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ORIGINAL ARTICLE

Mechanical ventilation weaning practices in neonatal and pediatric ICUs in Brazil: the Weaning Survey-Brazil

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ABSTRACT

Objective: The aim of this study was to describe practices for weaning from mechanical ventilation (MV), in terms of the use of protocols, methods, and criteria, in pediatric ICUs (PICUs), neonatal ICUs (NICUs), and mixed neonatal/pediatric ICUs (NPICUs) in Brazil. **Methods:** This was a cross-sectional survey carried out by sending an electronic questionnaire to a total of 298 NICUs, PICUs, and NPICUs throughout Brazil. **Results:** Completed questionnaires were assessed for 146 hospitals, NICUs accounting for 49.3% of the questionnaires received, whereas PICUs and NPICUs accounted for 35.6% and 15.1%, respectively. Weaning protocols were applied in 57.5% of the units. In the NICUs and NPICUs that used weaning protocols, the method of MV weaning most commonly employed (in 60.5% and 50.0%, respectively) was standardized gradual withdrawal from ventilatory support, whereas that employed in most (53.0%) of the PICUs was spontaneous breathing trial (SBT). During the SBTs, the most common ventilation mode, in all ICUs, was pressure-support ventilation (10.03 ± 3.15 cmH_2O) with positive end-expiratory pressure. The mean SBT duration was 35.76 ± 29.03 min in the NICUs, compared with 76.42 ± 41.09 min in the PICUs. The SBT parameters, weaning ventilation modes, and time frame considered for extubation failure were not found to be dependent on the age profile of the ICU population. The findings of the clinical evaluation and arterial blood gas analysis are frequently used as criteria to assess readiness for extubation, regardless of the age group served by the ICU. **Conclusions:** In Brazil, the clinical practices for weaning from MV and extubation appear to vary depending on the age group served by the ICU. It seems that weaning protocols and SBTs are used mainly in PICUs, whereas gradual withdrawal from ventilatory support is more widely used in NICUs and NPICUs.

Keywords: Ventilator weaning/methods; Respiration, artificial; Airway extubation/methods; Intensive care units, pediatric/standards; Intensive care units, neonatal/standards.

INTRODUCTION

Determining the optimal timing of weaning from mechanical ventilation (MV) and of extubation continues to be a challenge in ICUs.[1,2] In pediatrics and neonatology, there is no strong evidence of an effective and standardized method for MV weaning; nor are there any validated tests or criteria that are considered reliable means of determining patient readiness for extubation.[3-7]

A variety of strategies and criteria for weaning and extubation have been described in the literature, including evaluation of ventilatory parameters, clinical/biochemical criteria, and predictive indices of extubation that can be followed by or combined with spontaneous breathing trials (SBTs) or gradual withdrawal from ventilatory support.[3,4,6-9] It is important to standardize the criteria and methods of evaluating these variables, to identify accurate, reproducible predictors of weaning from MV and extubation.[1,2] Few studies have evaluated the weaning and extubation practices in pediatric and neonatal ICUs (PICUs and NICUs, respectively).[4,8-13]

To our knowledge, there have been no comprehensive studies characterizing the clinical practices for weaning and extubation in NICUs and PICUs. Therefore, this survey aims to describe the characteristics related to the application of protocols, methods, and criteria used in the process of MV weaning and extubation in such ICUs in Brazil.

METHODS

Study design and population

This was a cross-sectional analytical survey, designated the Weaning Survey-Brazil, involving a nationwide sample of 693 ICUs identified from the National Registry of

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Health Care Facilities of the Brazilian National Ministry of Health.[14] Of those 693 facilities, 337 are NICUs, 323 are PICUs, and 33 are mixed neonatal/pediatric units (NPICUs).

To define our study sample, the number of ICUs was calculated[15] so that the survey would represent all of Brazil. The sample size calculation considered a significance of $\alpha = 0.05$ and a statistical power of $1 - \beta = 0.95$, with a minimum recommended sample in each state/region according to the sample of ICUs registered with the National Registry of Health Care Facilities, resulting in a minimum sample size of 82 ICUs.

We obtained e-mail addresses or telephone numbers for professionals to contact at 298 ICUs by consulting the membership list of the Brazilian Association of Intensive Care Medicine and by making telephone calls to the hospitals whose ICUs were registered with the National Registry of Health Care Facilities (Figure 1). The ICU professionals contacted were the coordinator or intensivist in charge of each ICU (physical therapist/respiratory therapist, physician, or nurse).

Development of the survey

The survey was developed by the main researchers, who were experts in intensive care, and was based on a review of relevant literature and other surveys.[1,4,11,12] A pilot study was conducted with 10 practitioners representing each ICU type (NICUs, PICUs, and NPICUs) and from each profession, to allow correction for potential confounding factors in the items on the questionnaire. Using Google Forms, a web-based survey tool, we developed a survey questionnaire containing 23 questions, divided into 11 subscales, with mandatory responses.

