Likert Mean±SD**	**Recommendation statement**
Statement #1.6			
1	-	-	-
2	76% 0.26	3.82±0.97	Consider the use of high flow nasal cannula (HFNC) oxygen therapy prior to NIV, to alleviate work of breathing.
3	92% 0.19	4.37±0.81	High flow nasal cannula oxygen therapy (a form of oxygen therapy) is not a substitute for NIV. Consider the use of high flow nasal cannula oxygen therapy prior to NIV to alleviate work of breathing. However, the use of high flow oxygen therapy should not delay or replace the use of NIV, if NIV is more appropriate.
Section 2: ***Tidal volumes and inspiratory pressures***			
Round	**Consensus % CV**	**Likert Mean±SD**	**Recommendation statement**
Statement #2.1			
1	-	-	Use tidal volumes in the physiologic range (5-8ml/kg ideal body weight) for pediatric patients with healthy lungs.
2	92% 0.15	4.16±0.62	Target tidal volumes in the physiologic range (5-8ml/kg ideal body weight) for pediatric patients >10kg with healthy lungs. Target tidal volumes 5-8ml/kg measured weight for pediatric patients ≤10kg with healthy lungs.
3	81% 0.24	4.0±0.95	In pediatric patients >10kg, target tidal volumes in the physiologic range (5-8ml/kg ideal body weight). In pediatric patients ≤10kg, target tidal volumes 5-8ml/kg measured weight.
Statement #2.2			
1	-	-	Avoid using tidal volumes >8ml/kg ideal body weight in pediatric patients with restrictive lung, obstructive lung and/or congenital diseases. For cardiac patients, higher tidal volumes (>8ml/kg ideal body weight) can be used to allow a lower set respiratory rate to promote venous return.
2	60% 0.21	3.7±0.78	For specific congenital cardiac patients requiring optimal venous return, higher tidal volumes (>8ml/kg ideal body weight) may be used if peak pressures are within safe range (< 25cmH_2O). This would allow a lower set respiratory rate to minimize mean airway pressure.
3	98% 0.12	4.3±0.51	If unable to achieve physiologic tidal volumes (5-8ml/kg) within pressure limits (30cmH_2O), targeting ranges outside these limits should be discussed with the interprofessional team. For example, congenital lesions, congenital hypoplastic lung, severe PARDS. Similarly, there may be circumstances where tidal volumes >8ml/kg may be cautiously used but should not be routinely used.
Statement #2.4			
1	-	-	In absence of transpulmonary pressure measurements, limit the inspiratory plateau pressure to 28cmH_2O in pediatric patients with healthy lungs.
	-	-	In absence of transpulmonary pressure measurements, limit the inspiratory plateau pressure 32cmH_2O in patients with decreased chest wall compliance.

2	82% 0.21	4.02±0.85	In absence of transpulmonary pressure measurements, limit the inspiratory plateau pressure to 30cmH_2O in all pediatric patients.
3	93% 0.15	4.17±0.61	In absence of transpulmonary pressure measurements, the inspiratory plateau pressure should be limited to 30cmH_2O in pediatric patients. Site specific limits should be within 28 to 32 cmH_2O.
Section 5: ***Advanced modes of ventilation (#5.3)***			
Round	**Consensus % CV**	**Likert Mean±SD**	**Recommendation statement**
1	-	-	*-not included*
2	57% 0.31	3.4±1.06	When conventional mechanical ventilation has failed, consider high frequency jet ventilation (HFJV) in pediatric patients with restrictive or mixed diseases and severe oxygenation and/or ventilation failure.
3	90% 0.17	4.14±0.72	When conventional mechanical ventilation and/or HFOV has failed for pediatric patients, consider the use of other advanced modes, acknowledging that each has unique benefits and / or limitations. These modes include high frequency jet ventilation (HFJV) and Airway Pressure Release Ventilation (APRV) and severe oxygenation and/or ventilation failure. These advanced modes should not substitute or delay inevitable ECLS, if appropriate.
Section 10: ***Equipment adjuncts (#10.4)***			
Round	**Consensus % CV**	**Likert Mean±SD**	**Recommendation statement**
1	-	-	Measure tidal volumes proximally in pediatric patients < 10kg.
2	71% 0.26	3.88±1.02	Use a proximal flow sensor for accurate tidal volume measurements in small patients (< 10kg) or patients with small tidal volumes (< 10mL). Follow the specific ventilator's recommendations on its use.
3	84% 0.21	3.91±0.82	Proximal flow sensors are not routinely used for pediatric patients. Follow the specific ventilator's recommendations on proximal flow sensor use. In the absence of specific ventilator recommendations, use a proximal flow sensor for small tidal volumes (< 10mL).

Since all the recommendation statements reached consensus at the end of Round 3, further Rounds were not required. Supplementary table 6, Supplementary Table 7 and Supplementary table 9 presents consensus and descriptive statistics for each recommendation statement, and the original open-text feedback in Round 2 and 3. The guideline was finalized and included a total of 10 sections for a total of 59 recommendations with clinical remarks (Table 12). The full document is in Chapter 6- Finalized Canadian Pediatric MV management Consensus Guideline.

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Table 12: The 10 sections and the number of recommendations in each.

Section		# of recommendation statements
1	Noninvasive ventilation	8
2	Tidal Volumes and Inspiratory Pressures	4
3	Respiratory Rates and Inspiratory Times	3
4	PEEP and Fio2	6
5	Advanced Mechanical Ventilation modes	5
6	Weaning	5
7	Physiologic targets	7
8	Monitoring	9
9	General MV practices	7
10	Equipment adjuncts	5

4.3.5 Subgroup analyses: Years of PICU experience

The years of PICU experience in this expert panel ranged from 1 to 36 years. This variable was categorized into 2 subgroups: 1) ≤15 years (mean±SD age = 34.5±5.4 years) and 2) >15 years (age 47.8±6.4 years). For Round 2, the subsamples were 28 participants with ≤15 years and 23 participants with >15 years of PICU experience. In Round 3, each subgroup lost 1 participant (27 and 22 participants, subgroup 1 and 2 respectively). Of all the statements in both Rounds, only six statements from Round 2 showed significant differences between subgroups ($p<0.05$) (Supplementary Table 8). For each of these six statements, the Likert scores were higher for the less experienced group, compared to the group with > 15 years experience. The statistical data for these six statements are summarized in Supplementary Table 8.

4.3.6 Post Delphi review

There was no additional feedback returned from the participants. We assumed the participants agreed with the finalized guideline and clinical remarks.

4.4 Discussion

This is the first study to use the Delphi technique to develop pediatric MV consensus recommendations based on the expertise of Canadian RTs. Of the 152 European (ESPNIC) guideline statements, we derived 53 recommendation statements that were applicable to Canadian RT practices. These recommendation statements reached consensus by Round 3, ranging from 80% to 100% consensus. We almost achieved our original hypothesis that

consensus would be achieved by Round 2, as only three statements did not reach 75% consensus. However, we made the conservative decision to revise one statement that achieved 76% consensus (CV 0.25), and statements that did reach consensus and had a lot of feedback. The finalized consensus document on essential MV management in pediatrics, consisted of 59 recommendation statements, describing 10 different subtopics.

After Round 2, a high proportion of the survey achieved consensus: 55 out of 58 statements (95%). There could be a few reasons why this level was reached early. First, the Modified Delphi technique was used, allowing the research team to generate the topics to focus on. We decided to create our survey based on the existing ESPNIC consensus MV guideline (8), and taking in consideration practices that were applicable to Canadian RTs. Our Round 1 results were ample, but likely much more focused, especially in comparison to the Classical technique (where Round 1 is unstructured and seeks feedback using open-ended questions) (32, 34, 36, 39). Secondly, the main themes and concepts of our guideline, had already gone through a vigorous consensus process by another group of experts, international pediatric physicians, and the existing literature. Only the statements in the ESPNIC guideline that had *strong agreement* amongst their panelists were considered for our Delphi survey.

When looking at individual sections of our survey, we observed a few interesting points. The first section about NIV had eight practice statements which all reached at least 75% consensus at the end of Round 2, and only two of these statements had consensus <90%. These two statements were practice recommendations on NIV Neurally Adjusted Ventilatory Assist (NIV-NAVA) (85% consensus, CV 0.18) and HFNC (76% consensus, CV 0.25). In the ESPNIC recommendation guideline, the panel concluded there was insufficient evidence to recommend the use of NAVA or HFNC in children with mixed diseases (8).

Introduced within the last decade, NIV-NAVA has been trialed in adults. Although it may provide benefits, there are minimal studies to confirm its use in children (52, 53). In our study, 39 (76%) participants used NIV-NAVA in their institutes; the other 25% indicated it was unavailable at their center. Therefore, the minimal use and availability of NIV-NAVA in the pediatric population may be due to the lack of large clinical trials, high cost, and lack of guidance in its use and management (52). This suggests the use of NIV-NAVA in children is still relatively new (52, 53).

Another relatively new therapy is HFNC, which has become increasingly available, and

frequently used to treat adult and neonatal populations as a respiratory support. It has become more common for children to help reduce their work of breathing, and/ or as a treatment for respiratory failure (avoiding use of CPAP or intubation) (54, 55). There is also evidence supporting its efficacious and safe use for children, particularly in bronchiolitis (18, 54, 56). There is still a lack of large interventional trials to support its use, and clear national or international guidelines do not exist (55, 57). These may be the reasons why the HFNC recommendation statement required several revisions in this Delphi study. Originally, we did not include any recommendation statements for HFNC use in Round 1; however, a majority of participants emphasized that it is used regularly and should be included for Round 2. The new HFNC statement in Round 2 resulted in a consensus of 76% (CV 0.25, Likert mean±SD 3.82±0.97). Participants also stated that HFNC should be described as an option to alleviate work of breathing and should not delay NIV or intubation in children of specific diseases. The statement was revised to incorporate these factors, which led to an increase of consensus to 92% (CV 0.19; 4.37±0.81) in Round 3 (see Table 11 for the evolution of the statement #1.6 from Round 1 to 3 and Supplementary Table 7 for more details).

In the ESPNIC consensus guideline, the panelists could not agree on which ventilation mode, such as PC or VC, was ideal for children with healthy lungs, mixed diseases or cardiac diseases. In our survey, section 2 and 3 focused on ventilating children with specific goals and management considerations, including target tidal volumes, inspiratory pressures, minute ventilation, and ventilatory synchrony. These topics are discussed below.

With respect to tidal volume, one particular statement had poor consensus after Round 2 at 60% (CV 0.21; 3.72±0.78), in addition to large amounts of open text feedback. The evolution of this statement #2.2 is described in Table 11. The initial low consensus and substantive feedback of this statement in our survey, may have been due to participants balancing the benefits and harms of various tidal volume thresholds. Generally, the literature does not recommend tidal volumes greater than the physiologic range of 5 to 8ml/kg ideal body weight (IBW) (3-6ml/kg for children with poor lung compliance, 5-8ml/kg for children with better lung compliance) (4, 5, 22, 58, 59). Ventilating adult patients with acute respiratory distress syndrome (ARDS) over this physiologic range has resulted in increased mortality and lung injury risks (4, 19, 58, 60). Some studies support maintaining tidal volumes below and within these limits, however patients may need to be in “permissive” hypercapnia and hypoxemia (4, 19, 22). In

addition, for children post-cardiac surgery, higher tidal volumes with lower set respiratory rate may be indicated to minimize mean airway pressure (4). The decisions made to balance these factors must be discussed with the interprofessional team (61) (see Chapter 6- Finalized Canadian Pediatric MV management Consensus Guideline).

Another recommendation related to tidal volume also had several iterations. The evolution of this statement #2.1 is described in Table 11. This statement had a decrease from 92% to 81% consensus with an increase of CV of +0.09 from Round 2 to 3 (Likert mean 4.16 ±0.62, CV 0.15 vs. 4.0±0.95, CV0.24). We believed this was related to omitting "healthy lungs" from, and using IBW (versus actual measured weight) in the statement for Round 3. The ESPNIC consensus and Pediatric Acute Lung Injury Consensus Conference Group (PALICC) guidelines recommended that optimal tidal volumes be based on IBW (8, 59). The purpose of using the IBW is to normalize tidal volumes for MV, and may minimize the risk of under- or over-ventilating children, compared to using their actual weights (4, 62). In our survey there was significant feedback on whether to use IBW or actual measured weight for tidal volume settings. In Round 1, some participants noted that smaller children should be ventilated using their actual measured weight. Others suggested IBW should be used if the child is a specific weight (the range varied widely between 10kg to 50kg), or is a certain age group ("school aged"). Currently, there is no universal method to calculate IBW; it can be calculated using various techniques, all which yield different results (4, 62, 63). In addition, differences between IBW calculations and actual body weight, increase in children over 25kg (62). For our survey, we chose the lowest suggested threshold, using IBW for children > 10kg, and actual measured weight for children ≤ 10kg. This threshold captured a large proportion of the pediatric population, while minimizing overlapping with neonates. We also suggested that obesity or fluid overload should factor into the tidal volume setting (see Chapter 6- Finalized Canadian Pediatric MV management Consensus Guideline).

Another ventilatory mode/setting addressed in our survey was inspiratory pressures. The evolution of this statement #2.4 is described in Table 11. The ESPNIC consensus and PALICC guidelines do not provide specific plateau pressure recommendations, but suggest various limits in different pediatric diseases, ranging from 28 to 32 cmH_2O (8, 22). This may have explained the improvement in consensus from Round 2 to 3 (11% increase, CV difference -0.07), because throughout these Rounds, the plateau pressure limit changed from 28 to 32cmH_2O.

The result of Section 5- *Advanced Modes of Ventilation* included five statements. In Round 2, one statement describing the use of HFJV did not reach consensus (at 57%, CV 0.31). The evolution of this statement #5.3 is described in Table 11. Neither PALICC or ESPNIC guidelines provided definitive recommendations on the routine use of HFJV in any children, and we originally excluded it from our survey (8, 59). However, in Round 1, open-text feedback from participants highlighted that HFJV should be mentioned and has potential use in children, so we introduced the concept in Round 2. In Round 2, only certain centers used HFJV (participant response n=35, 69% in Round 2; n=42, 86% in Round 3), and open responses mentioned that HFJV could be used in children, though not regularly. Thus, we recommended HFJV and other modes like airway pressure release ventilation (APRV), NAVA and proportionally assist ventilation (PAV) as "other advanced modalities to consider". With respect to APRV, NAVA and PAV, research is still limited, and these modes are not extensively used in children (5, 8, 64). For our survey, we wanted to bring awareness of these modalities, but stress they should only be considered after evaluating the benefits and limitations. Though the Extracorporeal Life Support (ECLS) statement already had 81% consensus in Round 2 (CV 0.20; 4.15±0.83), we received feedback that the statement had many elements and could be reworded for clarity. Thus, we made adjustments to clearly state the indications, and had it reviewed by an ECLS specialist prior to including it in Round 3. This may have explained the improvement of consensus from 81% to 96% (CV 0.15; 4.45±0.65).

Another recommendation statement that required several revisions in our survey addressed the use of proximal flow sensors. The evolution of this statement #10.4 is described in Table 11. Our participants suggested that proximal flow sensors were not routinely used in the pediatric population and may not be available for certain ventilators. ESPNIC (8) recommended that proximal sensors be used in children under 10kg as delivered tidal volumes can be underestimated in small children. We modified our statement to acknowledge this, and recommended its use be based on ventilator manufacturer recommendations (8).

Sections 4- *PEEP and Fio2*, 6-*Weaning*, 7-*Physiologic targets*, 8- *Monitoring*, 9-*General MV practice* and 10-*Equipment adjuncts* achieved consensus for each statement by the end of Round 2. All the statements in Round 2 and 3 have CVs less than 0.5, indicating the dispersions of the responses relative to their means were minimal and consensus was achieved. Ideally, the CV values should decrease from Round 2 to 3, indicating even smaller variation in

the subsequent responses. This occurred for all our statements except one that decreased in consensus from Round 2 to 3, which unsurprisingly led to an increase in CV. The WSRT was also performed to analyze the change in Likert responses across Round 2 and 3. Of the 10 statements, the four statements with the greatest change in consensus percentage and CV, were significantly different between Rounds ($p<0.05$) (Table 10). These four statements described HFNC ($p=0.002$), tidal volume thresholds ($p<0.01$), HFJV ($p<0.01$) and ECLS ($p=0.03$).

Subgroup analyses by years of PICU experience (4.3.5 Subgroup analyses) demonstrated significant differences in several statements. The less experienced subgroup had higher Likert scores (closer to strongly agree), compared to the more experienced subgroup. We were unable to find Delphi studies that reported differences in Likert scoring across years of expert experience. However, it is possible that experienced RTs encountered more varieties of clinical scenarios and cases that could not be generalized, requiring unique decisions outside set recommendations. In a systematic review by Jordan et al (10), they reported that clinicians' values, preferences, knowledge and skills were factors that influenced the successful implementation of weaning protocols in the PICU. Additionally, weaning processes in the PICU depended on the workflow, context and clinicians' characteristics, which included years of experience (10). Though this review does not explicitly state whether clinical years of experience would result in decreased agreement with practice recommendations, it does suggest that clinical experience may influence successful implementations of weaning protocols. This demonstrates the necessity of designing recommendations with clinical remarks, to address unique and special circumstances seen in the clinical setting.

In summary, these consensus recommendation guidelines describe and emphasize mechanical ventilation goals and management considerations broadly for all critically ill children, based on RT perspectives. These statements were similar to the ESPNIC guideline recommendations, which are already supported by other evidence such as the PALICC guidelines and the ARDSnet protocol (5, 19). These statements also referred to other organizational and workgroup guidelines such as the Extracorporeal Life Support organization, American Heart and Stroke Foundation (Pediatric Advanced Life support program), Safer Healthcare now!, Canadian Institute for Health Information, Solutions to Patient Safety, for specific recommendations. This is the first Canadian RT consensus recommendations to provide an overview of pediatric MV practices, and respiratory care in critically ill children. It will serve

as a living document as more evidence, and innovative MV practices emerge.

4.5 Strengths and Limitations

There are several strengths in this study. There was a significant and diverse panel size; 51 participants from 12 pediatric facilities and 2 hospitals with dedicated pediatric beds, across nine provinces, with 27% males. This is a good representation of RT pediatric practices in Canada (12 of the 15 [80%] pediatric facilities; 64% of all Canadian facilities with stand-alone PICU or dedicated pediatric beds). Our sample size included RTs in various clinical roles. Participants were anonymous to each other, allowing them to independently provide honest feedback, and minimizing the risk of judgement from peers and influence of strongly opinionated members (32, 34, 36, 37). Another strength was the increasing response rate across the Rounds; Round 1 had a response rate of 78%, Round 2 of 91% and Round 3 of 97%. Round 1 likely had a lower response rate because participants were required to provide their own original text comments, compared to Round 2 and 3 which required selection of one numeric rating. Typically, the response rate decreases in subsequent Rounds (33, 34, 36). We had high response rates because our research team sent frequent reminders and were highly engaged with participants to address technical difficulties and clarify questions. Furthermore, the length and time required to complete each Round decreased (32, 34). In addition to our high response rate, we also had good participant retention. We had two participants withdraw from the study, and five lost to follow up by the end of Round 3; therefore, our retention rate for this Delphi study was 88% (49 participants/ 56 recruited and enrolled).

Prior to initiating this Delphi study, a pilot Round was conducted to confirm whether the survey contents were relevant and appropriate. In addition, a post-Delphi review was included, where participants were asked to review and provide feedback for the finalized version of the guideline. Both pilot and post-Delphi measures are not commonly performed or reported (34, 35, 38, 65), but we believe they helped enhance the content validity and trustworthiness of the results (34, 35, 38, 42).

There were a few limitations to the study. Our pilot phase only included three expert RTs, and they were all SickKids employees, thus the feedback incorporated may be limited to this center's practice. In addition, some practice perspectives might have been missed because there were several centers that were not involved in this study. These centers included B.C. Children's

Hospital, McMaster Children's hospital and Children's hospital at London Health Sciences. We contacted these centers but were unsuccessful with recruiting any participants. Although we did recruit RTs from Janeway Children's Hospital, CHUL et centre mere-enfant Soleil, Saint John Regional Hospital, Victoria General Hospital, and University of Northern B.C, we were unable to recruit at least three participants from each. We managed to recruit three participants from IWK Health center, but one participant did not have at least 5 years of PICU experience; we believed this person had the relevant expertise, and included them to increase representativeness. There was one more participant with approximately 4.5 years of PICU experience in Ontario, and they were included for the same reason.

It may have been possible that participants provided feedback from information they read, heard or witnessed, and not personally *experienced*. For example, 80% of our participants also practiced in the NICU, and some of the feedback mentioned neonatal practices (which were omitted for analyses). There was also an observed difference in the number of participants who selected "0 – No comment" for the same statements across Round 2 and 3. It is possible that as the statements evolved from Round 2 to 3, participants were clearer on whether the practices were applicable to their current approach in pediatric MV management. These factors could possibly explain why several statements in the guideline did not reach at least 90% consensus. Lastly, this Delphi study only included Canadian RTs working in PICU and may not be generalizable for other interdisciplinary team members with experience in pediatric MV and/or outside Canada.

Though this guideline is based on a strong consensus recommendation by ESPNIC, the concepts have little empirical scientific evidence supporting them. Therefore, the finalized Canadian consensus guideline for pediatric MV management should be practiced with caution and only by trained and experienced clinicians.

4.6 Future Research

This Delphi study provided insight into Canadian RTs' perspectives on the best pediatric MV management practices, however these recommendations are not definitive. Since many of the recommendation statements in this guideline were adopted from limited pediatric data and/ or adult and neonatal evidence (8, 22, 59), many of them will require updates as new evidence emerge. This guideline can serve as a foundational document at different Canadian pediatric critical care units to help standardize pediatric MV practices. This guideline may be utilized by

other clinicians involved in MV management and/or outside of Canada e.g respiratory physiotherapists, nurses, physicians. This guideline should be amended to consider practices variations across institutions, geographical regions, and countries.

The lack of scientific literature should encourage both researchers and clinicians to embark on clinical trials to understand the effects of pediatric MV therapies in critically ill children. The efficacy of the pediatric MV recommendations in this study on patient outcomes is unknown. It is essential to investigate this in order to boost consensus and optimize standardization of care for acutely ill children (8). Until the evidence emerges, applying the practices in this guideline may assist in standardizing pediatric MV care that RTs provide. To date, there is still limited information on the effects of standardized MV management in critically ill children (4, 8), and some studies report poor compliance to implemented protocols (8, 10, 66-71). Therefore, large interventional studies are required to address the efficacy of pediatric MV management guidelines and methods to maximize protocol adherence (3, 8, 10, 14, 68, 72, 73).

4.7 Conclusions

To date, this is the only Canadian pediatric MV management consensus guideline for critically ill children. It is based on the collective agreement and clinical experiences of RTs across Canada. Our modified e-Delphi study achieved consensus in 95% of the recommendation statements at the end of Round 2, and 100% by the end of Round 3. There was a total of 59 recommendations in the finalized guideline, organized into 10 sections: 1) *non-invasive ventilation*, 2) *Tidal volumes and inspiratory pressures*, 3) *respiratory rates and inspiratory times*, 4) *PEEP and Fio2*, 5) *Advanced Modes of Ventilation*, 6) *Weaning*, 7) *Physiologic targets*, 8) *Monitoring*, 9) *General MV* and 10) *Equipment Adjuncts*. This guideline may be incorporated into protocols and RT practice policies in Canadian pediatric critical care units as an initial step to standardize pediatric MV management. However, this guideline is not definitive and will require consistent updates as new evidence emerge. Future research will need to address the efficacy of these pediatric MV guidelines to understand their impact on clinical outcomes.

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Chapter 5 – General Discussion and Conclusions

Mechanical ventilation (MV) is a form of life support therapy, specifically used to assist patients' breathing to sustain life when they are unable to (1-5). MV management is dynamic and complex, as MV can be delivered in various forms, settings and modes by different devices for various diseases, either invasively or non-invasively (2, 6-8). Despite overall therapy improvement and decrease in pediatric mortality over the last few decades (3, 4, 9), practices in pediatric MV management still lack standardization as clinical studies on the best techniques are scarce. Protocols and guidelines are available but vary across centers and are not always integrated into the practice culture (10-13). Potential barriers to successful implementation may include, not considering the social and cultural work environment, the intensivists' level of acceptability to the protocol, and lack of large multicenter data to support the practice (10, 14-16). This inconsistency of MV practices make it difficult to determine which method is best practice, and are associated with adverse events. Therefore, minimizing practice variability may improve patients' safety, treatment efficiency and clinical outcomes (15, 17-19).

The European Society for Pediatric and Neonatal Intensive Care (ESPNIC) was the first group to establish a consensus guideline for pediatric MV recommendations, detailing use of many different modes, interventions and adjuncts across various diseases. In Canada, respiratory therapists (RTs) are specially trained health care professionals, responsible for providing respiratory support and care for patients, and are considered to be one of the experts in MV management. RTs are a unique group of professionals with a specific role in respiratory care (20, 21). This role does not exist in several geographical locations, including Europe. Since the ESPNIC recommendations were based on the perspectives of European physicians only, it would be of interest to compare and contrast the differences with Canadian RTs' perspectives. Therefore, this study aimed to answer: What are Canadian RTs consensus recommendations on pediatric MV practice and management in critical care?

A Modified e-Delphi Survey Technique was used to collect Canadian RT's consensus on pediatric MV management in this study. Raw scores with ≥75% of participants in a categorized group were considered as consensus and verified using the coefficient of variation (CV). The contents of this Delphi study were derived from the published ESPNIC recommendations into 53 statements, and were verified in a pilot Round. The expert panel (n=56) consisted of pediatric intensive care unit (PICU) RTs in various clinical roles with ≥5 years working at pediatric acute care facilities or centers with dedicated pediatric beds across Canada. In Round 1, expert

participants suggested a few new topics to include, for a total of 58 statements. For Round 2 and 3, participants ranked their level of agreement or disagreement using a 5-point Likert scale. Fifty five of the 58 statements in Round 2 achieved consensus, and only statements that received significant feedback on its content or *did not* receive consensus were revised for another reiteration in Round 3. In Round 3, all 11 statements achieved consensus. The final recommendation guideline consisted of 59 statements, divided into 10 subtopics.

This is the first Canadian pediatric MV management guideline for critically ill children, from the perspectives of RTs. The purpose of this guideline is to emphasize the goals and MV management recommendations for any critically ill child, not specific to a particular disease or type of MV therapy. The majority of the recommendation statements in our Delphi study achieved consensus by the end of Round 2 (95% of statements). By the end of Round 3, all statements received consensus with at least 80% consensus for each. Using a Modified e-Delphi technique to specifically tailor the survey to focus on the relevant Canadian RT practices from the ESPNIC guideline (7), may have contributed to this high consensus. The Modified form most likely orientated our participants to the available information, and encouraged RT-focused feedback and ideas. In addition, the content and topics of our survey had already gone through a vigorous consensus process by international physicians, and other existing literature (7).

There were a few statements that went through extensive revisions throughout the Rounds before its finalized version in the consensus guideline. This included the statement about the indications and use for high flow nasal cannula [HFNC] oxygen therapy, an increasingly popular respiratory support to alleviate work of breathing in children in respiratory failure and bronchiolitis (22, 23). Because the ESPNIC guideline could not provide a practice recommendation for the use of HFNC (7), we originally opted to exclude it. However, participants emphasized its common use and importance in clinical practice and the topic was introduced in Round 2 with 76% consensus (CV 0.25, Likert mean±SD 3.82±0.97). Participants suggested that the recommendation could be strengthened by clearly stating that HFNC should not delay non-invasive ventilation (NIV) initiation in children with specific diseases, which greatly improved the consensus to 93% (CV 0.19, 4.37±0.81), with a significant change in Likert score means from Round 2 to 3 (Wilcoxon Signed Rank test [WSRT] $p=0.002$).

Another topic that was not originally included was high frequency jet ventilation (HFJV). As ESPNIC was unable to comment on the use of HFJV in children (7), we decided to exclude

this modality in our survey as well. However, feedback led to its inclusion for the following Rounds. This statement gained poor consensus in Round 2 (60%, CV 0.31, 3.4± 1.06) but improved after the statement was modified to consider its limited use in children (98%, CV 0.17, 4.14 ±0.72).

One statement about target tidal volumes, gained poor consensus at 60% (CV 0.21, 3.72±0.78), and received substantial open-text feedback on the tidal volume thresholds. The literature suggests physiologic tidal volumes range of 5 to 8ml/kg ideal body weight (IBW) but there may be circumstances that make it difficult to achieve target tidal volumes (4, 5, 24-26). These factors were included into the next reiteration in Round 3, which demonstrated an improvement in consensus to 97% (CV 0.12, 4.31±0.51) with significant change in Likert response means from Round 2 to 3 (WRST $p<0.01$).

One other statement that required several revisions was the recommendation on the use of proximal flow sensors. The use of proximal flow sensors was inconsistent across centers and resulted in poor consensus (71%, CV 0.26, 3.88± 1.02). Thus, we incorporated ESPNIC's recommendation on proximal sensor use, and participants' feedback, to finalize a statement about its limited use (84%, CV 0.21, 3.91± 0.82).

A subgroup analysis were done for years of PICU experience. The less experienced group had higher Likert mean scores compared to the more experienced. The group with more clinical PICU experience, likely witnessed a wider variety of clinical scenarios and circumstances where generalized recommendations are not applicable. Different clinical scenarios and circumstances warrant special considerations that may not be within the limits of the recommendations. This makes the clinical remarks a crucial part of this consensus guideline.

There were several strengths in this study, including the diverse expert panel. Across nine provinces, a total of 14 facilities participated: 13 pediatric facilities and 2 hospitals with dedicated pediatric beds. The participants were in various clinical roles with a range of PICU experience. Our response rate was high across all three Rounds, Round 1 with 78%, Round 2 with 91% and Round 3 with 97%. Another strength of this study is the inclusion of a pilot trial and post-Delphi review to enhance the content validity and trustworthiness of the results (27-30). These are usually not performed or reported in previous Delphi studies.

There were a few limitations in this study. The pilot phase only included RTs from SickKids, limiting the feedback to this one center. Another limiting factor was that several

centers were not involved in this study. Although we managed to successfully recruit and engage participants from 14 facilities, our subgroup sizes for several centers were less than the goal of three per center. In addition, there were two identified participants with less than five years of PICU experience, but they were included to improve the representativeness in our study. Though we achieved consensus, these Canadian RT consensus guidelines must be practiced with caution as they are based on limited empirical evidence, and have limited applicability to other interprofessional team members with MV experience.

This is the first consensus guideline document to describe pediatric MV management for critically ill children in Canada, based on the perspectives of RTs across Canada. Our Delphi study received at least 80% consensus on all the statements by Round 3, with a total of 59 statements, organized into 10 sections: 1) *non-invasive ventilation*, 2) *Tidal volumes and inspiratory pressures*, 3) *respiratory rates and inspiratory times*, 4) *PEEP and Fio2*, 5) *Advanced Modes of Ventilation*, 6) *Weaning*, 7) *Physiologic targets*, 8) *Monitoring*, 9) *General MV* and 10) *Equipment Adjuncts*. The guideline can be integrated into Canadian RT practices and is the initial step to standardizing pediatric MV care.

Because many of the recommendations in this guideline are based on the existing literature, they will require constant updates and revisions as evidence emerges. The purpose of this guideline is to serve as a fundamental support document to encourage the use of standardized management techniques across different Canadian pediatric critical care units. Furthermore, this guideline could also be utilized by pediatric MV health care practitioners across different regions. The guideline must be used by trained professionals, and relevant practices discussed with the interprofessional team; special circumstances may warrant adjustments of these recommendations. The efficacy of the MV recommendations in this guideline and their effect on clinical outcomes are unknown at this time. Future research should focus on taking the steps to implement this guideline in clinical practice, and research its impact on important clinical outcomes.

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Chapter 6- Finalized Canadian Pediatric MV management Consensus Guideline

All the "patients" in this document are ***Pediatric patients*****.**
A list of all the abbreviations is provided at the end of the document

Section 1: Non-invasive ventilation (NIV) Recommendations

Non-invasive ventilation (NIV) refers to any positive pressure ventilation that is provided via a headgear, face mask or nasal interface. This includes CPAP or BiLevel non-invasive support e.g. NIV, spontaneous timed (ST), pressure control (PC), pressure support (PS), proportional assist ventilation (PAV), non-invasive neurally adjusted ventilatory assist (NIV-NAVA).

1.1 Consider the use of NIV in patients with mild to moderate cardiorespiratory failure, if not responsive to or in combination with other medical management (e.g. inotropes, diuretics).

1.2 Consider the use of NIV to reduce work of breathing and decrease afterload for patients with left ventricular failure, if not responsive to or in combination with other medical management (e.g. inotropes, diuretics).

1.3 Aim to use NIV interfaces with minimal leak and appropriate for their size, age and skin integrity. Monitor leaks within an acceptable range to optimize patient comfort, compliance, patient ventilator synchrony, and to preserve patient trigger sensitivity.

The factors that impact interface selection are varied, and each clinical situation will require the clinician to balance these factors. Other factors not listed in the statement that may impact the interface selection includes the intentional leak built into the device, head gear size, and the compressible volume of the mask. In addition to these, the development of any interface-related pressure injury may prompt an alternate mask selection.

