A Delphi Survey of Canadian Respiratory Therapists' Practice Statements on Pediatric Mechanical Ventilation

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BACKGROUND: Pediatric mechanical ventilation practice guidelines are not well established; therefore, the European Society for Paediatric and Neonatal Intensive Care (ESPNIC) developed consensus recommendations on pediatric mechanical ventilation management in 2017. However, the guideline's applicability in different health care settings is unknown. This study aimed to determine the consensus on pediatric mechanical ventilation practices from Canadian respiratory therapists' (RTs) perspectives and consensually validate aspects of the ESPNIC guideline. METHODS: A 3-round modified electronic Delphi survey was conducted; contents were guided by ESPNIC. Participants were RTs with at least 5 years of experience working in standalone pediatric ICUs or units with dedicated pediatric intensive care beds across Canada. Round 1 collected open-text feedback, and subsequent rounds gathered feedback using a 6-point Likert scale. Consensus was defined as $\geq$ 75% agreement; if consensus was unmet, statements were revised for re-ranking in the subsequent round. RESULTS: Fifty-two RTs from 14 different pediatric facilities participated in at least one of the 3 rounds. Rounds 1, 2, and 3 had a response rate of 80%, 93%, and 96%, respectively. A total of 59 practice statements achieved consensus by the end of round 3, categorized into 10 sections: (1) noninvasive ventilation and high-flow oxygen therapy, (2) tidal volume and inspiratory pressures, (3) breathing frequency and inspiratory times, (4) PEEP and F_{IO_2}, (5) advanced modes of ventilation, (6) weaning, (7) physiological targets, (8) monitoring, (9) general, and (10) equipment adjuncts. Cumulative text feedback guided the formation of the clinical remarks to supplement these practice statements. CONCLUSIONS: This was the first study to survey RTs for their perspectives on the general practice of pediatric mechanical ventilation management in Canada, generally aligning with the ESPNIC guideline. These practice statements considered information from health organizations and institutes, supplemented with clinical remarks. Future studies are necessary to verify and understand these practices' effectiveness. *Key words: pediatric critical care; mechanical ventilation; respiratory therapy; respiratory therapists; consensus.* [Respir Care 2022;67(11):1420–1436. © 2022 Daedalus Enterprises]

Introduction

Pediatric mechanical ventilation is a fundamental therapy provided in the pediatric intensive care environment. However, mechanical ventilation research in critically ill children is often complicated by many factors, such as variation in size, maturity, and underlying conditions.[1] Several guidelines and recommendations encourage standardized best practices, interprofessional collaboration, and decision making in pediatric mechanical ventilation management.[2] As examples, the consensus guidelines from the Pediatric Acute Lung Injury Consensus Conferences[3,4] and European Society of Paediatric and Neonatal Intensive Care

mechanical ventilation guideline (the ESPNIC guideline[1]) are essential resources for practicing pediatric professionals. These guidelines[3,4] were established by in-person consensus conferences and consisted of almost exclusively physician panel members.

The applicability of ESPNIC consensus statements[1] into practice remains unknown especially in settings outside of Europe (recommendations were developed by a panel of 15 European physician experts). In Canada, respiratory therapists (RTs) have a large clinical role in mechanical ventilation management,[5,6] yet the profession's existence and decision-making involvement vary internationally. Canadian respiratory therapy programs train students in all aspects of

respiratory care, including mechanical ventilation management, using a competency-based framework with national standards (https://www.csrt.com/rt-profession. *Accessed August 24, 2021*).[5,6] Some studies have shown RT involvement in mechanical ventilation management can positively impact patient outcomes, particularly during the weaning process.[7-10] The value of protocol-driven mechanical ventilation management is evident[7,8,10-15]; however, RTs remain infrequently listed as contributors to many published guidelines, even from regions where RTs have more widely adopted role. A systematic review by Ely et al[2] published a directional guideline recommending the inclusion of non−physician health care providers in the development and implementation of mechanical ventilation protocols.

Empirical evidence guides health care practices and education, but not all questions can be answered by conventional research methods.[16,17] Many treatment options may have insufficient evidence to support their use, but considerations for their use should not be discarded as clinicians require guidance on their safe application.[18] Iterative consensus surveys are a valid way to collect information and perspectives to inform health care practices, especially on topics with insufficient or unknown evidence.[16,19-21] One example is the Delphi survey technique, a common consensus method in health sciences that utilizes a well-informed expert panel to gather feedback to guide education and clinical practice.[22-24] This feedback can be informed by multiple sources (including personal professional experiences) by using structured focus groups and/or surveys referred to as rounds.[16,22] Cumulative expert knowledge and experiences provide validated opinions, rather than anecdotal claims,[16] and are used to understand and clarify priorities, establish guidelines, identify gaps in knowledge, and to standardize practices and policies.[17,18] Diverse information

QUICK LOOK

Current knowledge

There are limited pediatric mechanical ventilation practice guidelines to direct overall management in critically ill children. The European Society of Pediatric and Neonatal Intensive Care published a consensus pediatric mechanical ventilation management guideline in 2017; however, their international applicability across healthcare settings is unknown. Previous studies show the value of respiratory therapists' care experiences and role in protocol-driven mechanical ventilation management; however, they are rarely included in establishing respiratory care guidelines despite their large clinical role, especially in Canada and the USA.

What this paper contributes to our knowledge

Canadian respiratory therapists generally agree with the recommendations by the European Society of Pediatric and Neonatal Intensive Care. Their respiratory care experiences contributed to these practice statements that also incorporated elements from evidence-based national health and institutional care guidelines. Although the European guideline did not endorse the use of several modalities or therapies due to the lack of scientific data, our participants acknowledged this and emphasized that their use may be warranted in several clinical situations in collaboration with the interprofessional team.

can be gathered from experts in a timely manner, especially when geographical constraints are present.[22,24] Furthermore, the consensus product, such as a published guideline, should be continually reviewed and improved on through processes such as consensual validation.[25] Experts' practice deviations from published practice recommendations may highlight practical issues with application of guidelines to individualized care, knowledge translation of the recommendations, or the introduction of new practices

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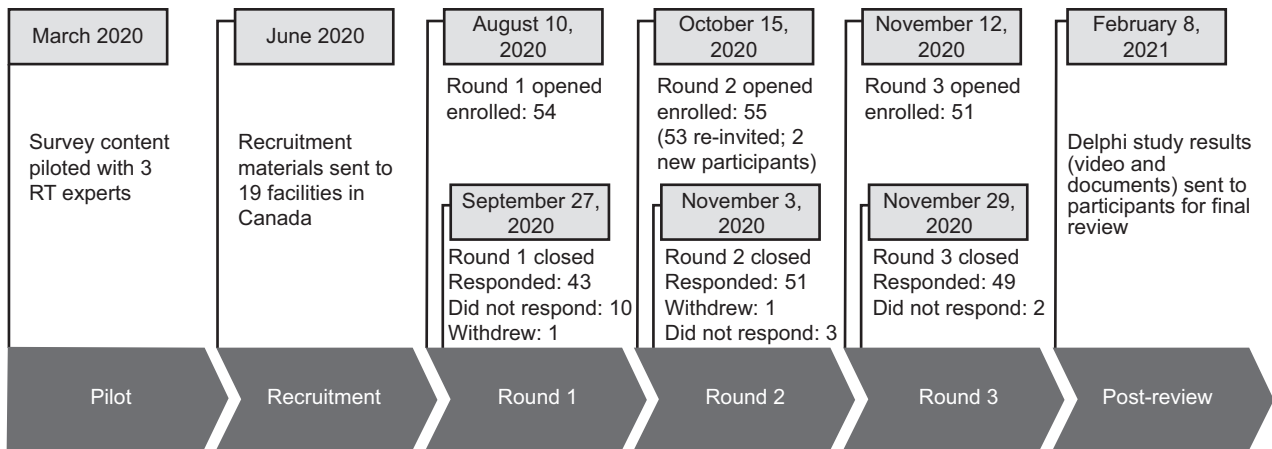
Fig. 1. Timeline of the 3-round Delphi survey from the pilot to post-Delphi review phase. Further details on the flow of participant engagement may be found in the supplementary materials. RT = respiratory therapist.

and therapies that have yet to have evidence defining their use. The aims of consensual validation are likely to address these practical issues by determining the guideline's content validity and identifying areas of improvements through additions, revisions, and deletions from the collective feedback of guideline authors and other targeted practitioners.[25,26]

The purpose of this study was to use a modified electronic Delphi (e-Delphi) method to determine the consensus on pediatric mechanical ventilation practices from the perspective of Canadian RTs and consensually validate components of the ESPNIC guideline recommendations.[1,25,26]

Methods

Survey Design

The ESPNIC consensus statements[1] informed the content of this survey, which followed a 3-round, modified e-Delphi method format.[17,22] The Hospital for Sick Children (SickKids) and Ontario Tech University research ethics boards approved this study (number 1000064842 and number 15636, respectively).