We collected data on the MV weaning and extubation processes in the neonatal and pediatric age groups. The issues addressed were aspects of ICU practice regarding the application of weaning protocols; weaning/

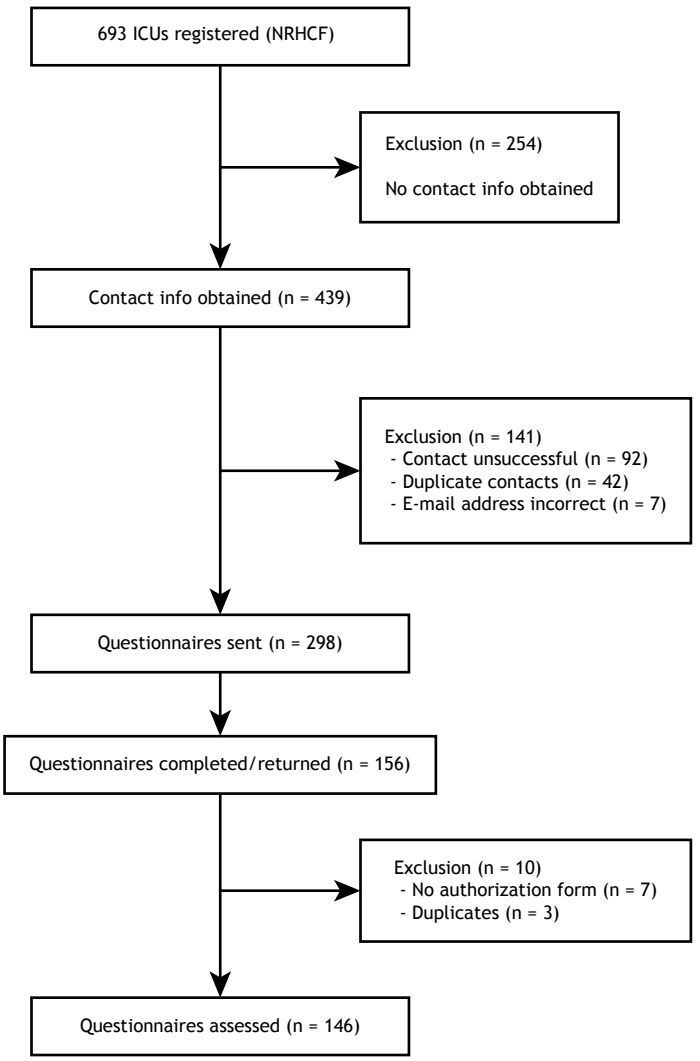

Figure 1. Flow chart of ICU selection process. NRHCF: (Brazilian National Ministry of Health) National Registry of Health Care Facilities.

extubation methods and strategies; application of SBTs; weaning ventilation modes; weaning/extubation readiness criteria; and the clinical indicators recorded. We also evaluated aspects related to weaning/extubation failure in each type of ICU (NICU, PICU, and NPICU).

The initial contact with eligible respondents was made through a personalized e-mail containing a link to the electronic survey, as well as an invitation to take part in the survey, and the authorization form was sent to the coordinator or intensivist in charge of each ICU (physical therapist/respiratory therapist, physician, or nurse). Only one of those was a representative of the ICU. After the initial invitation, reminders were sent and phone calls were made until the minimum sample size was reached for each state/region.

Ethical considerations

This study was approved by the Research Ethics Committee of the Federal University of Uberlandia (Reference no. 1.301.015). Participation was voluntary, and the survey included those ICUs for which the authorization form was signed by and received from the coordinator or intensivist in charge.

Statistical analysis

Multiple-response categorical variables were compared by using chi-square tests.[16] Continuous variables were evaluated for normality with the Kolmogorov-Smirnov test and were compared by using the Kruskal-Wallis test followed by the Games-Howell post hoc test. The results are expressed as absolute and relative frequencies or as medians and interquartile ranges (IQRs). Multiple comparisons of proportions were performed in the program R (R Development Core Team, 2017).[17] For all analyses, values of $p < 0.05$ were considered significant.

RESULTS

Of the 298 questionnaires sent, 156 were completed and returned, corresponding to a response rate of 52.3%. However, 10 questionnaires were excluded, either because of duplication (two questionnaires received from the same ICU) or because the authorization form was not received (Figure 1). Therefore, the final sample comprised 146 questionnaires: 72 (49.3%) received from NICUs; 52 (35.6%) received from PICUs; and 22 (15.1%) received from NPICUs. Our survey included ICUs in all 26 states and in the Federal District, across all regions of the country, the response rates ranging from 13.0% to 100.0% for each state and from 16.0% to 36.3% for each region.

Of the 146 respondents, 84 (57.5%) reported that weaning protocols were employed in their ICUs. Among those 84 ICUs, the most commonly applied method of MV weaning was standardized gradual withdrawal from ventilatory support, in 39 (46.4%), followed by SBT, in 34 (40.5%). Among the 61 ICUs (41.8%) for which the use of weaning protocols was not reported, the main weaning strategy, in 33 (54.1%), was gradual withdrawal from ventilatory support based on clinical judgment (Table 1).

Of the 145 ICUs for which data regarding the use of SBTs were available, 60 (41.3%) reported using them, although information regarding the ventilation modes used during SBT and the average pressure values applied were available for only 54: continuous positive airway pressure (CPAP) of 5 cmH_2O, in 7 (13.0%); pressure-support ventilation (PSV) at a median of 10.0 cmH_2O (IQR, 8.0-12.0 cmH_2O) together with positive end-expiratory pressure (PEEP) at a median of 5.0 cmH_2O (5.0-5.5 cmH_2O), in 43 (79.6%); and a T-piece connected to an oxygen source with an FiO_2 of 0.4, in 4 (7.4%). Regarding the median SBT duration, there was a significant difference among the ICU profiles ($p = 0.004$), as well as significant differences between them: 30.0 min (IQR, 20.0-60.0 min) in the NICUs vs. 67.5 min (IQR, 30.0-120.0 min) in the PICUs ($p = 0.001$); and 45.0 min (IQR, 30.0-60.0 min) in the NPICUs ($p > 0.050$ vs. the NICUs and PICUs). However, the median SBT duration did not differ significantly among the three ventilation modes ($p = 0.053$): 15.0 min (IQR, 10.0-30.0 min) for CPAP vs. 60.0 min (IQR, 30.0-120.0 min) for PSV+PEEP vs. 60.0 min (IQR, 20.0-75.0 min) for the T-piece trial. The time frame considered for extubation failure and other variables collected are presented in Table 2. The ventilation modes used during weaning are shown in Figure 2. The ventilation mode most often employed during the weaning of pediatric patients from MV (in PICUs and NPICUs) was the combination of synchronized intermittent mandatory ventilation (SIMV) and PSV, shifted to PSV alone before extubation. For neonatal patients, there was no one mode that was predominant, in the NICUs or the NPICUs.