1.4 Optimize patient ventilator synchrony by adjusting trigger sensitivity and optimizing mask seal in any triggered non-invasive ventilation mode (e.g. bilevel, S/T).

1.4a If available, specialty modes of NIV such as NIV-NAVA can be used to optimize patient-ventilator synchrony.

The use of specialty modes varies across centres, based on both the availability of specialty modes and the institutional clinical guidelines for use. Factors that may influence success of specialty modes may be user's clinical experience as well as alternative available strategies available at centres.

1.5 Consider the use of NIV prior to intubation, in patients with mixed diseases (decreased compliance and/or increased resistance), unless contraindicated. Common contraindications are decreased level of consciousness, impending respiratory failure/arrest, airway compromise, decreased respiratory drive, and poor skin integrity (e.g. burns, contusions).

The decision to use NIV prior to intubation should be carefully evaluated with the interprofessional team. There are additional situations whereby invasive ventilation may offer additional stability beyond the list of common contraindications.

1.6 Consider the use of HFNC prior to NIV, to alleviate any work of breathing. However, the use of HFNC is not a substitute for NIV and should not delay or replace the use of NIV, if NIV is more appropriate.

After careful evaluation, the use of HFNC may be considered in a variety of clinical situations prior to NIV. If a clinical situation warrants a stable or defined positive pressure level, NIV should be used. There are certain clinical situations where NIV is the preferred therapy (e.g. obstructive sleep apnea).

1.7 The use of HFNC and/or NIV should not delay inevitable intubation.

Using NIV and/or HFNC prior to intubation is a complex clinical decision which should consider the patient's clinical status, and discussed with the interprofessional team.

Section 2: Tidal Volume & Inspiratory Pressure Recommendations

2.1 Aim to achieve a tidal volume in the physiologic range (5-8ml/kg ideal body weight) in patients <10kg. Alternatively, aim to achieve tidal volumes of 5-8ml/kg measured weight in patients ≤10kg.

The recommendation for 5-8mL/kg tidal volume assumes the delivery of mechanical ventilation to two lungs of anatomically appropriate size. If patients have anatomical differences (e.g., single lung, known lung hypoplasia), the target tidal volume should be discussed with the interprofessional team.

There are a variety of opinions on the appropriate age or size threshold to estimate tidal volume based on ideal body weight (as opposed to measured weight). Some suggestions include school-age, or 20kg. Clinicians should avoid over estimating lung volume if patients are obese or have excess weight due to excessive fluid overload.

On occasion, higher tidal volume ranges may be warranted for post-operative cardiac surgeries to keep the set respiratory rate lower to optimize venous return to the heart (by keeping the mean airway pressure lower through the respiratory cycle).

2.2 Aim to achieve tidal volume in the physiological range (5-8ml/kg ideal body weight) with minimal driving pressure (PIP-PEEP) in patients on pressure limited modes.

2.3 Aim to limit inspiratory plateau pressure (Pplat) to approximately 30cmH_2O, in the absence of transpulmonary pressure measurements. Limits should be between 28 to 32 cmH_2O.

There are many centres that pressure ventilate and do not routinely measure Pplat. In the absence of a Pplat measurement, aim to limit peak pressure (PIP) to 30cmH_2O.

2.4 If unable to achieve physiologic tidal volumes (5-8ml/kg) within plateau pressure limits (30cmH_2O), targeting ranges outside these limits should be discussed with the interprofessional team. There may be circumstances where tidal volumes < 5mL/kg and >8ml/kg may be cautiously, but not routinely used.

Examples where smaller tidal volumes may be acceptable include congenital hypoplastic lung or severe PARDS.

On occasion, higher tidal volume ranges may be warranted for post-operative cardiac surgeries to keep the set respiratory rate lower to optimize venous return to the heart (by keeping the mean airway pressure lower through the respiratory cycle).

Section 3: Respiratory Rate and Inspiratory Time Recommendations

3.1 Set inspiratory time and respiratory rate based on the patient's age, respiratory mechanics (including waveforms), and clinical data (e.g. blood gases, vital signs) in controlled ventilation modes. This will allow for full exhalation (acceptable I:E ratio), optimized patient synchrony and ventilation.

3.2 Set the trigger setting and cycling setting on the ventilator to achieve the above goals (Recommendation 3.1) in all spontaneous ventilation modes.

3.3 Increase the set respiratory rate when tidal volumes and/or PIP are reaching limits to maintain minute ventilation. Ensure there is sufficient expiratory time to avoid air-trapping.

Increase the RR to a reasonable threshold based on age, maintaining adequate inspiratory time to deliver tidal volume, and maintaining I:E ratio (a specific threshold has not been defined, though should not be inverse).

Section 4: PEEP and FiO_2 Recommendations

4.1 Set a minimum PEEP level of 5-6cmH_2O, to maintain adequate lung inflation, in all patients.

PEEP is used to maintain adequate functional residual capacity (FRC). There may be rare circumstances in which PEEP may be set below 5-6 cmH_2O (Recommendation 4.2).

4.2 Set PEEP to maintain end expiratory lung volume, and an optimal balance between hemodynamic stability and oxygenation, in all patients.

4.3 Titrate PEEP incrementally while assessing lung compliance, oxygen saturation, hemodynamic stability and chest x-ray findings for patients with challenging oxygenation needs (e.g. PARDS).

The titration of PEEP should be based on multiple factors and aim to avoid over or under-distension.
New technology such as Electrical Impedance Tomography (EIT) can be considered when deciding the appropriate PEEP level.

4.4 Titrate PEEP to allow for the lowest possible FiO_2 (to maintain target oxygenation goals), while maintaining adequate hemodynamic status.
In the absence of other clinical status changes, FiO_2 requirements can be helpful to assess and support the titration of PEEP (in addition to factors listed in 4.3). Increased FiO_2s during PEEP weaning may indicate that lung inflation is worsening.

4.5 Set higher levels of PEEP ($\geq$10cmH_2O) to maintain adequate lung inflation in patients with moderate to severe PARDS, if necessary.

4.6 Set higher levels of PEEP ($\geq$10cmH_2O) to stabilize airways in patients with tracheomalacia and/or bronchomalacia, if necessary.
The level of PEEP for patients with tracheomalacia and/or bronchomalacia should consider patient WOB, and tidal volumes/waveforms. Flexible laryngoscopy may also be used in collaboration with otolaryngology services (or the designated care team that manage these patients).

Section 5: Advanced Mechanical Ventilation Recommendations

General remark: All forms of advanced mechanical ventilation recommendations assume that practitioners have experience with their use. Availability of devices may vary across different institutions/units, reflecting when they are used.

5.1 Consider the use of high frequency oscillatory ventilation (HFOV) in patients with restrictive or mixed diseases and severe oxygenation and/ or ventilation failure.
The decision to transition from conventional to HFOV should be individualized. Broadly it should occur when the limits of conventional ventilation have been reached (see tidal volume and inspiratory pressure, Section 2; respiratory rate and inspiratory time, Section 3; and PEEP and FiO_2, Section 4).

5.2 Consider the use of HFOV in patients with cardiac issues and severe respiratory failure. Cautious use of increased mean airway pressure is advised in patients with passive pulmonary blood flow or right ventricular dysfunction.
See clinical remarks from 5.1.

5.3 Consider the use of other advanced modes (such as HFJV or APRV) when conventional mechanical ventilation and/or HFOV has failed. Consider the unique benefits and/or limitations for each of these advanced modes. These advanced modes should not substitute or delay inevitable ECLS, if appropriate.
Decisions on the use of advanced modes should consider the quality of pediatric research evidence, frequency and consistency of use, and/or availability.

5.4 Consider the use of other advanced ventilation modes/techniques (such as NAVA, PAV, or automated weaning) to optimize patient-ventilator interactions. The unique benefits and/or limitations for each of these advanced modes must be acknowledged.

The use of specialty modes to optimize patient-ventilator interactions should be based on both the availability of specialty modes and institution-specific clinical guidelines. Factors that may the influence success of specialty modes may be user's clinical experience as well as alternative strategies available at centres.

Decisions on the use of advanced modes should also consider the quality of pediatric research evidence.

5.5 Consider the use of ECLS in patients with reversible diseases when conventional mechanical ventilation and/ or HFOV has failed, if available within the facility, and not contraindicated. Follow guidelines (e.g. ECLS organizations) for more specific criteria. Consider early consultation with an ECLS center when ECLS is not available within the facility.

Section 6: Weaning Recommendations

6.1 Routinely assess all patients, with the aim to wean ventilator settings as early and often as possible.

6.2 Use weaning principles guided by respiratory mechanics, pathologies and disease trajectory in patients with complex presentations (e.g. restrictive, obstructive, mixed or cardiac diseases).

6.3 Consider the use of pressure support ventilation when adequate respiratory drive is present and disease trajectory is improving. This allows the patient to breathe spontaneously to maximize comfort and avoid asynchrony/muscle atrophy.

Pressure support ventilation can be used for prolonged periods of time. Parameter changes should be based on ongoing assessments of tolerance and patient's overall clinical status.

6.4 Routinely assess the pressure support level, rise time and sensitivity of flow cycling to maintain patient comfort/synchrony and physiologic tidal volumes (5-8ml/kg) in patients on pressure support ventilation.

Please also see all recommendations related to tidal volume (Section 2).

6.5 Routine daily assessment for weaning and extubation readiness should be performed in all patients.

Section 7: Physiologic Target Recommendations

7.1 Physiological targets should be guided by patient respiratory mechanics, both respiratory and non-respiratory pathologies, and disease trajectories.

7.2 Target normal arterial CO_2 levels for patients with healthy lungs (i.e. no respiratory disease). If arterial CO_2 is not available, target normal venous and capillary CO_2 levels.

7.3 Permissive hypercapnia ($pH \geq 7.25$) may be acceptable for acutely ill patients, unless specific disease conditions dictate otherwise (e.g. pulmonary hypertension, traumatic brain injury).

7.4 Target a SpO_2 92-99% in patients with healthy lungs, in the absence of respiratory disease. If the patient is post-resuscitation, follow the Heart and Stroke PALS recommendations of SpO_2 94-99%.

Excessive use of oxygen should be avoided. Supplemental oxygen should be continuously titrated down if the patient maintains an SpO_2 within the target range. SpO_2 >97% is acceptable if a patient is on FiO_2 0.21 (or as minimal as possible) to avoid frequent desaturations.

7.5 Target SpO_2 92-97% when PEEP is <10cmH_2O in patients who meet the PARDS criteria (as described in the PALICC guidelines).

These recommendations are made in the context of PARDS alone. If patients have other clinical factors that warrant PEEP titration or higher levels of PEEP, these should be incorporated into PEEP and SpO_2 clinical decisions.

7.6 Target SpO_2 88-92% when PEEP is $\geq$ 10cmH_2O in patients who meet the PARDS criteria (as described in the PALICC guidelines).

These recommendations are made in the context of PARDS alone. If patients have other clinical factors that warrant PEEP titration or higher levels of PEEP, these should be incorporated into PEEP and SpO_2 clinical decisions.

7.7 Target SpO_2 75-85% (or as recommended by the interprofessional team), for patients with cyanotic cardiac lesions (e.g. fixed Right to Left shunts).

Section 8: Monitoring Recommendations

8.1 Use continuous SpO_2 monitoring to assess oxygen saturation in all patients on invasive and non-invasive mechanical ventilation.

8.2 Use CO_2 monitoring (preferably end-tidal CO_2) in all patients on invasive mechanical ventilation.

8.3 Consider the use of transcutaneous CO_2 in patients on advanced forms of mechanical ventilation (e.g. HFOV, HFJV). These monitoring options should be frequently correlated with arterial blood gas values.

8.4 Use arterial lines for accurate pH, PaO_2, and lactate measurements, in moderate to severely ill patients on mechanical ventilation.

8.5 Use central SvO_2 and lactate measurements to assess oxygen extraction and/or cardiac output, in cardiac and/or severely ill patients on mechanical ventilation.

8.6 Consider the use of capillary gases to assess gas exchange in mechanically ventilated patients with good perfusion and mild diseases. They may be used to provide estimates or trends when arterial/central lines are not available.

Before taking a peripheral venous sample, consider an arterial blood gas puncture or capillary gas. Balance this by considering patient perspectives including procedural pain, willingness, and frequency of measurements.

8.7 Cautiously use peripheral venous PCO_2 measurements to provide estimates and trends of ventilatory gas exchange, when arterial/ central lines are not available.

8.8 Use pH as a tool to modify the pulmonary vascular resistance for specific disease conditions, (e.g. pulmonary hypertension, single ventricle heart disease).

8.9 Aim to maintain normal pH, $PaCO_2$ and PaO_2 in pulmonary hypertension and traumatic brain injury. Consider targeting normal-high pH and normal-low CO_2 values.

The management of pulmonary vascular resistance may also include the use of oxygen, inhaled nitric oxygen, or other medications, and is beyond the scope of these recommendations.

Section 9: Other General Recommendations

9.1 Routinely assess patients to allow for spontaneous breathing, except for severely ill patients receiving muscle relaxants and sedation.

9.2 Routinely monitor and assess the impacts of muscle relaxants and sedation on mechanical ventilation (respiratory rate, tidal volumes, minute ventilation) when they are in use for the patient's clinical management.

Continuously assess the benefits and harms of muscle relaxants and sedation, with the goal to minimizing use. Wean the muscle relaxant or sedation using a safe approach and with careful monitoring.

9.3 Routinely assess ventilator waveforms (e.g. flow-volume loops, pressure-volume loops) as they provide real-time data about patient-ventilator interactions such as breath-by-breath ventilation status, response to therapies, and lung mechanics.

9.4 Use the Pediatric Acute Lung Injury Consensus Conference (2015) recommendations on nitric oxide, neuromuscular blockade, prone position and surfactant use, if safe to do so.

9.5 Reduce the risk of Ventilator acquired pneumonia (VAP) by following the VAP bundles published by safety groups (e.g. Safer Healthcare Now!, Canadian Institute for Health Information, Solutions to Patient Safety). Elements include: 1) elevate the head of the bed 30-45 degrees (15-30 degrees in infants), unless specific disease or conditions dictate otherwise, 2) perform consistent oral hygiene, 3) minimize unnecessary circuit disconnects, and 4) perform daily assessment for extubation readiness.

9.6 Different Organization and Working Group guidelines and recommendations may be incorporated into practice and may include, but are not limited to: Pediatric Acute Lung Injury Care Conference (PALICC), National Heart, Lung, and Blood Institute (NHLBI) ARDS Network Protocol, Pediatric Advanced Life Support (PALS), Neonatal Resuscitation Program (NRP), Extracorporeal Life Support Organization (ELSO).

9.7 Mechanical ventilation management and anticipated plans should be discussed as an interprofessional team, at minimum, on a daily basis. Any changes in the patients' trajectory or mechanical ventilation needs should be communicated with all members of the interprofessional team.

Section 10: Equipment adjuncts recommendations

10.1 Use dual-limb, heated, filtered circuits with active airway humidity for invasive mechanical ventilation.

10.2 Use active airway humidification at 100% relative humidity at 37°C in patients on invasive mechanical ventilation. Use active airway humidification in the range of 31- 37°C, and titrate to avoid excessive rain out in the interface in patients on NIV.

10.3 Minimize the use of apparatuses or connectors that add dead space to ventilator circuits, whenever possible.

Many devices have neonatal and pediatric-sized adaptors, use the appropriate size for the patient based on the devices' recommendations.

10.4 Do not routinely use proximal flow sensors, or follow the specific ventilator's recommendations on proximal flow sensor use. In the absence of specific ventilator recommendations, use a proximal flow sensor for small tidal volumes (<10mL).

The use of a proximal flow sensor should be guided by the accuracy of the ventilator tidal volume measurement, and its acceptability as a measurement. Use proximal flow sensors for accurate measurement of tidal volume in smaller patients when internal measurements are inaccurate. Variability in practice may exist based on ventilator measurement accuracy, with some centres never using proximal flow sensors, and others using it for all patients.

10.5 Minimize routine use of manual ventilation to avoid circuit disconnects. Manual ventilation may be used to augment pulmonary hygiene as part of chest physiotherapy. Manual resuscitation devices should be capable of maintaining PEEP, monitoring and limiting pressures.

Use manual ventilation judiciously. Circumstances include managing acute desaturation, facilitating emergent patient transports, patient repositions to new beds, and/or ventilator circuit changes. Patients with certain pathologies may require manual ventilation for chest physiotherapy or secretion clearance techniques such as In-exsufflation. When manual ventilation is used, assess the patient for any transient or prolonged clinical changes such as lung de-recruitment.

List of abbreviations

APRV	Airway Pressure Release Ventilation
CO_2	carbon dioxide
ECLS	Extracorporeal Life Support
ECMO	Extracorporeal membrane oxygenation
FiO_2	Fraction of inspired oxygen
HFJV	High frequency jet ventilation
HFNC	High flow nasal cannula
HFJV	High frequency jet ventilation
HFOV	High frequency oscillation ventilation
IBW	Ideal body weight
NAVA	Neurally adjusted ventilatory assist
NIV-NAVA	Non-invasive neurally ventilatory assist
PaO2	Arterial partial pressure of oxygenation
PALICC	Pediatric Acute Lung injury Consensus conference
PALS	Pediatric Advanced Life Support
PARDS	Pediatric acute respiratory distress syndrome
PAV	Proportional Assist ventilation
PCO_2	Partial pressure of carbon dioxide
PEEP	Positive end expiratory pressure
PICU	Pediatric intensive care unit
PIP	Peak inspiratory pressure
Pplat	Plateau pressure
PSV	Pressure support ventilation
SpO_2	oxygen saturation
SvO_2	Venous saturation
VAP	Ventilator acquired pneumonia
WOB	Work of breathing

Chapter 7 – Supplementary materials

Supplementary Table 1A

Outlined inclusion and exclusion criteria for literature review.

Item	Inclusion	Exclusion
Participants/ Population	• Children (pediatrics) • Critical Care setting/ pediatric intensive care unit (PICU)	• Adults • Neonates • Animals
Intervention	• Protocolized MV therapy • Any form of protocolized MV mode/settings were included e.g. Non-invasive MV, high flow oxygen therapy, high frequency oscillation/ jet ventilation, conventional MV	• Long term (chronic) / home MV • Transport ventilation • Medical treatments not outlined in the inclusion criteria
Comparison	• Non-protocolized MV therapy i.e. management not guided by protocols or guidelines • MV therapy management directed by physician or team	• Long term (chronic) / home MV • Transport ventilation • Medical treatments not outlined in the inclusion criteria
Outcomes	• Clinical outcomes of MV, including (but not limited to): length of stay, length of MV therapy, adverse events, mortality, quality of care indicators etc.	• Studies without reported outcomes
Publication	• Published in English • Within last 20 years (2000 to 2021) • Full text articles	• Duplicate publications • Not published in peer-reviewed journal
Study design/ Article type	• Primary research studies • Retrospective or prospective • Quantitative: randomized controlled trials (RCT), pseudo-RCTS, cohort studies, case-control studies, case series, cross-sectional studies • Peer-reviewed secondary research publications • Systematic reviews, meta-analysis • Theses • Reviews and summaries of recommendations, protocols, guidelines, consensus (Clinical practice guidelines/ protocols) • Mixed methods including surveys, questionnaires, conference reports on recommendations or guidelines	• Non-peer reviewed articles e.g. newsletters, commentaries, opinion-pieces, editorials, conference proceedings

Supplementary table 1B

Search results for each of the databases.

Database	Number of articles found	Number of relevant articles
Pubmed	251	25
Embase	213	9
MEDLINE	375	18
CINAHL	25	2
Cochrane Reviews	40	3
Cochrane Trials	188	6

Supplementary table 2

List of pediatric facilities and facilities with dedicated pediatric critical care bed(s). A total of 19 centers were contacted and 15 centers enrolled into the study.

Facilities with stand-alone pediatric unit/ or dedicated bed(s)	**Facilities that were contacted**	**Facilities involved in the study**
• British Columbia Children's hospital • Stollery Children's • Alberta Children's • Janeway Children's • Jim Pattison Children's • Children Hospital of Manitoba • McMaster Children's Hospital • Sick Kids Hospital • Children's Hospital of Eastern Ontario • Montreal children's hospital • IWK Healthcenter • Centre hospitalier universitaire Sainte-Justine • CHUL et centre mère-enfant Soliel • London Health • Saint John's Regional hospital • Victoria General Hospital • University Hospital of Northern British Columbia • Regina General hospital • Moncton hospital • CSSS Rimouski-Neigette • University of Cardiology and Respiratory Quebec • Hôpital Fleurimont (CHUS)	• British Columbia Children's • Stollery Children's • Alberta Children's • Janeway Children's • Jim Pattison Children's • Children Hospital of Manitoba • McMaster Children's Hospital • Sick Kids Hospital • Children's Hospital of Eastern Ontario • Montreal children's hospital • IWK Healthcenter • Centre hospitalier universitaire Sainte-Justine • CHUL et centre mère-enfant Soliel • London Health • Saint John's Regional Hospital • Victoria General Hospital • University Hospital of Northern British Columbia • Regina General hospital • Moncton hospital	• Stollery Children's • Alberta Children's • Janeway Children's • Jim Pattison Children's • Children Hospital of Manitoba • Sick Kids Hospital • Children's Hospital of Eastern Ontario • McMaster Children's hospital • Montreal Children's hospital • IWK Healthcenter • Centre hospitalier universitaire Sainte-Justine • CHUL et centre mère-enfant Soliel • Saint John's Regional hospital • Victoria General Hospital • University Hospital of Northern British Columbia

Supplementary table 3

Practice locations and centers of the RT expert panel (N=55*)

Province	# of RTs (%)	Practice location	# of RTs
Alberta	11 (20.0)	Stollery Children's hospital	6
		Alberta Children's hospital	5
British Columbia	3 (5.5)	Victoria General hospital	2
		University hospital of Northern BC	1
Manitoba	5 (9.1)	Children's hospital of Manitoba	5
Saskatchewan	7 (12.7)	Jim Pattison Children's hospital	7
Ontario	12 (21.8)	Hospital for Sick Children	7
		Children Hospital of Eastern Ontario	4
		McMaster Children's hospital	1
Quebec	11 (20.0)	Montreal Children's hospital	5
		CHU Sainte Justine	5
		CHUL et centre mere-enfant Soleil	1
New Brunswick	1 (1.8)	Saint John Regional hospital	1
Newfoundland	2 (3.6)	Janeway Children's hospital	2
Nova Scotia	3 (5.5)	IWK Health center	3

*Includes n=3 who did not complete any Rounds

Supplementary Table 4

Open responses from participants for Round 1. The open-text feedback in this chart are as written by participants. Minimal revisions.

	Recommendation statement from Round 1	**Original comments**
Non invasive ventilation (NIV)		
1.1	Consider the use of non-invasive ventilation in pediatric patients with moderate cardiorespiratory failure. If not responsive to other medical management e.g. inotropes, diuretics	• We use HFNC (Airvo or Optiflow) in pediatric patient, sometime prior to NIV. If not responsive, initiate NIV • We consider the use of NIV for all patients with mild to moderate cardio-respiratory failure, with or without response to other medical management. • We would use NIV either in conjunction with or before inotropes/diuretics, not after. Inotropes or diuretics imply cardiac failure, not necessarily cardiorespiratory failure due to other disease processes. • I would have serious concerns if a paediatric patient was on inotropes with a refractory response, and the next step chosen is to add NIV. As well, children often require sedation to tolerate NIV, which adds yet another layer of complexity to managing these patients (vasoplegia, decrease responsiveness therefore difficult to clinically assess the effectiveness of therapy) • Full list of contraindications to NIV therapy should be given in these guidelines as well (ex: too many oral secretions, facial contusions/burns, decreased level of consciousness etc). Duration of "trial" on NIV as well as signs it is/isn't working and where to go next can also be explained. • Assess patient's ability to protect his/her airway and level of consciousness. NIV should not be used in cases of respiratory failure where cardio-respiratory arrest is impending • We do not want to be recommending NIV in the presence of airway compromise. These guidelines will be read by rural sites that may or may not have ventilation experts like RRTs on site and may take the abridged original statement at face value. NIV is lethal on the wrong patient.
1.2	Use non-invasive ventilation to reduce work of breathing and decrease afterload for pediatric patients with left ventricular failure, if not responsive to other medical management e.g. inotropes, diuretics.	• "in conjunction with other medical management". Sometimes, you do not want to wait for other things to fail before trying some NIV!

		• The use of NIV may help to reduce the work of breathing and decrease afterload for pediatric patients with left ventricular failure (e.g. dilated cardiomyopathy), while awaiting other treatment or if the patients is not responding to other medical management. • Only in pediatric critical care settings where patients can be monitored by expert clinicians and if not responsive to other left ventricular failure management. • Or HFNC if patient is not comfortable with the mask
1.3	Before intubation, consider non-invasive ventilation as a first approach in pediatric patients with mixed respiratory diseases (decreased compliance, or increased resistance), if the clinical condition does not dictate otherwise.	• NIV may provide a bridge until other medical management becomes effective (eg ventolin, steroids)" • great caution should be taken when initiating NIV for diseases of increased resistance. e.g. using it in an asthmatic patient may increase work of breathing, as well as hasten respiratory failure. On the other hand, there are times when NIV will work by decreasing the WOB with application of PEEP to reduce large changes in intrathoracic pressure. One statement CANNOT be applied to all pathology and clinical conditions. • NIV is always a first approach for us at [site removed] and has deterred many intubations. Almost 100% of our pediatric patients are placed on NIV with a total face mask. and that includes our patients in resp distress transferred by the peds transport team. • Must have very specific guidelines for the "otherwise" situations. Example: pH<7.20, decreased LOC, decreased drive to breath etc. • NIV should be considered in pediatric patients with diverse respiratory disease processes (ie, restrictive or obstructive) unless otherwise contraindicated, or if the patient has progressed to respiratory failure. • Pressures MUST be titrated to clinical assessment, unlike in adults - there is no standard prescription • This is to be considered if it will not delay inevitable intubation • We would also include high flow therapy before intubation as well as NIV
1.4	During non-invasive ventilation, aim to use interfaces without excessive leak. Monitor leaks within an acceptable range to preserve patient trigger	• Always favor a nasal mask for security reasons as pediatric patients may not be able to remove a full-face mask in the event of vomiting and may aspirate gastric contents. Full face masks should

	sensitivity	be used with caution when nasal masks are not achieving good synchrony and under direct supervision • leak is very dependent upon the patient's age/size. • Excessive leak can also impact synchrony • Circuit leak, asynchrony, mask fit, mask selection, NIV devices vs critical care devices all need to be considered otherwise the application of NIV can make the situation worse. • Consider patient comfort for best leak and patient compliance. Monitor leaks within and acceptable range to preserve patient trigger sensitivity. • If optimal mask seal cannot be obtained, also consider changing the trigger sensitivity to optimize the patient. • Monitor leaks within an acceptable range to preserve patient trigger sensitivity as well as ensure patient compliance with therapy along with optimal ventilation and oxygenation... • excessive leak and/or excessive dead space minimize dead space and monitor leaks within an acceptable range... • aim to use age-appropriate interfaces that minimize excessive leak. Monitor leaks within an acceptable range and ensure patient is triggering effectively • Add "Regular assessment of skin integrity should be performed to limit potential injury" • There is also the aspect that skin can break down for those at higher risk with poor cardiac function, poor nutrition and prolonged use of NIV (on for 24 /7), and for those requiring higher pressures. • Would mention to assess interface frequently or as part of assessment to check for pressure sores/skin integrity. • Patient interfaces should be assessed often, using a collaborative approach with nursing and RT. • Consider interfaces that provide some level of comfort, to improve patient compliance • the good choice of interface is the most important thing as the wrong interface may be the failure of NIV. • Interface choice is crucial for NIV success. The goal of minimizing leak remains a key aim for successful NIV ventilation both to maximize ventilation but also improve patient ventilator

		synchrony. To reduce patient ventilator asynchrony, we use oronasal mask and performax mask for smaller patients. • devices with large dead spaces (helmet/performax etc.) have a large amount of compressible volume within them, and this can make triggering more difficult - choosing an interface with minimal dead space will preserve patient trigger sensitivity -- CO2 clearance is usually pretty good because overall flows in these circuits are high, but trigger sensitivity can be difficult especially in a case with leak + large mask deadspace volume\
1.5	Target optimal patient ventilator synchrony in any triggered non-invasive ventilation mode e.g. bilevel, spontaneous/timed (S/T).	• Avoid ST mode. Instead, stick to using a SPONT mode and check for optimal mask fit, adjust sensitivity etc before placing patient on a backup rate. • adjust the trigger to achieve optimal patient synchrony in any triggered mode. • adjust the patients device to more sensitive triggering or use other device settings (such as mask type/recognition of mask leak) to enhance triggering if needed. • Be watchful for non-triggered breaths and breath stacking • choose synchronizing modes whenever possible and not limited by equipment and/or patient size • We use NIV with NAVA to optimise the patient ventilator synchrony if we have problem of synchrony with standard triggered NIV
1.6	Additional comments for section	• There should be strong encouragement that NIV should not delay endotracheal intubation • For patients hypercapnea, consider BiLevel forms of respiratory support, unless hypercapnea is anticipated to be solely associated with lung collapse that can be solved by CPAP alone. Consider CPAP for patients with respiratory distress but reasonably preserved ventilation, or as an escalation of support if HFNC is failing.
Tidal volumes and Inspiratory Pressure		
2.1	Use tidal volumes in the physiologic range (5-8ml/kg ideal body weight) for pediatric patients with healthy lungs.	• We actually use 5-7 ml/kg in most cases • Depends on the size of the patient. We use IBW when patients are greater than 10 KG. If they are less than 10 kg we just use their weight in KG. Our doctors at [site removed] use 4 to 6.5 mls/kg. It is rare that they use anything higher. • We tend to use actual body weight, especially for our younger patient ie ideal body weight for older patients.

		• Consider adaptive ventilation modes to optimize patients with highly fluctuating Vts or patients with quickly changing compliance/resistance. (e.g. following surfactant administration) • daily chest x-rays to monitor for hyperinflation and daily blood gases for optimal settings.
2.2	Avoid using tidal volumes greater than 8ml/kg ideal body weight in pediatric patients with restrictive lung, obstructive lung and/or congenital diseases	• Avoid 8mL/kg for ALL patients, due to increased risks of high pressures, overdistension, volutrauma etc. Focus on smaller physiologic volumes and instead increase the respiratory rate if needed • For patients with a need for strict PCO2 targets, consider volume-targeted ventilation or adaptive modes of ventilation to maintain a stable MV • VTs of 8mL/kg or higher should only be considered in special circumstances, such as DKA to blow off CO2 or for pt comfort with healthy lungs, and should ESPECIALLY be avoided in restrictive lung, obstructive lung and congential diseases. • In certain pathologies, >8ml/kg may be acceptable. Greater than 8ml/kg can be acceptable if driving pressure is low. Driving pressure is tidal volume normalized for compliance and should be used to guide if tidal volume setting outside of a physiologic range (5-8ml/kg) is acceptable. • But for patients with bronchodysplasia, 10 ml/kg is recommended.
2.3	For cardiac patients, higher tidal volumes (>8ml/kg ideal body weight) can be used to allow a lower set respiratory rate to promote venous return	• We always use 5-8 ml/kg even for cardiac patient • For cardiac patients, higher tidal volumes (>8ml/kg ideal body weight) can be used to allow a lower set respiratory rate promoting venous return. • For cardiac patients, higher tidal volumes (>8ml/kg ideal body weight) may be used to allow a lower set respiratory rate to promote venous return. Include a line about acceptable driving pressure when doing this • We use 7-9 ml/kg in such cases with a lower respiratory rate and longer inspiratory time • This is only acceptable if other parameters such as driving pressure and plateau pressure are maintained at appropriate levels. • Also need to consider the pressure required to achieve the tidal volumes. If you increase the delta pressure and increasing your mean airway pressure then you may not be aiding venous return.