Expert Participants and Recruitment

The expert panelists for this e-Delphi study were RTs with experience in pediatric mechanical ventilation management. Specifically, participants were eligible if they were a Canadian registered RT who (1) had at least 5 years of pediatric critical care experience, (2) had leadership experience either as staff involved in leadership activities or a formal leadership position, (3) provided written consent, and (4) were fluent in English (reading and writing). The goal was to recruit at least one RT from each pediatric hospital in Canada (15 standalone pediatric ICUs [PICUs],

with another 7 hospitals with dedicated pediatric care beds[27]) for a minimum of 15 participants.[17] Recruitment began in July 2020 and closed after round 2 ended in November 2020 (Fig. 1). Full details of the survey design and recruitment can be found in the supplementary files (see related supplementary materials at http://www.rcjournal.com).

Survey Content and Development

The topics of this Delphi survey were derived from the ESPNIC recommendations,[1] which consisted of 12 sections and 152 recommendations (some of these recommendations were repeated across several disease-specific sections). The purpose of this study was to summarize the general pediatric mechanical ventilation practices. Therefore, the 7 sections that outlined practice recommendations for different lung conditions (obstructive, restrictive, mixed)[1] were reorganized, and recommendations that were repeated across different lung conditions were amalgamated. Sections on neuromuscular diseases and chronic and congenital lung conditions were omitted because focus of this study was on mechanical ventilation management in acute illness. Recommendations not explicitly related to mechanical ventilation (ie, chest physiotherapy) not commonly practiced in Canada and/or within the scope of RT practice were also omitted. Practices and topics that fall within the RT practices as outlined in the Canadian national competency (https://nartrb.ca/national-competency-profileframework. *Accessed March 20, 2022*) were incorporated into the survey. Some practice statements were revised to reflect a recent literature review and gray literature. Settings and target monitoring thresholds were refined to reflect national or international organizations' recommendations, such as the Heart and Stroke Foundation of Canada's Pediatric Advanced Life Support (PALS),[28] Pediatric Acute
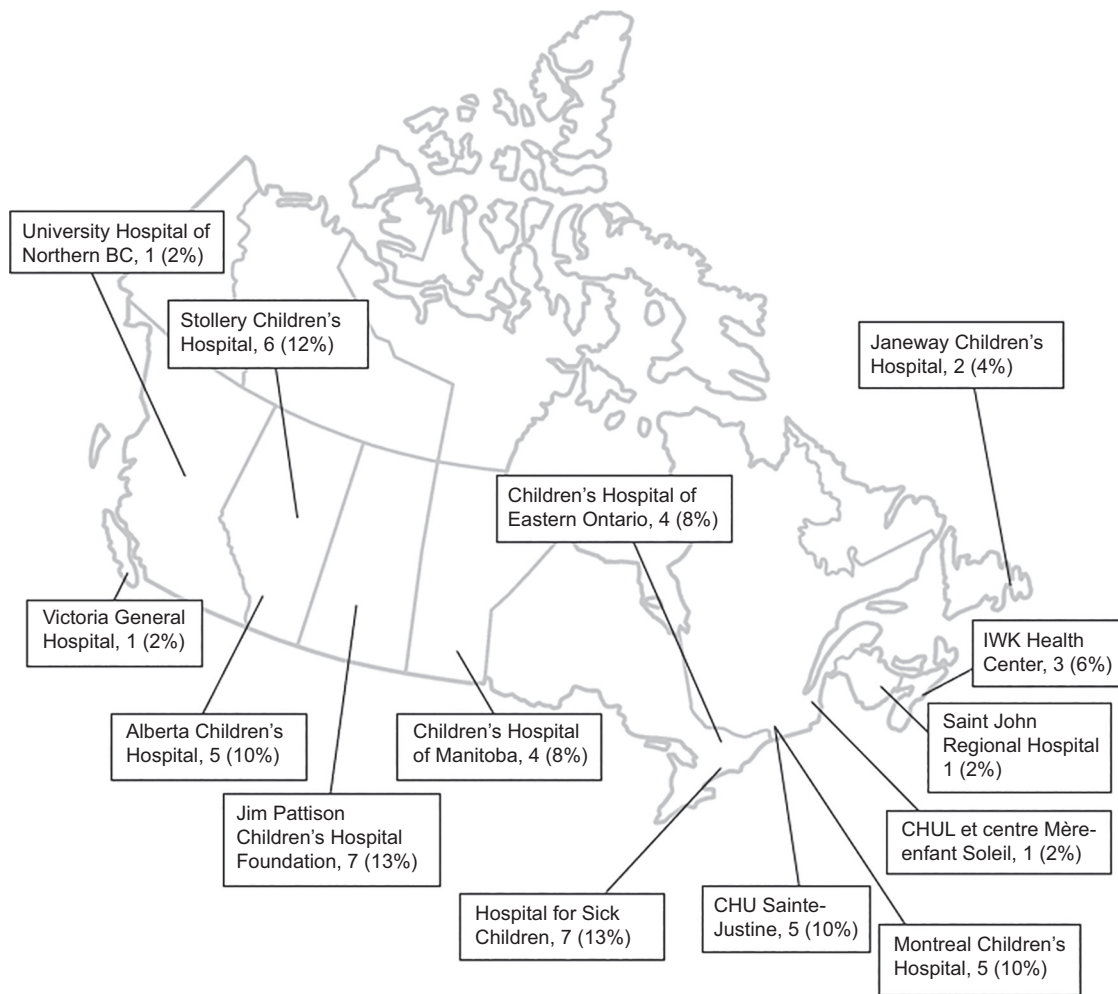
Fig. 2. Graphical representation of the Canadian expert panel. $N = 52$.

Lung Injury Consensus Conference (PALICC),[3] Extracorporeal Life Support Organization (ELSO; https://www.elso.org/Resources/Guidelines.aspx. *Accessed March 3, 2020*), Canadian Institute for Health Information (CIHI; https://www.cihi.ca/en. *Accessed March 3, 2020*), Canadian Patient Safety Institute (CPSI; https://www.patientsafety-institute.ca/en/toolsResources/psm/Pages/VAP-measurement.aspx. *Accessed March 3, 2020*), Children's Hospitals' Solution for Patient Safety (CHSPS; https://www.solutionsforpatientsafety.org. *Accessed March 3, 2020*), and National Institute of Health and National Heart, Lung, and Blood Institute ARDS Network clinical protocol (NIH-NHLBI ARDSNet; http://www.ardsnet.org/tools.shtml. *Accessed March 3, 2020*). A total of 64 recommendations were considered for review, reorganized, and revised for inclusion in our survey.

Three pediatric RTs (from SickKids, Toronto, Canada) piloted and provided feedback on a draft survey in collaboration with the research team. This process was to identify and refine statements to make them relevant to Canadian practices and reflect current practice guidelines from the aforementioned associations (PALICC, ELSO, CIHI, CPSI, CHSPS, ARDSNet). These revisions were incorporated into the final survey version for round 1, consisting of 53 statements. For round 1, participants were explicitly instructed to comment on the similarities or differences of their current practices and experiences to the survey items.

As part of round 1, participants also completed a demographics questionnaire that included personal characteristics (eg, age, sex, education), individual practice (eg, years of practice in pediatric critical care), and practice location.

Survey Analyses

Open feedback from round 1 was reviewed and guided the refinement of these statements for the next round. For subsequent rounds, participants rated their agreement using a 6-point Likert scale (with option 6-no comment if they

Table 1. Participants' Characteristics Across 14 Facilities

Variable	(N = 52)
Female	38 (73)
Age, y	40.9 ± 8.8
Education	
Bachelor's degree	25 (48)
Additional credentials	2 (3.8)
Practice experience	
Years as an RT	16.1 ± 8.6
Years in the PICU	15.0 ± 8.5
Hours of clinical work/wk	37.8 ± 12.9
% clinical work in PICU	72.0 ± 28.2
Clinical role*	
Charge supervisor	14 (27)
Practice lead	9 (17)
Team lead	14 (27)
Clinical educator	14 (27)
Core staff	26 (50)
Rotating staff	9 (17)
Transport	5 (10)
ECMO specialist	2 (4)
Other**	12 (23)
Additional practice areas	
Neonatal	42 (81)
Adults	11 (21)

Data are presented as *n* (%) or mean ± SD.
*Respondents may have chosen more than one role.
**Other: clinical practice coordinator, clinical educator for interprofessional committees, simulation lab facilitator, preceptor.
RT = respiratory therapist
PICU = pediatric ICU
ECMO = extracorporeal membrane oxygenation

did not have experience for the specific practice). The ranked responses were separated into 3 groups: Group 1 (disagree) included 1-strongly disagree and 2-disagree; group 2 (neutral) included 3-neutral; and group 3 (agree) included 4-agree and 5-strongly agree. Participants also were required to provide justification or rationale for their changes to statements when suggestions were made. These comments were reviewed by the authors (SQ, MN, KR), compared to existing literature, and statements were adjusted accordingly, if appropriate. Consensus was reached when 75% of the participants' votes fell within one of the ranked groups.