Among the NICUs, the main causes of extubation failure reported were apnea, in 68.1%, respiratory distress, in 54.2%, and clinical hemodynamic, infectious, or neurological worsening, in 34.7%. Among the NPICUs, the main causes of extubation failure reported for the neonatal patients were respiratory distress, in 59.1%, clinical worsening, in 59.1%, and apnea, in 50.0%. Among the PICUs, the main causes of extubation failure reported were upper airway obstruction, in 59.6%, neurological or neuromuscular disease, in 51.9%, and respiratory distress, in 44.2%. Among the pediatric patients admitted to the NPICUs, the most common cause of extubation failure was respiratory distress, in 59.1%, followed by upper airway obstruction, in 45.5%, and prolonged sedation time, in 36.4%.

The three types of ICU were compared in terms of the strategies employed in protocolized and non-protocolized MV weaning, as well as the SBT ventilation modes and other variables (Table 3). The proportion of ICUs using weaning protocols was comparable between the NICUs and NPICUs (52.8% and 57.1%, respectively), whereas it was higher (65.4%) among the PICUs. Regarding the methods of liberation from MV, 60.5% of the NICUs and 50.0% of the NPICUs reported using standardized gradual withdrawal from ventilatory

Table 1. Practices related to weaning from mechanical ventilation and spontaneous breathing trials in neonatal and pediatric ICUs in Brazil.

Practice	n (%)
Use of a weaning protocol (N = 146)	
Yes	84 (57.5)
No	61 (41.8)
Unknown	1 (0.7)
Weaning protocol employed (n = 84)[a]	
Standardized gradual withdrawal from ventilatory support	39 (46.4)
SBT with or without daily interruption of sedation	34 (40.5)
Other	11 (13.1)
Non-protocolized weaning strategies (n = 61)[a]	
Gradual withdrawal from ventilatory support based on clinical judgment	33 (54.1)
SBT after parameter reduction	26 (42.6)
Others	2 (3.3)
Ventilation modes during SBT (n = 54)[a]	
PSV+PEEP	43 (79.6)
CPAP	7 (13)
T-piece	4 (7.4)
Parameters monitored during SBT (n = 54)[a]	
Respiratory effort	53 (98.1)[b]
SpO_2	51 (94.4)[b]
Vital signs	47 (87)[b]
Conscious level	32 (59.3)[b]
Tidal volume	27 (50)[b]
Cough reflex	19 (35.2)[b]
PaO_2/FiO_2 ratio	12 (22.2)[b]
SpO_2/FiO_2 ratio	7 (13)[b]
Exhaled CO_2	6 (11.1)[b]

SBT: spontaneous breathing trial; PSV: pressure-support ventilation; PEEP: positive end-expiratory pressure; and CPAP: continuous positive airway pressure. [a]Number of respondents differed from the total. [b]Total may be greater than 100% because the respondents could choose more than one response.

support, whereas SBT was the most common method used in most (53.0%) of the PICUs and in 41.7% of the NPICUs, compared with 29.0% of the NICUs. Among the ICUs which did not report using weaning protocols, a gradual withdrawal from ventilatory support based on clinical judgment was employed in 67.6% of the NICUs and 77.8% of the NPICUs, compared with only 16.7% of the PICUs. The proportion of ICUs using the SBT strategy after withdrawal from ventilatory support was highest (83.3%) among the PICUs (Table 3).

Table 4 shows a comparison between the ICUs with protocolized weaning and those without, in terms of weaning and extubation criteria, as well as extubation failure and its characteristics. Some significant differences were identified.

DISCUSSION

To our knowledge, the Weaning Survey-Brazil is the first study to evaluate MV weaning practices in the pediatric and neonatal age groups in Brazil. We found that the clinical practice for weaning from MV and extubation varies according to the age group served by the ICU.

Our results indicate that most of the participating ICUs (57.5%) employ weaning and extubation protocols, and that such protocols are employed most often in the PICUs. Overall, the most common method of weaning from MV was found to be gradual withdrawal from ventilatory support, which was employed in 49.7% of the ICUs surveyed, especially in the NICUs and NPICUs, although most of the PICUs employed the SBT method.

Protocols are useful for conducting safe, efficient MV weaning, reducing unnecessary or harmful variations in the process.[18] However, we found that the MV weaning protocols employed differed from one ICU to another, demonstrating that there are no standardized protocols in the fields of pediatrics and neonatology. Although such protocols should be used as a complement to clinical judgment,[18] gradual withdrawal from ventilatory support, based on clinical judgment, is the weaning approach more frequently applied in neonatal and pediatric patients, extubation being performed after the minimal ventilation parameters have been reached or the patient has undergone a successful SBT.[3] There is no consensus on which MV weaning method is the best,[19] and it is possible that not all patients require gradual weaning.[3]

Table 2. Criteria for weaning from mechanical ventilation and extubation in neonatal and pediatric ICUs in Brazil.