		• It is worthwhile to include a statement about the rationale - "to lower mean airway pressure and promote venous return" • perhaps mentioning decreased mean airway pressure, decreasing thoracic pressure to promote venous return. • Mean airway pressure is often higher in this strategy as higher delta-P and longer insp. time are typically used to achieve similar minute ventilation when lower rate and high Vt strategy is used (however exp. time will be longer). • This is used when there is concern about venous return or right heart function however the respiratory rate should be set to the physiological normal for the age (especially when patients are not sedated and relaxed) • Closely monitor flow waveforms to ensure that inspiratory time is optimized, to allow for effective delivery of tidal volume but avoiding inspiratory holds --> a short It can limit your tidal volume delivery! • This should only be used once other management strategies are optimized.
2.4	Set a delta pressure (PIP-PEEP) to less than or equal to 10cmH_2O to achieve optimal tidal volume in the physiological range (5-8ml/kg ideal body weight) for all pediatric patients.	• When it comes to managing more acute patients with restrictive or obstructive lung diseases we need to set a delta P much greater than 10cmH_2O. • Try to minimize pressures in pediatric patients, but stating less than or equal to 10 for ALL patients is simply not achievable. Maybe something along the lines of "use the minimum set delta pressures possible to maintain tidal volumes in the physiological range and achieve normal blood gases". • I would aim at a delta pressure to less than or equal to 10 cmH_2O but I would not say that all patients have as low pressures • Pplat-PEEP 10cmH_2O appropriate for patients with normal respiratory system compliance. For patients that do not have a normal respiratory system compliance, it is unknown what is a safe pressure. Adult ARDS data suggests a driving pressure <15 • Delta P of 10 may be a good starting point if the patient doesn't have any lung issues (restrictive or obstructive), but we frequently use higher delta pressures with invasive ventilation, we will even start with a delta pressure of 15 cmH_2O. • Consider: Set a delta pressure (PIP-PEEP) to less than or equal to 15 cmH_2O to achieve

		optimal tidal volume in the physiological range (5-8ml/kg ideal body weight) for all pediatric patients. • We use delta pressure's set at whatever level will achieve optimal VTs (5-8ml/kg) while also maintaining our PIP's less than 25-30 cmH_2O in all pediatric patients. • Suggest using a PRVC/APVCMV mode, where you are targeting a set volume using the minimal amount of pressure possible. Often in extremely sick kids, this delta P will be much higher than 10 cmH_2O, although 10 is a fair starting point • If having trouble maintaining gases with Pplat>30, increase rate and accept smaller tidal volumes (4mL/kg) to obtain the same minute ventilation. • In patients with severe restriction (in upper or lower airways), use inspiratory plateau measurements to determine alveolar pressures. • Delta pressure should be Pplat-PEEP as this delta pressure (driving pressure) is tidal volume normalized for compliance (VT/CRS). This assists in setting the appropriate tidal volume for the amount of lung available for ventilation. It has been shown that compliance correlates with the amount of lung available for ventilation.
2.5	In absence of transpulmonary pressure measurements, limit the inspiratory plateau pressure to 28cmH_2O in pediatric patients with healthy lungs	• our site considers <32cmH_2O for poor compliance or lung pathologies • Use less than 25 cmH20, if the child is under 1 year and after that go with 30 cmH20. • We usually use <30 cmH_2O. However, sometimes we have to go above 30cmH_2O. I would add something like "all attempts should be made to limit the inspiratory plateau..." • In the absence of transpulmonary pressure measurements, limit the inspiratory plateau pressure to 28cmH_2O in pediatric patients with decreased chest wall compliance. • I would say to try to limit inspiratory plateau pressures to less than or equal to 25 cmH_2O in all pediatric patients, except in extreme circumstances eg. severe ARDS.
2.6	In absence of transpulmonary pressure measurements, limit the inspiratory plateau pressure 32cmH_2O in patients with decreased chest wall compliance	
2.7	Measure tidal volumes proximally in pediatric patients <10kg	• we use proximal flow monitoring for all pediatric patients ≤4kg, as this provides a reasonable compromise for us within our patient population. • Ideally measure flow, pressure and tidal volumes as proximally as you can in patients less than 10 kg.

		• Measure use proximal tidal volumes measurement based on ventilator machine's recommendations; this will typically be for Vts less than 10mL. Consider the value of precision Vt measurement versus the additional dead space and weight on the ETT. • The other big reason to do proximal flow monitoring / volume measurement is because of leaks & we're using more uncuffed tubes. • it increases complexity to ventilator circuit and additional weight at patient wye, increasing risk of unplanned extubation. I understand principle of having accurate tidal volume measurements however not sure the clinical impact is as significant as the risk. A small difference in flow sensor vs. ventilator measured tidal volumes, whereas clinical assessment of chest rise, gas exchange (ventilation and oxygenation) may be more impactful.
Respiratory rate and Inspiratory time		
3.1	Set inspiratory time and RR based on the patient's age, ventilatory waveforms and clinical evolution, to allow for full exhalation (good I:E ratio) and optimized pediatric-patient synchrony.	• “In controlled ventilation modes, [set insp time....]. On spontaneous modes, set end-inspiratory/cycling setting to achieve the same goals as above. • "recommend setting the inspiratory time and respiratory rate related to respiratory system mechanics and disease trajectory. Both are closely correlated and cannot be judged as independent from each other" • "use Vt and RR settings to achieve minute ventilation target desired to achieve acceptable CO2 clearance and appropriate blood gas values." • Recommend settings which avoid flow end inspiratory or expiratory flow interruption • We always assure our patients are fully exhaling by making sure the flow/time waveform returns to zero before the next breath is given • I might add something that too short of inspiratory times can be equally as detrimental to ventilation as an inspiratory hold. • Recommend taking into consideration the time constant of the respiratory system when deciding on rate and inspiratory time/I:E ratio in order to optimize patient synchrony and avoid air-trapping.
3.2	Increase the set RR when tidal volumes and/or PIP are reaching limits to maintain minute ventilation in restrictive diseases.	• Optimize Ti in pressure supported ventilation ie. rise time/expiratory flow cycling

		• Increase the set RR when tidal volumes, PIP or both reach limits to maintain minute ventilation in restrictive diseases. • "Increase the set RR when the tidal volumes >6ml/kg or Pplat >30 cmH_2O to maintain minute ventilation in restrictive diseases." • Consider: "set PIP/Vt appropriate for the patients compliance/resistance and use RR adjustments to achieve desired minute ventilation" • Consider inadequate inspiratory time, I:E ratio and observe inspiratory/expiratory flow waveforms. • Ensuring sufficient exp. time (good I;E ratio) to allow for complete emptying of lung units, avoid gas trapping • As long as our pH goals are being met, we would allow lower tidal volumes in restrictive disease patients • Other than alveolar ventilation, the other targets could be ordered goals for ABGs/ EtCO2/SpO2 • Include: "Set shorter inspiratory times and Allow for longer expiratory times in Obstructive diseases eg. asthma. Ensure flow waveform is returning to baseline to avoid air trapping."
PEEP and Fio2		
4.1	Set a minimum PEEP of 5cmH_2O, to prevent alveolar collapse in pediatric patients with healthy lungs	• Perhaps add "except where limiting mean airway pressure for venous return is a consideration (ie. some cardiac cases)." We will occasionally go down to PEEP of 3 or 4 in the more extreme cases. • Substitute: "to achieve optimal lung recruitment and adhere to protective lung ventilation strategies." And add "certain disease conditions may preclude this. eg Status Asthmaticus" • We typically use more than 5 cmH20 for most patients but it is fine as a minimum (minimum of 6cmH_2O for PEEP)
4.2	Set PEEP to maintain end expiratory lung volume, and an optimal balance between hemodynamics and oxygenation in all pediatric patients. Carefully titrate PEEP to avoid cardiovascular compromise	• Increase in increments of 2 cmH_2O every 15 minutes if unable to oxygenate patient. Carefully watch the monitor for all cardiac compromise signs, especially bradycardia/hypotension in children. Continue to monitor Pplat as PEEP is increased to maintain <30 cmH_2O. • Set PEEP to maintain appropriate end expiratory lung volume, and an optimal balance between hemodynamics and oxygenation/ventilation in all pediatric patients. Carefully titrate PEEP to avoid cardiovascular compromise.

		• I would also add: "Consider doing Optimal (or Best) PEEP studies in patient's requiring high PEEP and high FiO_2" • We encourage our staff to do an optimal PEEP exercise by looking at the dynamic compliance as well as the end inspiratory pressure vs PEEP as long as the patient is in constant flow and is not breathing above the set rate
4.3	High levels of PEEP (>10cmH_2O) may be required for pediatric patients with severe ARDS.	• PEEP level should be adjusted based on oxygen requirements and determination of optimal PEEP Maybe that could be rephrased as higher levels of PEEP, rather than calling 10 cmH_2O high. • If FiO2 is greater than 0.4, always consider optimizing PEEP by increasing in increments of 2 cmH_2O every 15 minutes. If patient is on 100% oxygen and has low oxygen saturations, may increase PEEP faster or use a recruitment maneuver to open up collapsed areas. • Potentially add "Consider using transpulmonary pressure monitoring (ie. esophageal balloon) in these cases." • Also for patients with pulmonary edema/hemorrhage/ bronchopulmonary Dysplasia.
4.4	High levels of PEEP (>10H2O) may be required to stabilize airways in pediatric patients with tracheomalacia and/or bronchomalacia.	• Maybe that could be rephrased as higher levels of PEEP, rather than calling 10 high. • PEEP >10cmH2O may be required to stabilize airways in pediatric patients with tracheomalacia and/or bronchomalacia.
4.5	Set the lowest possible FiO2 to maintain target oxygenation goals	• for patients with cardiac disease and right-to-left shunting, consider the value of increasing FiO2 but avoid high levels of oxygen when only minimal improvement in saturations is observed. • I would emphasize recruiting collapsed lung areas and protective lung strategies vs oxygenation. • Once optimal PEEP is achieved, set the lowest possible FiO2 to maintain target oxygenation goals • we use a peep fio2 table for optimization • 'target oxygenation goals' should be defined in the recommendations to include: ≥95 in most healthy kids breathing room air, >95% with pulmonary hypertension, 92-97% in ventilated kids with PEEP <10, 88-92% in ventilated kids with PEEP ≥10 or as otherwise defined by the institution
Advanced Mechanical ventilation		

5.1	Consider high frequency oscillatory ventilation (HFOV) in pediatric patients with restrictive or mixed diseases with severe oxygenation and/or ventilation failure	• should include "if conventional mechanical ventilation has failed" since there's no actual evidence to recommend it over conventional ventilation • Try conventional methods first with high respiratory rates, low tidal volumes, and high PEEPs before switching to HFOV. HFOV often causes cardiac compromise in pediatric patients, and should be used with caution. • Consider high frequency oscillatory ventilation (HFOV) in pediatric patients with restrictive or mixed diseases with severe oxygenation and/or ventilation failure who have failed conventional mechanical ventilation • Include High Frequency Jet Ventilation • We also look at the CXR; for HFOV, we recommend an homogeneous picture; for non-homogeneous and severe CO2 retention, we may go for high frequency jet ventilation
5.2	Careful use of high frequency oscillatory ventilation (HFOV) can be considered in pediatric patients with cardiac issues suffering from severe respiratory failure. Caution is advised in patients with passive pulmonary blood flow or right ventricular dysfunction	• Include High Frequency Jet Ventilation • I've rarely (if ever) seen HFOV used for cardiac patients; we would likely proceed directly to ECLS for a patient with this degree of failure. Time should not be spent on HFOV if it would be better spent elsewhere. • Cautious use of Mean Airway Pressure is advised in patients with passive pulmonary blood flow or right ventricular dysfunction. • If the patients cardiac system is compromised or the BP is unstable, that needs to be addressed first • Cardiac function should be assessed prior to initiation. • If the cardiac issues are being caused by severe respiratory failure despite conventional mechanical ventilation techniques, HFOV could be trialled, however, it will often worsen cardiac symptoms in children, so use extreme caution, and minimal settings. You may have to add cardiac medications to the child while the respiratory component of the illness is being managed/fixed.
5.3	Careful use of high frequency oscillatory ventilation (HFOV) can be considered in cardiac pediatric patients suffering from severe respiratory failure.	
5.4	Methods of ventilation such as Airway Pressure Release Ventilation (APRV), Neurally Adjusted Ventilatory Assist (NAVA), Proportional Assist Ventilation (PAV), automated weaning etc, may be considered to optimize patient-ventilator interactions	• and with adequate support and training to optimize ventilation. • These modes should be recommended with caution due to a lack of strong evidence regarding outcome or utility. • APRV isn't exactly in the same category as PAV or NAVA in that it's not a patient-physiology or effort-targeted mode. APRV is something else

		entirely (usually a non-conventional high mean airway pressure mode) and doesn't belong in this category. • APRV is not designed to improve patient ventilator interactions. The NAVA and PAV are
Weaning		
6.1	Start weaning ventilator settings as early as possible.	• Routine/daily assessments for weaning ventilator settings as early as possible is recommended. • As soon as patient begins triggering above set rate (when patients have sufficient respiratory drive), switch to a PSV/SPONT/CPAP mode of ventilation. Look for signs of increased work of breathing/deterioration of gases in order to determine whether child is tolerating the change. Titrate pressure support to obtain physiological volumes with minimal WOB present. • Attempt weaning ventilator settings once O2 saturation goals and CO2 goals have been met. As patient condition improves continue to wean down to extubatable settings. • Monitoring oxygenation & pH, work of breathing, patient comfort, etc. • Most current recommendations indicate that we should be frequently assessing the patient for weaning READINESS and then weaning as soon as readiness is identified. Seems like that should be defined.
6.2	In any complex cases (e.g. restrictive, obstructive, mixed or cardiac pediatric patients), use weaning principles specific to the pathology and titrate ventilator settings more carefully.	• In very difficult patients, a systematic "weaning schedule" may be used. Ex: on a patient who has been on a ventillator for an extended amount of time where muscle weakness is an issue, they may have to do "trials" of decreased pressure support each day until they can tolerate it for 24 hrs. Gradually increase the time the patient spends on the lower support in 30-60 min intervals each day. • it would probably be more correct to state that in disease states, the weaning principle should be guided by respiratory system mechanics, pathology, and disease trajectory. • Principles related to pathology should be used to titrate ventilator settings at all times, not just during the weaning phase. Pathologies do not just include lung and cardiac pathologies (e.g. restrictive, obstructive, mixed or cardiac) but other pathologies suggest as traumatic brain injury and sepsis need to be considered in ventilator titration.

		• whenever possible, adapt a multidisciplinary approach to difficult to wean patients. Use a regimented, gradually increasing workload/time trial approach to build respiratory muscles with regimented FULL rest periods. the only proven successful slow wean methods all involve careful regimented weaning that is consistent.
6.3	If adequate respiratory drive is present, pressure support ventilation may be considered allowing the pediatric patient to breathe spontaneously	• This is with the assumption that their time constants are appropriate and do not lead to shorter than needed inspiratory times. • And should be considered early to aid patient comfort /prevent dysynchrony • Patient should be changed to a spontaneous mode as soon as possible to avoid muscle fatigue/ventilator asynchrony. • If adequate respiratory drive is present, pressure support ventilation should be considered allowing the pediatric patient to breathe spontaneously, except in early ARDS • We use modes that allow supported spontaneous ventilation on all our patients to ensure their respiratory muscles are being used • This recommendation holds true for all but the most severely ill child with obstructive airway, restrictive airway or mixed disease. In these children sedation or neuromuscular blockade and controlled mandatory ventilation may be necessary to facilitate improved oxygenation.
6.4	If pressure support ventilation is used, the pressure support, sensitivity, flow cycling, and rise time should be adjusted to maintain patient comfort/synchrony and physiologic tidal volumes	• In spontaneous breathing modes, the support, sensitivity, flow cycling, and rise time should be adjusted to maintain patient comfort/synchrony and physiologic tidal volumes. • There are more than pressure support for spontaneous ventilator modes. Volume Support and ASV would be examples of other spontaneous modes that don't have a pressure support setting. These parameters (e.g. cycling, rise time, sensitivity, etc) should be adjusted for patient comfort/synchrony in control modes. • We never use a pressure support less then +6 in order to overcome the resistance of the ETT
6.5	Routine daily assessment for weaning and extubation should be performed.	• I think this also depends on the patient and the pathology/ why they are admitted.
Physiologic targets		
7.1	Target normal arterial CO2 levels for pediatric patients with healthy lungs and electively ventilated e.g. post-operative.	
7.2	Permissive hypercapnia ($pH \geq 7.2$) may be acceptable for acute pediatric	• Must be mindful of CO2 levels in brain injury pediatric patients.

	patients, unless specific disease conditions dictate otherwise e.g. pulmonary hypertension	• maybe add in acceptable CO2 levels. pH may be indicative of a metabolic issue, not only a respiratory one. • avoid focusing on PaCO2. focus on pH. • ARDSnet makes no mention of PaCO2 goals at all. make sure clinicians are targeting pH and not getting wrapped around the axle of PaCO2. • 7.20 seems low; we'd typically say 7.25 at a minimum and more likely 7.30. It may be worthwhile to specifically mention head trauma/ICP as a specific condition where hypercapnia is inappropriate.
7.3	Target a SpO2 > 95% on room air in pediatric ventilated patients with healthy lungs.	• Patients with SpO2 of 99-100% should have their oxygen weaned, if not on FiO2 =0.21. • We use SpO2>92%. Be mindful of SpO2 sitting at 100% and wean oxygen whenever possible to avoid oxygen free radical accumulation. Best to maintain 92-99% • I would remove "on room air", because if their saturations are not 95% oxygen will be added. • though healthy lungs can probably achieve >95%. But we wouldn't target on room air - we would simply give patients whatever FiO2 they need to achieve SpO2. In healthy lungs, minimal FiO2 should be required to achieve SpO2 goals though • Target an SpO2 > 95% on room air in pediatric ventilated patients with healthy lungs. • In the absence of severe disease or known shunt, provide FiO2 to achieve a SpO2 >92% . • pre-oxygenate for routine cares that may impede effective ventilation/oxygenation (e.g. suctioning), unless detrimental to patient (e.g. unrepaired cardiacs).
7.4	Target SpO2 92-97% when PEEP is less than 10cmH_2O in pediatric patients who meet the pediatric ARDS criteria as described in the PALICC guidelines (access article here).	• the PEEP and SpO2 relationship should not limit our target range. PEEP can be targeted using various methods that do not automatically mean we would lower their SpO2 targets if we end up on a higher level. • SpO2 Targets should not be linked to PEEP. PEEP should be titrated to based upon optimization of end-expiatory lung volume and pulmonary mechanics not FiO2 or SpO2.
7.5	Target SpO2 88-92% when PEEP is 10cmH_2O or higher in pediatric patients who meet the pediatric ARDS criteria as described in the PALICC guidelines (PALICC Guidelines 2015).	• PEEP may be set higher than 10 for various reasons, and if targeted to optimize end expiratory lung volume, may not always have to lower goals. • SpO2 Targets should not be linked to PEEP. PEEP should be titrated to based upon

		optimization of end-expiatory lung volume and pulmonary mechanics not FiO2 or SpO2. • Lower SpO2 can be tolerated if end organ/tissue oxygen demand is being met indicated by normal lactate and acceptable end organ function (ex. urine output, level of consciousness appropriate, etc.)
7.6	Target SpO2 75-85% for pediatric patients with cyanotic cardiac lesions e.g. fixed Right to Left shunts.	• keeping in mind there are some patients that we allow for lower SpO2 when sick. • depend on the shunt usually we target around 80% • Consider adding; "Target Spo2 75-85% or the defined range as determined by medical team"/ cardiologist • Can change depending on specific heart defects/surgeries performed, therefore we always have patient specific SpO2 ranges defined by a cardiologist. • Not all patients with cyanotic heart lesions will have saturations in this range. For example, a patient with hypoplastic left heart syndrome with forward flow can actually have saturations over 90% despite having a duct dependent physiology. As well, all patients with duct dependent lesions will have some degree of variablity in their saturations.
Monitoring		
8.1	CO2 monitoring should be used in every pediatric patient on invasive mechanical ventilation, preferably end-tidal CO2.	• CO2 monitoring should be used in every pediatric patient on invasive mechanical ventilation, preferably end-tidal CO2. • maybe mention transcutaneous monitoring for patients on HFOV. Since end tidal will not be accurate when ventilated in that mode. • Should be correlated to blood gas • We find that in some patients it doesn't give good feedback (not correlating with blood gases) therefore we may remove it as we are doing more blood gases chasing a poor monitor.
8.2	SpO2 monitoring should be used to assess oxygenation in every pediatric patient on invasive or non-invasive mechanical ventilation	-
8.3	Use indwelling arterial lines for accurate pH, PaO2, PaCO2, and lactate measurements, in severely ill pediatric patients on mechanical ventilation	• Moderately-severely ill patients should all have arterial lines for real time blood pressure measurements
8.4	Use central venous saturation (SvO2) and lactate measurements to assess presence or absence of oxygen debt and/or cardiac output, in severely ill	• Use central venous saturation (SvO2) and lactate measurements to assess the presence or absence of oxygen debt and cardiac output, in *severely ill*

	pediatric patients on mechanical ventilation	*pediatric patients/ cardiac patients* on mechanical ventilation. • It should be done when warranted. Lactate should be followed, and that can indicate when central sats should be followed.
8.5	Use central venous saturation (SvO2) and lactate measurements to assess presence or absence of oxygen debt and/or cardiac output, in cardiac pediatric patients on mechanical ventilation.	
8.6	Peripheral venous PCO2 measurements are of limited use in providing information about ventilatory gas exchange. However, they may be used for providing estimates or trending.	• Use caution when interpreting these results. In line with clinical presentation, they may be used for providing estimates or trending. • We actually use them quite a bit when we do not have an arterial or central line. Maybe "Peripheral venous PCO2 measurements may be used for providing estimates or trending values when arterial/central lines are not available".
8.7	Capillary gases are adequate to assess gas exchange in pediatric patients with mild diseases on mechanical Ventilation	• or in the absence of any indwelling lines. Use caution when interpreting these results. • if obtained using the correct procedure in patients with good peripheral perfusion eg. warming site, not milking etc. • would classify use of capillary gases as similar to peripheral PaCO2 monitoring and useful as trend or estimation. • Capillary blood gases can be used to assess ventilation (PaCO2) for patients with mild diseases however would not use to guide oxygenation. Also, lactate should not be interpreted from capillary blood gases as an assessment of end oxygen delivery.
8.8	Use pH as a tool to modify the pulmonary vascular resistance for specific disease conditions	• It would be helpful to have a list of or examples of specific disease conditions where this can be useful (pulmonary hypertension, PPHN, single ventricle heart disease after specific stages of surgical intervention)
8.9	Maintain normal pH and PCO2 in pulmonary hypertension	• as well as high normal PaO2 in these patients • I think it needs a qualifier of "attempt to maintain..." as by placing patients on harmful mechanical ventilation settings this may be doing more harm than accepting mild acidosis and some degree of hypercapnia in a patient with pulmonary hypertension especially if they have secondary lung disease (ex. viral or bacterial infection or pneumonia or PARDS on top of having pulmonary hypertension) • or the medically ordered pH/PCO2 range by medical team. Consider achievable pH/PCO2 goals and balance lung protection with severe cases.

		• We usually try to hyperventilate our patient with pulmonary hypertension (PH:7.40-7.45). Even with normal SPo2 we give O2 to help lower the capillary resistance in the lung • As a general rule, we would seek to avoid acidosis - either normal or alkalotic could be acceptable depending on the patient. • There should be a section about aiming for lower normal CO2 in Traumatic Brain Injury scenarios. "Target low-normal CO2 ranges (35-40) for Traumatic Brain Injury patients."
General		
9.1	All pediatric patients on mechanical ventilation should be allowed to breathe spontaneously, with the exception of the most severely ill and/or those requiring intermittent neuromuscular blockade or those with surgical contraindications (e.g. airway surgery).	• airway surgery should not be a contraindication for breathing ability...or drive to breath • Unless unstable, if a patient who underwent airway surgery is not agitated, we allow them to breathe spontaneously while intubated. Each case is different; we must consider the long term effects of sedation/paralytic agents vs patient's status • If patient is at risk of self extubating, optimize the medications so that the patient is still able to breathe, but is not waking up pulling at things. The goal is to always have the patient breathing, so this may mean using 3/4 sedatives instead of placing patient on a paralytic. Only times a paralytic should be used are in the patients that you cannot ventilate/oxygenate, uncontrollable seizures, or head injury patients who are shivering. • Routine assessments for assessing the need for sedation, neuro-muscular blockades and perhaps weaning these based upon these assessments, could enhance early weaning of respiratory and hemodynamic supports.
9.2	Ventilator waveforms e.g. flow volume loops, pressure volume loops, provide real-time data about patient-ventilator interactions such as breath-by-breath ventilation status, response to therapies, and lung mechanics.	• this is more of a statement than a recommendation. I think you're recommending that these waveforms be analyzed on a regular basis in order to glean data about status/response/mechanics
9.3	The Pediatric Acute Lung Injury Consensus Conference (2015) recommendations on nitric oxide, neuromuscular blockade, prone position and surfactant use should be followed. *Inhaled nitric oxide is not recommended for routine use in PARDS. However, its use may be	• We always start our nitric at 20 ppm and assess response. If no effect, it is turned off. If it has effect, we leave it on until ready to wean. Weaning process:20ppm --> 15 ppm-->10 ppm-->5 ppm, and then decrease in increments of 1 ppm until off. We usually decrease every 2-4 hours

	considered in patients with documented pulmonary hypertension or severe right ventricular dysfunction. In addition, it may be considered in severe cases of PARDS as a rescue from or bridge to extracorporeal life support. When used, assessment of benefit must be undertaken promptly and serially to minimize toxicity and to eliminate continued use without established effect. Finally, future study is needed to better define its role, if any, in the treatment of PARDS. (PALICC guidelines 2015)	• I think we should be cautious about prone positioning in PALICC guidelines as I feel that most adult centres now apply prone positioning to severe ARDS patients when lung protective ventilation is failing.
9.4	Caution is advised when using sedation and muscle relaxants in pediatric patients with altered cardiac function	• If patient is on ventilator; adjustments must be made to appropriately ventilate and oxygenate patient. • Sedation is an important factor in trying to ventilate sick patients. Optimizing sedation levels when trying to ventilate sick patients can be crucial. Also review optimizing peep.
9.5	Extracorporeal life support (ECLS) e.g. NovaLung, extracorporeal membrane oxygenation, should be considered when conventional and/or high frequency oscillatory ventilation fail in pediatric patients with reversible diseases. Follow guidelines for specific criteria eg. Extracorpeal Life Support Organization	• add HFJV in there too. Jet is now replacing HFOV as the go-to mode of choice for severe patients that are small enough for Jet to work on. • [name removed] doesn't have ECMO and must then transfer severely unstable patients by air transport to [name removed] Children's hospital. We trial Nitric on all severely ill pediatric ventilated patients in an effort to be able to keep the patient in our ICU rather than risk an unstable transfer. • In patients with a reversible condition, where their conventional ventilator settings are above recommendations and likely to cause further harm or a trial of HFOV fails, early consideration for extracorporeal life support or referral to a centre that offers extracorporeal life support should be made. • ECLS should be used only in established ECLS centres where appropriately trained personnel and expertise are available; early referral to an ECLS centre should occur when ECLS is not available at the current centre • Maybe add in the bit about consulting an ECMO center early before deterioration is such that transport is no longer safely feasible.
Equipment adjuncts		
10.1	Use double limb circuits for acute, invasive mechanical ventilation	•

10.2	Minimize the use of apparatuses that add dead space to ventilator circuits	• Consider the impact of additional airway devices to dead space, in particular for smaller patients (e.g. the addition of EtCo2 monitors or HME for transport). • Minimize the use of apparatuses that add dead space to ventilator circuits, whenever possible.
10.3	Elevate the head of the bed at 30-45 degrees in all pediatric patients, unless specific disease conditions dictate otherwise.	• Consider eliminating the word "disease" as the sentence would convey the message without this word. Often there is no specific disease process involved, however a specific head of bed may be indicated ie) post-operative procedure, neurological care, VAP protocols etc.....
10.4	Provide airway humidification, 100% relative humidity at 37°C, for all pediatric patients on mechanical ventilation.	• Provide "active" humidification • This is in reference to invasive mechanical ventilation; separate recommendations should be made for NIV • Because of the rainout seen when using NIV, we sometimes will turn our humidifiers to non-invasive (31 degrees)
10.5	Hand-ventilation should be avoided. If hand-ventilation is required, pressure measurements, pressure pop up and PEEP valves or flow-inflating bags should be used to match ventilation pressures.	• ROUTINE use of hand ventilation (using manual resuscitator) should be avoided. • Manual-ventilation should be avoided. If manual-ventilation is required, flow-inflating bags with pressure measurements should be used to match ventilation pressures. If a self-inflating bag is used, pressure measurements, a pressure pop off, and PEEP valves will be required. • To clarify, in an emergency arrest, it is suitable to bag • Caution with use of flow-inflating bags and matching pressures - still need to ensure patient is adequately supported by looking for chest rise and clinical indicators of adequate oxygenation/ventilation (SpO2, EtCO2). In my experience, typically requires higher pressures measured on flow inflating bag manometer as compared to ventilator settings to achieve similar oxygenation and ventilation targets. If clinician only relying and fixated on manometer, than may not adequately ventilate patient and cause harm.
10.6	Additional feedback	• Use EVAC tubes (suction set at -30 cmH_2O) when available to decrease rates of VAP. Use inline suction for all patients to avoid circuit disconnections. Use minimal occlusive volume for endotracheal cuffs. In our center we always use cuffed tubes in our pediatric patients. If there is no leak, the cuff is simply left down in order to avoid any unnecessary trauma.

		• Consider VAP protocols as equipment adjuncts. ie) EVAC endotracheal tubes, elevated HOB, oral care, OG tubes and respiratory circuits draining away from patient in a gravity dependant manner. • Routine instillation of saline is not recommended.

Supplementary Table 5

Comparison table of recommendation statements from Round 1 and the revised statements in Round 2.

	Recommendation statement (Round 1)	Revised Recommendation statement (Round 2)
Non invasive ventilation		
1.1	Consider the use of non-invasive ventilation in pediatric patients with moderate cardiorespiratory failure. If not responsive to other medical management e.g. inotropes, diuretics	Consider the use of non-invasive ventilation in pediatric patients with mild to moderate cardiorespiratory failure, if not responsive to or in combination with other medical management, e.g. inotropes, diuretics.
1.2	Use non-invasive ventilation to reduce work of breathing and decrease afterload for pediatric patients with left ventricular failure, if not responsive to other medical management e.g. inotropes, diuretics.	Consider the use of non-invasive ventilation to reduce work of breathing and decrease afterload for pediatric patients with left ventricular failure, if not responsive to or in combination with other medical management, e.g. inotropes, diuretics.
1.3	Before intubation, consider non-invasive ventilation as a first approach in pediatric patients with mixed respiratory diseases (decreased compliance, or increased resistance), if the clinical condition does not dictate otherwise.	Consider non-invasive ventilation as a first approach in pediatric patients with mixed diseases (decreased compliance or increased resistance), unless contraindicated, before intubation. Examples of contraindications: decreased level of consciousness, impending respiratory failure/arrest, airway compromise, decreased respiratory drive, poor skin integrity (e.g. burns, contusions)
1.4	During non-invasive ventilation, aim to use interfaces without excessive leak. Monitor leaks within an acceptable range to preserve patient trigger sensitivity	Aim to use interfaces with minimal leak and appropriate for the patient's size, age and skin integrity for patients on non-invasive ventilation. Monitor leaks within an acceptable range to optimize patient comfort, compliance, synchrony, and to preserve patient trigger sensitivity.
1.5	Target optimal patient ventilator synchrony in any triggered non-invasive ventilation mode e.g. bilevel, spontaneous/timed (S/T).	Optimize patient ventilator synchrony. This includes adjusting trigger sensitivity and optimizing mask seal in any triggered non-invasive ventilation mode e.g. bilevel, S/T. 5. a. If available, specialty modes of NIV such as non-invasive NAVA can be used to optimize patient ventilator synchrony.
1.6	Additional statements	Consider the use of high flow nasal cannula oxygen therapy (form of oxygen therapy) prior to NIV, to alleviate work of breathing.
1.7		The use of HFNC and/or NIV should not delay inevitable intubation.
Tidal volumes and inspiratory pressures		
2.1	Use tidal volumes in the physiologic range (5-8ml/kg ideal body weight) for pediatric patients with healthy lungs.	Target tidal volumes in the physiologic range (5-8ml/kg ideal body weight) for pediatric patients with healthy lungs, when >10kg. Target tidal volumes 5-8ml/kg measured weight for pediatric patients with healthy lungs,

		when ≤10kg.
2.2	Avoid using tidal volumes greater than 8ml/kg ideal body weight in pediatric patients with restrictive lung, obstructive lung and/or congenital diseases	***Removed, see original comments*
2.3	For cardiac patients, higher tidal volumes (>8ml/kg ideal body weight) can be used to allow a lower set respiratory rate to promote venous return.	For specific congenital cardiac patients requiring optimal venous return, higher tidal volumes (>8ml/kg ideal body weight) may be used if peak pressures are within safe range (<25cmH_2O). This would allow a lower set respiratory rate to minimize mean airway pressure.
2.4	Start at a delta pressure (PIP-PEEP) less than or equal to 10cmH_2O to achieve optimal tidal volume in the physiological range (5-8ml/kg ideal body weight) for all pediatric patients with presumed healthy lungs. Titrate pressures to achieve optimal tidal volumes.	In pressure-limited modes, aim to achieve optimal tidal volume in the physiological range (5- 8ml/kg ideal body weight) with minimal delta pressure (PIP-PEEP) for all pediatric patients.
2.5	In absence of transpulmonary pressure measurements, limit the inspiratory plateau pressure to 28cmH_2O in pediatric patients with decreased chest wall compliance	In absence of transpulmonary pressure measurements, limit the inspiratory plateau pressure to 30cmH_2O in all patients.
2.6	In absence of transpulmonary pressure measurements, limit the inspiratory plateau pressure 32cmH_2O in pediatric patients with decreased chest wall compliance.	
2.7	Measure tidal volumes proximally in pediatric patients <3kg	**MOVED TO SECTION 10** Follow the specific ventilator's recommendation for when a proximal flow sensor should be used, to allow for accurate tidal volume measurements in small patients <10kg or patients with small tidal volumes, <10mL.
Respiratory rate and inspiratory times		
3.1	Set inspiratory time and RR based on the patient's age, ventilatory waveforms and clinical evolution, to allow for full exhalation (good I:E ratio) and optimized pediatric-patient synchrony.	In controlled ventilation modes, set inspiratory time and respiratory rate based on the patient's age, respiratory mechanics (including waveforms), and clinical data such as blood gases and vitals. This will allow for full exhalation (good I:E ratio), optimized pediatric-patient synchrony and ventilation.
		In spontaneous ventilation modes, set the trigger, and cycling to achieve the above goals (Section 3, Statement #1).
3.2	Increase the set RR when tidal volumes and/or PIP are reaching	Increase the set respiratory rate when tidal volumes and/or PIP are reaching limits, to maintain minute ventilation.

	limits to maintain minute ventilation in restrictive diseases.	Ensure there is sufficient expiratory time to avoid air-trapping.
PEEP and Fio2		
4.1	Set a minimum PEEP of 5cmH_2O, to prevent alveolar collapse in pediatric patients with healthy lungs.	Set a minimum PEEP of at least 5-6cmH_2O, to prevent alveolar collapse in all pediatric patients.
4.2	Set PEEP to maintain end expiratory lung volume, and an optimal balance between hemodynamics and oxygenation in all pediatric patients. Carefully titrate PEEP to avoid cardiovascular compromise.	Set PEEP to maintain end expiratory lung volume, and an optimal balance between hemodynamic stability and oxygenation. Titrate PEEP incrementally while assessing tidal volumes, oxygen saturation, hemodynamic stability and chest x-ray findings, for patients with challenging oxygenation. i.e. PALICC recommendations, ARDSnet protocol
4.3	High levels of PEEP (>10cmH_2O) may be required for pediatric patients with severe ARDS.	Higher levels of PEEP (>10cmH_2O) may be required for adequate lung recruitment in pediatric patients with moderate to severe ARDS.
4.4	High levels of PEEP (>10H_2O) may be required to stabilize airways in pediatric patients with tracheomalacia and/or bronchomalacia.	Higher levels of PEEP (>10cmH_2O) may be required to stabilize airways in pediatric patients with tracheomalacia and/or bronchomalacia.
4.5	Set the lowest possible FiO_2 to maintain target oxygenation goals.	Optimize PEEP to allow for the lowest possible FiO_2 to maintain target oxygenation goals, while maintaining adequate hemodynamic status.
Advanced mechanical ventilation		
5.1	Consider high frequency oscillatory ventilation (HFOV) in pediatric patients with restrictive or mixed diseases with severe oxygenation and/or ventilation failure.	Consider high frequency oscillatory ventilation (HFOV) in pediatric patients with restrictive or mixed diseases and severe oxygenation and/or ventilation failure when they have failed conventional mechanical ventilation.
5.2	Careful use of high frequency oscillatory ventilation (HFOV) can be considered in pediatric patients with cardiac issues suffering from severe respiratory failure. Caution is advised in patients with passive pulmonary blood flow or right ventricular dysfunction.	Careful use of high frequency oscillatory ventilation (HFOV) can be considered in pediatric patients with cardiac issues suffering from severe respiratory failure. Cautious use of increased mean airway pressure is advised in patients with passive pulmonary blood flow or right ventricular dysfunction.
5.3	Careful use of high frequency oscillatory ventilation (HFOV) can be considered in cardiac pediatric patients suffering from severe respiratory failure.	Consider high frequency jet ventilation (HFJV) in pediatric patients with restrictive or mixed diseases and severe oxygenation and/or ventilation failure when they have failed conventional mechanical ventilation.
5.4	Methods of ventilation such as Airway Pressure Release	Consider the use of other modes of advanced ventilation techniques to optimize patient-ventilator interactions.