Other Data Analyses

Descriptive statistics, including measures of central tendencies, response frequencies, dispersion, consensus percentage, and mean comparisons (including Wilcoxon rank-sum test across rounds 2 and 3), were performed using Microsoft Excel (Microsoft, Redmond, Washington) and IBM SPSS Statistics (IBM, Armonk, New York). *P* values < .05 were considered significant.

Results

Participant Demographics

A total of 52 RTs completed at least one round of our survey (Fig. 1). The geographical representation of the participants included 12 facilities with standalone pediatric units and 2 with dedicated pediatric beds across Canada (Fig. 2). The mean (± SD) of pediatric RT experience was 15 (± 8.5) y. A full description of the demographics is available in Table 1.

Delphi Rounds

An overview of the Delphi rounds and response rates is illustrated in Figure 1 In round 1, participants provided a large volume of written open-text feedback and suggested new statements on high-flow nasal cannula (HFNC) oxygen therapy, high-frequency jet ventilation (HFJV), including ventilator-associated pneumonia prevention practices and incorporating practices from guidelines by various health associations (eg, PALICC,[3] PALS,[28] ELSO). Thus, the feedback of round 1 resulted in the expansion of the survey to include 58 recommendations from 53 for round 2.

In round 2, 55 of 58 statements (95%) reached consensus: one statement between 75−80% (1.7%), 16 statements between 81−90% (28%), and 38 between 91−100% (66%). Three did not reach consensus (5%), and an additional 7 (10%) that reached consensuses but had considerable open-text feedback were revised (Supplementary Table 1, see related supplementary materials at http://www.rcjournal.com). One additional statement was added, resulting in a total of 11 statements for evaluation in round 3.

In round 3, all 11 statements received consensus (Supplementary Table 2, see related supplementary materials at http://www.rcjournal.com), with 9 increasing between 1−38% and one decreasing from 92% to 81% (the new statement achieved 100%). The full consensus practice statements included 59 items in 10 sections with clinical remarks (Table 2). In a post-Delphi review, participants did not provide any additional feedback.

Pediatric Mechanical Ventilation Practice Consensus

Section 1: Noninvasive ventilation and high-flow oxygen therapy. In agreement with ESPNIC, noninvasive ventilation (NIV) should be considered in combination with other medical therapies for children experiencing cardiopulmonary failure (Table 2). In addition, maximizing NIV patient-ventilator synchrony is crucial. Practice statements on HFNC oxygen therapy were not included in round 1 because ESPNIC did not provide recommendations on its use. However, participants identified HFNC oxygen therapy as a commonly used intervention in several clinical

Table 2. Compilation of the Finalized Consensus Practice Statements

No.	Consensus Practice Statements	Consensus Percentage	Derived Originally From ESPNIC Mechanical Ventilation Guideline (section, No.)
	1: NIV and High-Flow Oxygen Therapy		
1.1	Consider the use of NIV in patients with mild-to-moderate cardiorespiratory failure if unresponsive to or in combination with other medical management (eg, inotropes, diuretics).	96	K, 1
1.2	Consider the use of NIV to reduce WOB and decrease afterload for patients with left ventricular failure if unresponsive to or in combination with other medical management (eg, inotropes, diuretics).	98	K, 4
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.	94	A, 10; A, 11
Clinical remark	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 may impact interface selection, including 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 NIV mode (eg, bi-level noninvasive support).	100	A, 2
1.4a	If available, specialty modes of NIV such as NIV-NAVA can be used to optimize patient-ventilator synchrony.	85	
Clinical remark	The use of specialty modes varies across centers based on availability and the institutional clinical guidelines. Factors that may influence success of specialty modes may be user's clinical experience as well as alternative available strategies at institutions.		
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 (eg, wounds).	98	I, 2
Clinical remark	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 stability beyond the list of common contraindications.		
1.6	Consider the use of HFNC prior to NIV to alleviate any WOB. 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.	92	
Clinical remark	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 instead. There are clinical situations where NIV may be the preferred therapy (eg, obstructive sleep apnea).		
1.7	The use of HFNC and/or NIV should not delay inevitable intubation.	100	A, 1; I, 3
Clinical remark	Using HFNC and/or NIV prior to intubation is a complex clinical decision that should consider the patient's clinical status and be discussed with the interprofessional team.		
	2: Tidal Volume and Inspiratory Pressure		
2.1	Aim to achieve a tidal volume in the physiologic range (5–8 mL/kg IBW) in patients > 10 kg. Aim to achieve tidal volumes of 5–8 mL/kg measured weight in patients ≦ 10 kg.	81	F, 3; G, 4; H, 6; I, 6;K, 5
Clinical remark	The range of 5–8 mL/kg tidal volume assumes the delivery of mechanical ventilation to 2 lungs of anatomically appropriate size. If patients have anatomical differences (eg, single lung, known lung hypoplasia), the target tidal volume should be discussed with the interprofessional team. There is a variety of opinions on the appropriate age or size threshold to estimate tidal volume based on IBW (as opposed to measured weight). Some suggestions include school age or 20 kg. Clinicians should avoid overestimating lung volume if patients are obese or have excess weight due to fluid overload. Higher tidal volume ranges may be appropriate for		

(Continued)

Table 2. Continued

No.	Consensus Practice Statements	Consensus Percentage	Derived Originally From ESPNIC Mechanical Ventilation Guideline (section, No.)
	postoperative cardiac surgeries to keep the set breathing frequency lower. This optimizes venous return to the heart by keeping the mean airway pressure lower through the respiratory cycle.		
2.2	Aim to achieve target tidal volume with minimal driving pressure (PIP-PEEP) in patients on pressure-limited modes.	98	F, 2; G, 4; H, 5; I, 10
2.3	Aim to limit inspiratory P_{plat} to approximately 30 cm H_2O, in the absence of transpulmonary pressure measurements. Limits should be between 28–32 cm H_2O.	96	F, 2; G, 5; H, 7; H, 8;I, 9
Clinical remark	There are many institutions that pressure ventilate and do not routinely measure P_{plat}. In the absence of a P_{plat} measurement, aim to limit PIP to 30 cm H_2O.		
2.4	If unable to achieve target tidal volume within P_{plat} limits (30 cm H_2O), targeting ranges outside these limits should be discussed with the interprofessional team. There may be circumstances where tidal volumes < 5 mL/kg and > 8 mL/kg may be cautiously but not routinely used.	93	F, 3; G, 5; I, 9
Clinical remark	Examples where smaller tidal volumes may be appropriate include congenital hypoplastic lung or severe pediatric ARDS. See clinical remarks for statement 2.1.		
	3: Breathing Frequency and Inspiratory Time		
3.1	Set inspiratory time and breathing frequency based on the patient's age, respiratory mechanics (including waveforms), and clinical data (eg, blood gases, vital signs) in controlled ventilation modes. This will allow for full exhalation (acceptable I-E ratio), optimized patient-ventilator synchrony, and ventilation.	98	A, 7; A, 18; B, 18;G, 10; H, 9
3.2	Set the trigger setting and cycling setting on the ventilator to achieve the above goals (statement 3.1) in all spontaneous ventilation modes.	98	
3.3	Increase the set breathing frequency when tidal volumes and/or PIP is reaching limits to increase or maintain the desired minute ventilation. Ensure there is sufficient expiratory time to avoid air trapping.	92	
Clinical remark	Increase the breathing frequency to a reasonable threshold based on age, maintaining adequate inspiratory time to deliver tidal volume, and maintaining acceptable I-E ratio (a specific threshold has not been defined, though should not be inverse). Use waveforms to help in the assessment of gas trapping.		
	4: PEEP and F_{IO_2}		
4.1	Set a minimum PEEP level 5–6 cm H_2O, to maintain adequate lung inflation, in all patients.	86	A, 8; F, 4; I, 8
Clinical remark	PEEP is used to maintain adequate FRC. There may be rare circumstances in which PEEP may be set below 5–6 cm H_2O (statement 4.2).		
4.2	Set PEEP to maintain end-expiratory lung volume, and an optimal balance between hemodynamic stability and oxygenation, in all patients.	100	G, 10; I, 8
4.3	Titrate PEEP incrementally while assessing lung compliance, oxygen saturation, hemodynamic stability, and chest radiograph findings for patients with challenging oxygenation needs (eg, pediatric ARDS).	96	G, 10; K, 6
Clinical remark	The titration of PEEP should be based on multiple factors and aim to avoid overdistention or underdistention. Other technology such as EIT can be considered when deciding the appropriate PEEP level.		
4.4	Titrate PEEP to allow for the lowest possible F_{IO_2} (to maintain target oxygenation goals), while maintaining adequate hemodynamic status.	98	C, 1
	(Continued)		

