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Spontaneous breathing trial in the weaning process from mechanical ventilation in pediatrics: outcome and predictive factors

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ABSTRACT

Introduction. spontaneous breathing trial (SBT) in weaning from pediatric invasive mechanical ventilation (IMV) is an endorsed practice, its positivity is based on clinical parameters; however, its results could be better documented.

Objective. To describe the results of the SBT in the IMV weaning process.

Population and methods. Retrospective analysis. Patients with ≥48 h in IMV from March 1, 2022 to January 31, 2024.

Results. A total of 493 SBT were analyzed in 304 patients; 71% (348) were positive, and 87% (302) resulted in successful extubations. The causes of negative SBT were increased work of breathing (70%), respiratory rate (57%), and heart rate (27%). In univariate analysis, respiratory distress as the reason for admission, peak inspiratory pressure before SBT and T-tube use, were predictors of negative SBT. In multivariate analysis, this association persisted for admission for respiratory cause, the higher programmed respiratory rate in IMV, as the T-tube modality. Those with negative SBT stayed more days in IMV (9 [7-12] vs. 7 [4-10]) and in PICU (11 [9-15] vs. 9 [7-12]).

Conclusion. Positive SBT predicted successful extubation in a high percentage of cases. Respiratory distress on admission, higher programmed respiratory rate, and a higher proportion of T-tube mode were negative predictors of the test. Negative SBT was associated with more extended stays in IMV and PICU.

Keywords: *pediatric intensive care unit; mechanical ventilation; tracheal extubation.*

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INTRODUCTION

In pediatrics, weaning from invasive mechanical ventilation (IMV) is a process that culminates with removing the endotracheal tube (ETT) and is considered a failure if it is reinserted within 48 hours.[1] Prolonged IMV and extubation failures (EF) are associated with adverse clinical outcomes;[2,3] hence the importance of optimizing resources to minimize eventualities and correctly identify patients who are candidates for extubation.

The IMV weaning guide recommends the performance of a spontaneous breathing trial (SBT) as part of the preparation for extubation.[4] This SBT must be preceded by elements that determine the candidate's eligibility and constitute the preparation test.[1]

SBT is segmented into those without any support (TT: T-tube) and those with partial support [pressure support (PS) or continuous positive airway pressure (CPAP)] or total support (PS + CPAP). No SBT modality guarantees extubation success; supported trials, being less demanding, could harbor the possibility of false positives.[5,6] The current guidelines recommend using total or partial support in children without risk of extubation failure while reserving CPAP without PS for at-risk patients.[4] The different surveys of routine practice report a preference for SBT with total support, with a use rate between 60% and 80%.[7,8]

The purpose of this study was to describe the SBT in the IMV weaning process in our setting, evaluate its outcome and determine the existence of predictors of negative SBT and their impact.

OBJECTIVES

General

To analyze the outcome of SBT and its impact on the on the IMV release process in the PICU of the Hospital of the Hospital General de Niños Pedro de Elizalde (HGNPE).

Specific

To describe and compare demographic data and clinical characteristics of patients with positive versus negative SBT; and variables related to SBT, in order to determin predictors of negativity.

POPULATION AND METHODS

Design and population

Secondary retrospective database analysis of the study Implementation of a mechanical ventilation weaning protocol in a pediatric intensive care unit in Argentina,[9] carried out in the PICU of the HGNPE. The PICU is polyvalent, level 1, with 22 beds, receiving patients from 1 month to 18 years of age with different pathologies, except for cardiovascular and post-transplant post-surgical care.

All patients who required IMV for more than 48 hours between March 1, 2022, and January 31, 2024 were admitted consecutively. Deceased patients, those who required referral to another institution, and those with tracheostomy were excluded.

The demographic characteristics of the patients (age, weight, cause of admission, presence of comorbidities, and pre-established mortality index [PIM III: Paediatric Index of Mortality 3])[10] and variables related to SBT (type, duration, previous ventilatory status, arterial blood gases, and IMV parameters) were analyzed.

In our PICU, SBT has been protocolized since January 2022, using total support (CPAP and PS of 5 cmH_2O, respectively) in patients at risk (*Figure 1*), in whom preventive noninvasive ventilation (NIV) is used after extubation and, in the other cases, a TT is used. The SBT duration is 30 to 120 minutes (according to the treating team´s criteria).

SBT was defined as negative if: O_2 saturation <92% with fraction of inspired O_2 >50%; exhaled tidal volume <5 ml/kg; respiratory rate and heart rate greater than 30% and 20% of baseline, respectively; increased work of breathing (use of accessory muscles: costal, sternal and/or supraclavicular and/or supraclavicular retractions) and/or agitation, diaphoresis, and anxiety.