	Ventilation (APRV), Neurally Adjusted Ventilatory Assist (NAVA), Proportional Assist Ventilation (PAV), automated weaning etc, may be considered to optimize patient-ventilator interactions	These forms of advanced ventilation have unique benefits and/ or limitations. These modes include Airway Pressure Release Ventilation (APRV), Neurally Adjusted Ventilatory Assist (NAVA), Proportional Assist Ventilation (PAV), high frequency jet ventilation (HFJV), automated weaning etc.
Weaning		
6.1	Start weaning ventilator settings as early as possible.	Routinely assess (work of breathing, blood gases, synchrony etc) and wean ventilator settings as early and often, as possible.
6.2	In any complex cases (e.g. restrictive, obstructive, mixed or cardiac pediatric patients), use weaning principles specific to the pathology and titrate ventilator settings more carefully.	Use weaning principles guided by the respiratory mechanics, pathologies and disease trajectory of the diseases present in complex cases (e.g. restrictive, obstructive, mixed or cardiac pediatric patients).
6.3	If adequate respiratory drive is present, pressure support ventilation may be considered allowing the pediatric patient to breathe spontaneously.	Consider pressure support ventilation if adequate respiratory drive is present and disease trajectory is improving. This allows the pediatric patient to breathe spontaneously to maximize comfort and avoid asynchrony/ muscle atrophy.
6.4	If pressure support ventilation is used, the pressure support, sensitivity, flow cycling, and rise time should be adjusted to maintain patient comfort/synchrony and physiologic tidal volumes.	Routinely assess the pressure support, sensitivity of flow cycling, and rise time in pressure support ventilation to maintain patient comfort/synchrony and physiologic tidal volumes.
6.5	Routine daily assessment for weaning and extubation should be performed	Routine daily assessment for weaning and extubation readiness should be performed.
Physiologic Targets		
7.1	Target normal arterial CO2 levels for pediatric patients with healthy lungs and electively ventilated e.g. post-operative	Target normal arterial CO2 levels for pediatric patients with healthy lungs and electively ventilated e.g. post-operative. if arterial CO2 is not available, target normal venous and capillary CO2 levels.
7.2	Permissive hypercapnia (pH ≥ 7.2) may be acceptable for acute pediatric patients, unless specific disease conditions dictate otherwise e.g. pulmonary hypertension	Permissive hypercapnia (with pH ≥ 7.25) may be acceptable for acute pediatric patients, unless specific disease conditions dictate otherwise e.g. pulmonary hypertension, traumatic brain injury.
7.3	Target a SpO2 > 95% on room air in pediatric ventilated patients with healthy lungs.	Target a SpO2 > 92% (92-99%) in pediatric patients with healthy lungs, in the absence of disease.
7.4	Target SpO2 92-97% when PEEP is less than 10cmH_2O in pediatric patients who meet the pediatric ARDS criteria	Target SpO2 92-97% when PEEP is less than 10cmH_2O in pediatric patients who meet the pediatric ARDS criteria as described in the PALICC guidelines.

	as described in the PALICC guidelines	
7.5	Target SpO2 88-92% when PEEP is 10cmH_2O or higher in pediatric patients who meet the pediatric ARDS criteria as described in the PALICC guidelines (PALICC Guidelines 2015).	Target SpO2 88-92% when PEEP is 10cmH_2O or higher in pediatric patients who meet the pediatric ARDS criteria as described in the PALICC guidelines
7.6	Target SpO2 75-85% for pediatric patients with cyanotic cardiac lesions e.g. fixed Right to Left shunts.	Target SpO2 75-85% or as recommended by the interprofessional collaborative teams, for pediatric patients with cyanotic cardiac lesions e.g. fixed Right to Left shunts.
7.7	Additional statements	Physiological targets may be guided by patient respiratory mechanics, and respiratory and non-respiratory pathologies and disease trajectory.
Monitoring		
8.1	CO_2 monitoring should be used in every pediatric patient on invasive mechanical ventilation, preferably end-tidal CO_2.	Use CO_2 monitoring in every pediatric patient on invasive mechanical ventilation, preferably endtidal CO_2.
		Consider the use of transcutaneous CO_2 in pediatric patients on non-conventional mechanical ventilation, e.g. HFOV, HFJV. These monitoring options should be frequently assessed for its correlation to the blood gases.
8.2	SpO_2 monitoring should be used to assess oxygenation in every pediatric patient on invasive or non-invasive mechanical ventilation.	Use continuous SpO_2 monitoring to assess oxygen saturation in all pediatric patients on invasive and non-invasive mechanical ventilation.
8.3	Use indwelling arterial lines for accurate pH, PaO_2, $PaCO_2$, and lactate measurements, in severely ill pediatric patients on mechanical ventilation.	Use arterial lines for accurate pH, PaO_2, and lactate measurements, in moderate to severely ill pediatric patients on mechanical ventilation.
8.4	Use central venous saturation (SvO_2) and lactate measurements to assess presence or absence of oxygen debt and/or cardiac output, in severely ill pediatric patients on mechanical ventilation.	Use central venous saturation (SvO_2) and lactate measurements to assess oxygen extraction and/or cardiac output, in cardiac and/or severely ill pediatric patients on mechanical ventilation
8.5	Use central venous saturation (SvO_2) and lactate measurements to assess presence or absence of oxygen debt and/or cardiac output, in cardiac pediatric patients on mechanical ventilation.	
8.6	Peripheral venous PCO_2 measurements are of limited use in providing information about ventilatory gas exchange. However, they may be used for	Cautiously use peripheral venous PCO_2 measurements to provide estimates and trends of ventilatory gas exchange, when arterial/ central lines are not available.

	providing estimates or trending.	
8.7	Capillary gases are adequate to assess gas exchange in pediatric patients with mild diseases on mechanical ventilation.	Consider the use of capillary gases to assess gas exchange in pediatric patients with good perfusion and with mild diseases on mechanical ventilation. They may be used to provide estimates or trends when arterial/ central lines are not available.
8.8	Use pH as a tool to modify the pulmonary vascular resistance for specific disease conditions.	Use pH as a tool to modify the pulmonary vascular resistance for specific disease conditions, e.g. pulmonary hypertension, single ventricle heart disease.
8.9	Maintain normal pH and PCO_2 in pulmonary hypertension.	Aim to maintain normal pH, PCO_2 and PaO_2 in pulmonary hypertension and traumatic brain injury. Consider targeting normal-high pH and normal-low CO_2 values.
General		
9.1	All pediatric patients on mechanical ventilation should be allowed to breathe spontaneously, with the exception of the most severely ill and/or those requiring intermittent neuromuscular blockade or those with surgical contraindications (e.g. airway surgery).	Routinely assess patients to allow for spontaneous breathing, except for severely ill pediatric patients requiring intermittent neuromuscular blockade and sedation.
9.2	Ventilator waveforms e.g. flow volume loops, pressure volume loops, provide real-time data about patient-ventilator interactions such as breath-by-breath ventilation status, response to therapies, and lung mechanics.	Routinely assess ventilator waveforms (e.g. flow volume loops, pressure volume loops) as they provide real-time data about patient-ventilator interactions such as breath-by-breath ventilation status, response to therapies, and lung mechanics.
9.3	The Pediatric Acute Lung Injury Consensus Conference (2015) recommendations on nitric oxide, neuromuscular blockade, prone position and surfactant use should be followed. *Inhaled nitric oxide is not recommended for routine use in PARDS. However, its use may be considered in patients with documented pulmonary hypertension or severe right ventricular dysfunction. In addition, it may be considered in severe cases of PARDS as a rescue from or bridge to extracorporeal life support. When used, assessment of benefit must be undertaken promptly and serially to minimize toxicity and to eliminate	Use The Pediatric Acute Lung Injury Consensus Conference (2015) recommendations on nitric oxide, neuromuscular blockade, prone position and surfactant use, if safe to do so. Inhaled nitric oxide is not recommended for routine use in PARDS. However, its use may be considered in patients with documented pulmonary hypertension or severe right ventricular dysfunction. In addition, it may be considered in severe cases of PARDS as a rescue from or bridge to ECLS. When used, assessment of benefit must be undertaken promptly and serially to minimize toxicity and to eliminate continued use without established effect. Finally, future study is needed to better define its role, if any, in the treatment of PARDS.

	continued use without established effect. Finally, future study is needed to better define its role, if any, in the treatment of PARDS. (PALICC guidelines 2015)	
9.4	Caution is advised when using sedation and muscle relaxants in pediatric patients with altered cardiac function.	Routinely monitor and assess the impacts of muscle relaxants and sedation on mechanical ventilation (respiratory rate, tidal volumes, minute ventilation).
9.5	Extracorporeal life support (ECLS) e.g. NovaLung, extracorporeal membrane oxygenation, should be considered when conventional and/or high frequency oscillatory ventilation fail in pediatric patients with reversible diseases. Follow guidelines for specific criteria eg. Extracorpeal Life Support Organization	**MOVED TO SECTION 5** Strongly consider Extracorporeal life support (ECLS) e.g. NovaLung, extracorporeal membrane oxygenation, if available and not contraindicated, when conventional and/or high frequency oscillatory ventilation fail in pediatric patients with reversible diseases. Follow guidelines for specific criteria e.g. extracorporeal life support organization. Early consultation from an ECLS center should be considered if this therapy is not available within the facility.
9.6	Additional statements	Different organizational and workgroup guidelines and recommendations may be incorporated into practice and may include, but are not limited to: Pediatric Acute Lung Injury Care Conference (PALICC), National Heart, Lung, and Blood Institute (NHLBI) ARDS Network Protocol, Pediatric Advanced Life Support (PALS), Neonatal Resuscitation Program (NRP), Extracorporeal Life Support Organization (ELSO)
Equipment adjuncts		
10.1	Use double limb circuits for acute, invasive mechanical ventilation	Use double limbed, heated humidified, filtered circuits for invasive mechanical ventilation.
10.2	Minimize the use of apparatuses that add dead space to ventilator circuits	Minimize the use of apparatuses that add dead space to ventilator circuits, whenever possible.
10.3	Elevate the head of the bed at 30-45 degrees in all pediatric patients, unless specific disease conditions dictate otherwise.	**MOVED TO SECTION 9** Reduce the risk of ventilator associated pneumonia (VAP) by following the VAP bundles published by safety groups e.g. Safer Healthcare Now!, Canadian Institute for Health Information, Solutions to Patient Safety. Elements include: 1) elevate the head of the bed 30-45 degrees (15 degrees in infant cribs), unless specific (disease) conditions dictate otherwise, e.g. post-operative, indwelling catheters, 2) perform consistent oral hygiene, 3) minimize unnecessary circuit disconnects, 4) perform daily assessment for extubation readiness
10.4	Provide airway humidification, 100% relative humidity at 37°C, for all pediatric patients on	Provide active airway humidification, 100% relative humidity at 37°C, for all pediatric patients on invasive mechanical ventilation. In the case of non-invasive

	mechanical ventilation.	ventilation, humidification at 31°C should be provided to avoid excessive rain out in the circuit.
10.5	Hand-ventilation should be avoided. If hand-ventilation is required, pressure measurements, pressure pop up and PEEP valves or flow-inflating bags should be used to match ventilation pressures.	Avoid routine use of manual hand-ventilation to minimize frequent circuit disconnects. If manual hand-ventilation is required, pressure manometers, pressure relief valves and PEEP valves should be used on self-inflating and flow-inflating bags.

Supplementary table 6

Statistical results of each recommendation statement in Round 2.

Statement	Consensus %	Mean	Median	Mode	Standard deviation	Min.	Max.	Interquartile range	Coefficient of variation
Section 1- Noninvasive ventilation									
1.1	96	4.37	4	4	0.56	3	5	1	0.13
1.2	98	4.53	5	5	0.54	3	5	1	0.12
1.3	94	4.49	5	5	0.73	2	5	1	0.16
1.4	98	4.71	5	5	0.50	3	5	1	0.11
1.5	100	4.75	5	5	0.44	4	5	1	0.09
1.5a	85	4.23	4	4	0.76	2	5	1	0.18
1.6	76	3.82	4	4	0.97	1	5	0	0.25
1.7	100	4.76	5	5	0.43	4	5	0	0.09
Section 2- Tidal volumes and inspiratory pressures									
2.1	92	4.16	4	4	0.62	2	5	1	0.15
2.2	60	3.72	4	4	0.78	2	5	1	0.21
2.3	92	4.32	4	4	0.79	1	5	1	0.18
2.4	82	4.02	4	4	0.85	2	5	1	0.21
Section 3- Respiratory rate and inspiratory time									
3.1	98	4.65	5	5	0.52	3	5	1	0.11
3.2	98	4.63	5	5	0.53	3	5	1	0.11
3.3	92	4.31	4	5	0.86	1	5	1	0.20
Section 4- PEEP and FiO_2									
4.1	86	4.29	5	5	1.10	1	5	1	0.26
4.2	100	4.63	5	5	0.49	4	5	1	0.11
4.3	96	4.45	5	5	0.73	1	5	1	0.16
4.4	98	4.61	5	5	0.53	3	5	1	0.12
4.5	94	4.39	4	4	0.67	2	5	1	0.15
4.6	94	4.37	5	5	0.87	1	5	1	0.20
Section 5- Advanced modes of ventilation									
5.1	90	4.25	4	4	0.63	3	5	1	0.15
5.2	86	4.22	4	4	0.67	3	5	1	0.16
5.3	57	3.4	4	4	1.06	1	5	1	0.31
5.4	83	3.94	4	4	0.82	1	5	0	0.21
5.5	81	4.15	4	4	0.83	2	5	1	0.20
Section 6- Weaning									
6.1	96	4.49	5	5	0.73	1	5	1	0.16
6.2	94	4.39	4	4	0.60	3	5	1	0.14
6.3	96	4.51	5	5	0.64	2	5	1	0.14
6.4	98	4.53	5	5	0.54	3	5	1	0.12
6.5	86	4.33	5	5	0.82	2	5	1	0.19
Section 7- Physiologic targets									
7.1	94	4.33	4	4	0.65	2	5	1	0.15
7.2	98	4.43	4	4	0.54	3	5	1	0.12

7.3	98	4.51	5	5	0.54	3	5	1	0.12
7.4	88	4.24	4	5	0.93	1	5	1	0.22
7.5	84	4.08	4	4	0.85	2	5	1	0.21
7.6	86	4.18	4	4	0.85	1	5	1	0.20
7.7	94	4.33	4	4	0.65	2	5	1	0.15
Section 8- Monitoring									
8.1	98	4.71	5	5	0.58	2	5	1	0.12
8.2	94	4.49	5	5	0.73	2	5	1	0.16
8.3	84	4.34	4.5	5	0.75	3	5	1	0.17
8.4	98	4.68	5	5	0.52	3	5	1	0.11
8.5	92	4.47	5	5	0.64	3	5	1	0.14
8.6	90	4.14	4	4	0.65	2	5	1	0.16
8.7	96	4.37	4	4	0.56	3	5	1	0.13
8.8	88	4.16	4	4	0.67	2	5	1	0.16
8.9	96	4.39	4	4	0.57	3	5	1	0.13
Section 9- General MV									
9.1	96	4.43	4	4	0.58	3	5	1	0.13
9.2	90	4.27	4	4	0.75	2	5	1	0.18
9.3	98	4.49	5	5	0.54	3	5	1	0.12
9.4	87	4.24	4	4	0.67	3	5	1	0.16
9.5	100	4.53	5	5	0.50	4	5	1	0.11
9.6	88	4.24	4	4	0.66	3	5	1	0.15
Section 10- Equipment adjuncts									
10.1	98	4.71	5	5	0.50	3	5	1	0.11
10.2	94	4.45	5	5	0.86	1	5	1	0.19
10.3	100	4.65	5	5	0.48	4	5	1	0.10
10.4	71	3.88	4	4	1.02	2	5	2	0.26
10.5	84	4.22	4	5	0.95	2	5	1	0.22

The numbered statements in this table correspond to the statements in Round 2's survey.

Supplementary Table 7

Statistical results of the 10 revised recommendation statements in Round 3.

Statement #	Consensus %	Mean	Median	Mode	Standard deviation	Min.	Max.	Interquartile range	Coefficient of variation
1.6	92	4.37	5	5	0.81	2	5	1	0.19
2.1	81	4.0	4	4	0.95	2	5	1	0.24
2.2	98	4.31	4	4	0.51	3	5	1	0.12
2.3	96	4.31	4	4	0.77	1	5	1	0.18
2.4	93	4.17	4	4	0.61	2	5	1	0.15
5.3	90	4.14	4	4	0.72	2	5	1	0.17
5.4	84	4.03	4	4	0.76	1	5	0.5	0.19
5.5	96	4.43	4	5	0.65	2	5	1	0.15
9.7	100	4.65	5	5	0.48	4	5	1	0.10
10.4	84	3.91	4	4	0.82	2	5	0	0.21
10.5	94	4.33	4	4	0.66	2	5	1	0.15

Supplementary Table 8

Statements that were significantly different between subgroups, identified by the KWT ($p<0.05$).

Subgroups 1= ≤15 years 2= >15 years	Likert Score Mean	95% confidence interval	Standard deviation	p-value
2.1- *Target tidal volumes in the physiologic range (5-8ml/kg ideal body weight) for pediatric patients >10kg with healthy lungs. Target tidal volumes 5-8ml/kg measured weight for pediatric patients ≤10kg with healthy lungs.*				
1	4.32	4.09, 4.55	0.56	
2	3.95	3.63, 4.27	0.69	0.04
4.4- *Higher levels of PEEP (>10cmH_2O) may be required for adequate lung recruitment in pediatric patients with moderate to severe ARDS.*				
1	4.76	4.58, 4.96	0.44	
2	4.4	4.12, 4.68	0.60	0.04
7.4- *Target Spo2 92-99% in pediatric patients with healthy lungs, in the absence of disease.*				
1	4.52	4.23, 4.81	0.71	
2	3.9	3.42, 4.38	1.02	<0.01
8.1- *Use of continuous Spo2 monitoring to assess oxygen saturation in all pediatric patients on invasive and non-invasive mechanical ventilation.*				
1	4.88	4.74, 5.02	0.33	
2	4.6	4.36, 4.84	0.50	<0.01
8.9- *Aim to maintain normal pH, PCO2 and PaO2 in pulmonary hypertension and traumatic brain injury. Consider targeting normal-high pH and normal-low CO2 values.*				
1	4.6	4.39, 4.81	0.5	
2	4.15	3.88, 4.42	0.59	0.02
9.4- *Use the Pediatric Acute Lung Injury Consensus Conference (2015) recommendations*				
1	4.48	4.21, 4.75	0.65	
2	3.9	3.64, 4.16	0.55	<0.01

Supplementary table 9

Open text feedback from Round 2 and 3

	Recommendation statement from Round 2/ 3	Original comments
1- Non invasive ventilation (NIV)		
1.4	Consider the use of non-invasive ventilation in pediatric patients with moderate cardiorespiratory failure. If not responsive to other medical management e.g. inotropes, diuretics	• dual limb NIV with full face mask is used as the approach prior to intubation. NAVA recently discontinued at our facility due to poor success rate • NIV NAVA should not simply be used "if available" - this will lead to the unnecessary introduction of an invasive catheter (not to mention increased cost of equipment). NIV NAVA should primarily be used "if required" to correct insufficient patient-vent synchrony.
1.5 1.5a 1.6 1.7	Optimize patient ventilator synchrony. This includes adjusting trigger sensitivity and optimizing mask seal in any triggered NIV mode e.g. bilevel, S/T. If available, specialty modes of NIV such as NIV NAVA can be used to optimize patient ventilator synchrony. Consider the use of high flow nasal cannula (HFNC) oxygen therapy prior to NIV, to alleviate work of breathing. The use of HFNC and/or NIV should not delay inevitable intubation.	• This [NIV] should not be a "first approach" - other approaches such as medications or HFNC should be considered first. NIV should only be considered as a "second approach" should these more basic interventions fail • If you need to start NIV for cardiac or obstructive reasons such as an asthma attack, then don't waste time with HFNC • I don't feel all patients should try HFNC prior to NIV. Consider, yes. But if not appropriate, move right to NIV. • HFNC should not be tried in patients when NIV has been proven effective in patients with certain sicknesses or disease processes. It just delays treatment • For certain cases, prioritizing the use of HFNC before NIV is not appropriate, like bronchiolitis on small babies: a lot of secretions is not compatible with HFNC, NIV is more comfortable for them and more effective treatment. • Simply because patient has increased WOB, should not try HFNC simply because. Should assess work of breathing and reason causing it. If patient requires more support like pressure due to cardiopulmonary effects then NIV should be started verses increase in oxygen needs and work of breathing due to common respiratory infection. • There may be some role in early respiratory failure as dead space washout effects may reduce PCO2; this is not the same as ventilation and they should not be confused! Similarly, it is not CPAP as the pressure is not constant! The

		system provides positive pressure primarily on expiration. • HFNC can be used initially as a substitute to NIV depending on how severe the WOB/CO2 retention. Often you will find the HFNC alone will reduce CO2 levels sufficiently, especially in smaller children. • I strongly agree that HFNC is not a substitute for NIV. And while yes, one should CONSIDER HFNC before NIV, I don't believe that one should automatically try it based on the fact that it a) is not a substitute, and b) should not delay or replace NIV if that is more appropriate. • some studies show that HFNC can be used as an alternative to NIV and that there is no statistical difference in intubation rates between the two. The tolerance of HFNC in the pediatric population tends to be much greater compared to NIV via facemask. This is also difficult to use a generalized statement for because the age range of pediatrics is very large, and the specific patient and situation can also be a factor to consider what the patient may tolerate better. • There are currently indications to provide HFNC prior to intubation, and immediately post op, post extubation in lieu of low flow. I agree it should not delay or replace NIV IF NIV is more appropriate • For such things as pulmonary edema OR pleural effusions, or anything you want some PEEP to be applied HFNC is not appropriate. But HFNC may be used for tachypnea or work of breathing. • HFNC and NIV are not interchangeable, and their application is suitable for different reasons.
2- Tidal volumes and inspiratory pressures		
2.1	*Round 2:* Target tidal volumes in the physiologic range (5-8ml/kg ideal body weight) for pediatric patients >10kg with healthy lungs. Target tidal volumes 5-8ml/kg measured weights for patients ≤ 10kg with healthy lungs. *Round 3:* In pediatric patients >10kg, target tidal volumes in the physiologic range (5-8ml/kg ideal body weight). In pediatric patients ≤10kg, target tidal volumes 5-8ml/kg measured weight.	• The ped patients we use IBW are usually school age and up. • "Measured weight" may be inappropriate if the patient is greatly fluid overloaded. • We use measured weight until the patients are in teenage years or severely overweight then we convert to IBW. For patients less than 20 kg, for sure, we use actual measured weight. • Certain medical conditions (ie. CDH) may experience volutrauma if a global volume target of 5-8ml/kg is used. Perhaps some caveat regarding "anatomically or functionally normal lungs" should be included. • For post cardiac surgeries (excluding PDA ligation), our approach is 7-9 ml/kg with a lower

		respiratory rate and longer i-time to optimize venous return to the heart; this is done in our PICU patients
2.2 2.3 2.4	*Round 2:* For specific congenital cardiac patients requiring optimal venous return, higher tidal volumes (>8ml/kg ideal body weight) may be used if peak pressures are within safe range (< 25cmH2O). This would allow a lower set respiratory rate to minimize mean airway pressure. *Round 3:* If unable to achieve physiologic tidal volumes (5-8ml/kg) within pressure limits (30cmH2O), targeting ranges outside these limits should be iscussed with the interprofessional team. For example, congenital lesions, congenital hypoplastic lung, severe PARDS. Similarly, there may be circumstances where tidal volumes >8ml/kg may be cautiously used, but should not be routinely used. 2.3 For all pediatric patients on pressure-limited modes, aim to achieve optimal tidal volume in the physiological range (5-8ml/kg ideal body weight) with minimal delta pressure (PIP-PEEP). 2.4 In absence of transpulmonary pressure measurements, the inspiratory plateau pressure should be limited to 30cmH2O in pediatric patients. Site specific limits should be within 28 to 32 cmH2O.	• I agree with statement but disagree that delta pressure is PIP-PEEP. I think this is better represented as Pplat- PEEP, whenever Pplat can be obtained. • Targeting Vt as low as 4ml/kg seems reasonable. Goals to limit Pplats to <25 cmH_2O as much as possible seems reasonable, and default to a lower Vt rather than accepting higher Pplats, depending on pathophysiology. • PPlat <28 cmH_2O as goal, allowable up to <32 cmH_2O given specific poor compliance patient conditions • I agree that the Pplat should be limited to less than 30 cmH_2O unless you have measurements that you can follow to provide safe ventilation, electrical impedence tomography (EIT) can be used as well. There are patients where maintaining low Pplats is not possible. I would like to see it as 'attempt to limit' or something like that. And the driving pressure is what will be important, rather than just a Pplat. • In my opinion I think the part about "site specific limits..." is a bit confusing. I would suggest instead of writing specific targets for specific sites that it could just read specific sites may have variability in targets however should be around 30 cmH_20. • Goals to limit Pplats to <25 cmH_2O as much as possible seems reasonable, and default to a lower Vt rather than accepting higher Pplats, depending on pathophysiology. • I would be more comfortable with stating "appropriate Vt" rather than a specific number.
3- Respiratory Rates and inspiratory time		
3.3	To maintain minute ventilation, increase the set respiratory rate when tidal volumes and/or PIP are reaching limits. Ensure there is sufficient expiratory time to avoid air-trapping.	• to optimize alveolar ventilation, there is a physical limit to how high the rate can be - irrespective of the I:E ratio. A rate of 60 breaths/minute cannot allow for laminar flow and alveolar gas exchange. At this point a small increase in Vt, is indicated. (the exception may be for patients with congenital diaphragmatic hernia, as it is imperative to use a lung protective strategy). • To maintain minute volume, increase the set respiratory rate when Vt ARE LOW and when Pplat is approaching limit (<30 cmH_2O)

		• to related to previous statements; OR if Vt are within range yet (PCO2) needs to be lower, or pH higher
4- PEEP and FiO2		
4.1	Set a minimum PEEP of 5-6cmH2O, to prevent alveolar collapse in all pediatric patients.	• Peep levels of 5-6cmH_2O are used in most instances except cardiac pts (who may need lower) and the other cases mentioned in the further questions (ARDS, bronchomalacia). • there will always be a singular case where PEEP is contraindicated; perhaps it is a status asthmaticus scenario, or some other type of obstructive process. or extreme hemodynamic instability. If the statement was that the goal should be to prevent alveolar collapse in all ventilated patients this is more general and encompassing. I do not think religious application of PEEP to all pediatric patients regardless of disease process is a good idea • Post op Glen and Fontan will have PEEP of 4cmH_2O usually. • A min PEEP of 5-6 cmH_2O in not to prevent collapse but to maintain an appropriate FRC • We have set PEEP at 4 (or even 3 cmH_2O) on rare occasions where RV failure is a consideration, with good effect.
4.3	For patients with challenging oxygenation needs (e.g. ARDS) titrate PEEP incrementally while assessing tidal volumes, oxygen saturation, hemodynamic stability and chest x-ray findings.	• The use of oxygenation is not a good parameter to set PEEP, setting PEEP using oxygenation can cause significant regional over distension. Mechanics such as Compliance or driving pressure are more appropriate. Also, if assessing Vt with PEEP changes you are assuming a pressure mode of ventilation. Compliance would be a better parameter or also include driving pressure.
4.5	Higher levels of PEEP (>10cmH2O) may be required to stabilize airways in pediatric patients with tracheomalacia and/or bronchomalacia.	• an ENT consultation with flexible laryngoscopy is typically utilized to determine the optimal PEEP needed to stabilize airways in pediatric patients with moderate-to-severe tracheomalacia and/or bronchomalacia.
4.6	Optimize PEEP to allow for the lowest possible FiO2 (to maintain target oxygen saturation goals), while maintaining adequate hemodynamic status.	• PEEP should not be set/targeted based upon oxygenation alone. • The goal should not be to achieve the "lowest possible FiO2", regardless of PEEP. FiO2 of 0.21 and PEEP of 15, for example, would not be an appropriate way of maintaining target O2 saturation (spO2).
5- Advanced modes of Ventilation		

5.3	*Round 2:* Consider the use of other advanced ventilation techniques to optimize patient-ventilator interactions, acknowledging that each has unique benefits and/or limitations. These modes include NAVA, Airway Pressure Release Ventilation (APRV), Proportional Assist Ventilation (PAV), high frequency jet ventilation (HFJV), automated weaning etc. *Round 3:* When conventional mechanical ventilation and/or HFOV has failed for pediatric patients, consider the use of other advanced modes, acknowledging that each has unique benefits and / or limitations. These modes include high frequency jet ventilation (HFJV) and Airway Pressure Release Ventilation (APRV) and severe oxygenation and/or ventilation failure. These advanced modes should not substitute or delay inevitable ECLS, if appropriate. Other advanced ventilation techniques may optimize patient-ventilator interactions. Consider their use while acknowledging that each has unique benefits and/or limitations. These modes include Neurally Adjusted Ventilatory Assist (NAVA), Proportional Assist Ventilation (PAV), automated weaning etc.	• APRV is prohibited for use by RTs as agreed by the intensivists' team at the [name removed] PICU due to lack of evidence • Advanced therapies such as JET and HFOV may be beneficial if used as a protective strategy on certain pts versus being used as a rescue therapies. • APRV is available but prohibited to use as agreed by the PICU physician team due to the lack of pediatric evidence. PAV is not available therefore not practiced • NAVA was previously trialed but not found effective therefore being phased out. PAV is not available to use in the [name removed] PICU • We currently don't use NAVA or PAV. (Have used NAVA in the, past, but not consistently or well. Will likely use PAV with our incoming fleet of new vents.) • NAVA was previously used but often inappropriately (didn't meet indications or not ideal candidate etc) or used off recommendation (indicators and reading interpreted but not used for weaning or escalation of care due to various MRP reasoning) and as result is no longer available at our center
5.4	*Round 2:* Strongly consider Extracorporeal life support (ECLS) such as NovaLung, or extracorporeal membrane oxygenation. Use ECLS in pediatric patients with reversible diseases, if available within the facility, not contraindicated, and/or when conventional and/or high frequency oscillatory ventilation has failed. Follow guidelines (e.g. extracorporeal life support organizations) for specific criteria. Early consultation with an ECLS center should be considered if this therapy is not available within the facility.	• Perhaps there should be a recommendation/statement regarding early consultation to a higher level of care for sites that do not have advanced therapies such as HFOV, jet ventilation, novalung, ECMO etc., available... in order to ensure earlier and safer transports for these patients? • I would rewrite to read "Strongly consider ECLS such as extracorporeal membrane oxygenation (ECMO)". Remove NovaLung as this is a brand name of a device and the pediatric use of this device is very limited. In its truest configuration (femoral artery to femoral vein) as the device was intended, would not be able to be used in patients less than 20-30 kg as would be unable to

	Round 3: When conventional mechanical ventilation and/ or HFOV has failed, consider the use of Extracorporeal life support (ECLS) in pediatric patients with reversible diseases, if available within the facility and not contraindicated. Follow guidelines (e.g. ECLS organizations) for more specific criteria. Consider early consultation with an ECLS center when ECLS is not available within the facility.	generate sufficient driving pressure to prevent clotting of the device over time. The most common approach for supporting these patients would be VV ECMO if they were large enough for double lumen cannula or two site VV ECMO. If they are small infants, the approach is VA ECMO. There is still small usage of NovaLung device for bridge to lung transplant pediatric patients > 20 kg with pulmonary hyptertension who are centrally cannulated from PA to LA as a means to offload right heart to prevent RV failure. However this is a very specific subset of pediatric patients with a specific respiratory disease. Otherwise agree with rest of statement. • Consider the use of iNO in the instances where patient has oxygenation, PHTN or RV dysfunction prior to considering ECLS.
6- Weaning		
6.3	Consider pressure support ventilation when adequate respiratory drive is present and disease trajectory is improving. This allows the pediatric patient to breathe spontaneously to maximize comfort, and avoid asynchrony/muscle atrophy	• it does not appear to be clear how long one can leave a patient breathing on PSV who is not ready for extubation; in my practice, patients with minimal WOB and otherwise good indicators of gas exchange may stay on PSV as long as they're tolerating it, with a minimal delta P to compensate for ETT resistance (ie 5-10 cmH_2O) • Important to know what their drive is, but I typically would not leave a patient on PS ventilation for days on end as they recover, unless I am unable to achieve good synchrony and comfort in other modes.
7- Physiological Targets		
7.4 7.5 7.6	Target SpO2 92-99% in pediatric patients with healthy lungs, in the absence of disease. Target SpO2 92-97% when PEEP is less than 10cmH2O in pediatric patients who meet the pediatric ARDS criteria (as described in the PALICC guidelines). Target SpO2 88-92% when PEEP is 10cmH2O or higher in pediatric patients who meet the pediatric ARDS criteria (as described in the PALICC guidelines).	• We should not target an SpO2 of 99%, unless on room air [healthy lungs]. I don't know if the statement is referring to a non-intubated patient, invasively or non. As it reads, it could include patients ventilated for other reasons than respiratory disease (post op). • PALs Post-rosc guidelines state SpO2 94-99%. • should just state >or = 92% if on room air and minimum PEEP and spo2 can be 100% [healthy lungs] • I don't like mixing PEEP value with oxygenation definitely. Depending on body habitus of the patient, we could be using higher PEEPs regardless of ARDS status. We should treat the patients as individuals. For a patient with a BMI near ideal, I agree with the statement, but not for all patients.