Table 2. Continued

No.	Consensus Practice Statements	Consensus Percentage	Derived Originally From ESPNIC Mechanical Ventilation Guideline (section, No.)
Clinical remark	In the absence of other clinical changes, F_{IO_2} requirements can be helpful to assess and support the titration of PEEP (in addition to factors listed in statement 4.3). Increased F_{IO_2} during PEEP weaning may indicate that lung inflation is worsening.		
4.5	Set a higher PEEP level ($\geq$ 10 cm H_2O) to maintain adequate lung inflation in patients with moderate-to-severe pediatric ARDS if necessary.	94	B, 4
4.6	Set a higher PEEP level ($\geq$ 10 cm H_2O) to stabilize airways in patients with tracheomalacia and/or bronchomalacia if necessary.	94	J, 10
Clinical remark	The PEEP level for patients with tracheomalacia and/or bronchomalacia should consider patient WOB and tidal volumes/waveforms. Flexible laryngoscopy in collaboration with otolaryngology services (or the designated care team that manages these patients) may assist with PEEP titration.		
	5: Advanced Mechanical Ventilation		
Clinical remark for all advanced mechanical ventilation statements: Practitioners should have competency prior to using advanced mechanical ventilation. Availability of devices may vary across different institutions/units, reflecting when they are used. Decisions on use should also consider the quality of pediatric research evidence.			
5.1	Consider the use of HFOV in patients with restrictive or mixed diseases and severe oxygenation and/or ventilation failure.	90	H, 12; I, 12
Clinical remark	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 statements, section 2; breathing frequency and inspiratory time, section 3; and PEEP and F_{IO_2}, section 4).		
5.2	Consider the use of HFOV in patients with cardiac disease and severe respiratory failure. Cautious use of increased mean airway pressure is advised in patients with passive pulmonary blood flow or right ventricular dysfunction.	86	K, 3; K, 8
Clinical remark	Practitioners should carefully evaluate the response to increased mean airway pressures in this patient population. See clinical remarks from statement 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.	90	A, 3; A, 4
Clinical remark	See clinical remark for all advanced mechanical ventilation statements.		
5.4	Consider the use of other advanced ventilation modes/techniques (such as NAVA, PAV, or automated weaning) to optimize patient-ventilator interactions. Consider the unique benefits and/or limitations for each of these advanced modes.	84	-
Clinical remark	Many of these modes/techniques are only available in specific ventilators. See clinical remark for all advanced mechanical ventilation statements.		
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 institution, and not contraindicated. Follow guidelines (eg, ELSO) for more specific criteria. Consider early consultation with an ECLS institution when ECLS is not available within the institution.	96	A, 9
	6: Weaning		
6.1	Routinely assess all patients, with the aim to wean ventilator settings as early and as often as possible.	96	E, 1
6.2	Use weaning principles guided by respiratory mechanics, pathologies, and disease trajectory in patients with complex presentations (eg, restrictive, obstructive, mixed, or cardiac diseases).	94	E, 2; K, 9

(Continued)

Table 2. Continued

No.	Consensus Practice Statements	Consensus Percentage	Derived Originally From ESPNIC Mechanical Ventilation Guideline (section, No.)
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.	96	A, 7
Clinical remark	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 flow cycling settings to maintain patient comfort/synchrony and target tidal volumes in patients on pressure support ventilation.	98	-
Clinical remark	Please also see all statements related to tidal volume (section 2).		
6.5	Routine daily assessment for weaning and extubation readiness should be performed in all patients.	86	E, 4
7: Physiologic Target			
7.1	Physiological targets should be guided by patient respiratory mechanics, both respiratory and non−respiratory pathologies, and disease trajectories.	94	
7.2	Target normal arterial CO_2 levels for patients with healthy lungs (ie, no respiratory disease). If arterial CO_2 is not available, target normal venous and capillary CO_2 levels.	98	C, 3
7.3	Permissive hypercapnia with pH $\geq$ 7.25 may be acceptable for acutely ill patients unless specific disease conditions dictate otherwise (eg, pulmonary hypertension, traumatic brain injury).	98	C, 4
7.4	Target S_{pO_2} 92−99% for patients with healthy lungs (ie, no respiratory disease). If the patient is post resuscitation, follow the Heart and Stroke Foundation of Canada recommendations of 94−99%.	88	B, 3; C, 1
Clinical remark	Excessive use of oxygen should be avoided. Supplemental oxygen should be continuously titrated down if the patient maintains an S_{pO_2} within the target range. S_{pO_2} > 97% is acceptable if a patient is on F_{IO_2} 0.21 (or as minimal as possible) to avoid frequent desaturations.		
7.5	Target S_{pO_2} 92−97% when PEEP is < 10 cm H_2O in patients who meet the pediatric ARDS criteria (as described in the PALICC[2] guidelines).	84	B, 4
Clinical remark	The S_{pO_2} range is in the context of pediatric ARDS alone. If patients have other clinical factors that warrant higher PEEP levels, these should be incorporated into PEEP and S_{pO_2} clinical decisions.		
7.6	Target S_{pO_2} 88−92% when PEEP is $\geq$ 10 cm H_2O in patients who meet the pediatric ARDS criteria (as described in the PALICC[2] guidelines).	86	B, 4
Clinical remark	See clinical remarks for statement 7.5.		
7.7	Target S_{pO_2} 75−85% (or as recommended by the interprofessional team) for patients with cyanotic cardiac lesions.	94	C, 2
Clinical remark	Consider individualized ranges for patients as needed, assessing the patients' response to oxygen and the balance of pulmonary and systemic circulation. The larger specialized interprofessional team (including pediatric cardiologists) will be essential for determining the optimal range for each patient.		
8: Monitoring			
8.1	Use continuous S_{pO_2} monitoring to assess oxygen saturation in all patients on invasive and noninvasive mechanical ventilation.	98	B, 2; B, 9
8.2	Use CO_2 monitoring (preferably end-tidal CO_2) in all patients on IMV.	94	B, 1
8.3	Consider the use of transcutaneous CO_2 in patients on advanced forms of mechanical ventilation (eg, HFOV, HFJV). These monitoring options should be frequently correlated with arterial blood gas values.	84	B, 14

(Continued)