Criteria and other variables	n (%)
Weaning and extubation readiness criteria (N = 146)	
Clinical criteria	11 (7.5)
Clinical and biochemical criteria	101 (69.2)
Clinical criteria, biochemical criteria, and predictive indices	33 (22.6)
Clinical criteria and predictive indices	1 (0.7)
Biochemical criteria (n = 134)[a]	
Arterial blood gas analysis	129 (96.3)[b]
Other	80 (59.7)[b]
Predictive indices (n = 33)[a]	
RSBI	14 (42.4)[b]
MV parameters	11 (33.3)[b]
MIP, MEP, or both	6 (18.2)[b]
SBT	4 (12.1)[b]
PaO_2/FiO_2 ratio	4 (12.1)[b]
Other	15 (45.4)[b]
Time frame considered for extubation failure (N = 146)	
24 h	39 (26.7)
48 h	68 (46.6)
72 h	14 (9.6)
Undefined	25 (17.1)
Number of extubation attempts (N = 146)	
Most patients are successfully extubated on the first attempt	130 (89)
Most patients require up to 3 attempts	13 (8.9)
Most patients require more than 3 attempts	0 (0.0)
Could not inform	3 (2.1)
Use of a weaning protocol after extubation failure on the first attempt (N = 146)	
No	94 (64.4)
Yes	41 (28.1)
In some cases	11 (7.5)
Registration of clinical indicators (N = 146)	
Time on MV	139 (95.2)[b]
Cause of extubation failure	88 (60.3)[b]
Weaning time	40 (27.4)[b]

RSBI: rapid shallow breathing index; MV: mechanical ventilation; and SBT: spontaneous breathing trial. [a]Number of respondents differed from the total. [b]Total may be greater than 100% because the respondents could choose more than one response.

Two previous studies carried out in PICUs in Europe showed that weaning protocols were either available in few (22%) of the PICUs[20] or were seldom used, being employed in only 9%.[10] Regarding the weaning methods, those same studies indicated that the weaning methods adopted varied according to clinical preferences[10] and that SBTs were applied in 44%.[20] A prospective cohort[9] evaluating PICUs in the United States found that most (62%) use SBT as a method of weaning from MV, similar to the 83.3% found in the present study. However, the proportion of NICUs using weaning protocols has varied across surveys carried out in different countries,[11,12] where an SBT was either not part of the weaning practice[12] or was rarely used.[11]

In general, SBTs are applied as an early means of determining whether a patient is capable of spontaneous autonomous breathing and is ready to be extubated.[7] Studies involving pediatric patients[21-24] and neonatal patients[6,25,26] suggest that SBTs are applicable in those age groups, showing that the trials have high sensitivity for predicting successful extubation. In the present study, we found that the SBT ventilation mode most often employed was CPAP in the NICUs, whereas it was PSV+PEEP in the PICUs. Ventilatory support and SBT duration varied regardless of the method chosen, as has been described in previous studies conducted in other countries.[4,9-11] When PSV+PEEP is employed, the PSV is typically ≤ 10 cmH_2O.[21,22,24,27-29] In keeping with our findings, most neonatology studies of SBT have used the CPAP ventilation mode, with rates of 3-5 cmH_2O and a duration of 3-120 min.[6,11,25,26,30] In the present survey, we found that the parameters usually monitored during SBT are respiratory effort, SpO_2, and vital signs, as shown in previous studies of pediatric patients[21-23,28,29] and neonatal patients.[6,25,26,30]