		• We tolerate 88%-92% if ABG and lactate are stable [even with PEEP <10cmH2O] • SpO2 targets in ARDS should not be based upon PEEP alone. PEEP setting alone will not identify the severity of their ARDS nor their arterial content requirements. For example, obese or morbidly obese patients may require a PEEP >10 to maintain EELV but this doesn't indicate the severity of the patient's lung pathology or ability to safely oxygenate.
8- Monitoring		
8.2	Use CO2 monitoring (preferably end-tidal CO2) in all pediatric patients on invasive mechanical ventilation.	• preferably inline CO2 monitoring, preferably through the vent so volumetric data is available. • ETCO2 would be inappropriate for a patient ventilated using HFOV.
8.6	Cautiously use peripheral venous PCO2 measurements to provide estimates and trends of ventilatory gas exchange, when arterial/ central lines are not available.	• Use capillary blood gas tests when arterial/central lines are not available. Capillary should be a first line test versus venous.
8.8	Use pH as a tool to modify the pulmonary vascular resistance for specific disease conditions, e.g. pulmonary hypertension, single ventricle heart disease.	• We also aim for adequate oxygenation, and use iNO. By omitting these other principles, it is a bit misleading
9- General MV		
9.1 9.2	Routinely assess patients to allow for spontaneous breathing, except for severely ill pediatric patients requiring intermittent neuromuscular blockade and sedation. Routinely monitor and assess the impacts of muscle relaxants and sedation on mechanical ventilation (respiratory rate, tidal volumes, minute ventilation).	• I would not only assess but encourage. Perhaps a statement to include the concept of: "when patients are heavily sedated and not breathing (without reason), discuss with the interprofessional team to decrease sedatives safely." • wouldn't routinely give NMB to assess how it affects the other variables, unless indicated. However I would assess if NMB is continuing to be beneficial to the patient if being used routinely.
10- Equipment Adjuncts		
10.2	For all pediatric patients on invasive mechanical ventilation, provide active airway humidification at 100% relative humidity at 37°C.	• Reword to say, for patients on NIV, provide active airway humidification in the range of 31-37C, titrated to avoid excessive rainout in the interface. • Addendum - we routinely use 37°C for our HFNC patients as well. • For the majority of NIV patients at [name removed], the humidifier is kept at 37 degrees C to optimize gas humidification. Rain out has not been found to be an issue in most cases.
10.4	*Round 2:*	• proximal flow sensors are of limited utility in larger Vts, in our practice we're using proximal

	Use a proximal flow sensor for accurate tidal volume measurements in small patients (< 10kg) or patients with small tidal volumes (< 10mL). Follow the specific ventilator's recommendations on its use. *Round 3:* Proximal flow sensors are not routinely used for pediatric patients. Follow the specific ventilator's recommendations on proximal flow sensor use. In the absence of specific ventilator recommendations, use a proximal flow sensor for small tidal volumes (< 10mL).	flow for kids 4kg and less who would correspond (at 5mL/kg) to tidal volumes of 20mL and less. • Not all proximal flow is created equal obviously and some ventilators will have bias against the proximal flow sensor to compensate for this. The technology used for proximal flow affects how much I trust it as well; heated wire anemometers appear to be far more accurate in my experience than pressure differential flow sensors. • "Consider" use of a proximal flow sensor. It may not be required unless there is concern about the accuracy of vent-derived measurements. Also consider the impact of added dead space without observable benefit. • Reword to make the principal idea to follow the specific ventilator recommendations on proximal flow sensor use.... in the absence of available recommendations, consider flow sensor use in small patients (insert limits). • We use proximal flow sensors for all patients less than 10 kg in both our ICUs (PICU and NICU) • we use proximal flow sensors on all our pediatric and neonatal patients • we use proximal flow sensors for up to 5kg babies i.e: up to 50mL tidal volumes
10.5	*Round 2*: Avoid routine use of manual hand-ventilation to minimize frequent circuit disconnects. If manual hand-ventilation is required, pressure manometers, pressure relief valves and PEEP valves should be used on self-inflating and flow-inflating bags. *Round 3:* Minimize routine use of manual ventilation to avoid circuit disconnects. Manual ventilation may be used to augment pulmonary hygiene as part of chest physiotherapy. Manual resuscitation devices should be capable of maintaining PEEP, limiting and monitoring pressures.	• We try to avoid the use of manual hand-ventilation especially when PEEP levels are higher but we occasionally use hand-ventilation to help take off the secretions in combination with respiratory physiotherapy • take out self-inflating or flow inflating bags, as PEEP valves are not used with flow inflating bags. Change it to read "if manual ventilation is required, a method of monitoring pressures, limiting excessive pressures and providing PEEP should be used with hand ventilation". • we use flow inflating bags with no pressure relief valves, and no PEEP valves. Agree that we should avoid routine hand ventilation. • We do "Open bag suction" osmose of our patients with bad secretion management. We also had started using "Flusso" valves before it went Backordered. • It is prudent to minimize circuit disconnection, but I would not go so far as to say "avoid" it. COVID precautions notwithstanding, manual ventilation is often necessary in pediatric

		patients to assess compliance and for effective pulmonary toilet. • Avoid routine use "if patient condition allows". Some critically-ill patients will require routine manual ventilation to assist with secretion clearance or for post-suction re-recruitment. • Individual assessment may be required in order to optimize pulmonary hygiene • For patients requiring higher PEEP levels, we tend to clamp the ETT prior to disconnecting from the ventilator and reconnecting to the manual resuscitator in order not to de-recruit alveoli; flow-inflating bags are preferred to self-inflating ones as they maintain PEEP better • Patients often suctioned, using cough assist or have frequent disconnect due to moves or transports get recruited post disconnect as tolerated

Chapter 8- Appendix

8.1 - REB approval- SickKids Hospital and Ontario Tech University

SickKids

Research Ethics Board (REB)
Study Approval Letter

2020-02-19

Mika Nonoyama
Respiratory Therapy

REB number: 1000064842
Study Title: The Pediatric Mechanical Ventilation in Canada (PeMViC) Study: A Delphi Survey of Pediatric Mechanical Ventilation Practices by Canadian Respiratory Therapists

Date of Approval: 2020-02-19
Expiry Date: 2021-02-19

Thank you for the application submitted on **2020-01-27.** The above referenced study was reviewed through a delegated process (not by Full Board review). Any concerns arising from this review have been documented and resolved.

The REB voted to approve this study, and your participation as Principal Investigator, as it is found to comply with relevant research ethics guidelines, as well as the Ontario Personal Health Information Protection Act (PHIPA), 2004.

The Hospital for Sick Children Research Ethics Board hereby issues approval for the above named study. This approval is effective from **2020-02-19** to **2021-02-19.** Continuation beyond that date will require further review of REB approval.

The following documents have been reviewed and are approved:

Documents to Approve:

1. **Protocol, version date 13JAN2020 [Paed MV survey Protocol 13Jan2020.docx]**
2. **Participant Consent, version date 05FEB2020 [Paed MV survey Consent Form 05Feb2020 CLEAN.docx]**
3. **Data Collection Form, version date 13JAN2020 [Paed MV survey R1 survey RT experts 13Jan2020.docx]**
4. **Data Collection Form, version date 13JAN2020 [Paed MV survey Demographic CRF 13Jan2020.docx]**
5. **Volunteer Certificate, version date 05FEB2020 [Paed MV survey volunteer hrs certificate 05Feb2020.docx]**
6. **Poster, version date 13JAN2020 [Paed MV survey Poster 13Jan2020.pptx]**
7. **Reminder Email, version date 05FEB2020 [Paed MV survey reminder emails 05Feb2020.docx]**
8. **Recruitment Email, version date 07FEB2020 [Paed MV survey Email Recruitment 07Feb2020.docx]**
9. **Phone Script, version date 07FEB2020 [Paed MV survey Phone Script Consent 07Feb2020.docx]**

Documents to Acknowledge:

1. **Master Linking Log, version date 05feb2020 [Paed MV survey Coded Identifier List 13Jan2020.xlsx]**

During the course of this investigation, any significant deviations from the approved protocol and/or unanticipated developments or significant adverse events should immediately be brought to the attention of the REB.

Kathy Boutis

555 University Avenue, Toronto, ON M5G 1X8
Tel: (416) 813-8279 Fax: (416) 813-6515

The SickKids REB operates in compliance with the Tri-Council Policy Statement; ICH Guideline for Good Clinical Practice E6(R1); Ontario Personal Health Information Protection Act (2004); Part C Division 5 of the Food and Drug Regulations; Part 4 of the Natural Health Products Regulations and the Medical Devices Regulations of Health Canada. The approval and the views of the REB have been documented in writing. The REB has reviewed and approved the clinical trial protocol and informed consent form for the trial. All investigational drug trials at SickKids are conducted by qualified investigators.

Furthermore, members of the Research Ethics Board who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB.

Mika Nonoyama

From:	researchethics@uoit.ca
Sent:	Tuesday, April 7, 2020 2:22 PM
To:	Mika Nonoyama
Cc:	Carolyn McGregor; Efrosini Papaconstantinou; Quach I Chia Shirley(Student Lead/Post-Doctoral Lead); Reise Katherine(Knowledge Expert); researchethics@uoit.ca
Subject:	Approval Notice - REB File #15636

[EXTERNAL EMAIL]

Date:	*April 07, 2020*
To:	*Mika Nonoyama*
From:	*Ruth Milman, REB Chair*
File # & Title:	*15636 - The Pediatric Mechanical Ventilation in Canada (PeMViC) Study: A Delphi Survey of Pediatric Mechanical Ventilation Practices by Canadian Respiratory Therapists*
Status:	***APPROVED***
Current Expiry:	***April 01, 2021***

Notwithstanding this approval, you are required to obtain/submit, to Ontario Tech Research Ethics Board, any relevant approvals/permissions required, prior to commencement of this project.

The Ontario Tech Research Ethics Board (REB) has reviewed and approved the research study named above to ensure compliance with the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS2 2014), the Ontario Tech Research Ethics Policy and Procedures and associated regulations. As the Principal Investigator (PI), you are required to adhere to the research protocol described in the REB application as last reviewed and approved by the REB. In addition, you are responsible for obtaining any further approvals that might be required to complete your project.

Thank you for your clarifications and amendments. We have considered your comments with respect to the study incentives and though we typically do not allow incentives to be conditional on participation, there are cases where we make exceptions to this standard of practice and due to the multi-phase structure of your Delphi survey we will do so for your study. Additionally, we note that your study does not involve any direct person to person contact with the participants and as such it can continue as approved during the current Covid-19 pandemic. As such, Round 1 of your Delphi survey is approved in full and you may commence recruitment and data collection for the study. We wish you success in this and all of your research endeavours.

Please note that prior to commencing with any future rounds you will need to submit a change request with those study materials. When doing so, please ensure that you submit both a document for collecting continued consent to participate as well as the survey itself. The continued consent document can be shorter than the original consent letter, but should include in a reminder of any withdrawal procedures. We note that the recruitment for these phases has already been included and as such it does not need to be added at that time. Additionally, please note that if you do hire a research assistant then you will need to submit a change request to add them onto your research team prior to having them commence any work on this study.

Under the Tri-Council Policy Statement 2, the PI is responsible for complying with the continuing research ethics reviews requirements listed below:

Renewal Request Form: All approved projects are subject to an annual renewal process. Projects must be renewed or closed by the expiry date indicated above ("Current Expiry"). Projects not renewed 30 days post expiry date will be automatically suspended by the REB; projects not renewed 60 days post expiry date will be automatically closed by the REB. Once your file has been formally closed, a new submission will be required to open a new file.

Change Request Form: If the research plan, methods, and/or recruitment methods should change, please submit a change request application to the REB for review and approval prior to implementing the changes.

Adverse or Unexpected Events Form: Events must be reported to the REB within 72 hours after the event occurred with an indication of how these events affect (in the view of the Principal Investigator) the safety of the participants and the continuation of the protocol (i.e. un-anticipated or un-mitigated physical, social or psychological harm to a participant).

Research Project Completion Form: This form must be completed when the research study is concluded.

Always quote your REB file number (**15636**) on future correspondence. We wish you success with your study.

Sincerely,

Dr. Ruth Milman	Emma Markoff
REB Chair	Research Ethics Assistant
ruth.milman@uoit.ca	researchethics@uoit.ca

NOTE: If you are a student researcher, your supervisor has been copied on this message.

Consent to Participate in a Research Study
Participant Consent

Study Title: The Pediatric Mechanical Ventilation in Canada (PeMViC) Study: A Delphi Survey of Pediatric Mechanical Ventilation Practices by Canadian Respiratory Therapists

Shortened Title: A Survey of Pediatric Mechanical Ventilation Practices

Principal Investigator:
Mika L. Nonoyama, Registered Respiratory Therapist (RRT), PhD
SickKids: Department of Respiratory Therapy, contact number 416-813-7654 x228064
Ontario Tech University: Faculty of Health Sciences, contact number 905-721-8668 x5329

Co-Principal Investigator:
Shirley Quach, RRT, MHSc (c)
SickKids: Department of Respiratory Therapy
Ontario Tech University: Faculty of Health Sciences, contact number 416-720-6588

Co-Investigator(s):
Katherine Reise, RRT, MScCH (c)
Department of Respiratory Therapy, Contact number 416-813-7654 x201530

Efrosini Papaconstantinou, PhD, Registered Nurse
Ontario Tech University: Faculty of Health Sciences, contact number 905-721-8668 x3736

Carolyn McGregor, PhD
Ontario Tech University: Faculty of Health Sciences, contact number 905-721-8668 x3697

Research Contact: Shirley Quach, 416-720-6588

Study Sponsor or Funder: Mika L. Nonoyama Ontario Tech University Research Funds

Conflict of Interest: None of the study team members have a conflict of interest to declare

Introduction
We would like to invite you to take part in our research study. This consent form describes the research study and what it means to participate. This consent form may have words that you do not understand. Please ask the study staff to explain anything that you do not understand. Please take as much time as you need to think about your decision to participate or not, and ask any questions you have. If it is helpful to you, you are encouraged to discuss the study with family, friends, other health professionals, or any members of your community that you trust. All participation is voluntary and you are not under any obligation to participate.

Why am I being asked to participate?

You are being invited to participate in this study because you are a registered respiratory therapist in Canada, working in pediatric critical care for more than five years, and in a leadership position.

Why is this study being done?

The best way to provide and manage respiratory life support (mechanical ventilation [MV]) for children is not known. Treatment plans for MV can differ widely based on the child's size, how they grow, and the illness they have. These plans also can vary based on the healthcare professional's experience and opinion. In Europe, a group of medical experts have created a set of guiding principles for healthcare providers on children's MV management. These guidelines are at times vague because the best way to provide care is often not described in previous research. In Canada, respiratory therapists (RTs) play a vital role in making decisions about a child's MV treatment. The perspectives and experiences of RTs are not known, but can offer important information on the best way to manage children's MV.

This study is being done because we want to create Canadian guidelines for the management of MV in children, based on the perspectives and expertise of RTs who work with children.

How long will the study take?

Your participation in this study will be for 1.5 to 2 hours. You will be asked to complete 3 surveys. Each survey is expected to take about 30 to 45 minutes.

The overall study should take about 6 to 8 months (August 2020) to complete and the final results should be known in about 10 months (October 2020).

How many participants will be in this study?

This is a multi-centre study being done in various centres in Canada. It is anticipated that about 45 people (RTs) will participate in this study throughout Canada. About three people (RTs) will participate in this study at SickKids.

What will happen if I join this study?

Your participation in this study will involve three surveys, about 30 to 45 minutes in length, with the option to leave the survey and complete it later. We may contact you to ask you to complete additional surveys depending on the responses received in the first three surveys. The overall study will take about 1.5 to 2 hours (with additional time added if you choose to complete additional surveys).

We will use a survey method called the "Delphi Method" that aims to get a set of experts (like yourself) to agree on statements by the end of the surveys. There will be at least fifteen expert RTs in the study with at least five years' experience working at a children's critical care hospital in Canada. You will go through several rounds of questionnaires; your opinions will be collected and de-identified prior to analysis. The data will be summarized and sent back to the participant group with the next questionnaire. Each round aims to move the group closer to agreement on the statements, which will make up the guideline. We will consider agreement reached when at

least three-quarters or more of survey responses agree with each other, which is expected after three rounds.

The surveys will be completed electronically on REDCap (a secure web application system). Hard copies of the survey can be provided if you prefer. The survey items for our Delphi survey will be based on this European MV treatment plan:

> Kneyber MCJ, de Luca D, Calderini E, et al. Recommendations for mechanical ventilation of critically ill children from the Paediatric Mechanical Ventilation Consensus Conference (PEMVECC). Intensive Care Med. Dec 2017;43(12):1764-1780.

First survey round (R1):

1. For R1, you will review and reflect on a shortened version of the European MV treatment plans based on their own personal practice and experiences. You will be asked to provide feedback in a maximum of 500 characters. Your feedback will be used to create a survey for the second round (R2).

2. You will also be asked to complete a demographic questionnaire that includes descriptions of your personal characteristics (e.g. age, sex), individual practice (e.g. years of pediatric critical care experience), and practice location (e.g. number of beds for pediatric critical care).

Second and third survey rounds (R2, R3)

1. For R2 you will rate your agreement or disagreement on each survey item using a 5-point Likert scale: 1=strongly disagree, 2=disagree, 3=no opinion, 4=agree, 5=strongly agree. Results will be analyzed, and if consensus is reached, the study will be complete. If consensus is not reached, the survey items that did not reach consensus, will be reassessed and rephrased for the next round (R3).

2. For R3 (if necessary) you will review and rate your agreement or disagreement with the same 5-point Likert scale used in R2. Results will be analyzed in the same way as R2. If consensus is not reached in R3 another round will be necessary.

Please note for each round, a reminder email to complete the survey if a completed survey has been received in 8 days, again on Day 15, and again on day 20.

Paper questionnaires are available upon request. If this is your preference, we will require your mailing address.

Determining the Consensus

Individual Survey Items. For each survey item, responses will be categorized into 3 groups: agree (score 4 or 5), no opinion (score 3) or disagree (score 1 or 2). We will consider consensus reached for a statement when ≥75% of expert participants' responses fall within one of the three categorized groups.

Overall Consensus. To consider consensus reached for the overall Delphi survey, ≥75% of *all* the survey items in the last round must reach consensus.

What are the risks, harms or discomforts of the study?

We don't know of any risks or harms associated with participating in this study. During the questionnaires and/or the interview, you may experience some anxiety, emotional and/or psychological distress due to the nature of the questions. You can skip questions, take a break or stop answering at any time.

If your responses indicate that there is a serious risk of harm to yourself or others, confidentiality will be broken in order to protect you or another person. If we feel that you need urgent care as result of participating in this research study, we will intervene according to routine clinical care practices.

There is an inconvenience of time. Each study visit will take about 30 to 45 minutes, for a total of 1.5 to 2 hours for the entire research study. If more survey rounds are necessary, this may be longer. You will have the option to leave the survey and complete it later.

Despite protections being in place, there is a risk of unintentional release of information. Even though the risk of identifying you from the study data is very small, it can never be completely eliminated.

Are there benefits from being in the study?

There are no direct benefits to you for participating in this research study. However, we hope that the information learned from this study can be used in the future, to benefit future pediatric mechanical ventilation practices in Canada.

Can I choose to leave the study?

It is your choice to take part in this study, participation is voluntary. You can change your mind at any time during the research study. The study team may ask why you are withdrawing for reporting purposes, but you do not need to give a reason to withdraw from the study if you do not want to. Withdrawal from the study will not have any effect on your employment at your workplace. If you decide to leave the study, you can contact the Principal Investigator or a member of the study team to let them know.

If you no longer want your study information to be used in this research you can request your data to be withdrawn and destroyed. Please note that any study data that has been included as part of the analysis or that has been shared cannot be withdrawn.

Will I be paid and/or reimbursed if I join this study?

To compensate for your time, you will be reimbursed with a $10 gift card (e.g. Amazon, Chapters, Starbucks, or Tim Horton's) for each completed survey round.

In recognition of your time, you will also be given a certificate of participation that includes number of volunteer hours, and 1.0 Canadian Society of Respiratory Therapists (CSRT) Continuing Education/Continuing Professional Development (CE/CPD) credits for each completed survey round.

How will my privacy be protected?

We will respect your privacy. No information about you will be given to anyone or be published without your permission, unless the law requires us to do this. The Hospital for Sick Children, and Ontario Tech University are also committed to respecting your privacy.

If you decide to participate in this study, the research team (study investigators, coordinators, nurses, and delegates) will collect personal information about you, including things learned from the study procedures. They will collect only the information they need for this study. The research team will also collect your information (e.g. name, phone number, and email) for the purposes of contacting you. This personal information will not be shared outside of the SickKids and Ontario Tech University research teams. "Personal information" is information about you that could identify you.

All information collected about you will be "de-identified" by replacing your identifiable information (i.e., name) with a "study number". Only the "study code key" can connect the information collected about you to your identity. The study code key will be safeguarded by the research team. Even though the risk of identifying you from the study data is very small, it can never be completely eliminated.

The following people may look at your personal information to check that the information collected for the study is correct and to make sure the study followed the required laws and guidelines:

- Representatives of the SickKids Research Ethics Board and/or Research Quality and Risk Management team
- Representatives of the Ontario Tech University Research Ethics Board

The research team will keep any personal health information about you in a secure and confidential location for seven years and then destroy it according to SickKids policy.

How will I be informed about new information?

We may learn new information during the study that you may need to know. We may also learn about things that might make you want to stop participating in the study. If this happens, you will be notified about any new information in a timely manner. You may also be asked to sign a new consent form that describes these new findings if you decide to continue in the research study.

What are my rights when participating in a research study?

You have the right to receive all information that could help you make a decision about participating in this study. You also have the right to ask questions about this study at any time and to have them answered to your satisfaction. Your rights to privacy are legally protected by federal and provincial laws that require safeguards to ensure that your privacy is respected.

By signing this form, you do not give up any of your legal rights against the study team, or involved institutions for compensation, nor does this form relieve the study team or their agents of their legal and professional responsibilities.

You will be given a copy of this signed and dated consent form prior to participating in this

study.

Will I receive study results?

Research results will be shared through academic conferences, journal publications, and health profession webinars. When the results of this study are shared, your identity will not be disclosed. You have the right to be informed of the results of this study once the entire study is complete.

If you would like to be informed of the results of this study, please contact the study team. You will only be provided with overall study results (aggregate results from all participants). This means you will not know the results as they relate to you specifically.

Who can I call if I have questions about the study?

If you have any questions during your participation in this research study you can contact the Principal Investigator, Mika Nonoyama at 416-813-7654 x228064 or 905-721-8668 x5329; or the research team members listed at the beginning of this consent form.

Research Ethics Board Contact Information

The study protocol and consent form have been reviewed by the SickKids Research Ethics Board (REB). If you have any questions regarding your rights as a research participant, you may contact the SickKids Office of the Research Ethics Board at 416-813-8279, and/or the Ontario Tech Office of the Research Ethics Board at 905-721-8668 x3693 or by email, researchethics@uoit.ca during business hours.

Consent to Participate in a Research Study

Study Title: The Pediatric Mechanical Ventilation in Canada (PeMViC) Study: A Delphi Survey of Pediatric Mechanical Ventilation Practices by Canadian Respiratory Therapists

By signing this research consent form, I understand and confirm that:

1. All of my questions have been answered,
2. I understand the information within this informed consent form,
3. I do not give up any of my legal rights by signing this consent form,
4. I have been told I will be given a signed and dated copy of this consent form.
5. I agree to take part in this study.

I consent to participate in this study.

Printed Name of Participant	Participant signature & date (DD/MMM/YYYY)

Printed Name of person who obtained consent	Role of person obtaining consent	Signature & date (DD/MMM/YYYY)

8.3- Recruitment materials

8.31- Recruitment poster

Join our study on pediatric mechanical ventilation practices

Study title: The Pediatric Mechanical Ventilation in Canada (PeMViC) Study: A Delphi Survey of Pediatric Mechanical Ventilation Practices by Canadian Respiratory Therapists

Principal Investigators:
Mika L. Nonoyama, RRT PhD

Shirley Quach, RRT, MHSc (c)

Interested? To ask questions contact:
Mika L Nonoyama

416-813-7654 x228064

Mika.Nonoyama@sickkids.ca
or
Mika.Nonoyama@ontariotechu.ca

SCAN ME

Are you a respiratory therapist (RT) working in pediatric critical care? Consider participating in our study:

What is the study about?

This study is being done because we want to create Canadian mechanical ventilation recommendations for all children, based on the expertise of experienced RTs.

Who can participate?

We are looking for registered RTs in Canada, working in pediatric critical care for more than five years, and in a leadership (or equivalent) position.

What's involved?

Three online surveys, about 30 to 45 minutes each.

Are there benefits to participating?

There are no direct benefits to participants, but it may help future pediatric mechanical ventilation healthcare practices.

Participants will be given a gift certificate, participation certificate & 3.0 CSRT CE/CPD credits in recognition of their contribution.

This study has been reviewed by the University of Ontario Institute of Technology (Ontario Tech University) (#15636) and SickKids Research Ethics Board (#1000064842) on [OTU date/19Feb2020]

Version: 11Mar2020

8.32 -Recruitment email templates

Date

Dear [name of organization],
We are requesting your assistance in distributing our advertisement to recruit participants for our study: **The Pediatric Mechanical Ventilation in Canada (PeMViC) Study: A Delphi Survey of Pediatric Mechanical Ventilation Practices by Canadian Respiratory Therapists.** The European Society of Pediatric and Neonatal Intensive Care (ESPNIC) outlined best pediatric mechanical ventilation (MV) management strategies (1). ESPNIC consisted of a European and physician-exclusive perspective but was the first to establish consensus recommendations on many aspects of pediatric MV management.

Because Respiratory therapists (RRTs) do not exist in Europe, the recommendations published by ESPNIC may not represent Canadian pediatric MV practices. This study will help standardize Canadian pediatric MV management and facilitate future research to understand their clinical impact on patient outcomes.

We have attached our recruitment poster in this message. If you would kindly distribute this to your Listserv, it will be greatly appreciated.

Please do not hesitate to contact us if you have any questions.
Sincerely,

Shirley Quach, RRT
Master's student, Ontario Tech U
Ichiashirley.quach@ontariotechu.net

Mika Nonoyama, RRT, PhD
Assistant professor, Ontario Tech U
Mika.nonoyama@ontariotechu.net

1. Kneyber MCJ, de Luca D, Calderini E, Jarreau P-H, Javouhey E, Lopez-Herce J, et al. Recommendations for mechanical ventilation of critically ill children from the Paediatric Mechanical Ventilation Consensus Conference (PEMVECC). Intensive Care Med. 2017 Dec;43(12):1764–80.

Subject line: Invitation to Participate in Research: Pediatric Mechanical Ventilation Survey

Dear [participant's name]

We are a research team from the Respiratory Therapy Department at The Hospital for Sick Children (SickKids) and Ontario Tech University. You are invited to participate in our research study called "The Pediatric Mechanical Ventilation in Canada (PeMViC) Study: A Delphi Survey of Pediatric Mechanical Ventilation Practices by Canadian Respiratory Therapists."

Why am I being asked to participate?
You are a candidate for this research because you are a respiratory therapist (RT) working in a pediatric critical care hospital, with over 5 years of clinical experience in Canada. The goal of the research study is to create Canadian guidelines for the management of mechanical ventilation in children, based on the perspective and expertise in RTs.

Your contact information was obtained from [describe where/from whom contact information was obtained].

What will happen if I join this study?
We will use a survey method called the "Delphi Method" that aims to get a set of experts (like yourself) to provide feedback on statements through a series of surveys. Your voluntary participation in this study will involve three surveys, about 30 to 45 minutes in length, with the option to leave the survey and complete it later. We may contact you to ask you to complete additional surveys depending on the responses received in the first three surveys. The overall study will take about 1.5 to 2 hours (with additional time added if you choose to complete additional surveys).

Surveys will be distributed and completed online. If you prefer, we can provide you with a hard copy of the survey, and a pre-stamped return envelope.

Your participation is voluntary, and you may opt to leave the study at any time. If you decide to participate, we will reimburse you for your time. You will receive a $10 gift card after you complete each survey. In addition, our study is approved by the Canadian Society of Respiratory Therapists (CSRT) for Continuing Education (CE) credits. The time spent on completing each survey is eligible for 1.0 CE credit, and the entire study is eligible for 3.0 CE credits.

How can I find out more information?
We are attaching the Participant Consent Form, which contains more details about the study. If you have questions, and/or would like to participate please reply to this email, or telephone any of the investigators below. Signed Participant Consent Forms can be emailed, completed verbally over the phone, or we can send you a pre-stamped return envelope to be mailed.

If you decide to not participate, please also let us know, and we will not contact you in the future.

If we have not heard from you in 7 business days, a research team member will get in touch with you again.

Thank you for your consideration in participating in our study. Your participation is crucial to us, and may inform future pediatric mechanical ventilation practices in Canada.

Sincerely,

Principal Investigator:
Mika L. Nonoyama, Registered Respiratory Therapist (RRT), PhD
SickKids: Department of Respiratory Therapy, contact number 416-813-7654 x228064
Ontario Tech University: Faculty of Health Sciences, contact number 905-721-8668 x5329

Co-Principal Investigator:
Shirley Quach, RRT, MHSc (c)
SickKids: Department of Respiratory Therapy
Ontario Tech University: Faculty of Health Sciences, contact number 416-720-6588

Co-Investigator(s):
Katherine Reise, RRT, MScCH (c)
Department of Respiratory Therapy, Contact number 416-813-7654 x201530

Efrosini Papaconstantinou, PhD, Registered Nurse
Ontario Tech University: Faculty of Health Sciences, contact number 905-721-8668 x3736

Carolyn McGregor, PhD
Ontario Tech University: Faculty of Health Sciences, contact number 905-721-8668 x3697

8.4- Survey instructions and reminder emails for all Rounds

FIRST EMAIL

Subject line: Pediatric Mechanical Ventilation Survey

Dear *[Participants name]*,

Thank you for participating in this study titled "The Pediatric Mechanical Ventilation in Canada (PeMViC) Study: A Delphi Survey of Pediatric Mechanical Ventilation Practices by Canadian Respiratory Therapists".