Table 2. Continued

No.	Consensus Practice Statements	Consensus Percentage	Derived Originally From ESPNIC Mechanical Ventilation Guideline (section, No.)
8.4	Use arterial lines for accurate pH, P_{aO_2}, and lactate measurements for patients with moderate-to-severe critical illness on mechanical ventilation.	98	B, 10
8.5	Use central S_{vO_2} and lactate measurements to assess oxygen extraction and/or cardiac output in patients with cardiac and/or severe critical illness on mechanical ventilation.	92	B, 16; B, 17
8.6	Consider the use of capillary blood gases to assess gas exchange in mechanically ventilated patients with good perfusion and mild diseases. Capillary blood gases can be used to provide estimates or trends when arterial/central lines are not available.	90	B, 12
Clinical remark	Consider if an arterial blood gas puncture is appropriate before using capillary blood gases in older patients. Balance this by considering patients' perspectives including procedural pain, willingness, and frequency of measurements.		
8.7	Cautiously use peripheral venous P_{CO_2} measurements to provide estimates and trends of ventilatory gas exchange when arterial/central lines are not available.	96	B, 13
Clinical remark	This may be appropriate if patient is intolerant to procedural pain and minimizing punctures for patients.		
8.8	Use pH as a tool to modify the pulmonary vascular resistance for specific disease conditions (eg, pulmonary hypertension, single-ventricle heart disease).	88	K, 12
8.9	Aim to maintain normal pH, P_{aCO_2} and P_{aO_2} in acute pulmonary hypertension and traumatic brain injury. Consider targeting normal-high pH and normal-low CO_2 values.	96	K, 11
Clinical remark	The management of pulmonary vascular resistance may also include the use of oxygen, inhaled nitric oxide, and medications.		
	9: Other General		
9.1	Routinely assess patients to allow for spontaneous breathing, except for patients with severe critical illness receiving muscle relaxants and sedation.	96	A, 21
9.2	Routinely monitor and assess the impacts of muscle relaxants and sedation on mechanical ventilation (breathing frequency, tidal volumes, minute ventilation) when they are in use for the patient's clinical management.	90	A, 6; A, 22
Clinical remark	Continuously assess the benefits and harms of muscle relaxants and sedation, with the goal to minimize use. Wean the muscle relaxant or sedation using a safe approach and with careful monitoring.		
9.3	Routinely assess ventilator waveforms (eg, 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.	98	-
9.4	Reduce the risk of VAP using VAP bundles published by safety groups (eg, Safer Healthcare Now!, Canadian Institute for Health Information, Children's Hospitals' Solutions to Patient Safety). Elements include (1) elevate the head of the bed 30–45° (15–30° 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.	87	A, 15
9.5	Different organization and working group guidelines and recommendations may be incorporated into practice and may include but are not limited to PALICC,[2] NHLBI ARDS Network protocol, PALS,[24] NRP, and ELSO.	100	-
9.6	Use the PALICC[2] recommendations on nitric oxide, neuromuscular blockade, prone position, and surfactant use if safe to do so	88	H, 13; I, 7
9.7	Mechanical ventilation management and anticipated plans should be discussed as an interprofessional team, at minimum daily. Any changes in the patients' trajectory or mechanical ventilation needs should be communicated with all members of the interprofessional team.	100	-
	10: Equipment Adjuncts		
10.1	Use dual-limb, heated, filtered circuits with active airway humidity for IMV.	98	A, 10; J, 11

(Continued)

Table 2. Continued

No.	Consensus Practice Statements	Consensus Percentage	Derived Originally From ESPNIC Mechanical Ventilation Guideline (section, No.)
10.2	Use active airway heated humidification at 37°C in patients on IMV. Use active airway heated humidification in the range of 31–37°C and titrate to avoid excessive rainout in the interface in patients on NIV.	94	A, 17
10.3	Minimize the use of apparatuses or connectors that add dead space to ventilator circuits whenever possible. Neonatal- and pediatric-sized apparatuses or connectors are available; use the appropriate size based on the manufacturers' recommendations.	100	D, 3
10.4	Do not routinely use proximal flow sensors. 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 (< 10 mL).	84	B, 5
Clinical remark	The use of a proximal flow sensor should be guided by the accuracy of the ventilator tidal volume measurement. Use proximal flow sensors for accurate measurement of tidal volume in smaller patients when internal measurements are inaccurate. Variability in practice exists based on ventilator measurement accuracy, with some institutions 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.	94	D, 1
Clinical remark	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.		

The final consensus is presented, and if applicable, the matching European Society for Paediatric and Neonatal Intensive Care recommendation(s) for that specific statement is outlined.

ESPNIC = European Society for Paediatric and Neonatal Intensive Care
NIV = noninvasive ventilation
WOB = work of breathing
NAVA = neurally adjusted ventilatory assist
HFNC = high-flow nasal cannula
PIP = positive inspiratory pressure
IBW = ideal body weight
P_{plat} = plateau pressure
I-E = inspiratory-expiratory
FRC = functional residual capacity
EIT = electrical impedance tomography
HFOV = high-frequency oscillatory ventilation
HFJV = high-frequency jet ventilation
APRV = airway pressure release ventilation
ECLS = extracorporeal life support
PAV = proportional assist ventilation
ELSO = Extracorporeal Life Support Organization
PALICC = Pediatric Acute Lung Injury Consensus Conference
IMV = intermittent mandatory ventilation
VAP = ventilator-acquired pneumonia
NHLBI = National Heart, Lung, and Blood Institute
PALS = Pediatric Advanced Life Support
NRP = Neonatal Resuscitation Program

scenarios, and a practice statement was included for round 2. All NIV and HFNC practice statements achieved consensus by the end of round 2; however, the HFNC-specific statement received extensive feedback that warranted its revision and reassessment in round 3. The modified statement (number 1.6) was well accepted by participants and gained consensus by the end of round 3. For both NIV and HFNC oxygen therapy, ESPNIC and participants in this study strongly agreed that neither therapies should delay inevitable intubation.

Section 2: Tidal volume and inspiratory pressure. Many participants agreed that the least amount of δ pressure (positive inspiratory pressure [PIP]-PEEP) with limited plateau pressures should be used to achieve target tidal volumes of 5−8 mL/kg, as recommended in the ESPNIC guideline. Participants mentioned tidal volumes may fall outside these target ranges to ensure adequate ventilation in specific clinical scenarios that should be discussed with the medical care team (number 2.2). Some participants emphasized that using ideal body weight (IBW) for target tidal volumes was ideal for certain weight or age, but these thresholds seem to vary across locations. This feedback was reflected in a clinical remark (number 2.1) to convey the importance of evaluating each child individually and discussing with the medical team to ensure target tidal volumes are not underestimated or overestimated.

Section 3: Breathing frequency and inspiratory time and Section 4: PEEP and F_{IO_2}. Consensus was achieved for all items in these sections at the end of round 2. It was suggested that the children who require mechanical ventilation should have their settings routinely assessed and readjusted if required to optimize patient-ventilator synchrony, target tidal volumes, and minimize peak inspiratory pressures, and minute ventilation. Minimum PEEP levels slightly varied across practice locations, but ESPNIC and participants expected PEEP levels to be titrated to maintain adequate lung inflation and meet oxygenation goals. Similar to ESPNIC, our practice statement emphasized that in cases where pediatric ARDS was suspected PEEP titration should follow the guideline set by PALICC group.[3]

Section 5: Advanced modes of ventilation. Many advanced modes of ventilation were not strongly recommended by ESPNIC due to limited evidence; however, both ESPNIC and the study participants (expressed through feedback during the rounds) indicated that different advanced modes (number 5.3 or 5.4) can be used in practice when appropriate. Thus, advanced modes were cautiously included in specific scenarios, and the practice statements were modified several times before reaching consensus in round 3. In the case of extracorporeal life support, participants endorsed the use of an established guideline by ELSO (96%

consensus). Although all practice statements under section 5 eventually received consensus, a generic clinical remark for the whole advanced modes section is provided to emphasize their limited evidence.

Section 6: Weaning. Specific weaning parameters were not provided by ESPNIC due to the lack of evidence. Therefore, practice statements in this section were generic in nature, suggesting clinicians consider spontaneous modes, routine weaning, and extubation readiness tests when patients are spontaneously breathing.

Section 7: Physiologic targets and Section 8: Monitoring. Many of these practice statements were outlined in the ESPNIC guideline, and specific target thresholds were incorporated from other consensus recommendations such as PALICC[3] and Heart and Stroke Foundation of Canada.[28] It was important to emphasize that the physiologic targets and monitoring parameters are not definitive but could be tailored to fit the needs of the patients' respiratory mechanics and pathologies. Participants strongly agreed with the incorporation of these elements, and clinical remarks were made to provide additional considerations toward physiologic targets and monitoring in different scenarios.

Section 9: General. Many of the practice statements in this section were generic and could be applied to all clinical cases when children require mechanical ventilation, unless otherwise indicated. Though RTs are not commonly responsible for administering or managing sedation and muscle relaxants directly, it is within the Canadian scope of practice, and these practice statements were included to emphasize their role and impact on mechanical ventilation management. Though not mentioned in the ESPNIC guideline, participants emphasized the routine use of many organizational and working group guidelines and/or recommendations across many locations (number 9.5). The necessity of interprofessional collaboration and communication to facilitate mechanical ventilation management in children was emphasized; thus, this statement (number 9.7) was included for round 3, which achieved 100% consensus.

Section 10: Equipment adjuncts. All practice statements in this section were from the ESPNIC guideline and were minimally revised to be more specific. Routine use of manual ventilation was not recommended by ESPNIC, but participants indicated that several scenarios would warrant its need (which were incorporated into the accompanying clinical remark). Indications for proximal flow sensors use appeared to be unclear and varied across practice locations. Though use of proximal flow sensors was recommended by ESPNIC, participants felt the statement was too vague. Thus, it was revised to suggest following the ventilator manufacturers' guide or when tidal volumes were

extremely small (< 10 mL). In addition, the need of proximal flow sensor use should be assessed, along with their measurement accuracy, and whether their measurements bring value to their overall mechanical ventilation management.