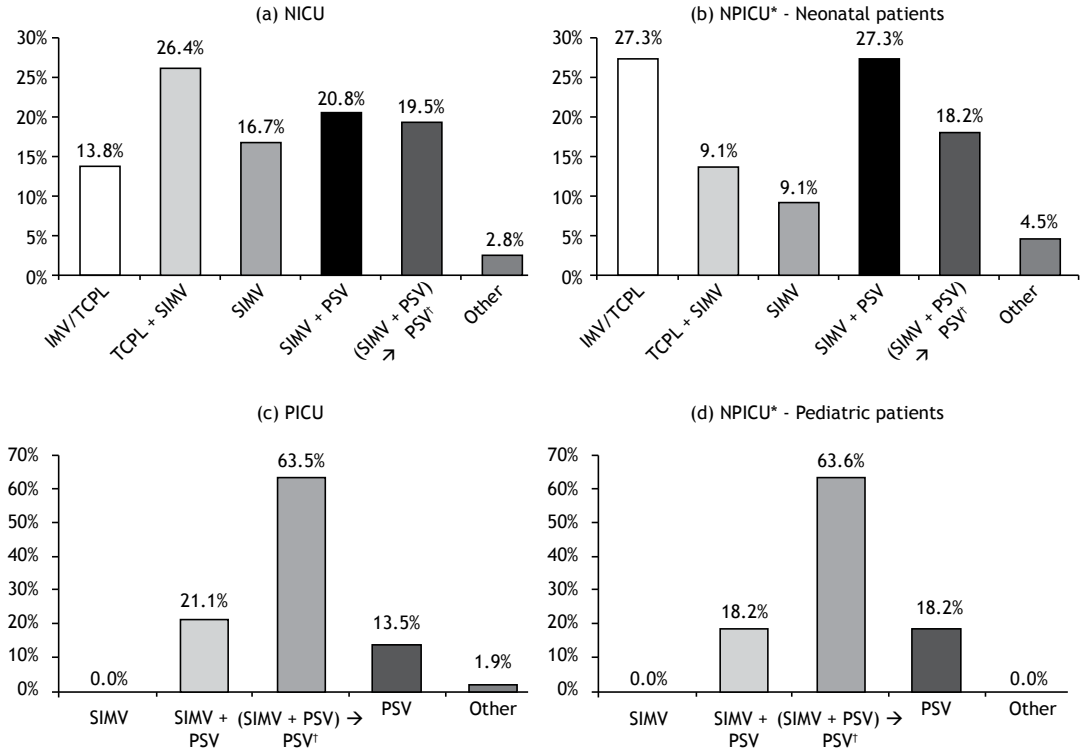

Figure 2. Ventilation modes during weaning in neonatal ICUs (NICUs, n = 72), pediatric ICUs (PICUs, n = 52), and mixed neonatal/pediatric ICUs (NPICUs, n = 22). IMV: intermittent mandatory ventilation; TCPL: time-cycled pressure-limited (ventilation); SIMV: synchronized intermittent mandatory ventilation; and PSV: pressure-support ventilation. *NPICUs answered questions related to ventilation modes during weaning separately for neonatal and pediatric patients. †Shifted from SIMV+PSV to PSV alone before extubation.

The impact of applying MV weaning protocols is typically evaluated by clinical indicators such as the time on MV, weaning time, and extubation failure rate.[5,19,22,27,31] In the present survey, the time on MV was an indicator recorded in all ICUs, although weaning time was not commonly recorded. In one systematic review,[5] it was suggested that weaning protocols decrease the time on MV in children. However, there is still insufficient evidence to support that suggestion, especially as it applies to neonates.[19]

In the present survey, we found that the majority of patients were successfully extubated on the first attempt, regardless of whether the ICU employed protocolized weaning or not. We also found that ICU teams that did not apply weaning protocols also did not apply protocols after extubation failure. Extubation failure is defined as the need for reintubation within the first 24-72 h after extubation.[3,6,22,29,30,32] Many of the ICUs evaluated in the present survey defined extubation failure as a need for reintubation within the first 48 h after extubation. That definition was more often used in the PICUs than in the NICUs and NPICUs.

The causes of extubation failure were more often recorded in the PICUs and in the ICUs that employed weaning protocols. Obstruction of the upper airways was the most common cause of extubation failure, as has been reported in previous studies involving pediatric patients.[8,21,23,27] Among the neonates, apnea was the most commonly reported cause of extubation failure, as has also been reported previously.[26,30,32,33]

The use of a combination of subjective and objective criteria might have greater predictive accuracy in assessing fitness for liberation from ventilatory support and has provided major insights into the mechanisms of weaning failure.[18,34] Clinical and laboratory criteria, as well as the application of predictive indexes[2] can assist in assessing readiness for extubation.[3,35] In our survey, we observed that 69.2% of the ICUs evaluated were using clinical and laboratory criteria, mainly the arterial blood gas data, to evaluate patient readiness for weaning and extubation. The predictive index most often employed was the rapid shallow breathing index. However, when asked about the predictive indices employed, 33.3% of the respondents reported using the MV parameters and 45.4% reported using other criteria, which shows that there is a lack of knowledge regarding the correct terms related to the predictive indices.

Corroborating our findings, previous surveys conducted in other countries have found that the criteria most often evaluated to determine extubation readiness were clinical criteria in PICUs,[4] whereas the criteria most often evaluated in NICUs were ventilation parameters (in 98%), blood gas analyses (in 92%), and clinical

Table 3. Comparison among ICUs serving different age groups, in terms of ventilator weaning and extubation practices, in Brazil.

Practice	NICU (n = 75)	PICU (n = 52)	NPICU (n = 22)
Use of a weaning protocol, %			
Yes	52.8^{aA}	65.4^{aA}	57.1^{aA}
No	47.2^{aA}	34.6^{bA}	42.9^{aA}
Weaning protocol employed, %			
Standardized gradual withdrawal from ventilatory support	60.5^{aA}	29.4^{abB}	50.0^{aAB}
SBT with or without daily interruption of sedation	29.0^{bA}	53.0^{aA}	41.7^{aA}
Other	10.5^{bA}	17.6^{bA}	8.3^{aA}
Non-protocolized weaning strategies, %			
Gradual withdrawal from ventilatory support based on clinical judgment	67.6^{aA}	16.7^{bB}	77.8^{aA}
SBT after parameter reduction	26.5^{bB}	83.3^{aA}	22.2^{bB}
Other	5.9^{b}	---	---
Ventilation modes during SBT, %			
CPAP	27.8^{bA}	6.7^{bB}	---
PSV+PEEP	66.7^{aA}	86.7^{aA}	83.3^{aA}
T-piece	5.5^{bA}	6.7^{bA}	16.7^{bA}
Weaning and extubation readiness criteria, %			
Clinical criteria	4.1^{bA}	13.7^{bA}	4.5^{bA}
Clinical and biochemical criteria	73.6^{aA}	58.9^{aA}	81.8^{aA}
Clinical criteria, biochemical criteria, and predictive indices	22.3^{bA}	27.4^{bA}	13.7^{bA}
Clinical criteria and predictive indices	---	---	---
Time frame considered for extubation failure, %			
24 h	27.8^{aA}	23.1^{bA}	31.8^{abA}
48 h	36.1^{aB}	59.6^{aA}	50.0^{aAB}
72 h	12.5^{bA}	5.8^{bA}	9.1^{bA}
Undefined	23.6^{aA}	11.5^{bA}	9.1^{bA}
Use of a weaning protocol after extubation failure on the first attempt, %			
Yes	26.4^{bA}	26.9^{bA}	36.4^{abA}
No	65.3^{aA}	65.4^{aA}	59.1^{aA}
In some cases	8.3^{bA}	7.7^{bA}	4.5^{bA}
Time on MV recorded, %			
Yes	94.4^{aA}	96.2^{aA}	95.5^{aA}
No	5.6^{bA}	3.8^{bA}	4.5^{bA}
Weaning time recorded, %			
Yes	25.0^{bA}	32.7^{bA}	22.7^{bA}
No	75.0^{aA}	67.3^{aA}	77.3^{aA}
Causes of extubation failure recorded, %			
Yes	56.9^{aA}	65.4^{aA}	59.1^{aA}
No	43.1^{aA}	34.6^{bA}	40.9^{aA}