Your participation is critical because we want to create Canadian mechanical ventilation guidelines for all children, based on the expertise of experienced respiratory therapists (RTs) like yourself. It involves completing two to three surveys, each about 45 to 60 minutes in length, with the option to leave the survey and complete it later.

To compensate for your time, you will be reimbursed with a $10 gift card a certificate of participation that includes number of volunteer hours, and 1.0 Canadian Society of Respiratory Therapists (CSRT) CE/CPD credits for each completed survey round.

Your participation is voluntary, and you may opt to leave the study at any time.

In about a week, we will send you a friendly reminder email if you have not completed the survey. If you have any questions about the survey, or have any challenges before then please call or leave a message with Mika Nonoyama at 416-813-7654 x228064 or email mika.nonoyama@sickkids.ca or mika.nonoyama@ontariotechu.ca.

As always, your responses are confidential, and only aggregate data will be reported.

[Content for Round 1]
For this first survey, we will ask you some questions on your individual practice (e.g. years of pediatric critical care experience), and practice location (e.g. number of beds for pediatric critical care). We will then ask you will review and reflect on a series of pediatric mechanical ventilation recommendations based on your own personal practice and experiences.

Please complete the entire survey and submit your responses by clicking "submit" on the last page of the form. Remember you have the option to leave and complete it later. Here is the WebAccess-protected survey: REDCap URL.

[Content for Subsequent Rounds 2, 3]
For the second survey (R2/ R3), we ask you to rate your agreement or disagreement to an item. Please complete the entire survey and submit your responses by clicking "submit" on the last page of the form. Remember you have the option to leave and complete it later. Here is the WebAccess-protected R2 *[R3 if necessary]* survey: REDCap URL.

Thank you very much for your help.
The PeMViC Research team: Mika Nonoyama, Shirley Quach, Katie Reise, Efrosini Papaconstantinou, and Carolyn McGregor

SECOND EMAIL: sent to non-responders on Day 8

Subject line: REMINDER 1: Pediatric Mechanical Ventilation Survey

Dear *[Participants name]*,

About a week ago we sent you an email regarding your participation in the study titled "The Pediatric Mechanical Ventilation in Canada (PeMViC) Study: A Delphi Survey of Pediatric Mechanical Ventilation Practices by Canadian Respiratory Therapists". **We noticed you have not yet responded. Your response is greatly appreciated. We kindly ask that you fill out the survey at this time.** Here is the WebAccess-protected survey: REDCap URL.

As you recall this study is being done because we want to create Canadian mechanical ventilation guidelines for all children, based on the expertise of experienced respiratory therapists (RTs) like yourself. This study involves getting a group opinion by surveying experts, which is why we really need your response. It involves completing two to three surveys, about 45 to 60 minutes in length each, with the option to leave the survey and complete it later. **To compensate for your time, you will be reimbursed with a $10 gift card a certificate of participation that includes number of volunteer hours, and 1.0 CSRT CE/CPD credits for each completed survey round..**

Your participation is voluntary, and you may opt to leave the study at any time.

If you have any questions or wish to leave the study please call or leave a message with Mika Nonoyama at 416-813-7654 x228064 or email mika.nonoyama@sickkids.ca or mika.nonoyama@ontariotechu.ca.

As always, your responses are confidential, and only aggregate data will be reported.

[Content for Round 1]
For this first survey, we will ask you some questions on your individual practice (e.g. years of pediatric critical care experience), and practice location (e.g. number of beds for pediatric critical care). We will then ask you will review and reflect on a series of pediatric mechanical ventilation recommendations based on your own personal practice and experiences.

Please complete the entire survey and submit your responses by clicking "submit" on the last page of the form. Remember you have the option to leave and complete it later. Here is the WebAccess-protected R1 survey: REDCap URL.

[Content for Subsequent Rounds]
For the second survey (R2/ R3), we ask you to rate your agreement or disagreement to an item. Please complete the entire survey and submit your responses by clicking "submit" on the last page of the form. Remember you have the option to leave and complete it later. Here is the WebAccess-protected R2 *[R3 if necessary]* survey: REDCap URL.

Thank you very much for your help.
The PeMViC Research team: Mika Nonoyama, Shirley Quach, Katie Reise, Efrosini Papaconstantinou, and Carolyn McGregor

SECOND EMAIL: sent to partial responders on Day 8

Subject line: REMINDER 1: Pediatric Mechanical Ventilation Survey

Dear *[Participants name]*,

About a week ago we sent you an email regarding your participation in the study titled "The Pediatric Mechanical Ventilation in Canada (PeMViC) Study: A Delphi Survey of Pediatric Mechanical Ventilation Practices by Canadian Respiratory Therapists". **You started to fill in our survey, but we noticed that you have not finished. Would you please take the time to complete the rest of the survey? Your response is greatly appreciated.**

As you recall this study is being done because we want to create Canadian mechanical ventilation guidelines for all children, based on the expertise of experienced respiratory therapists (RTs) like yourself. **To compensate for your time, you will be reimbursed with a $10 gift card a certificate of participation that includes number of volunteer hours, and 1.0 CSRT CE/CPD credits for each completed survey round.**

Your participation is voluntary, and you may opt to leave the study at any time.

If you have any questions or wish to leave the study please call or leave a message with Mika Nonoyama at 416-813-7654 x228064 or email mika.nonoyama@sickkids.ca or mika.nonoyama@ontariotechu.ca.

As always, your responses are confidential, and only aggregate data will be reported.

[Content for Round 1]
By following the WebAccess-protected link [REDCap URL] you will return to the survey where you stopped. Please complete the entire survey and submit your responses by clicking "submit" on the last page of the form. You can always return to the survey where you stopped if you only have short periods of time to work at completing the survey.

[Content for Subsequent Rounds. R2/R3]
By following the WebAccess-protected link [REDCap URL] you will return to the survey where you stopped. Please complete the entire survey and submit your responses by clicking "submit" on the last page of the form.

Thank you very much for your help.
The PeMViC Research team: Mika Nonoyama, Shirley Quach, Katie Reise, Efrosini Papaconstantinou, and Carolyn McGregor

THIRD EMAIL: sent to non-responders on Day 15

Subject line: REMINDER 2: Pediatric Mechanical Ventilation Survey

Dear *[Participants name]*,

About a week ago we sent you an email regarding your participation in the study titled "The Pediatric Mechanical Ventilation in Canada (PeMViC) Study: A Delphi Survey of Pediatric Mechanical Ventilation Practices by Canadian Respiratory Therapists". **We noticed you have not yet responded. Your response is greatly appreciated. We kindly ask that you fill out the survey at this time.** If it is easier to receive a paper copy of this survey, we will be happy to mail it to you, along with a postage-paid return envelope.

As you recall this study is being done because we want to create Canadian mechanical ventilation guidelines for all children, based on the expertise of experienced respiratory therapists (RTs) like yourself. This study involves getting a group opinion by surveying experts. It involves completing two to three surveys, about 45 to 60 minutes in length each, with the option to leave the survey and complete it later. **To compensate for your time, you will be reimbursed with a $10 gift card a certificate of participation that includes number of volunteer hours, and 1.0 CSRT CE/CPD credits for each completed survey round.**

Your participation is voluntary, and you may opt to leave the study at any time.

If you have any questions, wish to receive a paper copy of the survey, or wish to leave the study please call or leave a message with Mika Nonoyama at 416-813-7654 x228064 or email mika.nonoyama@sickkids.ca or mika.nonoyama@ontariotechu.ca.

As always, your responses are confidential, and only aggregate data will be reported.

[Content for Round 1]
For this first survey, we will ask you some questions on your individual practice (e.g. years of pediatric critical care experience), and practice location (e.g. number of beds for pediatric critical care). We will then ask you will review and reflect on a series of pediatric mechanical ventilation recommendations based on your own personal practice and experiences.

Please complete the entire survey and submit your responses by clicking "submit" on the last page of the form. Remember you have the option to leave and complete it later. Here is the WebAccess-protected R1 survey: REDCap URL.

[Content for Subsequent Rounds]
For the second survey (R2/ R3), we ask you to rate your agreement or disagreement to an item. Please complete the entire survey and submit your responses by clicking "submit" on the last page of the form. Remember you have the option to leave and complete it later. Here is the WebAccess-protected R2 *[R3 if necessary]* survey: REDCap URL.

Thank you very much for your help.
The PeMViC Research team: Mika Nonoyama, Shirley Quach, Katie Reise, Efrosini Papaconstantinou, and Carolyn McGregor

THIRD EMAIL: sent to partial responders on Day 15

Subject line: REMINDER 2: Pediatric Mechanical Ventilation Survey

Dear *[Participants name]*,

About a week ago we sent you an email regarding your participation in the study titled "The Pediatric Mechanical Ventilation in Canada (PeMViC) Study: A Delphi Survey of Pediatric Mechanical Ventilation Practices by Canadian Respiratory Therapists". **You started to fill in our survey, but you did not finish it. Would you please take the time to complete the rest of the survey? Your response is greatly appreciated.** If it is easier to receive a paper copy of this survey, we will be happy to mail it to you (with your partial responses), along with a postage-paid return envelope.

As you recall this study is being done because we want to create Canadian mechanical ventilation guidelines for all children, based on the expertise of experienced respiratory therapists (RTs) like yourself. **To compensate for your time, you will be reimbursed with a $10 gift card a certificate of participation that includes number of volunteer hours, and 1.0 CSRT CE/CPD credits for each completed survey round.**

Your participation is voluntary, and you may opt to leave the study at any time.

If you have any questions, wish to receive a paper copy of the survey, or wish the leave the study, please call or leave a message with Mika Nonoyama at 416-813-7654 x228064 or email mika.nonoyama@sickkids.ca or mika.nonoyama@ontariotechu.ca.

As always, your responses are confidential, and only aggregate data will be reported.

[Content for Round 1]
By following the WebAccess-protected link [REDCap URL] you will return to the survey where you stopped. Please complete the entire survey and submit your responses by clicking "submit" on the last page of the form. You can always return to the survey where you stopped if you only have short periods of time to work at completing the survey.

[Content for Subsequent Rounds]
By following the WebAccess-protected link [REDCap URL] you will return to the survey where you stopped. Please complete the entire survey and submit your responses by clicking "submit" on the last page of the form.

Thank you very much for your help.
The PeMViC Research team: Mika Nonoyama, Shirley Quach, Katie Reise, Efrosini Papaconstantinou, and Carolyn McGregor

FOURTH AND FINAL EMAIL: sent to non-responders on Day 20

Subject line: FINAL REMINDER: Pediatric Mechanical Ventilation Survey

Dear *[Participants name]*,

About a week ago we sent you an email regarding your participation in the study titled "The Pediatric Mechanical Ventilation in Canada (PeMViC) Study: A Delphi Survey of Pediatric Mechanical Ventilation Practices by Canadian Respiratory Therapists". **We noticed you have not yet responded. Your response is greatly appreciated. We kindly ask that you fill out the survey at this time.** If it is easier to receive a paper copy of this survey, we will be happy to mail it to you, along with a postage-paid return envelope.

As you recall this study is being done because we want to create Canadian mechanical ventilation guidelines for all children, based on the expertise of experienced respiratory therapists (RTs) like yourself. This study involves getting a group opinion by surveying experts. It involves completing two to three surveys, about 45 to 60 minutes in length each, with the option to leave the survey and complete it later. **To compensate for your time, you will be reimbursed with a $10 gift card a certificate of participation that includes number of volunteer hours, and 1.0 CSRT CE/CPD credits for each completed survey round.**

Your participation is voluntary, and you may opt to leave the study at any time.

If you have any questions, wish to receive a paper copy of the survey, or wish to leave the study please call or leave a message with Mika Nonoyama at 416-813-7654 x228064 or email mika.nonoyama@sickkids.ca or mika.nonoyama@ontariotechu.ca.

As always, your responses are confidential, and only aggregate data will be reported.

[Content for Round 1]
For this first survey, we will ask you some questions on your individual practice (e.g. years of pediatric critical care experience), and practice location (e.g. number of beds for pediatric critical care). We will then ask you will review and reflect on a series of pediatric mechanical ventilation recommendations based on your own personal practice and experiences.

Please complete the entire survey and submit your responses by clicking "submit" on the last page of the form. Remember you have the option to leave and complete it later. Here is the WebAccess-protected R1 survey: REDCap URL.

[Content for Subsequent Rounds]
For the second survey (R2/ R3), we ask you to rate your agreement or disagreement to an item. Please complete the entire survey and submit your responses by clicking "submit" on the last page of the form. Remember you have the option to leave and complete it later. Here is the WebAccess-protected R2 *[R3 if necessary]* survey: REDCap URL.

Thank you very much for your help.
The PeMViC Research team: Mika Nonoyama, Shirley Quach, Katie Reise, Efrosini Papaconstantinou, and Carolyn McGregor

FOURTH AND FINAL EMAIL: sent to partial responders on Day 20

Subject line: FINAL REMINDER: Pediatric Mechanical Ventilation Survey

Dear *[Participants name]*,

About a week ago we sent you an email regarding your participation in the study titled "The Pediatric Mechanical Ventilation in Canada (PeMViC) Study: A Delphi Survey of Pediatric Mechanical Ventilation Practices by Canadian Respiratory Therapists". **You started to fill in our survey, but you did not finish it. Would you please take the time to complete the rest of the survey? Your response is greatly appreciated**. If it is easier to receive a paper copy of this survey, we will be happy to mail it to you (with your partial responses), along with a postage-paid return envelope.

As you recall this study is being done because we want to create Canadian mechanical ventilation guidelines for all children, based on the expertise of experienced respiratory therapists (RTs) like yourself. This study involves something called a "Delphi Survey", getting a group opinion or decision by surveying experts like yourself. It involves completing two to three "Rounds" of surveys, about 30 to 45 minutes in length each, with the option to leave the survey and complete it later. **To compensate for your time, you will be reimbursed with a $10 gift card a certificate of participation that includes number of volunteer hours, and 1.0 CSRT CE/CPD credits for each completed survey round.**

Your participation is voluntary, and you may opt to leave the study at any time.

If you have any questions before then, wish to receive a paper copy of the survey, or wish to leave the study please call or leave a message with Mika Nonoyama at 416-813-7654 x228064 or email mika.nonoyama@sickkids.ca or mika.nonoyama@ontariotechu.ca.

As always, your responses are confidential, and only aggregate data will be reported.

[Content for Round 1]
For this first survey Round (R1) you reviewed and reflected on some of the European pediatric mechanical ventilation recommendations based on your own personal practice and experiences.

For this session only, we also ask you to complete a demographic questionnaire that includes questions on your personal characteristics (e.g. age, gender), individual practice (e.g. years of pediatric critical care experience), and practice location (e.g. number of beds for pediatric critical care).

By following the WebAccess-protected link [REDCap URL] you will return to the R1 survey where you stopped. Please complete the entire survey and submit your responses by clicking "submit" on the last page of the form. Remember you have the option to leave and complete it later. Here is the WebAccess-protected R2 *[R3 if necessary]* survey: REDCap URL.

[Content for Subsequent Rounds]
For the second survey (R2/ R3), we ask you to rate your agreement or disagreement to an item. By following the WebAccess-protected link [REDCap URL] you will return to the survey where

you stopped. Please complete the entire survey and submit your responses by clicking “submit” on the last page of the form. Remember you have the option to leave and complete it later. Here is the WebAccess-protected R2 *[R3 if necessary]* survey: REDCap URL.

Thank you very much for your help.
The PeMViC Research team: Mika Nonoyama, Shirley Quach, Katie Reise, Efrosini Papaconstantinou, and Carolyn McGregor

8.5 - Demographic Information survey

The Pediatric Mechanical Ventilation in Canada (PeMViC) Study [Participant's Demographic Information]

The purpose of the following survey is to collect your demographic information. Please complete all fields.You may save your work any time throughout the survey. Please click on the "Save and Resume later" button available at the bottom of each webpage. REDCap will save your work and generate an unique code for you to return to complete the survey at a later time. You may do this as many times as you wish.Thank you for contributing to a very important health study to take steps forward in improving respiratory care for children. We appreciate your time and dedication.For technical problems or questions, please contact Shirley (shirley.quach@sickkids.ca) .

Last name	_____
First name	_____
What is your current age?	_____
What is your sex?	◯ Female ◯ Male ◯ Transgender ◯ Gender Variant ◯ Not Listed ◯ Prefer not to answer
What are your designation(s)?	_____ (Include ALL levels of education eg. RRT, CRE, Bachelor's, Master's...)
Which Respiratory Therapy Program/ School did you graduate from?	_____
Which year did you graduate?	_____
How many years have you been practicing as a respiratory therapist?	_____
How many years have you been practicing in pediatric critical care?	_____
Where do you currently reside in?	◯ Alberta ◯ British Columbia ◯ Manitoba ◯ New Brunswick ◯ Newfoundland ◯ Nova Scotia ◯ Ontario ◯ Quebec ◯ Saskatchewan (Select answer)

Where is your primary location of practice?	◯ BC Children's Hospital ◯ Victoria General Hospital (Island Health Authority) ◯ University of Hospital of Northern BC ◯ Stollery Children's Hospital (Alberta Health services) ◯ Alberta Children's Hospital ◯ Jim Patterson's Children (Previously Royal University Hospital) ◯ Regina General Hospital ◯ The Children's Hospital of Manitoba ◯ Children's Hospital of Eastern Ontario ◯ Children's Health Services of London Health ◯ McMaster Children's Hospital (Hamilton Health Services) ◯ SickKids (Hospital for Sick Children) ◯ Montreal Children's Hospital ◯ Center hospitalier universitaire Saint Justine ◯ CHUL et Centre mere-enfant Soleil ◯ University Institute of Cardiology and Respirology of Quebec ◯ CHUS/Hôpital Fleurimont and CHUS Hotel-Dieu Combined ◯ CSSS R-N./Hôp. R. Rimouski ◯ IWK Health Center ◯ Janeway Children's Hospital ◯ St. John's Regional Hospital (Select answer)
How many years have you practiced at this current location?	◯ Less than 1 year ◯ 1 to 5 years ◯ Over 5 years
What is your primary role and duties at this practice location?	☐ Charge/Supervisor/Manager ☐ Practice Lead ☐ Team Lead ☐ Clinical Educator (Staff or student clinical coordinator) ☐ Core Clinical Staff ☐ Rotating Staff ☐ Other, please describe (Check all that apply)
Other	_____
What is your current position at this practice location?	◯ Full time ◯ Part Time ◯ Casual
Approximately how many average hours per week do you work as a respiratory therapist?	_____ (h/ week)
Approximately what percentage of your working hours occurs in the pediatric critical care environment?	_____ (%)
Do you work at an additional pediatric center?	◯ Yes ◯ No

If yes, please select the site(s).	☐ BC Children's Hospital ☐ Victoria General Hospital (Island Health Authority) ☐ University of Hospital of Northern BC ☐ Stollery Children's Hospital (Alberta Health services) ☐ Alberta Children's Hospital ☐ Jim Patterson's Children (Previously Royal University Hospital) ☐ Regina General Hospital ☐ The Children's Hospital of Manitoba ☐ Children's Hospital of Eastern Ontario ☐ Children's Health Services of London Health ☐ McMaster Children's Hospital (Hamilton Health Services) ☐ SickKids (Hospital for Sick Children) ☐ Montreal Children's Hospital ☐ Center hospitalier universitaire Saint Justine ☐ CHUL et Centre mere-enfant Soleil ☐ University Institute of Cardiology and Respirology of Quebec ☐ CHUS/Hôpital Fleurimont and CHUS Hotel-Dieu Combined ☐ CSSS R-N./Hôp. R. Rimouski ☐ IWK Health Center ☐ Janeway Children's Hospital ☐ St. John's Regional Hospital
Which of the following patient populations do you currently practice respiratory therapy? Check ALL that apply.	☐ Neonatal ☐ Pediatric ☐ Adults
In the past year, which of the following professional development activities have you completed? Check ALL that apply.	☐ Read research articles or medical literature related to critical care ☐ Attended presentations, in-services or medical rounds within my hospital organization (e.g. research rounds, journal club, grand rounds, education days) ☐ Attended conferences external to my hospital organization (e.g. CSRT Annual Conference) ☐ Attended courses (e.g. PALS) or workshops (e.g. emergency airway workshop) ☐ Participated in simulation training (e.g. mock codes) ☐ Other, please describe below
Other	_____
In the past year, what has prompted you to attend professional development activities? Check ALL that apply.	☐ A challenging clinical case ☐ A supervisor and/or colleague who highlights an opportunity (e.g. an email containing an article or upcoming conference). ☐ A mandatory staff education event ☐ An identified area for improvement through self-reflection or performance review ☐ Other, please describe below
Other	_____

8.6- Round 1 survey

The Pediatric Mechanical Ventilation in Canada (PeMViC) Study [Round 1: Respiratory Therapist Expert Panel]

For this survey, you will be asked to review and reflect on European pediatric mechanical ventilation recommendations, based on your own clinical practice and experiences. These recommendations are from the following conference paper: Kneyber MCJ, de Luca D, Calderini E, et al. Recommendations for mechanical ventilation of critically ill children from the Paediatric Mechanical Ventilation Consensus Conference (PEMVECC). Intensive Care Med. Dec 2017;43(12):1764-1780.Access the article here For the purposes of this study, the listed recommendations apply to critically ill children, requiring acute mechanical ventilation. These recommendations are not meant to be applied to congenital, neuromuscular diseases or children requiring home-ventilation.

You will be asked to provide open text feedback. Your feedback will be used to create a survey for the second round.Leave the answer box blank if you do not have any feedback on a recommendation e.g. you believe the recommendation is acceptable the way it is written.If it is not relevant in your clinical practice, please put N/A in the answer box. Abbreviations and definitions are available here.For any technical problems or questions, please contact Shirley (shirley.quach@sickkids.ca).

Thank you for contributing to a very important health study to take steps forward in improving respiratory care for children.

You may save your work any time throughout the survey. Please click on the "Save and Return later" button available at the bottom of each webpage. REDCap will save your work and generate an unique code for you to return to complete the survey at a later time. You may do this as many times as you wish.

Section 1: Non-invasive Ventilation Recommendations

Non-invasive ventilation refers to any positive pressure ventilation that is provided via a mask or nasal interface. This includes CPAP or BiLevel non-invasive support e.g. NIV, ST, PC, PS, PAV.

---

1. Consider the use of non-invasive ventilation in pediatric patients with mild to moderate cardiorespiratory failure, if not responsive to other medical management e.g. inotropes, diuretics.

---

a. Do you have content or grammar change suggestions for this recommendation?

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b. Additional space for feedback

---

2. Use non-invasive ventilation to reduce work of breathing and decrease afterload for pediatric patients with left ventricular failure, if not responsive to other medical management e.g. inotropes, diuretics.

---

a. Do you have content or grammar change suggestions for this recommendation?

---

b. Additional space for feedback

3. Before intubation, consider non-invasive ventilation as a first approach in pediatric patients with mixed diseases (decreased compliance, or increased resistance), if the clinical condition does not dictate otherwise.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

4. During non-invasive ventilation, aim to use interfaces without excessive leak. Monitor leaks within an acceptable range to preserve patient trigger sensitivity.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

5. Target optimal patient ventilator synchrony in any triggered non-invasive ventilation mode e.g. bilevel, spontaneous/timed (S/T).

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

6. Do you have any recommendations to add that were not outlined in this section?

Please remember to save your answers before exiting the browser. Click on the "Save and Return Later" button at the bottom of the webpage to get your unique code.

Section 2: Tidal Volume & Inspiratory Pressure Recommendations

1. Use tidal volumes in the physiologic range (5-8ml/kg ideal body weight) for pediatric patients with healthy lungs.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

2. Avoid using tidal volumes greater than 8ml/kg ideal body weight in pediatric patients with restrictive lung, obstructive lung and/or congenital diseases.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

3. For cardiac patients, higher tidal volumes (>8ml/kg ideal body weight) can be used to allow a lower set respiratory rate to promote venous return.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

4. Set a delta pressure (PIP-PEEP) to less than or equal to 10cmH2O to achieve optimal tidal volume in the physiological range (5-8ml/kg ideal body weight) for all pediatric patients.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

5. In absence of transpulmonary pressure measurements, limit the inspiratory plateau pressure to 28cmH2O in pediatric patients with healthy lungs

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

6. In absence of transpulmonary pressure measurements, limit the inspiratory plateau pressure 32cmH2O in patients with decreased chest wall compliance.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

7. Measure tidal volumes proximally in pediatric patients < 10kg.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

8. Do you have any recommendations to add that were not outlined in this section?

Please remember to save your answers before exiting the browser. Click on the "Save and Return Later" button at the bottom of the webpage to get your unique code.

Section 3: Respiratory Rate and Inspiratory Time Recommendations

1. Set inspiratory time and RR based on the patient's age, ventilatory waveforms and clinical evolution, to allow for full exhalation (good I:E ratio) and optimized pediatric-patient synchrony.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

2. Increase the set RR when tidal volumes and/or PIP are reaching limits to maintain minute ventilation in restrictive diseases.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

3. Do you have any recommendations to add that were not outlined in this section?

Please remember to save your answers before exiting the browser. Click on the "Save and Return Later" button at the bottom of the webpage to get your unique code.

Section 4: PEEP and FiO2 Recommendations

1. Set a minimum PEEP of 5cmH2O, to prevent alveolar collapse in pediatric patients with healthy lungs.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

2. Set PEEP to maintain end expiratory lung volume, and an optimal balance between hemodynamics and oxygenation in all pediatric patients. Carefully titrate PEEP to avoid cardiovascular compromise.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

3. High levels of PEEP (>10cmH2O) may be required for pediatric patients with severe ARDS.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

4. High levels of PEEP (>10H2O) may be required to stabilize airways in pediatric patients with tracheomalacia and/or bronchomalacia.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

5. Set the lowest possible FiO2 to maintain target oxygenation goals.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

6. Do you have any recommendations to add that were not outlined in this section?

Please remember to save your answers before exiting the browser. Click on the "Save and Return Later" button at the bottom of the webpage to get your unique code.

Section 5: Advanced Mechanical Ventilation Recommendations

1. Consider high frequency oscillatory ventilation (HFOV) in pediatric patients with restrictive or mixed diseases with severe oxygenation and/or ventilation failure.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

2. Careful use of high frequency oscillatory ventilation (HFOV) can be considered in pediatric patients with cardiac issues suffering from severe respiratory failure. Caution is advised in patients with passive pulmonary blood flow or right ventricular dysfunction.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

3. Careful use of high frequency oscillatory ventilation (HFOV) can be considered in cardiac pediatric patients suffering from severe respiratory failure.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

4. Methods of ventilation such as Airway Pressure Release Ventilation (APRV), Neurally Adjusted Ventilatory Assist (NAVA), Proportional Assist Ventilation (PAV), automated weaning etc, may be considered to optimize patient-ventilator interactions.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

5. Do you have any recommendations to add that were not outlined in this section?

Please remember to save your answers before exiting the browser. Click on the "Save and Return Later" button at the bottom of the webpage to get your unique code.

Section 6: Weaning Recommendations

1. Start weaning ventilator settings as early as possible.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

2. In any complex cases (e.g. restrictive, obstructive, mixed or cardiac pediatric patients), use weaning principles specific to the pathology and titrate ventilator settings more carefully.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedbak

3. If adequate respiratory drive is present, pressure support ventilation may be considered allowing the pediatric patient to breathe spontaneously.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

4. If pressure support ventilation is used, the pressure support, sensitivity, flow cycling, and rise time should be adjusted to maintain patient comfort/synchrony and physiologic tidal volumes.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

5. Routine daily assessment for weaning and extubation should be performed.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

6. Do you have any recommendations to add that were not outlined in this section?

Please remember to save your answers before exiting the browser. Click on the "Save and Return Later" button at the bottom of the webpage to get your unique code.

Section 7: Physiologic Target Recommendations

1. Target normal arterial CO2 levels for pediatric patients with healthy lungs and electively ventilated e.g. post-operative.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

2. Permissive hypercapnia (pH ≥ 7.2) may be acceptable for acute pediatric patients, unless specific disease conditions dictate otherwise e.g. pulmonary hypertension.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

3. Target a SpO2 > 95% on room air in pediatric ventilated patients with healthy lungs.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

4. Target SpO2 92-97% when PEEP is less than 10cmH2O in pediatric patients who meet the pediatric ARDS criteria as described in the PALICC guidelines (access article here).

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

5. Target SpO2 88-92% when PEEP is 10cmH2O or higher in pediatric patients who meet the pediatric ARDS criteria as described in the PALICC guidelines (PALICC Guidelines 2015).

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

6. Target SpO2 75-85% for pediatric patients with cyanotic cardiac lesions e.g. fixed Right to Left shunts.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

7. Do you have any recommendations to add that were not outlined in this section?

Please remember to save your answers before exiting the browser. Click on the "Save and Return Later" button at the bottom of the webpage to get your unique code.

Section 8: Monitoring Recommendations

1. CO_2 monitoring should be used in every pediatric patient on invasive mechanical ventilation, preferably end-tidal CO_2.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

2. SpO_2 monitoring should be used to assess oxygenation in every pediatric patient on invasive or non-invasive mechanical ventilation.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

3. Use indwelling arterial lines for accurate pH, PaO_2, $PaCO_2$, and lactate measurements, in severely ill pediatric patients on mechanical ventilation.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

4. Use central venous saturation (SvO_2) and lactate measurements to assess presence or absence of oxygen debt and/or cardiac output, in severely ill pediatric patients on mechanical ventilation.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

5. Use central venous saturation (SvO2) and lactate measurements to assess presence or absence of oxygen debt and/or cardiac output, in cardiac pediatric patients on mechanical ventilation.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

6. Peripheral venous PCO2 measurements are of limited use in providing information about ventilatory gas exchange. However, they may be used for providing estimates or trending.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

7. Capillary gases are adequate to assess gas exchange in pediatric patients with mild diseases on mechanical ventilation.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

8. Use pH as a tool to modify the pulmonary vascular resistance for specific disease conditions.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

9. Maintain normal pH and PCO2 in pulmonary hypertension.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

10. Do you have any recommendations to add that were not outlined in this section?

Please remember to save your answers before exiting the browser. Click on the "Save and Return Later" button at the bottom of the webpage to get your unique code.

Section 9: Other General Recommendations

1. All pediatric patients on mechanical ventilation should be allowed to breathe spontaneously, with the exception of the most severely ill and/or those requiring intermittent neuromuscular blockade or those with surgical contraindications (e.g. airway surgery).

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

2. Ventilator waveforms e.g. flow volume loops, pressure volume loops, provide real-time data about patient-ventilator interactions such as breath-by-breath ventilation status, response to therapies, and lung mechanics.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

3. The Pediatric Acute Lung Injury Consensus Conference (2015) recommendations on nitric oxide, neuromuscular blockade, prone position and surfactant use should be followed. *Inhaled nitric oxide is not recommended for routine use in PARDS. However, its use may be considered in patients with documented pulmonary hypertension or severe right ventricular dysfunction. In addition, it may be considered in severe cases of PARDS as a rescue from or bridge to extracorporeal life support. When used, assessment of benefit must be undertaken promptly and serially to minimize toxicity and to eliminate continued use without established effect. Finally, future study is needed to better define its role, if any, in the treatment of PARDS. (PALICC guidelines 2015)

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

4. Caution is advised when using sedation and muscle relaxants in pediatric patients with altered cardiac function.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

5. Extracorporeal life support (ECLS) e.g. NovaLung, extracorporeal membrane oxygenation, should be considered when conventional and/or high frequency oscillatory ventilation fail in pediatric patients with reversible diseases. Follow guidelines for specific criteria eg. Extracorpeal Life Support Organization

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

6. Do you have any recommendations to add that were not outlined in this section?

Please remember to save your answers before exiting the browser. Click on the "Save and Return Later" button at the bottom of the webpage to get your unique code.

Section 10: Equipment adjuncts

1. Use double limb circuits for acute, invasive mechanical ventilation.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

2. Minimize the use of apparatuses that add dead space to ventilator circuits.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

3. Elevate the head of the bed at 30-45 degrees in all pediatric patients, unless specific disease conditions dictate otherwise.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

4. Provide airway humidification, 100% relative humidity at 37°C, for all pediatric patients on mechanical ventilation.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

5. Hand-ventilation should be avoided. If hand-ventilation is required, pressure measurements, pressure pop up and PEEP valves or flow-inflating bags should be used to match ventilation pressures.

a. Do you have content or grammar change suggestions for this recommendation?

b. Additional space for feedback

6. Do you have any recommendations to add that were not outlined in this section?

Please remember to save your answers before exiting the browser. Click on the "Save and Return Later" button at the bottom of the webpage to get your unique code.

Section 11: Additional comments

1. Please list consensus recommendations or guidelines you use in your practice.
(Additionally, you may upload up to 5 documents for this answer.)

2. Do you have further comments or recommendations not addressed in this survey?
(Point form please)

If you are satisfied with your answers, please click on the "SUBMIT" button at the bottom of the webpage.

8.7- Round 2 Survey

Pediatric Mechanical Ventilation in Canada (PeMViC) - ROUND 2

For this survey Round, you will be asked to review and rank your level of agreement or disagreement to the recommendation statements using a 5 point numeric scale.