Discussion

This is the first study to use a modified e-Delphi survey to report the consensus of Canadian RTs' pediatric mechanical ventilation practices and consensually validate aspects of the ESPNIC guideline. We achieved consensus for all practice statements by round 3. Broadly, participants agreed, indicating that they practiced similarly to the recommendations from the ESPNIC consensus guideline. Consensus was reached relatively quickly (55/58 statements [95%] in round 2), likely because the ESPNIC guideline was used as the foundation of the survey, with consideration to the literature and other evidence-based sources. Additional clinical remarks for these practice statements were from participants' clinical experiences and feedback, likely reflective of current, common RT practices in Canadian PICUs. Whereas an interprofessional survey of practices would be of interest, we provided a cohesive perspective from RTs because they are one of the experts in pediatric mechanical ventilation management but are underrepresented participants in research.[29]

This study provided a form of consensual validation[25] to the ESPNIC guideline. Other studies have utilized similar forms of validation. For example, a 2021 study engaged with nurses, physicians, and patients to consensually validate a renal replacement therapy care guideline derived from the literature.[26] The care guideline was informed by the literature and congruent with patients' treatment needs and clinicians' priorities.[26] Since our group of clinicians was not part of the development process of the ESPNIC guideline, this study shows that Canadian RT practices generally align or are consensually valid with European recommendations.

All the practice statements in our survey reached consensus by round 3; however, there were discrepancies across responses, highlighting the differences in pediatric mechanical ventilation practices across Canada. These practice statements required several refinements before consensus was achieved. The ESPNIC recommendations omitted statements on HFNC therapy due to the lack of evidence,[1] but HFNC usage has increased over the years, and the timing of HFNC initiation relative to NIV continues to generate debate.[30,31] Participants described HFNC as an option to alleviate work of breathing or treat respiratory failure in children with bronchiolitis, which is supported by existing publications.[31-33] HFNC has been used in various clinical scenarios[34] and practice locations (PICU and wards[20]) and has been shown to be safe and effective for treating bronchiolitis.[33,35] An international survey identified HFNC as a frequently used modality with variable use across PICUs and a common preceding step to NIV.[36] These surveys highlight the increasing popularity of HFNC and the necessity to evaluate its effectiveness in a broad range of clinical scenarios beyond bronchiolitis, as international guidelines on HFNC management do not exist.[20,30,33,36,37] In a randomized controlled trial with 600 children, HFNC was compared to CPAP for postextubation respiratory support.[38] HFNC did not meet the noninferiority criterion; HFNC was significantly associated with higher median time to respiratory support liberation and higher mortality.[38] These findings support our HFNC practice statement that acknowledged HFNC is frequently used when NIV or intubation is not immediately indicated but also recognized HFNC is a distinct therapy from NIV and not interchangeable, nor should it delay escalation of care.[30]

There were also many comments regarding noninvasive and invasive neurally-adjusted ventilatory assist (NAVA) as an optional advanced mode of ventilation. ESPNIC did not recommend the routine use of NAVA, possibly due to the limited evidence and underutilization of NAVA in PICUs, its high costs,[39,40] or lack of universal availability. In our study, about 25% of facilities indicated NAVA was unavailable, as NAVA is currently proprietary to Servo ventilators. We chose to incorporate participants' feedback because highlighting NAVA use for future pediatric mechanical ventilation practice investigations is necessary because in recent years its use has increased along with evidence showing its effectiveness.[40-44]

In contrast to ESPNIC, our survey provided specific considerations regarding target tidal volumes, pressures, minute ventilation, and ventilator synchrony by referencing additional organizational guidelines (eg, PALICC,[3] NIH-NHLBI ARDSNet). In our practice statements on tidal volumes, participants may have balanced the benefits, harms, or general applicability of various thresholds. Use of tidal volumes outside the physiologic range of 5−8 mL/kg IBW was uncommon; however, participants reported that tidal volumes outside this range may be used after collaborative discussions with the interprofessional team. Several studies have outlined that target tidal volumes < 5 mL/kg may be acceptable to achieve permissive hypercapnia and hypoxemia.[3,4,45] Participants stated that tidal volumes are rarely set > 8 mL/kg but may be seen in children post-cardiac surgery, with lower breathing frequencies as a strategy to minimize mean airway pressure.[45] We report the results of our Delphi study, though are cautious to suggest that high tidal volumes are best practices; but it may be seen in some children with cardiac pathologies but normal lung mechanics, resulting in low driving pressures with tidal volumes > 8 mL/kg. Overall, there is a lack of studies that have assessed and reported the effect of larger tidal volumes.[46,47] We

wanted to acknowledge participants' remarks in regard to tidal volume individualization (> 8 mL/kg) as justified because it is supported by the literature,[46,47] and we stress that target tidal volumes should be in the physiologic range, being mindful of universally lung-protective approaches.[31]

A similar statement (Table 2) (number 2.1) on tidal volume thresholds in patients with healthy lungs had decreased consensus from 92% to 81%, even with iterative changes. This may be because IBW was suggested when standardizing tidal volumes in all groups of children. Feedback revealed discrepancies regarding the use of IBW compared to actual weight and thresholds used to determine their tidal volumes. ESPNIC[1] and PALICC[3] guidelines recommend using IBW to normalize tidal volumes and minimize the risk of underventilating or overventilating children compared to using their actual weight.[45,48] However, neither guideline provided direction as to how the IBW should be calculated, and PALICC recommended predicted body weight be used for all monitored values. Estimated target tidal volumes may need to be based on the measured or predicted body weight depending on the child's body mass index.[49] A few studies have shown lung volumes of overweight children are best estimated with predicted body weight, whereas normal-to-lower-weight children had lung volumes that aligned to their measured weight.[47,49] To note, using IBW may estimate higher target tidal volumes compared to actual weight, except in overweight children, where tidal volumes set using IBW had decreased mortality.[47] These inconsistencies on the use of standardized weights may be due to the lack of an universally accepted method and equation to calculate IBW in children, leading to differences in IBW values.[50] In addition, there is still a debate on whether actual (instead of IBW) should be used and when.[48,51] Furthermore, the differences in IBW and actual body weight appear to increase when children are > 25 kg.[48] Based on our participants' feedback, we summarized that IBW could be used for children > 10 kg and actual weight for those < 10 kg to minimize the overlap with neonatal thresholds. Guidance on which IBW calculation should be used remains unclear, and factors such as obesity and fluid overload should be considered when determining tidal volume.[47,48,50]

Two statements regarding advanced modes of ventilation received poor consensus in round 2 and generated variable feedback. Evidence surrounding the use of advanced modes of ventilation in children is relatively weak,[52] and ESPNIC[1] did not provide definitive recommendations on their routine use. Collective statements on different advanced ventilation modes were included in our practice statements as several participants wanted to acknowledge these options (eg, proportional assist ventilation [PAV], NAVA, automated weaning, airway pressure release ventilation [APRV]), despite their very limited use, reported harms, and lack of pediatric evidence.[1,52] Originally, an HFJV practice statement was omitted for round 1, but participants mentioned that HFJV could be considered, though not regularly, in children (Table 2) (number 5.3). HFJV may be considered in children with acute respiratory failure or congenital heart diseases, as HFJV may improve ventilation and median pH.[53,54] However, there are still uncertainties about HFJV for children as there are limited large and prospective studies describing its usefulness and effectiveness. APRV was another advanced mode that ESPNIC[1] did not provide direction on. Recent studies have provided more understanding and knowledge on this mode; however, they appear to be conflicting.[55-57] Studies have shown that APRV may have benefits such as decreased ventilation days,[55,57] improved ventilation,[55] oxygenation,[56] and lung compliance.[57] However, 2 prospective randomized studies in children with ARDS demonstrated that APRV was associated with increased mortality compared to low tidal volume ventilation[57,58] and no significant benefits compared to high-frequency oscillatory,[56] respectively. Of all the advanced modes of ventilation, there is minimal evidence to support the use of PAV in children. A systematic review and meta-analysis that evaluated the effects of PAV in adults and children reported no clinical trials in children.[59] Overall, the medical team must discuss and balance the benefits, limitations, and available evidence when considering the use of any of these advanced modalities in children.