NICU: neonatal ICU; PICU: pediatric ICU; NPICU: (mixed) neonatal/pediatric ICU; SBT: spontaneous breathing trial; CPAP: continuous positive airway pressure; PSV: pressure-support ventilation; PEEP: positive end-expiratory pressure; and MV: mechanical ventilation. Proportions followed by the same superscript letters (in lower case for columns and in upper case for rows) did not differ statistically from each other in the multiple comparison tests, $p < 0.05$ being considered significant.

stability/hemodynamics (in 86%).[11] However, other studies involving pediatric patients have shown that ventilatory parameters prior to extubation and arterial blood gas values were not associated with the success or failure of extubation.[8,36] Another study involving pediatric patients in Brazil,[37] observed that the rapid shallow breathing index and blood gas analyses were not predictors of extubation failure in the postoperative period after cardiac surgery. There are as yet no accurate, reliable criteria to predict success in weaning and extubation in neonatal and pediatric populations.[33,35] Therefore, subjective rather than evidence-based criteria are employed in most ICUs around the world.[2,32]

A variety of ventilation modes are used for MV weaning in pediatric patients.[5] A survey carried out in PICUs in Italy[38] found that SIMV+PSV was the ventilation mode most commonly used for weaning, whereas another study[9] reported that the PSV weaning mode was more

Table 4. Comparison between ICUs with protocolized ventilator weaning and those without.

Criteria and other variables	Use of a weaning protocol	
	Yes	No
Weaning and extubation readiness criteria, %		
Clinical criteria	8.3[c]	6.7[c]
Clinical and biochemical criteria	59.6[a]	83.3[a]
Clinical criteria, biochemical criteria, and predictive indices, %	32.1[b]	10.0[b]
Clinical criteria and predictive indices	---	---
Time frame considered for extubation failure, %		
24 h	34.5[a]	14.7[c]
48 h	42.9[a]	52.5[a]
72 h	14.3[b]	3.3[c]
Undefined	8.3[b]	29.5[b]
Frequency of extubation attempts, %		
Patients successfully extubated on the first attempt	92.9[a]	87.9[a]
Patients required up to 3 extubation attempts	7.1[b]	12.1[b]
Use of a weaning protocol after extubation failure on the first attempt, %		
Yes	46.4[a]	3.3[b]
No	47.6[a]	88.5[a]
In some cases	6.0[b]	8.2[b]
Time on MV recorded, %		
Yes	94.0[a]	96.7[a]
No	6.0[b]	3.3[b]
Weaning time recorded, %		
Yes	36.9[b]	14.8[b]
No	63.1[a]	85.2[a]
Causes of extubation failure recorded, %		
Yes	71.4[a]	45.9[a]
No	28.6[b]	54.1[a]

MV: mechanical ventilation. Proportions followed by the same superscript lowercase letters in columns did not differ statistically from each other in the multiple comparison tests, $p < 0.05$ being considered significant.

widely used in PICUs in other countries. However, other surveys showed that SIMV is the preferential weaning or pre-extubation ventilation mode in NICUs in the United Kingdom[13] and Canada.[12] The best ventilation mode for weaning from MV has not been established in the field of neonatology.[39]

The Weaning Survey-Brazil has some limitations. First, we were unable to obtain contact information for all of the relevant ICUs in Brazil, due to the absence of a single registry containing all such information. In addition, some ICU coordinators did not sign the authorization form. Another limitation is that each questionnaire was completed by only one individual. However, we believe that the questionnaire reliably evaluated the practices in each ICU, because it was completed by the coordinator or intensivist responsible for the unit. In fact, it is possible that the respondents adopted better weaning and extubation practices as they completed the questionnaire. This is a limitation of surveys. Nonetheless, it is noteworthy that this was the first survey to evaluate the profile, in terms of weaning and extubation practices, of NICUs and PICUs in Brazil. In addition, our survey included all of the states and regions of the country. Furthermore, the size of the survey sample (n = 146) was larger than the minimum calculated (n = 82) as being required to be representative of all ICUs in Brazil. The results allow us to understand the practices related to the weaning and extubation processes in the NICUs and PICUs of Brazil, enabling the planning and development of future standardized protocols for the MV weaning in each age group. Optimization of the weaning process could reduce variations in clinical practice, as well as reducing the time on MV, thus reducing the risks associated with ventilation and the costs to the public health system.