5 4 3 2 1 0

Strongly Agree Agree Neutral Disagree Strongly Disagree No Comment*

*Please select 0 if your center does not use/ practice a certain recommendation

If you strongly disagree or disagree with a recommendation, please elaborate on your choice(s) at the end of each section.

The statements on this survey reflect your feedback from Round 1 and the European pediatric mechanical ventilation recommendations. These recommendations are from the following conference paper:

Kneyber MCJ, de Luca D, Calderini E, et al. Recommendations for mechanical ventilation of critically ill children from the Paediatric Mechanical Ventilation Consensus Conference (PEMVECC). Intensive Care Med. Dec 2017;43(12):1764-1780.

Access the article here.

Please note:

Assume recommendations in this survey would be executed in consultation with the appropriate specialists and interprofessional medical teams Assume recommendations in this survey would be executed when there are appropriate resources and trained professionals available. If a certain therapy does not appear in this survey, it is because there is limited evidence supporting a recommendation The recommendations in this survey focuses on respiratory mechanical ventilation treatments for different diseases The recommendations in this survey will not address the infection control practices related to the therapies outlined

For a list of abbreviations and definitions please click here.

If you would like to review the instructions and statements prior to or during the survey, please find the document here.

PeMViC No.

_____ (Please enter your study number (This was emailed to you))

Introduction

Please refer to this numeric scale when ranking your answers:

5 4 3 2 1 0
Strongly Agree Agree Neutral Agree Strongly Agree No comment*
*Please select 0 if your center does not use/ practice a certain recommendation

If you strongly disagree or disagree with a recommendation, please elaborate on your choice(s) at the end of each section.

You may save your work any time throughout the survey. Please click on the "Save and Return later" button available at the bottom of each webpage. REDCap will save your work and generate an unique code for you to return to complete the survey at a later time. You may do this as many times as you wish.

Please contact Shirley (shirley.quach@sickkids.ca) if you experience any technical difficulties or lose your Return code.

Please reconfirm:
PeMViC No.

_____
(Please enter your study number (This was emailed to you))

Thank you for contributing to a very important health study that will help improve respiratory care for children.

Section 1: Non-invasive ventilation Recommendations

Non-invasive ventilation (NIV) refers to any positive pressure ventilation that is provided via a headgear, face mask or nasal interface. This includes CPAP or BiLevel non-invasive support e.g. NIV, spontaneous timed (ST), pressure control (PC), pressure support (PS), proportional assist ventilation (PAV), non-invasive neurally adjusted ventilatory assist (NIV-NAVA).

*Please select 0 if your center does not use/practice the recommendation.

	5 Strongly agree	4 Agree	3 Neutral	2Disagree	1Strongly Disagree	0 No comment
1. Consider the use of NIV in pediatric patients with mild to moderate cardiorespiratory failure, if not responsive to or in combination with other medical management, e.g. inotropes, diuretics.	○	○	○	○	○	○
2. Consider the use of NIV to reduce work of breathing and decrease afterload for pediatric patients with left ventricular failure, if not responsive to or in combination with other medical management, e.g. inotropes, diuretics.	○	○	○	○	○	○
3. Consider NIV as a first approach before intubation, in pediatric patients with mixed diseases (decreased compliance and/or increased resistance), unless contraindicated. Examples of contraindications: decreased level of consciousness, impending respiratory failure/arrest, airway compromise, decreased respiratory drive, poor skin integrity (e.g. burns, contusions)	○	○	○	○	○	○
4. For patients on NIV, aim to use interfaces with minimal leak and appropriate for their size, age and skin integrity. Monitor leaks within an acceptable range to optimize patient comfort, compliance, synchrony, and to preserve patient trigger sensitivity.	○	○	○	○	○	○

5. Optimize patient ventilator synchrony. This includes adjusting trigger sensitivity and optimizing mask seal in any triggered non-invasive ventilation mode e.g. bilevel, S/T.	○	○	○	○	○	○
5. a. If available, specialty modes of NIV such as NIV NAVA can be used to optimize patient-ventilator synchrony.	○	○	○	○	○	○
6. Consider the use of high flow nasal cannula (HFNC) oxygen therapy (form of oxygen therapy) prior to NIV, to alleviate work of breathing.	○	○	○	○	○	○
7. The use of HFNC and/or NIV should not delay inevitable intubation.	○	○	○	○	○	○

For any statements that you disagree or strongly disagree with, please provide your comments and feedback in the field below.

Section 2: Tidal volume and Inspiratory Pressure Recommendations

*Please select 0 if your center does not use/practice the recommendation.

	5 Strongly agree	4 Agree	3 Neutral	2Disagree	1Strongly Disagree	0 No comment
1. Target tidal volumes in the physiologic range (5-8ml/kg ideal body weight) for pediatric patients >10kg with healthy lungs. Target tidal volumes 5-8ml/kg measured weight for pediatric patients ≤10kg with healthy lungs.	○	○	○	○	○	○
2. For specific congenital cardiac patients requiring optimal venous return, higher tidal volumes (>8ml/kg ideal body weight) may be used if peak pressures are within safe range (< 25cmH2O). This would allow a lower set respiratory rate to minimize mean airway pressure.	○	○	○	○	○	○
3. For all pediatric patients on pressure-limited modes, aim to achieve optimal tidal volume in the physiological range (5-8ml/kg ideal body weight) with minimal delta pressure (PIP-PEEP).	○	○	○	○	○	○
4. In absence of transpulmonary pressure measurements, limit the inspiratory plateau pressure to 30cmH2O in all pediatric patients.	○	○	○	○	○	○

For any statements that you disagree or strongly disagree with, please provide your comments and feedback in the field below.

Please remember to save your answers before exiting the browser. Click on the "Save and Return Later" button at the bottom of the webpage to get your unique code.

Section 3: Respiratory Rate and Inspiratory Time Recommendations

*Please select 0 if your center does not use/practice the recommendation.

	5 Strongly agree	4 Agree	3 Neutral	2Disagree	1Strongly Disagree	0 No comment
1. In controlled ventilation modes, set inspiratory time and respiratory rate based on the patient's age, respiratory mechanics (including waveforms), and clinical data (e.g. blood gases, vitals). This will allow for full exhalation (good I:E ratio), optimized pediatric-patient synchrony and ventilation.	○	○	○	○	○	○
2. In spontaneous ventilation modes, set the trigger, and cycling to achieve the above goals (Section 3, Statement #1).	○	○	○	○	○	○
3. To maintain minute ventilation, increase the set respiratory rate when tidal volumes and/or PIP are reaching limits. Ensure there is sufficient expiratory time to avoid air-trapping.	○	○	○	○	○	○

For any statements that you disagree or strongly disagree with, please provide your comments and feedback in the field below.

Please remember to save your answers before exiting the browser. Click on the "Save and Return Later" button at the bottom of the webpage to get your unique code.

Section 4: PEEP and FiO2 Recommendations

*Please select 0 if your center does not use/practice the recommendation.

	5 Strongly agree	4 Agree	3 Neutral	2Disagree	1Strongly Disagree	0 No comment
1. Set a minimum PEEP of 5-6cmH2O, to prevent alveolar collapse in all pediatric patients.	○	○	○	○	○	○
2. Set PEEP to maintain end expiratory lung volume, and an optimal balance between hemodynamic stability and oxygenation, in all pediatric patients.	○	○	○	○	○	○
3. For patients with challenging oxygenation needs (e.g. ARDS) titrate PEEP incrementally while assessing tidal volumes, oxygen saturation, hemodynamic stability and chest x-ray findings,.	○	○	○	○	○	○
4. Higher levels of PEEP (>10cmH2O) may be required for adequate lung recruitment in pediatric patients with moderate to severe ARDS.	○	○	○	○	○	○
5. Higher levels of PEEP (>10cmH2O) may be required to stabilize airways in pediatric patients with tracheomalacia and/or bronchomalacia.	○	○	○	○	○	○
6. Optimize PEEP to allow for the lowest possible FiO2 (to maintain target oxygen saturation goals), while maintaining adequate hemodynamic status.	○	○	○	○	○	○

For any statements that you disagree or strongly disagree with, please provide your comments and feedback in the field below.

Please remember to save your answers before exiting the browser. Click on the "Save and Return Later" button at the bottom of the webpage to get your unique code.

Section 5: Advanced Mechanical Ventilation Recommendations

All forms of advanced mechanical ventilation should only be used by trained and experienced practitioners. Availability of devices may vary across different institutions/units, reflecting when they are used.

*Please select 0 if your center does not use/practice the recommendation.

	5 Strongly agree	4 Agree	3 Neutral	2Disagree	1Strongly Disagree	0 No comment
1. When conventional mechanical ventilation has failed, consider high frequency oscillatory ventilation (HFOV) in pediatric patients with restrictive or mixed diseases and severe oxygenation and/or ventilation failure.	○	○	○	○	○	○
2. Careful use of high frequency oscillatory ventilation (HFOV) can be considered in pediatric patients with cardiac issues and severe respiratory failure. Cautious use of increased mean airway pressure is advised in patients with passive pulmonary blood flow or right ventricular dysfunction.	○	○	○	○	○	○
3. When conventional mechanical ventilation has failed, consider high frequency jet ventilation (HFJV) in pediatric patients with restrictive or mixed diseases and severe oxygenation and/or ventilation failure.	○	○	○	○	○	○
4. Consider the use of other advanced ventilation techniques to optimize patient-ventilator interactions, acknowledging that each has unique benefits and/or limitations. These modes include NAVA, Airway Pressure Release Ventilation (APRV), Proportional Assist Ventilation (PAV), high frequency jet ventilation (HFJV), automated weaning etc.	○	○	○	○	○	○

5. Strongly consider Extracorporeal life support (ECLS) such as NovaLung, or extracorporeal membrane oxygenation. Use ECLS in pediatric patients with reversible diseases, if available within the facility, not contraindicated, and/or when conventional and/or high frequency oscillatory ventilation has failed. Follow guidelines (e.g. extracorporeal life support organizations) for specific criteria. Early consultation with an ECLS center should be considered if this therapy is not available within the facility.	○	○	○	○	○	○

For any statements that you disagree or strongly disagree with, please provide your comments and feedback in the field below.

Please remember to save your answers before exiting the browser. Click on the "Save and Return Later" button at the bottom of the webpage to get your unique code.

Section 6: Weaning Recommendations

*Please select 0 if your center does not use/practice the recommendation.

	5 Strongly agree	4 Agree	3 Neutral	2Disagree	1Strongly Disagree	0 No comment
1. Routinely assess all pediatric patients (e.g. work of breathing, blood gases, synchrony) in order to wean ventilator settings as early and often as possible.	○	○	○	○	○	○
2. In pediatric patients with complex presentations (e.g. restrictive, obstructive, mixed or cardiac diseases), use weaning principles guided by their respiratory mechanics, pathologies and disease trajectory.	○	○	○	○	○	○
3. Consider pressure support ventilation when adequate respiratory drive is present and disease trajectory is improving. This allows the pediatric patient to breathe spontaneously to maximize comfort, and avoid asynchrony/muscle atrophy.	○	○	○	○	○	○
4. During pressure support ventilation, routinely assess the pressure support level, sensitivity of flow cycling, and rise time to maintain patient comfort/synchrony and physiologic tidal volumes.	○	○	○	○	○	○
5. Routine daily assessment for weaning and extubation readiness should be performed in all pediatric patients.	○	○	○	○	○	○

For any statements that you disagree or strongly disagree with, please provide your comments and feedback in the field below.

Please remember to save your answers before exiting the browser. Click on the "Save and Return Later" button at the bottom of the webpage to get your unique code.

Section 6: Physiologic Target Recommendations

*Please select 0 if your center does not use/practice the recommendation.

	5 Strongly agree	4 Agree	3 Neutral	2Disagree	1Strongly Disagree	0 No comment
1. Physiological targets should be guided by patient respiratory mechanics, and both respiratory and non-respiratory pathologies and disease trajectories.	○	○	○	○	○	○
2. Target normal arterial CO2 levels for pediatric patients with healthy lungs and electively ventilated e.g. post-operative. If arterial CO2 is not available, target normal venous and capillary CO2 levels.	○	○	○	○	○	○
3. Permissive hypercapnia (pH ≥ 7.25) may be acceptable for acute pediatric patients, unless specific disease conditions dictate otherwise e.g. pulmonary hypertension, traumatic brain injury.	○	○	○	○	○	○
4. Target SpO2 92-99% in pediatric patients with healthy lungs, in the absence of disease.	○	○	○	○	○	○
5. Target SpO2 92-97% when PEEP is less than 10cmH2O in pediatric patients who meet the pediatric ARDS criteria (as described in the PALICC guidelines).	○	○	○	○	○	○
6. Target SpO2 88-92% when PEEP is 10cmH2O or higher in pediatric patients who meet the pediatric ARDS criteria (as described in the PALICC guidelines).	○	○	○	○	○	○
7. Target SpO2 75-85% (or as recommended by the interprofessional collaborative team), for pediatric patients with cyanotic cardiac lesions e.g. fixed Right to Left shunts.	○	○	○	○	○	○

For any statements that you disagree or strongly disagree with, please provide your comments and feedback in the field below.

Please remember to save your answers before exiting the browser. Click on the "Save and Return Later" button at the bottom of the webpage to get your unique code.

Section 8: Monitoring Recommendations

*Please select 0 if your center does not use/practice the recommendation.

	5 Strongly agree	4 Agree	3 Neutral	2Disagree	1Strongly Disagree	0 No comment
1. Use continuous SpO2 monitoring to assess oxygen saturation in all pediatric patients on invasive and non-invasive mechanical ventilation.	○	○	○	○	○	○
2. Use CO2 monitoring (preferably end-tidal CO2) in all pediatric patients on invasive mechanical ventilation.	○	○	○	○	○	○
3. Consider the use of transcutaneous CO2 in pediatric patients on advanced forms of mechanical ventilation, e.g. HFOV, HFJV. These monitoring options should be frequently assessed for its correlation to the blood gases.	○	○	○	○	○	○
4. Use arterial lines for accurate pH, PaO2, and lactate measurements, in moderate to severely ill pediatric patients on mechanical ventilation.	○	○	○	○	○	○
5. Use central venous saturation (SvO2) and lactate measurements to assess oxygen extraction and/or cardiac output, in cardiac and/or severely ill pediatric patients on mechanical ventilation .	○	○	○	○	○	○
6. Cautiously use peripheral venous PCO2 measurements to provide estimates and trends of ventilatory gas exchange, when arterial/ central lines are not available.	○	○	○	○	○	○

7. Consider the use of capillary gases to assess gas exchange in mechanically ventilated pediatric patients with good perfusion and with mild diseases. They may be used to provide estimates or trends when arterial/central lines are not available.	○	○	○	○	○	○
8. Use pH as a tool to modify the pulmonary vascular resistance for specific disease conditions, e.g. pulmonary hypertension, single ventricle heart disease.	○	○	○	○	○	○
9. Aim to maintain normal pH, PCO_2 and PaO_2 in pulmonary hypertension and traumatic brain injury. Consider targeting normal-high pH and normal-low CO_2 values.	○	○	○	○	○	○

For any statements that you disagree or strongly disagree with, please provide your comments and feedback in the field below.

Please remember to save your answers before exiting the browser. Click on the "Save and Return Later" button at the bottom of the webpage to get your unique code.

Section 9: Other General Recommendations

*Please select 0 if your center does not use/practice the recommendation.

	5 Strongly agree	4 Agree	3 Neutral	2Disagree	1Strongly Disagree	0 No comment
1. Routinely assess patients to allow for spontaneous breathing, except for severely ill pediatric patients requiring intermittent neuromuscular blockade and sedation.	○	○	○	○	○	○
2. Routinely monitor and assess the impacts of muscle relaxants and sedation on mechanical ventilation (respiratory rate, tidal volumes, minute ventilation).	○	○	○	○	○	○
3. Routinely assess ventilator waveforms (e.g. flow volume loops, pressure volume loops) as they provide real-time data about patient-ventilator interactions such as breath-by-breath ventilation status, response to therapies, and lung mechanics.	○	○	○	○	○	○
4. Use The Pediatric Acute Lung Injury Consensus Conference (2015) recommendations on nitric oxide, neuromuscular blockade, prone position and surfactant use, if safe to do so. Inhaled nitric oxide is not recommended for routine use in PARDS. However, its use may be considered in patients with documented pulmonary hypertension or severe right ventricular dysfunction. In addition, it may be considered in severe cases of PARDS as a rescue from or bridge to ECLS. When used, assessment of benefit must be undertaken promptly and serially to minimize toxicity and to eliminate continued use without established effect. Finally, future study is needed to better define its role, if any, in the treatment of PARDS	○	○	○	○	○	○

5. Reduce the risk of ventilator associated pneumonia (VAP) by following the VAP bundles published by safety groups e.g. Safer Healthcare Now!, Canadian Institute for Health Information, Solutions to Patient Safety. Elements include: 1) elevate the head of the bed 30-45 degrees (15 degrees in infant cribs), unless specific disease or conditions dictate otherwise, e.g. post-operative, indwelling catheters, 2) perform consistent oral hygiene, 3) minimize unnecessary circuit disconnects, 4) perform daily assessment for extubation readiness	○	○	○	○	○	○
6. Different Organization and Working Group guidelines and recommendations may be incorporated into practice and may include, but are not limited to: PALICC, National Heart, Lung, and Blood Institute (NHLBI) ARDS Network Protocol, Pediatric Advanced Life Support (PALS), Neonatal Resuscitation Program (NRP), Extracorporeal Life Support Organization (ELSO)	○	○	○	○	○	○

For any statements that you disagree or strongly disagree with, please provide your comments and feedback in the field below.

Please remember to save your answers before exiting the browser. Click on the "Save and Return Later" button at the bottom of the webpage to get your unique code.

Section 10: Equipment Adjuncts Recommendations

*Please select 0 if your center does not use/practice the recommendation.

	5 Strongly agree	4 Agree	3 Neutral	2Disagree	1Strongly Disagree	0 No comment
1. Use double limbed, heated humidified, filtered circuits for invasive mechanical ventilation.	○	○	○	○	○	○
2. For all pediatric patients on invasive mechanical ventilation, provide active airway humidification at 100% relative humidity at 37°C. For all pediatric patients on NIV, provide active airway humidification at 31°C to avoid excessive rain out in the circuit.	○	○	○	○	○	○
3. Minimize the use of apparatuses that add dead space to ventilator circuits, whenever possible.	○	○	○	○	○	○
4. Use a proximal flow sensor for accurate tidal volume measurements in small patients (< 10kg) or patients with small tidal volumes (< 10mL). Follow the specific ventilator's recommendations on its use.	○	○	○	○	○	○
5. Avoid routine use of manual hand-ventilation to minimize frequent circuit disconnects. If manual hand-ventilation is required, pressure manometers, pressure relief valves and PEEP valves should be used on self-inflating and flow-inflating bags.	○	○	○	○	○	○

For any statements that you disagree or strongly disagree with, please provide your comments and feedback in the field below.

Please remember to save your answers before exiting the browser. Click on the "Save and Return Later" button at the bottom of the webpage to get your unique code.

If you are satisfied with your answers, please click on the "SUBMIT" button at the bottom of the webpage.

Thank you for contributing to a very important health study that will help improve respiratory care for children.

8.8 – Round 3 Survey

Pediatric Mechanical Ventilation in Canada (PeMViC) - ROUND 3

For this survey Round, you will be asked to review and rank your level of agreement or disagreement to the recommendation statements using a 5 point numeric scale.

5 4 3 2 1 0

Strongly Agree Agree Neutral Disagree Strongly Disagree No Comment*

*Please select 0 if your center does not use/ practice a certain recommendation

If you strongly disagree or disagree with a recommendation, please elaborate on your choice(s) at the end of each section.

Please complete this survey to your earliest convenience, by November 29, 2020 11:59PM EST.

In the case you are completing the survey prior to the updated version (REDCap approval is required for all revisions), please be advised that Section #5, statement #1 should read:

"When conventional mechanical ventilation and/or HFO has failed for pediatric patients, consider the use of other advanced modes, acknowledging that each has unique benefits and / or limitations. These modes include high frequency jet ventilation (HFJV) and Airway Pressure Release Ventilation (APRV)*. These advanced modes should not substitute or delay inevitable ECLS, if appropriate."

*"and severe oxygenation and/or ventilation failure" was removed.

The statements on this survey reflect your feedback from Round 2 and the European pediatric mechanical ventilation recommendations. These recommendations are from the following conference paper:

Kneyber MCJ, de Luca D, Calderini E, et al. Recommendations for mechanical ventilation of critically ill children from the Paediatric Mechanical Ventilation Consensus Conference (PEMVECC). Intensive Care Med. Dec 2017;43(12):1764-1780.

Access the article here.

Please note:

Assume recommendations in this survey would be executed in consultation with the appropriate specialists and interprofessional medical teams Assume recommendations in this survey would be executed when there are appropriate resources and trained professionals available. If a certain therapy does not appear in this survey, it is because there is limited evidence supporting a recommendation The recommendations in this survey focuses on respiratory mechanical ventilation treatments for different diseases The recommendations in this survey will not address the infection control practices related to the therapies outlined

For a list of abbreviations and definitions please click here.

To view Round 2's results, please click here.

If you would like to review the instructions and statements prior to completing the electronic survey, please find the document here.

PeMViC No. _____

Introduction

Please refer to this numeric scale when ranking your answers:

5 4 3 2 1 0
Strongly Agree Agree Neutral Disgree Strongly Disagree No comment*
*Please select 0 if your center does not use/ practice a certain recommendation

If you strongly disagree or disagree with a recommendation, please elaborate on your choice(s) at the end of each section.

You may save your work any time throughout the survey. Please click on the "Save and Return later" button available at the bottom of each webpage. REDCap will save your work and generate an unique code for you to return to complete the survey at a later time. You may do this as many times as you wish.

Please contact Shirley (shirley.quach@sickkids.ca) if you experience any technical difficulties or lose your Return code.

Thank you for contributing to a very important health study to take steps forward in improving respiratory care for children.

Please reconfirm:
PeMViC No.

_____
(Please enter your study number (This was emailed to you))

Section 1: Non-invasive Ventilation and High-Flow Oxygen Therapy Recommendations

Non-invasive ventilation (NIV) refers to any positive pressure ventilation that is provided via a headgear, face mask or nasal interface. This includes CPAP or BiLevel non-invasive support e.g. NIV, spontaneous timed (ST), pressure control (PC), pressure support (PS), proportional assist ventilation (PAV), non-invasive neurally adjusted ventilatory assist (NIV-NAVA).

*Please select 0 if your center does not use/practice the recommendation.

	5 Strongly agree	4 Agree	3 Neutral	2Disagree	1Strongly Disagree	0 No comment
1. High flow nasal cannula oxygen therapy (a form of oxygen therapy) is not a substitute for NIV. Consider the use of high flow nasal cannula oxygen therapy prior to NIV, to alleviate work of breathing. However, the use of high flow oxygen therapy should not delay or replace the use of NIV, if NIV is more appropriate.	○	○	○	○	○	○

For any statements that you disagree or strongly disagree with, please provide your comments and feedback in the field below.

Please remember to save your answers before exiting the browser. Click on the "Save and Return Later" button at the bottom of the webpage to get your unique code.

Section 2: Tidal Volume and Inspiratory Pressure Recommendations

*Please select 0 if your center does not use/practice the recommendation.

	5 Strongly agree	4 Agree	3 Neutral	2Disagree	1Strongly Disagree	0 No comment
1. In pediatric patients >10kg, target tidal volumes in the physiologic range (5-8ml/kg ideal body weight). In pediatric patients ≤10kg, target tidal volumes 5-8ml/kg measured weight.	○	○	○	○	○	○
2. For all pediatric patients on pressure-limited modes, aim to achieve optimal tidal volume in the physiological range (5-8ml/kg ideal body weight) with minimal delta pressure (PIP-PEEP).	○	○	○	○	○	○
3. In absence of transpulmonary pressure measurements, the inspiratory plateau pressure should be limited to 30cmH2O in pediatric patients. Site specific limits should be within 28 to 32 cmH2O.	○	○	○	○	○	○
4. If unable to achieve physiologic tidal volumes (5-8ml/kg) within pressure limits (30cmH2O), targeting ranges outside these limits should be discussed with the interprofessional team. For example, congenital lesions, congenital hypoplastic lung, severe PARDS. Similarly, there may be circumstances where tidal volumes >8ml/kg may be cautiously used, but should not be routinely used.	○	○	○	○	○	○

For any statements that you disagree or strongly disagree with, please provide your comments and feedback in the field below.

Please remember to save your answers before exiting the browser. Click on the "Save and Return Later" button at the bottom of the webpage to get your unique code.

Section 5: Advanced Modes of Ventilation

All forms of advanced mechanical ventilation should only be used by trained and experienced practitioners. Availability of devices may vary across different institutions/units, reflecting when they are used.

PLEASE NOTE:

To avoid overwriting other participants' existing data, the following change could not be directly applied onto the survey field below.

Please be advised, that statement #1 should read:

"When conventional mechanical ventilation and/or HFO has failed for pediatric patients, consider the use of other advanced modes, acknowledging that each has unique benefits and / or limitations. These modes include high frequency jet ventilation (HFJV) and Airway Pressure Release Ventilation (APRV)*. These advanced modes should not substitute or delay inevitable ECLS, if appropriate."

*"and severe oxygenation and/or ventilation failure" should not be present in the sentence.

*Please select 0 if your center does not use/practice the recommendation.

	5 Strongly agree	4 Agree	3 Neutral	2Disagree	1Strongly Disagree	0 No comment
1. When conventional mechanical ventilation and/or HFO has failed for pediatric patients, consider the use of other advanced modes, acknowledging that each has unique benefits and / or limitations. These modes include high frequency jet ventilation (HFJV) and Airway Pressure Release Ventilation (APRV) and severe oxygenation and/or ventilation failure. These advanced modes should not substitute or delay inevitable ECLS, if appropriate.	○	○	○	○	○	○
2. Other advanced ventilation techniques may optimize patient-ventilator interactions. Consider their use while acknowledging that each has unique benefits and/or limitations. These modes include Neurally Adjusted Ventilatory Assist (NAVA), Proportional Assist Ventilation (PAV), automated weaning etc.	○	○	○	○	○	○

3. When conventional mechanical ventilation and/ or HFO has failed, consider the use of Extracorporeal life support (ECLS) in pediatric patients with reversible diseases, if available within the facility and not contraindicated. Follow guidelines (e.g. ECLS organizations) for more specific criteria. Consider early consultation with an ECLS center when ECLS is not available within the facility.	○	○	○	○	○	○

For any statements that you disagree or strongly disagree with, please provide your comments and feedback in the field below.

Please remember to save your answers before exiting the browser. Click on the "Save and Return Later" button at the bottom of the webpage to get your unique code.

Section 10: Equipment Adjuncts Recommendations

*Please select 0 if your center does not use/practice the recommendation.

	5 Strongly agree	4 Agree	3 Neutral	2Disagree	1Strongly Disagree	0 No comment
1. Proximal flow sensors are not routinely used for pediatric patients. Follow the specific ventilator's recommendations on proximal flow sensor use. In the absence of specific ventilator recommendations, use a proximal flow sensor for small tidal volumes (< 10mL).	○	○	○	○	○	○
2. Minimize routine use of manual ventilation to avoid circuit disconnects. Manual ventilation may be used to augment pulmonary hygiene as part of chest physiotherapy. Manual resuscitation devices should be capable of maintaining PEEP, limiting and monitoring pressures.	○	○	○	○	○	○

For any statements that you disagree or strongly disagree with, please provide your comments and feedback in the field below.

Section 11: General Recommendations

	5 Strongly agree	4 Agree	3 Neutral	2Disagree	1Strongly Disagree	0 No comment
1. Mechanical ventilation management and anticipated plans should be discussed as an interprofessional (IP) team at minimum on a daily basis. Any changes in the patients' trajectory or mechanical ventilation needs should be communicated between all members of the IP team.	○	○	○	○	○	○

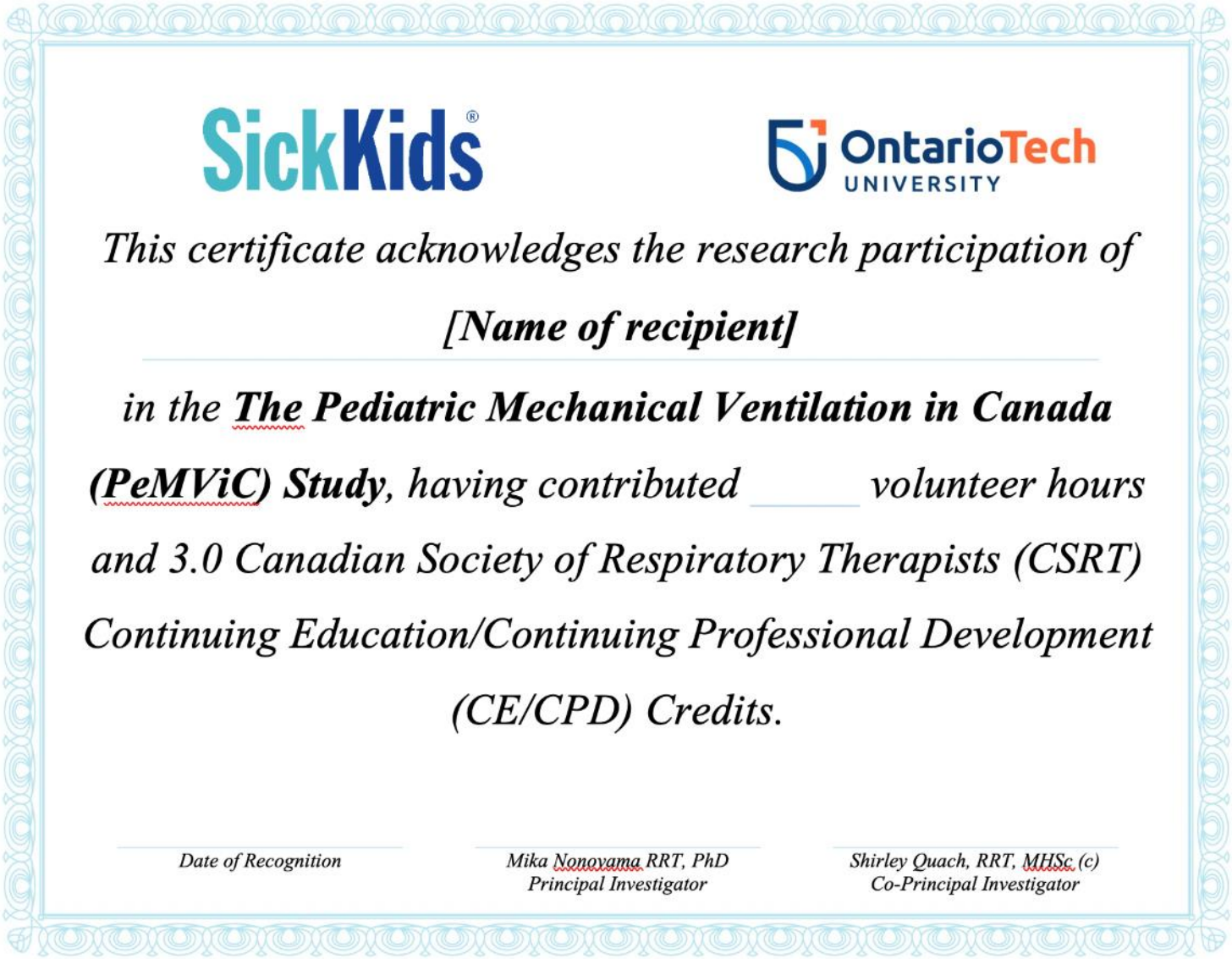
For any statements that you disagree or strongly disagree with, please provide your comments and feedback in the field below.

Please remember to save your answers before exiting the browser. Click on the "Save and Return Later" button at the bottom of the webpage to get your unique code.

If you are satisfied with your answers, please click on the "SUBMIT" button at the bottom of the webpage.

Thank you for contributing to a very important health study to take steps forward in improving respiratory care for children.

8.9 - Participation certificate



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OntarioTech UNIVERSITY

This certificate acknowledges the research participation of

[Name of recipient]

in the ***The Pediatric Mechanical Ventilation in Canada (PeMViC) Study****, having contributed _____ volunteer hours and 3.0 Canadian Society of Respiratory Therapists (CSRT) Continuing Education/Continuing Professional Development (CE/CPD) Credits.*

Date of Recognition	*Mika Nonoyama RRT, PhD* *Principal Investigator*	*Shirley Quach, RRT, MHSc (c)* *Co-Principal Investigator*

Version: v1.0-FEB2020

8.10- Post-Delphi summary for participants

Pediatric Mechanical Ventilation in Canada (PeMViC)
Summary: All Recommendations

Thank you for taking the time to provide us with your feedback on all Rounds of the Delphi Survey. The following document describes all the finalized recommendations, percent rankings, and original feedback (if received) from participants.

The rankings were categorized into 3 different groups:

1. Strongly disagree (SD) + Disagree (D)
2. Neutral
3. Strongly agree (SA) + Agree (A)

Consensus was achieved when any category 1, 2, or 3 achieved over 75% of responses. *For all the statements, consensus was achieved in the "strongly agree + agree" category.*

The number of participants who selected "0 - No comment" is reported for each recommendation statement. "0 - No comment" was selected if a participant's location of practice did not use/ practice a certain recommendation.

A list of abbreviations is available at the end of the document.

Original feedback from participants can be found at the end of the document.