For equipment adjuncts, ESPNIC strongly recommended the use of proximal flow sensors,[1] but participants mentioned they were not routinely used and may not be available in certain ventilators (in pediatric/adult patient categories). A previous study reported that tidal volumes measured by mechanical ventilators with compensation for tubing compliance or proximal flow sensors at the endotracheal tube were significantly lower than values measured using a calibrated pneumotachometer.[60] This discrepancy may be a point of concern as underestimated volumes could have a clinical impact on the ventilation management, especially in children with ARDS.[60] We acknowledged participants' feedback on their use by stressing the use of proximal flow sensors should be based on local protocols, availability of devices, technical specifications of devices, availability of trained health care providers, and the interprofessional team's decision (Table 2) (number 10.4). It is also important to note that many participants stated that proximal flow sensors were common in their local neonatal ICU (NICU) instead of PICU, indicating that care location may be a contextual factor in their use.

In round 2, it was universally emphasized that RTs are part of the interdisciplinary team and that mechanical ventilation management is collaborative. Thus, we added the practice statement (number 9.7). We chose to highlight this important statement, as it achieved 100% consensus in one

round. We believe this highlights the interprofessional nature of mechanical ventilation management and the importance of collaboration with the interprofessional team.

In summary, these consensus statements are the first to describe pediatrics mechanical ventilation practices for critically ill children from the lens of Canadian RTs. Though the ESPNIC guideline did not provide strong recommendations for several therapies or management techniques, our survey suggests that their use exists as part of Canadian practices. Because there is limited evidence for some of these practices, clinical remarks were included to provide greater context and considerations in various scenarios. Furthermore, the increased use of therapies such as HFNC or NAVA demonstrates the need for future large multi-center studies to assess their effectiveness and safe use. It is important to note these practices were agreed upon by experienced PICU RTs and should only be performed by trained providers within their scope of practice and expertise and after discussion with the interprofessional team.

Strengths and Limitations

There are several strengths in this study. The survey contents were derived from the ESPNIC recommendations and incorporated elements supported by other health organizations or guidelines (eg, PALICC,[3] PALS,[28] ELSO, CIHI, NIH-NHLBI ARDSNet) pertinent to Canadian practices. Although we did not enroll participants from every pediatric center in Canada, our panel was demographically diverse with a total of 52 participants from 14 facilities across 9 provinces. Third, we had good survey response rates, increasing from 80% to 93% to 97% across rounds (typically, survey response rates decrease[17,24]). Lastly, we included a post-Delphi review stage of the finalized practice statements and to seek additional feedback from participants, as a method to enhance content validity and trustworthiness of the results.[17,23] Both pilot and post-Delphi stages are not commonly performed or reported in previous Delphi studies.

There are also limitations to the study. We cannot exclude the possibility of response bias in our results; participants may have provided feedback that reflected local practice protocols; known best practices; or information read, heard, or witnessed instead of providing their own practice experience. Another potential source of bias may exist as 80% of our participants also practiced in the NICU, and responses could have reflected their neonatal practice or experiences. This study also sought feedback from participants during the Canadian first and second waves of the COVID-19 pandemic, and practice changes may have been implemented and influenced their perspectives in mechanical ventilation practices.

The participants in this study were limited to those who were fluent in English as we did not have the resources to translate our study materials into other languages. To mitigate this limitation, English-fluent participants were sought from health care facilities that used either English or French as their service language.

Conclusions

This is the first Delphi study utilizing RTs to create the first Canadian practice consensus on pediatric mechanical ventilation management for critically ill children. These broadly aligned with and were consensually validated with the ESPNIC guideline. All practice statements reached consensus by the end of round 3, and the final report included 59 items organized into 10 sections. In future investigations, considerations must be made for different institutional and jurisdictional practices, other health care practitioners, and emerging evidence.

REFERENCES

1. Kneyber MCJ, de Luca D, Calderini E, Jarreau P-H, Javouhey E, Lopez-Herce J, et al; section Respiratory Failure of the European Society for Paediatric and Neonatal Intensive Care. Recommendations for mechanical ventilation of critically ill children from the Paediatric Mechanical Ventilation Consensus Conference (PEMVECC). Intensive Care Med 2017;43(12):1764-1780.
2. Ely EW, Meade MO, Haponik EF, Kollef MH, Cook DJ, Guyatt GH, et al. Mechanical ventilator weaning protocols driven by nonphysician health care professionals: evidence-based clinical practice guidelines. Chest 2001;120(6 Suppl):454S-463S.
3. The Pediatric Acute Lung Injury Consensus Conference Group. Pediatric acute respiratory distress syndrome: consensus recommendations from the Pediatric Acute Lung Injury Consensus Conference*. Pediatric Crit Care Med 2015;16(5):428-439.
4. Rimensberger PC, Cheifetz IM; Pediatric Acute Lung Injury Consensus Conference Group. Ventilatory support in children with pediatric acute respiratory distress syndrome: Proceedings from the pediatric acute lung injury consensus conference. Pediatr Crit Care Med 2015;16(5 Suppl 1):S51-S60.
5. Kacmarek RM. Mechanical ventilation competencies of the respiratory therapist in 2015 and beyond. Respir Care 2013;58(6):1087-1096.
6. Kollef MH. Evaluating the value of the respiratory therapist: where is the evidence? Focus on the Barnes-Jewish Hospital experience. Respir Care 2017;62(12):1602-1610.
7. Chia JY, Clay AS. Effects of respiratory therapist−driven protocols on house-staff knowledge and education of mechanical ventilation. Clin Chest Med 2008;29(2):313-321.
8. Wood G, MacLeod B, Moffatt S. Weaning from mechanical ventilation: physician-directed vs a respiratory therapist−directed protocol. Respir Care 1995;40(3):219-224.
9. Radosevich MA, Wanta BT, Meyer TJ, Weber VW, Brown DR, Smischney NJ, et al. Implementation of a goal-directed mechanical ventilation order set driven by respiratory therapists improves

compliance with best practices for mechanical ventilation. J Intensive Care Med 2019;34(7):550-556.

10. Hermeto F, Bottino MN, Vaillancourt K, Sant'Anna GM. Implementation of a respiratory therapist−driven protocol for neonatal ventilation: impact on the premature population. Pediatrics 2009;123(5):e907-916-e916.

11. Randolph AG, Wypij D, Venkataraman S, Hanson JH, Gedeit RG, Meert KL, et al. Effect of mechanical ventilator weaning protocols on respiratory outcomes in infants and children: a randomized controlled trial. JAMA 2002;288(20):2561-2568.

12. Jordan J, Rose L, Dainty KN, Noyes J, Blackwood B. Factors that impact on the use of mechanical ventilation weaning protocols in critically ill adults and children: a qualitative evidence-synthesis. Cochrane Database Syst Rev 2016;10:CD011812

13. Blackwood B, Murray M, Chisakuta A, Cardwell CR, O'Halloran P; Cochrane Emergency and Critical Care Group. Protocolized versus non−protocolized weaning for reducing the duration of invasive mechanical ventilation in critically ill pediatric patients. Cochrane Database of Systematic Reviews 2013.

14. Koch RL. Therapist-driven protocols: a look back and moving into the future. Crit Care Clin 2007;23(2):149-159.

15. Schultz TR, Lin RJ, Watzman HM, Durning SM, Hales R, Woodson A, et al. Weaning children from mechanical ventilation: a prospective randomized trial of protocol-directed versus physician-directed weaning. Respir Care 2001;46(8):772-782.

16. Niederberger M, Spranger J. Delphi technique in health sciences: a map. Front Public Health 2020;8:457.

17. Keeney S, Hasson F, McKenna H. The Delphi technique in nursing and health research: Keeney/the Delphi technique in nursing and health research. Oxford, UK: Wiley-Blackwell; 2011.

18. Neumann I, Schünemann HJ. Guideline groups should make recommendations even if the evidence is considered insufficient. CMAJ 2020;192(2):E23-E24.

19. Santschi M, Randolph AG, Rimensberger PC, Jouvet P; Pediatric Acute Lung Injury Mechanical Ventilation Investigators; Pediatric Acute Lung Injury and Sepsis Investigators Network; European Society of Pediatric and Neonatal Intensive Care. Mechanical ventilation strategies in children with acute lung injury: a survey on stated practice pattern. Pediatr Crit Care Med 2013;14(7):e332-337.

20. Hosheh O, Edwards CT, Ramnarayan P. A nationwide survey on the use of heated-humidified high-flow oxygen therapy on the pediatric wards in the UK: current practice and research priorities. BMC Pediatr 2020;20(1):109.

21. Mayordomo-Colunga J, Pons-Odena M, Medina A, Rey C, Milesi C, Kallio M, et al. Noninvasive ventilation practices in children across Europe. Pediatr Pulmonol 2018;53(8):1107-1114.

22. Hsu C-C, Sandford BA. The Delphi technique: making sense of consensus. Practical Assessment, Research and Evaluation 2007;12(10):8.