In conclusion, the present survey showed that the weaning and extubation practices in Brazil vary widely as a function of the age group served by the ICU. The most common weaning strategy in Brazil is a gradual withdrawal from ventilatory support, and protocolized weaning is more common in PICUs. In PICUs, an SBT is more often performed in the PSV+PEEP ventilation mode, although the duration of the trial was quite variable. In most NICUs and PICUs in Brazil, readiness for extubation is further assessed by clinical and blood gas analysis.

Further studies are needed in order to evaluate the clinical impact of the methods and strategies adopted for MV weaning and extubation of pediatric and neonatology patients in Brazil. Such studies should be

based on the safety, quality, and productivity indicators applicable in ICUs.

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REFERENCES

1. Soo Hoo GW, Park L. Variations in the measurement of weaning parameters: a survey of respiratory therapists. Chest. 2002;121(6):1947-1955. https://doi.org/10.1378/chest.121.6.1947
2. Johnston C, da Silva PSL. Weaning and Extubation in Pediatrics. Curr Respir Med Rev. 2012;8(1):68-78. https://doi.org/10.2174/157339812798868852
3. Newth CJL, Venkataraman S, Willson DF, Meert KL, Harrison R, Dean JM, et al. Weaning and extubation readiness in pediatric patients. Pediatr Crit Care Med. 2009;10(1):1-11. https://doi.org/10.1097/PCC.0b013e318193724d
4. Mhanna MJ, Anderson IM, Iyer NP, Baumann A. The Use of Extubation Readiness Parameters: A Survey of Pediatric Critical Care Physicians. Respir Care. 2014;59(3):334-339. https://doi.org/10.4187/respcare.02469
5. Blackwood B, Murray M, Chisakuta A, Cardwell CR, O'Halloran P. Protocolized versus non-protocolized weaning for reducing the duration of invasive mechanical ventilation in critically ill paediatric patients. Cochrane Database Syst Rev. 2013;2013(7):CD009082. https://doi.org/10.1002/14651858.CD009082.pub2
6. Andrade LB, Melo TM, Morais DF, Lima MR, Albuquerque EC, Martimiano PH. Spontaneous breathing trial evaluation in preterm newborns extubation. Rev Bras Ter Intensiva. 2010;22(2):159-165. https://doi.org/10.1590/S0103-507X2010000200010
7. Kamlin CO, Davis PG, Argus B, Mills B, Morley CJ. A trial of spontaneous breathing to determine the readiness for extubation in very low birth weight infants: a prospective evaluation. Arch Dis Child Fetal Neonatal Ed. 2008;93(4):F305-F306. https://doi.org/10.1136/adc.2007.129890
8. Laham JL, Breheny PJ, Rush A. Do clinical parameters predict first planned extubation outcome in the pediatric intensive care unit? J Intensive Care Med. 2015;30(2):89-96. https://doi.org/10.1177/0885066613494338
9. Farias JA, Fernández A, Monteverde E, Flores JC, Baltodano A, Menchaca A, et al. Mechanical ventilation in pediatric intensive care units during the season for acute lower respiratory infection: a multicenter study. Pediatr Crit Care Med. 2012;13(2):158-164. https://doi.org/10.1097/PCC.0b013e3182257b82
10. Blackwood B, Tume L. The implausibility of "usual care" in an open system: sedation and weaning practices in Paediatric Intensive Care Units (PICUs) in the United Kingdom (UK). Trials. 2015;16:325. https://doi.org/10.1186/s13063-015-0846-3
11. Al-Mandari H, Shalish W, Dempsey E, Keszler M, Davis PG, Sant'Anna G. International survey on periextubation practices in extremely preterm infants. Arch Dis Child Fetal Neonatal Ed. 2015;100(5):F428-F431. https://doi.org/10.1136/archdischild-2015-308549
12. Shalish W, Anna GM. The use of mechanical ventilation protocols in Canadian neonatal intensive care units. Paediatr Child Health. 2015;20(4):e13-e19. https://doi.org/10.1093/pch/20.4.e13
13. Sharma A, Greenough A. Survey of neonatal respiratory support strategies. Acta Paediatr. 2007;96(8):1115-1117. https://doi.org/10.1111/j.1651-2227.2007.00388.x
14. Brasil. Ministério da Saúde. Agência Nacional de Vigilância Sanitária [homepage on the Internet]. Brasília: o Ministério; [cited 2017 Jun 8]. Resolução Nº 7, de 24 de fevereiro de 2010. Dispõe sobre os requisitos mínimos para funcionamento de Unidades de Terapia Intensiva e dá outras providências. Available from: http://bvsms.saude.gov.br/bvs/saudelegis/anvisa/2010/res0007_24_02_2010.html
15. Miot HA. Sample size in clinical and experimental trials. J Vasc Bras. 2011;10(4):275-8. http://dx.doi.org/10.1590/S1677-54492011000400001 https://doi.org/10.1590/S1677-54492011000400001
16. Biase N, Ferreira D. Comparações múltiplas e testes simultâneos para parâmetros binomiais de K populações independentes. Rev Bras Biometria. 2009;27(3):301-323.
17. R Development Core Team. R: A language and environment for statistical computing. Vienna, Austria: The R Project for Statistical Computing; 2017.
18. Teixeira C, Maccari JG, Vieira SR, Oliveira RP, Savi A, Machado AS, et al. Impact of a mechanical ventilation weaning protocol on the extubation failure rate in difficult-to-wean patients. J Bras Pneumol. 2012;38(3):364-371. https://doi.org/10.1590/S1806-37132012000300012
19. Wielenga JM, van den Hoogen A, van Zanten HA, Helder O, Bol B, Blackwood B. Protocolized versus non-protocolized weaning for reducing the duration of invasive mechanical ventilation in newborn infants. Wielenga JM, editor. Cochrane Database Syst Rev. 2016;3:CD011106. https://doi.org/10.1002/14651858.CD011106.pub2
20. Tume LN, Kneyber MC, Blackwood B, Rose L. Mechanical Ventilation, Weaning Practices, and Decision Making in European PICUs. Pediatr Crit Care Med. 2017;18(4):e182-e188. https://doi.org/10.1097/PCC.0000000000001100
21. Farias JA, Retta A, Alía I, Olazarri F, Esteban A, Golubicki A, et al. A comparison of two methods to perform a breathing trial before extubation in pediatric intensive care patients. Intensive Care Med. 2001;27(10):1649-1654. https://doi.org/10.1007/s001340101035
22. Foronda FK, Troster EJ, Farias JA, Barbas CS, Ferraro AA, Faria LS, et al. The impact of daily evaluation and spontaneous breathing test on the duration of pediatric mechanical ventilation: a randomized controlled trial. Crit Care Med. 2011;39(11):2526-2533. https://doi.org/10.1097/CCM.0b013e3182257520
23. Chavez A, dela Cruz R, Zaritsky A. Spontaneous breathing trial predicts successful extubation in infants and children. Pediatr Crit Care Med. 2006;7(4):324-328. https://doi.org/10.1097/01.PCC.0000225001.92994.29
24. Faustino EV, Gedeit R, Schwarz AJ, Asaro LA, Wypij D, Curley MA, et al. Accuracy of an Extubation Readiness Test in Predicting Successful Extubation in Children With Acute Respiratory Failure From Lower Respiratory Tract Disease. Crit Care Med. 2017;45(1):94-102. https://doi.org/10.1097/CCM.0000000000002024
25. Kamlin CO, Davis PG, Morley CJ. Predicting successful extubation of very low birthweight infants. Arch Dis Child Fetal Neonatal Ed. 2006;91(3):F180-F183. https://doi.org/10.1136/adc.2005.081083
26. Chawla S, Natarajan G, Gelmini M, Kazzi SN. Role of spontaneous breathing trial in predicting successful extubation in premature infants. Pediatr Pulmonol. 2013;48(5):443-448. https://doi.org/10.1002/ppul.22623
27. Randolph AG, Wypij D, Venkataraman ST, 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. https://doi.org/10.1001/jama.288.20.2561
28. Farias JA, Alía I, Retta A, Olazarri F, Fernández A, Esteban A, et al. An evaluation of extubation failure predictors in mechanically ventilated infants and children. Intensive Care Med. 2002;28(6):752-757. https://doi.org/10.1007/s00134-002-1306-6
29. Ferguson LP, Walsh BK, Munhall D, Arnold JH. A spontaneous