All the "patients" in this document are ***Pediatric patients.***

Section 1: Non-invasive ventilation (NIV) Recommendations

Non-invasive ventilation (NIV) refers to any positive pressure ventilation that is provided via a headgear, face mask or nasal interface. This includes CPAP or BiLevel non-invasive support e.g. NIV, spontaneous timed (ST), pressure control (PC), pressure support (PS), proportional assist ventilation (PAV), non-invasive neurally adjusted ventilatory assist (NIV-NAVA).

1. Consider the use of NIV in patients with mild to moderate cardiorespiratory failure, if not responsive to or in combination with other medical management (e.g. inotropes, diuretics).

2. Consider the use of NIV to reduce work of breathing and decrease afterload for patients with left ventricular failure, if not responsive to or in combination with other medical management (e.g. inotropes, diuretics).

3. For patients on NIV, aim to use interfaces with minimal leak and appropriate for their size, age and skin integrity. Monitor leaks within an acceptable range to optimize patient comfort, compliance, patient ventilator synchrony, and to preserve patient trigger sensitivity.

4. Optimize patient ventilator synchrony. This includes adjusting trigger sensitivity and optimizing mask seal in any triggered non-invasive ventilation mode (e.g. bilevel, S/T).

    4a. If available, specialty modes of NIV such as NIV-NAVA can be used to optimize patient-ventilator synchrony.

5. High flow nasal cannula oxygen therapy (a form of oxygen therapy) is not a substitute for NIV. Consider the use of high flow nasal cannula oxygen therapy prior to NIV, to alleviate work of breathing. However, the use of high flow oxygen therapy should not delay or replace the use of NIV, if NIV is more appropriate.

6. Consider the use of NIV prior to intubation, in patients with mixed diseases (decreased compliance and/or increased resistance), unless contraindicated. Common contraindications are decreased level of consciousness, impending respiratory failure/arrest, airway compromise, decreased respiratory drive, and poor skin integrity (e.g. burns, contusions).

7. The use of HFNC and/or NIV should not delay inevitable intubation.

Statement	# of no comments*	Strongly Disagree (SD)	Disagree (D)	Neutral	Agree (A)	Strongly Agree (SA)	Consensus (A+ SA)
1.1	0	0	0	4%	56%	40%	96%
1.2	0	0	0	2%	44%	54%	98%
1.3	0	0	0	2%	26%	72%	98%
1.4	0	0	0	0	26%	74%	100%
1.4a	12	0	2.5%	13%	44%	41%	85%
1.5	0	0	6%	2%	41%	51%	92%
1.6	0	0	4%	2%	36%	58%	94%
1.7	0	0	0	0	24%	76%	100%

* Participants are supposed to select 0 if their location of practice did not use/ practice a certain recommendation

Section 2: Tidal Volume & Inspiratory Pressure Recommendations

1. Aim to achieve a tidal volume in the physiologic range (5-8ml/kg ideal body weight) in patients <10kg. Alternatively, aim to achieve tidal volumes of 5-8ml/kg measured weight in patients ≤10kg.

2. Aim to achieve tidal volume in the physiological range (5-8ml/kg ideal body weight) with minimal driving pressure (PIP-PEEP) in patients on pressure limited modes.

3. Aim to limit inspiratory plateau pressure (Pplat) to approximately 30cmH_2O, in the absence of transpulmonary pressure measurements. Limits should be between 28 to 32 cmH_2O.

4. If unable to achieve physiologic tidal volumes (5-8ml/kg) within plateau pressure limits (30cmH_2O), targeting ranges outside these limits should be discussed with the interprofessional team. There may be circumstances where tidal volumes < 5mL/kg and >8ml/kg may be cautiously, but not routinely used.

Statement	# of no comments*	Strongly Disagree (SD)	Disagree (D)	Neutral	Agree (A)	Strongly Agree (SA)	Consensus (A+ SA)
2.1	1	0	13%	6%	50%	31%	81%
2.2	1	2%	2%	0%	55%	26%	96%
2.3	0	0	2%	4%	67%	26%	93%
2.4	4	0	0	2%	65%	33%	98%

* Participants are supposed to select 0 if their location of practice did not use/ practice a certain recommendation

Section 3: Respiratory Rate and Inspiratory Time Recommendations

1. Set inspiratory time and respiratory rate based on the patient's age, respiratory mechanics (including waveforms), and clinical data (e.g. blood gases, vital signs) in controlled ventilation modes. This will allow for full exhalation (acceptable I:E ratio), optimized patient synchrony and ventilation.

2. Set the trigger setting and cycling setting on the ventilator to achieve the above goals (Recommendation 3.1) in all spontaneous ventilation modes.

3. Increase the set respiratory rate when tidal volumes and/or PIP are reaching limits to maintain minute ventilation. Ensure there is sufficient expiratory time to avoid air-trapping.

Statement	# of no comments*	Strongly Disagree (SD)	Disagree (D)	Neutral	Agree (A)	Strongly Agree (SA)	Consensus (A+ SA)
3.1	0	0	0	2%	32%	66%	98%
3.2	0	0	0	2%	34%	64%	98%
3.3	0	2%	4%	2%	44%	48%	92%

* Participants are supposed to select 0 if their location of practice did not use/ practice a certain recommendation

Section 4: PEEP and FiO_2 Recommendations

1. Set a minimum PEEP of 5-6cmH_2O, to prevent alveolar collapse, in all patients.

2. Set PEEP to maintain end expiratory lung volume, and an optimal balance between hemodynamic stability and oxygenation, in all patients.

3. Titrate PEEP incrementally while assessing lung compliance, oxygen saturation, hemodynamic stability and chest x-ray findings for patients with challenging oxygenation needs (e.g. PARDS).

4. Higher levels of PEEP (>10cmH_2O) may be required for adequate lung recruitment in patients with moderate to severe ARDS.

5. Higher levels of PEEP (>10cmH_2O) may be required to stabilize airways in patients with tracheomalacia and/or bronchomalacia.

6. Titrate PEEP to allow for the lowest possible FiO_2 (to maintain target oxygenation goals), while maintaining adequate hemodynamic status.

Statement	# of no comments*	Strongly Disagree (SD)	Disagree (D)	Neutral	Agree (A)	Strongly Agree (SA)	Consensus (A+ SA)
4.1	0	4%	8%	2%	28%	58%	86%
4.2	0	0	0	0	38%	62%	100%
4.3	0	2%	0	2%	44%	52%	96%
4.4	0	0	0	2%	36%	62%	98%
4.5	0	0	2%	4%	48%	46%	94%
4.6	0	4%	0	2%	44%	50%	94%

* Participants are supposed to select 0 if their location of practice did not use/ practice a certain recommendation

Section 5: Advanced Mechanical Ventilation Recommendations

All forms of advanced mechanical ventilation should only be used by trained and experienced practitioners. Availability of devices may vary across different institutions/units, reflecting when they are used.

1. Consider the use of high frequency oscillatory ventilation (HFOV) in patients with restrictive or mixed diseases and severe oxygenation and/ or ventilation failure.

2. Consider the use of HFOV in patients with cardiac issues and severe respiratory failure. Cautious use of increased mean airway pressure is advised in patients with passive pulmonary blood flow or right ventricular dysfunction.

3. Consider the use of other advanced modes (such as HFJV or APRV) when conventional mechanical ventilation and/or HFOV has failed. Consider the unique benefits and/or limitations for each of these advanced modes. These advanced modes should not substitute or delay inevitable ECLS, if appropriate.

4. Consider the use of other advanced ventilation modes/techniques (such as NAVA, PAV, or automated weaning) to optimize patient-ventilator interactions. The unique benefits and/or limitations for each of these advanced modes must be acknowledged.

5. Consider the use of ECLS in patients with reversible diseases when conventional mechanical ventilation and/ or HFOV has failed, if available within the facility, and not contraindicated. Follow guidelines (e.g. ECLS organizations) for more specific criteria. Consider early consultation with an ECLS center when ECLS is not available within the facility.

Statement	# of no comments*	Strongly Disagree (SD)	Disagree (D)	Neutral	Agree (A)	Strongly Agree (SA)	Consensus (A+ SA)
5.1	0	0	5%	5%	62%	29%	91%
5.2	0	0	0	14%	50%	36%	86%
5.3	16	0	5%	5%	62%	29%	90%
5.4	4	0	5%	11%	59%	24%	84%
5.5	3	0	2%	2%	47%	49%	96%

* Participants are supposed to select 0 if their location of practice did not use/ practice a certain recommendation

Section 6: Weaning Recommendations

1. Routinely assess all patients, with the aim to wean ventilator settings as early and often as possible.

2. Use weaning principles guided by respiratory mechanics, pathologies and disease trajectory in patients with complex presentations (e.g. restrictive, obstructive, mixed or cardiac diseases).

3. Consider pressure support ventilation when adequate respiratory drive is present and disease trajectory is improving. This allows the patient to breathe spontaneously to maximize comfort and avoid asynchrony/muscle atrophy.

4. Routinely assess the pressure support level, rise time and sensitivity of flow cycling to maintain patient comfort/synchrony and physiologic tidal volumes (5-8ml/kg) in patients on pressure support ventilation.

5. Routine daily assessment for weaning and extubation readiness should be performed in all patients.

Statement	# of no comments*	Strongly Disagree (SD)	Disagree (D)	Neutral	Agree (A)	Strongly Agree (SA)	Consensus (A+ SA)
6.1	0	2%	0	2%	38%	58%	96%
6.2	0	0	0	6%	48%	46%	94%
6.3	0	0	2%	2%5	38%	58%	96%
6.4	0	0	0	2%	42%	56%	98%
6.5	0	0	4%	10%	34%	52%	86%

* Participants are supposed to select 0 if their location of practice did not use/ practice a certain recommendation

Section 7: Physiologic Target Recommendations

1. Physiological targets should be guided by patient respiratory mechanics, and both respiratory and non-respiratory pathologies and disease trajectories.

2. Target normal arterial CO_2 levels for patients with healthy lungs (i.e. no respiratory disease). If arterial CO_2 is not available, target normal venous and capillary CO_2 levels.

3. Permissive hypercapnia ($pH \geq 7.25$) may be acceptable for acute patients, unless specific disease conditions dictate otherwise (e.g. pulmonary hypertension, traumatic brain injury).

4. Target a SpO_2 92-99% in patients with healthy lungs, in the absence of respiratory disease. If the patient is post-resuscitation, follow the Heart and Stroke PALS recommendations of SpO_2 94-99%.

5. Target SpO_2 92-97% when PEEP is < $10cmH_2O$ in patients who meet the PARDS criteria (as described in the PALICC guidelines).

6. Target SpO_2 88-92% when PEEP is ≥10cmH_2O in patients who meet the PARDS criteria (as described in the PALICC guidelines).

7. Target SpO_2 75-85% (or as recommended by the interprofessional collaborative team), for patients with cyanotic cardiac lesions (e.g. fixed Right to Left shunts).

Statement	# of no comments*	Strongly Disagree (SD)	Disagree (D)	Neutral	Agree (A)	Strongly Agree (SA)	Consensus (A+ SA)
7.1	0	0	2%	4%	52%	42%	94%
7.2	0	0	0	2%	52%	46%	98%
7.3	0	0	0	2%	44%	54%	98%
7.4	0	2%	6%	4%	42%	88%	88%
7.5	1	0	8%	8%	51%	32%	84%
7.6	0	2%	2%	10%	47%	39%	86%
7.7	0	0	2%	4%	52%	42%	94%

* Participants are supposed to select 0 if their location of practice did not use/ practice a certain recommendation

Section 8: Monitoring Recommendations

1. Use continuous SpO_2 monitoring to assess oxygen saturation in all patients on invasive and non-invasive mechanical ventilation.

2. Use CO_2 monitoring (preferably end-tidal CO_2) in all patients on invasive mechanical ventilation.

3. Consider the use of transcutaneous CO_2 in patients on advanced forms of mechanical ventilation, (e.g. HFOV, HFJV). These monitoring options should be frequently assessed for its correlation to the blood gases.

4. Use arterial lines for accurate pH, PaO_2, and lactate measurements, in moderate to severely ill patients on mechanical ventilation.

5. Use central venous saturation (SvO_2) and lactate measurements to assess oxygen extraction and/or cardiac output, in cardiac and/or severely ill patients on mechanical ventilation.

6. Cautiously use peripheral venous PCO_2 measurements to provide estimates and trends of ventilatory gas exchange, when arterial/ central lines are not available.

7. Consider the use of capillary gases to assess gas exchange in mechanically ventilated patients with good perfusion and with mild diseases. They may be used to provide estimates or trends when arterial/central lines are not available.

8. Use pH as a tool to modify the pulmonary vascular resistance for specific disease conditions, (e.g. pulmonary hypertension, single ventricle heart disease).

9. Aim to maintain normal pH, PCO_2 and PaO_2 in pulmonary hypertension and traumatic brain injury. Consider targeting normal-high pH and normal-low CO_2 values.

Statement	# of no comments*	Strongly Disagree (SD)	Disagree (D)	Neutral	Agree (A)	Strongly Agree (SA)	Consensus (A+ SA)
8.1	0	0	2%	0	22%	76%	98%
8.2	0	0	4%	2%	45%	60%	94%
8.3	0	0	0	16%	33%	51%	84%
8.4	0	0	0	8%	28%	70%	98%
8.5	0	0	0	8%	36%	56%	92%
8.6	0	0	2%	8%	63%	27%	90%
8.7	0	0	4%	4%	54%	42%	96%
8.8	0	0	2%	10%	58%	30%	88%
8.9	0	0	0	4%	52%	44%	96%

* Participants are supposed to select 0 if their location of practice did not use/ practice a certain recommendation

Section 9: Other General Recommendations

1. Routinely assess patients to allow for spontaneous breathing, except for severely ill patients requiring intermittent neuromuscular blockade and sedation.

2. Routinely monitor and assess the impacts of muscle relaxants and sedation on mechanical ventilation (respiratory rate, tidal volumes, minute ventilation) when they are in use for the patient's clinical management.

3. Routinely assess ventilator waveforms (e.g. flow volume loops, pressure volume loops) as they provide real-time data about patient-ventilator interactions such as breath-by-breath ventilation status, response to therapies, and lung mechanics.

4. Use The Pediatric Acute Lung Injury Consensus Conference (2015) recommendations on nitric oxide, neuromuscular blockade, prone position and surfactant use, if safe to do so.

5. Reduce the risk of Ventilator acquired pneumonia (VAP) by following the VAP bundles published by safety groups (e.g. Safer Healthcare Now!, Canadian Institute for Health Information, Solutions to Patient Safety). Elements include: 1) elevate the head of the bed 30-45 degrees (15-30 degrees in infants), unless specific disease or conditions dictate otherwise, 2) perform consistent oral hygiene, 3) minimize unnecessary circuit disconnects, and 4) perform daily assessment for extubation readiness.

6. Different Organization and Working Group guidelines and recommendations may be incorporated into practice and may include, but are not limited to: Pediatric Acute Lung Injury Care Conference (PALICC), National Heart, Lung, and Blood Institute (NHLBI) ARDS Network Protocol, Pediatric Advanced Life Support (PALS), Neonatal Resuscitation Program (NRP), Extracorporeal Life Support Organization (ELSO).

7. Mechanical ventilation management and anticipated plans should be discussed as an interprofessional (IP) team at minimum on a daily basis. Any changes in the patients'

trajectory or mechanical ventilation needs should be communicated between all members of the IP team.

Statement	# of no comments*	Strongly Disagree (SD)	Disagree (D)	Neutral	Agree (A)	Strongly Agree (SA)	Consensus (A+ SA)
9.1	0	0	0	4%	48%	48%	96%
9.2	0	0	4%	6%	48%	42%	90%
9.3	0	0	0	2%	46%	52%	98%
9.4	5	0	0	13%	49%	38%	87%
9.5	0	0	0	0	46%	54%	100%
9.6	0	0	0	12%	51%	37%	88%
9.7	0	0	0	0	34%	65%	100%

* Participants are supposed to select 0 if their location of practice did not use/ practice a certain recommendation

Section 10: Equipment adjuncts recommendations

1. Use dual-limb, heated, filtered circuits with active airway humidity for invasive mechanical ventilation.

2. Use active airway humidification at 100% relative humidity at 37°C in patients on invasive mechanical ventilation. Use active airway humidification in the range of 31- 37°C, and titrate to avoid excessive rain out in the interface in patients on NIV.

3. Minimize the use of apparatuses or connectors that add dead space to ventilator circuits, whenever possible.

4. Do not routinely use proximal flow sensors, or follow the specific ventilator's recommendations on proximal flow sensor use. In the absence of specific ventilator recommendations, use a proximal flow sensor for small tidal volumes (<10mL).

5. Minimize routine use of manual ventilation to avoid circuit disconnects. Manual ventilation may be used to augment pulmonary hygiene as part of chest physiotherapy. Manual resuscitation devices should be capable of maintaining PEEP, monitoring and limiting pressures.

Statement	# of no comments*	Strongly Disagree (SD)	Disagree (D)	Neutral	Agree (A)	Strongly Agree (SA)	Consensus (A+ SA)
10.1	0	0	0	2%	26%	72%	98%
10.2	0	2%	4%	0	36%	58%	94%
10.3	0	0	0	0	36%	64%	100%
10.4	3	0	11%	4%	67%	18%	97%
10.5	0	0	2%	4%	53%	41%	84%

* Participants are supposed to select 0 if their location of practice did not use/ practice a certain recommendation

List of abbreviations

APRV	Airway Pressure Release Ventilation
CO_2	carbon dioxide
ECLS	Extracorporeal Life Support
ECMO	Extracorporeal membrane oxygenation
FiO_2	Fraction of inspired oxygen
HFJV	High frequency jet ventilation
HFNC	High flow nasal cannula
HFJV	High frequency jet ventilation
HFOV	High frequency oscillation ventilation
IBW	Ideal body weight
NAVA	Neurally adjusted ventilatory assist
NIV-NAVA	Non-invasive neurally ventilatory assist
PaO2	Arterial partial pressure of oxygenation
PALICC	Pediatric Acute Lung injury Consensus conference
PALS	Pediatric Advanced Life Support
PARDS	Pediatric acute respiratory distress syndrome
PAV	Proportional Assist ventilation
PCO_2	Partial pressure of carbon dioxide
PEEP	Positive end expiratory pressure
PICU	Pediatric intensive care unit
PIP	Peak inspiratory pressure
Pplat	Plateau pressure
PSV	Pressure support ventilation
SpO_2	oxygen saturation
SvO_2	Venous saturation
VAP	Ventilator acquired pneumonia
WOB	Work of breathing

OPEN TEXT FEEDBACK FOR ROUND 2-3

**The following are free text responses from participants and were not revised*

Section 1: Non-invasive ventilation (NIV) Recommendations

Recommendation 1.4 (all Rounds)
• dual limb NIV with full face mask is used as the approach prior to intubation. NAVA recently discontinued at our facility due to poor success rate • NIV NAVA should not simply be used "if available" - this will lead to the unnecessary introduction of an invasive catheter (not to mention increased cost of equipment). NIV NAVA should primarily be used "if required" to correct insufficient patient-vent synchrony.
Recommendation 1.5, 1.6, 1.7
• This [NIV] should not be a "first approach" - other approaches such as medications or HFNC should be considered first. NIV should only be considered as a "second approach" should these more basic interventions fail • If you need to start NIV for cardiac or obstructive reasons such as an asthma attack, then don't waste time with HFNC • I don't feel all patients should try HFNC prior to NIV. Consider, yes. But if not appropriate, move right to NIV. • HFNC should not be tried in patients when NIV has been proven effective in patients with certain sicknesses or disease processes. It just delays treatment • For certain cases, prioritizing the use of HFNC before NIV is not appropriate, like bronchiolitis on small babies: a lot of secretions is not compatible with HFNC, NIV is more comfortable for them and more effective treatment. • Simply because patient has increased WOB, should not try HFNC simply because. Should assess work of breathing and reason causing it. If patient requires more support like pressure due to cardiopulmonary effects then NIV should be started verses increase in oxygen needs and work of breathing due to common respiratory infection. • There may be some role in early respiratory failure as dead space washout effects may reduce PCO2; this is not the same as ventilation and they should not be confused! Similarly, it is not CPAP as the pressure is not constant! The system provides positive pressure primarily on expiration. • HFNC can be used initially as a substitute to NIV depending on how severe the WOB/CO2 retention. Often you will find the HFNC alone will reduce CO2 levels sufficiently, especially in smaller children. • I strongly agree that HFNC is not a substitute for NIV. And while yes, one should CONSIDER HFNC before NIV, I don't believe that one should automatically try it based on the fact that it a) is not a substitute, and b) should not delay or replace NIV if that is more appropriate. • some studies show that HFNC can be used as an alternative to NIV and that there is no statistical difference in intubation rates between the two. The tolerance of HFNC in the pediatric population tends to be much greater compared to NIV via facemask. This is also difficult to use a generalized statement for because the age range of pediatrics is very large, and the specific patient and situation can also be a factor to consider what the patient may tolerate better. • There are currently indications to provide HFNC prior to intubation, and immediately post op, post extubation in lieu of low flow. I agree it should not delay or replace NIV IF NIV is more appropriate • For such things as pulmonary edema OR pleural effusions, or anything you want some PEEP to be applied HFNC is not appropriate. But HFNC may be used for tachypnea or work of breathing. • HFNC and NIV are not interchangeable, and their application is suitable for different reasons.

Section 2: Tidal Volume & Inspiratory Pressure Recommendations

Recommendation 2.1 (all Rounds)

- The ped patients we use IBW are usually school age and up.
- "Measured weight" may be inappropriate if the patient is greatly fluid overloaded.
- We use measured weight until the patients are in teenage years or severely overweight then we convert to IBW. For patients less than 20 kg, for sure, we use actual measured weight.
- Certain medical conditions (ie. CDH) may experience volutrauma if a global volume target of 5-8ml/kg is used. Perhaps some caveat regarding "anatomically or functionally normal lungs" should be included.
- For post cardiac surgeries (excluding PDA ligation), our approach is 7-9 ml/kg with a lower respiratory rate and longer i-time to optimize venous return to the heart; this is done in our PICU patients

Recommendation 2.2, 2.3, and 2.4 (All Rounds)

- I agree with statement but disagree that delta pressure is PIP-PEEP. I think this is better represented as Pplat- PEEP, whenever Pplat can be obtained.
- Targeting Vt as low as 4ml/kg seems reasonable. Goals to limit Pplats to <25 cmH2O as much as possible seems reasonable, and default to a lower Vt rather than accepting higher Pplats, depending on pathophysiology.
- PPlat <28 cmH2O as goal, allowable up to <32 cmH2O given specific poor compliance patient conditions
- I agree that the Pplat should be limited to less than 30 cmH2O unless you have measurements that you can follow to provide safe ventilation, electrical impedence tomography (EIT) can be used as well. There are patients where maintaining low Pplats is not possible. I would like to see it as 'attempt to limit' or something like that. And the driving pressure is what will be important, rather than just a Pplat.
- In my opinion I think the part about "site specific limits..." is a bit confusing. I would suggest instead of writing specific targets for specific sites that it could just read specific sites may have variability in targets however should be around 30 cmH20.
- Goals to limit Pplats to <25 cmH2o as much as possible seems reasonable, and default to a lower Vt rather than accepting higher Pplats, depending on pathophysiology.
- I would be more comfortable with stating "appropriate Vt" rather than a specific number.

Section 3: Respiratory Rate and Inspiratory Time Recommendations

Recommendation 3.3 (Round 2)

- to optimize alveolar ventilation, there is a physical limit to how high the rate can be - irrespective of the I:E ratio. A rate of 60 breaths/minute cannot allow for laminar flow and alveolar gas exchange. At this point a small increase in Vt, is indicated. (the exception may be for patients with congenital diaphragmatic hernia, as it is imperative to use a lung protective strategy).
- To maintain minute volume, increase the set respiratory rate when Vt ARE LOW and when Pplat is approaching limit (<30 cmH2O) - to related to previous statements; OR if Vt are within range yet (PCO2) needs to be lower, or pH higher

Section 4: PEEP and FiO_2 Recommendations

Recommendation 4.1 (Round 2)

- Peep levels of 5-6cmH20 are used in most instances except cardiac pts (who may need lower) and the other cases mentioned in the further questions (ARDS, bronchomalacia).
- there will always be a singular case where PEEP is contraindicated; perhaps it is a status asthmaticus scenario, or some other type of obstructive process. or extreme hemodynamic instability. If the statement was that the goal should be to prevent alveolar collapse in all ventilated

patients this is more general and encompassing. I do not think religious application of PEEP to all pediatric patients regardless of disease process is a good idea • Post op Glen and Fontan will have PEEP of 4cmH2O usually. • A min PEEP of 5-6 cmH2O in not to prevent collapse but to maintain an appropriate FRC • We have set PEEP at 4 (or even 3 cmH2O) on rare occasions where RV failure is a consideration, with good effect.
Recommendation 4.3 (Round 2)
• The use of oxygenation is not a good parameter to set PEEP, setting PEEP using oxygenation can cause significant regional over distension. Mechanics such as Compliance or driving pressure are more appropriate. Also, if assessing Vt with PEEP changes you are assuming a pressure mode of ventilation. Compliance would be a better parameter or also include driving pressure.
Recommendation 4.5 (Round 2)
• an ENT consultation with flexible laryngoscopy is typically utilized to determine the optimal PEEP needed to stabilize airways in pediatric patients with moderate-to-severe tracheomalacia and/or bronchomalacia.
Recommendation 4.6 (Round 2)
• PEEP should not be set/targeted based upon oxygenation alone. • The goal should not be to achieve the "lowest possible FiO2", regardless of PEEP. FiO2 of 0.21 and PEEP of 15, for example, would not be an appropriate way of maintaining target O2 saturation (spO2).

Section 5: Advanced Mechanical Ventilation Recommendations

Recommendation 5.1 (All Rounds)
• APRV is prohibited for use by RTs as agreed by the intensivists' team at the [name removed] PICU due to lack of evidence
Recommendation 5.3 (all Rounds)
• Advanced therapies such as JET and HFO may be beneficial if used as a protective strategy on certain pts versus being used as a rescue therapies. • APRV is available but prohibited to use as agreed by the PICU physician team due to the lack of pediatric evidence. PAV is not available therefore not practiced • NAVA was previously trialed but not found effective therefore being phased out. PAV is not available to use in the [name removed] PICU • We currently don't use NAVA or PAV. (Have used NAVA in the, past, but not consistently or well. Will likely use PAV with our incoming fleet of new vents.) • NAVA was previously used but often inappropriately (didn't meet indications or not ideal candidate etc) or used off recommendation (indicators and reading interpreted but not used for weaning or escalation of care due to various MRP reasoning) and as result is no longer available at our center
Recommendation 5.4 (All Rounds)
• Perhaps there should be a recommendation/statement regarding early consultation to a higher level of care for sites that do not have advanced therapies such as HFOV, jet ventilation, novalung, ECMO etc., available... in order to ensure earlier and safer transports for these patients? • I would rewrite to read "Strongly consider ECLS such as extracorporeal membrane oxygenation (ECMO)". Remove NovaLung as this is a brand name of a device and the pediatric use of this device is very limited. In its truest configuration (femoral artery to femoral vein) as the device was intended, would not be able to be used in patients less than 20-30 kg as would be unable to generate sufficient driving pressure to prevent clotting of the device over time. The most common approach for supporting these patients would be VV ECMO if they were large enough for double

lumen cannula or two site VV ECMO. If they are small infants, the approach is VA ECMO. There is still small usage of NovaLung device for bridge to lung transplant pediatric patients > 20 kg with pulmonary hyptertension who are centrally cannulated from PA to LA as a means to offload right heart to prevent RV failure. However this is a very specific subset of pediatric patients with a specific respiratory disease. Otherwise agree with rest of statement.

- Consider the use of iNO in the instances where patient has oxygenation, PHTN or RV dysfunction prior to considering ECLS.

Section 6: Weaning Recommendations

Recommendation 6.3

- it does not appear to be clear how long one can leave a patient breathing on PSV who is not ready for extubation; in my practice, patients with minimal WOB and otherwise good indicators of gas exchange may stay on PSV as long as they're tolerating it, with a minimal delta P to compensate for ETT resistance (ie 5-10 cmH2O)
- Important to know what their drive is, but I typically would not leave a patient on PS ventilation for days on end as they recover, unless I am unable to achieve good synchrony and comfort in other modes.

Section 7: Physiologic Target Recommendations

Recommendation 7.4, 7.5, and 7.6 (Round 2)

- We should not target an SpO2 of 99%, unless on room air [healthy lungs]. I don't know if the statement is referring to a non-intubated patient, invasively or non. As it reads, it could include patients ventilated for other reasons than respiratory disease (post op).
- PALs Post-rosc guidelines state SpO2 94-99%.
- should just state >or = 92% if on room air and minimum PEEP and spo2 can be 100% [healthy lungs]
- I don't like mixing PEEP value with oxygenation definitely. Depending on body habitus of the patient, we could be using higher PEEPs regardless of ARDS status. We should treat the patients as individuals. For a patient with a BMI near ideal, I agree with the statement, but not for all patients.
- We tolerate 88%-92% if ABG and lactate are stable [even with PEEP <10cmH2O]
- SpO2 targets in ARDS should not be based upon PEEP alone. PEEP setting alone will not identify the severity of their ARDS nor their arterial content requirements. For example, obese or morbidly obese patients may require a PEEP >10 to maintain EELV but this doesn't indicate the severity of the patient's lung pathology or ability to safely oxygenate.

Section 8: Monitoring Recommendations

Recommendation 8.2 (Round 2)
• preferably inline CO2 monitoring, preferably through the vent so volumetric data is available. • ETCO2 would be inappropriate for a patient ventilated using HFO.
Recommendation 8.6 (Round 2)
• Use capillary blood gas tests when arterial/central lines are not available. Capillary should be a first line test versus venous.
Recommendation 8.8 (round 2)
• We also aim for adequate oxygenation, and use iNO. By omitting these other principles, it is a bit misleading

Section 9: Other General Recommendations

Recommendation 9.1 (Round 2)
• I would not only assess but encourage. Perhaps a statement to include the concept of: "when patients are heavily sedated and not breathing (without reason), discuss with the interprofessional team to decrease sedatives safely."
Recommendation 9.2
• wouldn't routinely give NMB to assess how it affects the other variables, unless indicated. However I would assess if NMB is continuing to be beneficial to the patient if being used routinely.
Recommendation 9.7
• I agree with the statement, other than the entire IP team. Physio, pharmacy, dietary staff, social work and others, generally do not need to be included in discussions on mechanical ventilation, just as I am not valuable in a discussion in many of their areas of expertise.

Section 10: Equipment adjuncts recommendations

Recommendation 10.2 (Round 2)
• Reword to say, for patients on NIV, provide active airway humidification in the range of 31-37C, titrated to avoid excessive rainout in the interface. • Addendum - we routinely use 37°C for our HFNC patients as well. • For the majority of NIV patients at [name removed], the humidifier is kept at 37 degrees C to optimize gas humidification. Rain out has not been found to be an issue in most cases.
Recommendation 10.4 (All Rounds)
• proximal flow sensors are of limited utility in larger Vts, in our practice we're using proximal flow for kids 4kg and less who would correspond (at 5mL/kg) to tidal volumes of 20mL and less. • Not all proximal flow is created equal obviously and some ventilators will have bias against the proximal flow sensor to compensate for this. The technology used for proximal flow affects how much I trust it as well; heated wire anemometers appear to be far more accurate in my experience than pressure differential flow sensors. • "Consider" use of a proximal flow sensor. It may not be required unless there is concern about the accuracy of vent-derived measurements. Also consider the impact of added dead space without observable benefit. • Reword to make the principal idea to follow the specific ventilator recommendations on proximal flow sensor use.... in the absence of available recommendations, consider flow sensor use in small patients (insert limits). • We use proximal flow sensors for all patients less than 10 kg in both our ICUs (PICU and NICU) • we use proximal flow sensors on all our pediatric and neonatal patients • we use proximal flow sensors for up tp 5kg babies i.e: up to 50mL tidal volumes
Recommendation 10.5 (All Rounds)
• We try to avoid the use of manual hand-ventilation especially when PEEP levels are higher but we occasionally use hand-ventilation to help take off the secretions in combination with respiratory physiotherapy • take out self-inflating or flow inflating bags, as PEEP valves are not used with flow inflating bags. Change it to read "if manual ventilation is required, a method of monitoring pressures, limiting excessive pressures and providing PEEP should be used with hand ventilation". • we use flow inflating bags with no pressure relief valves, and no PEEP valves. Agree that we should avoid routine hand ventilation. • We do "Open bag suction" osmose of our patients with bad secretion management. We also had started using "Flusso" valves before it went Backordered. • It is prudent to minimize circuit disconnection, but I would not go so far as to say "avoid" it. COVID precautions notwithstanding, manual ventilation is often necessary in pediatric patients to assess compliance and for effective pulmonary toilet. • Avoid routine use "if patient condition allows". Some critically-ill patients will require routine manual ventilation to assist with secretion clearance or for post-suction re-recruitment. • Individual assessment may be required in order to optimize pulmonary hygiene • For patients requiring higher PEEP levels, we tend to clamp the ETT prior to disconnecting from the ventilator and reconnecting to the manual resuscitator in order not to de-recruit alveoli; flow-inflating bags are preferred to self-inflating ones as they maintain PEEP better • Patients often suctioned, using cough assist or have frequent disconnect due to moves or transports get recruited post disconnect as tolerated