23. Hasson F, Keeney S. Enhancing rigor in the Delphi technique research. Technol Forecast Soc Change 2011;78(9):1695-1704.

24. Keeney S, Hasson F, McKenna H. Consulting the oracle: ten lessons from using the Delphi technique in nursing research. J Adv Nurs 2006;53(2):205-212.

25. Westmoreland D, Wesorick B, Hanson D, Wyngarden K. Consensual validation of clinical practice model practice guidelines. Journal of Nursing Care Quality 2000;14(4).

26. Nascimento JC, Sanches MB, Souza RCS. Validation of guidelines for the care of patients undergoing continuous renal replacement therapy. Nurs Crit Care 2021.

27. Fowler RA, Abdelmalik P, Wood G, Foster D, Gibney N, Bandrauk N, et al; Canadian ICU Capacity Group. Critical care capacity in Canada: results of a national cross-sectional study. Crit Care 2015;19:133.

28. Duff JP, Topjian AA, Berg MD, Chan M, Haskell SE, Joyner BL, et al. 2019 American Heart Association focused update on pediatric advanced life support: an update to the American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. Circulation 2019;140(24):e904-e914.

29. Murphy MK, Black NA, Lamping DL, McKee CM, Sanderson CF, Askham J, et al. Consensus development methods and their use in clinical guideline development. Health Technol Assess 1998;2(3):i-iv, 1-88.

30. Egbuta C, Easley RB. Update on ventilation management in the pediatric intensive care unit. Paediatr Anaesth 2022;32(2):354-362.

31. Rimensberger PC, Cheifetz IM, Kneyber MCJ. The top ten unknowns in pediatric mechanical ventilation. Intensive Care Med 2018;44(3):366-370.

32. Al-Mukhaini KS, Al-Rahbi NM. Noninvasive ventilation and high-flow nasal cannula therapy for children with acute respiratory failure. Sultan Qaboos Univ Med J 2018;18(3):e278-e285.

33. Milési C, Boubal M, Jacquot A, Baleine J, Durand S, Odena MP, et al. High-flow nasal cannula: recommendations for daily practice in pediatrics. Ann Intensive Care 2014;4(1).

34. Coletti KD, Bagdure DN, Walker LK, Remy KE, Custer JW. High-flow nasal cannula utilization in pediatric critical care. Respir Care 2017;62(8):1023-1029.

35. Kline J, Kalburgi S, Halley T, High-flow nasal cannula therapy for bronchiolitis across the emergency department and acute care floor. Clin Pediatr Emerg Med 2018;19(1):40-45.

36. Kawaguchi A, Garros D, Joffe A, DeCaen A, Thomas NJ, Schibler A, et al. Variation in practice related to the use of high-flow nasal cannula in critically ill children. Pediatr Crit Care Med 2020;21(5):e228-e235.

37. Hutchings FA, Hilliard TN, Davis PJ. Heated-humidified high-flow nasal cannula therapy in children. Arch Dis Child 2015;100(6):571-575.

38. Ramnarayan P, Richards-Belle A, Drikite L, Saull M, Orzechowska I, Darnell R, et al; FIRST-ABC Step-Down RCT Investigators and the Paediatric Critical Care Society Study Group. Effect of high-flow nasal cannula therapy vs continuous positive airway pressure following extubation on liberation from respiratory support in critically ill children: a randomized clinical trial. JAMA 2022;327(16):1555.

39. Andrade LB, Ghedini RG, Dias AS, Piva JP. Neurally adjusted ventilatory assist in pediatrics: why, when, and how? Rev Bras Ter Intensiva 2017;29(4):408-413.

40. Beck J, Emeriaud G, Liu Y, Sinderby C. Neurally adjusted ventilatory assist (NAVA) in children: a systematic review. Minerva Anestesiol 2016;82(8):874-883.

41. Karikari S, Rausa J, Flores S, Loomba RS. Neurally adjusted ventilatory assist versus conventional ventilation in the pediatric population: are there benefits? Pediatr Pulmonol 2019;54(9):1374-1381.

42. Gupta M, Bergel M, Betancourt N, Mahan V. Neurally adjusted ventilatory assist mode in pediatric intensive care unit and pediatric cardiac care unit. Explor Res Hypothesis Med 2017;2(2):33-37.

43. Chidini G, De Luca D, Calderini E, Catenacci SS, Marchesi T, Langer T, et al. Implementation of noninvasive neurally adjusted ventilatory assist in pediatric acute respiratory failure: a controlled before-after quality improvement study. J Anesth Analg Crit Care 2021;1(1):1.

44. Spinazzola G, Costa R, De Luca D, Chidini G, Ferrone G, Piastra M, et al. Pressure support ventilation (PSV) versus neurally adjusted ventilatory assist (NAVA) in difficult to wean pediatric ARDS patients: a physiologic crossover study. BMC Pediatr 2020;20(1):334.

45. Smallwood CD, Davis MD. Year in review 2018: pediatric mechanical ventilation. Respir Care 2019;64(7):855-863.

46. de Jager P, Burgerhof JG, van Heerde M, Albers MJ, Markhorst DG, Kneyber MC. Tidal volume and mortality in mechanically ventilated

children: a systematic review and meta-analysis of observational studies. Crit Care Med 2014;42(12):2461-2472.

47. Imber DA, Thomas NJ, Yehya N. Association between tidal volumes adjusted for ideal body weight and outcomes in pediatric acute respiratory distress syndrome. Pediatr Crit Care Med 2019;20(3):e145-e153.

48. Bilharz JR, Wheeler CR, Walsh BK, Smallwood CD. A comparative analysis of ideal body weight methods for pediatric mechanical ventilation. Respir Care 2018;63(9):1079-1084.

49. Kim GJ, Newth CJL, Khemani RG, Wong SL, Coates AL, Ross PA. Does size matter when calculating the "Correct" tidal volume for pediatric mechanical ventilation?: a hypothesis based on FVC. Chest 2018;154(1):77-83.

50. Ward SL, Quinn CM, Steurer MA, Liu KD, Flori HR, Matthay MA. Variability in pediatric ideal body weight calculation: implications for lung-protective mechanical ventilation strategies in pediatric acute respiratory distress syndrome. Pediatr Crit Care Med 2018;19(12):e643-e652.

51. Khemani RG, Newth CJ. The design of future pediatric mechanical ventilation trials for acute lung injury. Am J Respir Crit Care Med 2010;182(12):1465-1474.

52. Miller AG, Bartle RM, Feldman A, Mallory P, Reyes E, Scott B, et al. A narrative review of advanced ventilator modes in the pediatric intensive care unit. Transl Pediatr 2021;10(10):2700-2719.

53. Miller AG, Haynes KE, Gates RM, Kumar KR, Cheifetz IM, Rotta AT. High-frequency jet ventilation in pediatric acute respiratory failure. Respir Care 2021;66(2):191-198.

54. Miller AG, Scott BL, Gates RM, Haynes KE, Lopez Domowicz DA, Rotta AT. High-frequency jet ventilation in infants with congenital heart disease. Respir Care 2021;66(11):1684-1690.

55. Yener N, Ûdürgücü M. Airway pressure release ventilation as a rescue therapy in pediatric acute respiratory distress syndrome. The. Indian J Pediatr 2020;87(11):905-909.

56. Ning B, Liang L, Lyu Y, Yu Y, Li B. The effect of high-frequency oscillatory ventilation or airway pressure release ventilation on children with acute respiratory distress syndrome as a rescue therapy. Transl Pediatr 2020;9(3):213-220.

57. Zhou Y, Jin X, Lv Y, Wang P, Yang Y, Liang G, et al. Early application of airway pressure release ventilation may reduce the duration of mechanical ventilation in acute respiratory distress syndrome. Intensive Care Med 2017;43(11):1648-1659.

58. Lalgudi Ganesan S, Jayashree M, Chandra Singhi S, Bansal A. Airway pressure release ventilation in pediatric acute respiratory distress syndrome. a randomized controlled trial. Am J Respir Crit Care Med 2018;198(9):1199-1207.

59. Tirupakuzhi Vijayaraghavan BK, Hamed S, Jain A, Chimunda T, Telias I, Friedrich JO, et al. Evidence supporting clinical use of proportional assist ventilation: a systematic review and meta-analysis of Clinical Trials. J Intensive Care Med 2020;35(7):627-635.

60. Kim P, Salazar A, Ross PA, Newth CJL, Khemani RG. Comparison of tidal volumes at the endotracheal tube and at the ventilator. Pediatric Crit Care Med 2015;16(9).