breathing trial with pressure support overestimates readiness for extubation in children. Pediatr Crit Care Med. 2011;12(6):e330-e335. https://doi.org/10.1097/PCC.0b013e3182231220

30. Gillespie LM, White SD, Sinha SK, Donn SM. Usefulness of the minute ventilation test in predicting successful extubation in newborn infants: a randomized controlled trial. J Perinatol. 2003;23(3):205-207. https://doi.org/10.1038/sj.jp.7210886
31. 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-e916. https://doi.org/10.1542/peds.2008-1647
32. Giaccone A, Jensen E, Davis P, Schmidt B. Definitions of extubation success in very premature infants: a systematic review. Arch Dis Child Fetal Neonatal Ed. 2014;99(2):F124-F127. https://doi.org/10.1136/archdischild-2013-304896
33. Sant'Anna GM, Keszler M. Weaning Infants from Mechanical Ventilation. Clin Perinatol. 2012;39(3):543-562. https://doi.org/10.1016/j.clp.2012.06.003
34. Nemer SN, Barbas CS. Predictive parameters for weaning from mechanical ventilation. J Bras Pneumol. 2011;37(5):669-679. https://doi.org/10.1590/S1806-37132011000500016
35. Valenzuela J, Araneda P, Cruces P. Weaning from mechanical ventilation in paediatrics. State of the art. Arch Bronconeumol. 2014;50(3):105-112. https://doi.org/10.1016/j.arbres.2013.02.003
36. Johnston C, de Carvalho WB, Piva J, Garcia PC, Fonseca MC. Risk factors for extubation failure in infants with severe acute bronchiolitis. Respir Care. 2010;55(3):328-333.
37. Johnston C, Piva JP, Carvalho WB, Garcia PC, Fonseca MC, Hommerding PX. Post Cardiac Surgery In Children: Extubation Failure Predictor's [Article in Portuguese]. Rev Bras Ter Intensiva. 2008;20(1):57-62. https://doi.org/10.1590/S0103-507X2008000100009
38. Wolfler A, Calderoni E, Ottonello G, Conti G, Baroncini S, Santuz P, et al. Daily practice of mechanical ventilation in Italian pediatric intensive care units: a prospective survey. Pediatr Crit Care Med. 2011;12(2):141-146. https://doi.org/10.1097/PCC.0b013e3181dbaeb3
39. Sant'Anna GM, Keszler M. Developing a neonatal unit ventilation protocol for the preterm baby. Early Hum Dev. 2012;88(12):925-929. https://doi.org/10.1016/j.earlhumdev.2012.09.010