Statistical analysis

Categorical variables were expressed as absolute values or percentages, while continuous variables were expressed as measures of position and dispersion according to their parametric or nonparametric distributions. The Shapiro-Wilk test, frequency histograms, kurtosis and skewness metrics were used for distribution analysis.

When comparing groups, bivariate analysis was performed using Pearson's chi-square test for discrete variables and Student's t-test or Wilcoxon rank-sum (Mann-Whitney) for quantitative variables (depending on whether normality criteria were met).

A logistic regression was performed, where the dependent variable was the presence of negative SBT at any time during hospitalization, and the independent variables were patient demographics and outcome variables. In a second logistic regression of SBT events, negative SBT was considered the dependent variable, and the independent variables were those related to pre-trial ventilatory status and those related to SBT characteristics.

Statistical significance was established at *p* values <0.05. Data analysis was performed using STATA 13.0 for Mac (StataCorp LLC).

Bioethical aspects

The exception of informed consent for the study was requested since the IMV disengagement protocol was a standard of care. The recorded patient information was anonymized.

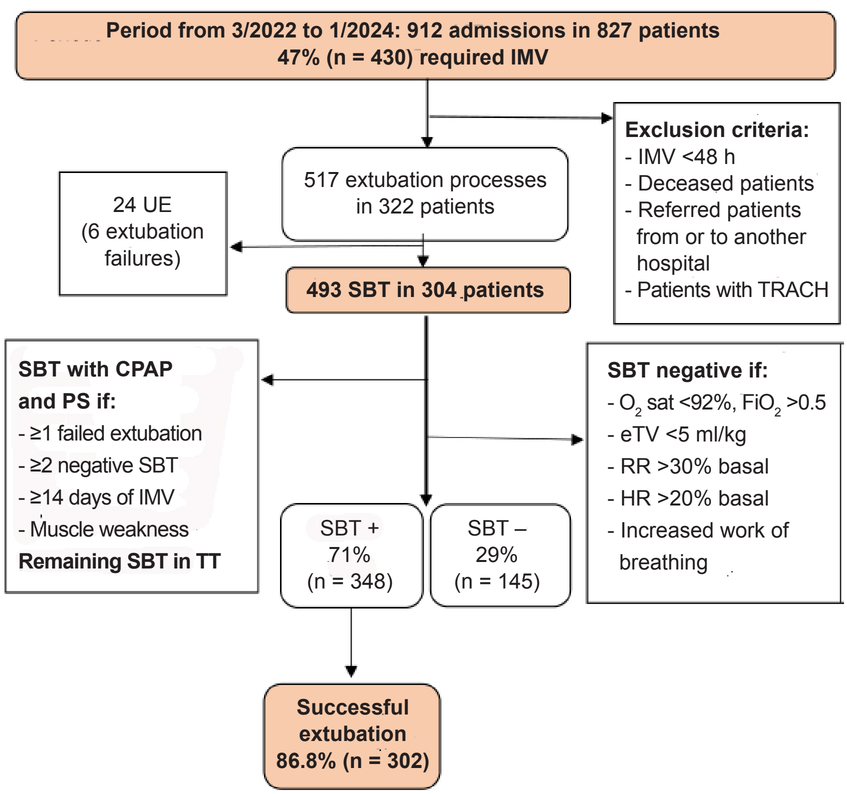
The present work is a secondary analysis of the data from the project approved by the Ethics Committee and the Department of Teaching and Research of the HGNPE and registered in the Registry of Research Projects of the Autonomous City of Buenos Aires (N.° 7026).

RESULTS

A sum of 912 admissions of 827 patients were recorded; 47% (430) required IMV. Inclusion criteria were met in 322 patients (*Figure 1*). The median age of the patients at admission was nine months (3-31 months), with a PIM 3 of 0.89 (0.52-4.45). Twenty-four percent had comorbidities (n = 78); respiratory distress was the leading cause of admission (85%, n = 274).

Of the 517 extubation processes analyzed, an SBT preceded 493; 24 patients had unplanned extubation (UE), with 6 EFs. Seventy-one percent of SBT were positive (n = 348), and 87% (n = 302) resulted in successful extubation. The TT modality was the most used (80.5%, n = 397). The causes of negative SBT (n = 145) were increased work of breathing (70%, n = 102), increased respiratory and heart rate (57% and 27% respectively, n = 83

Figure 1. Patient flow chart



n: number; IMV: invasive mechanical ventilation; h: hours; UE: unplanned extubations; SBT: spontaneous breathing trial:; CPAP: continuous positive airway pressure; PS: pressure support;; TT: T-tube; TRACH: tracheostomy;; O_2 sat: arterial O_2 saturation; FiO_2: fraction of inspired oxygen; eTV: exhaled tidal volume; RR: respiratory rate; HR: heart rate.

and 39), depressed sensorium (12%, n = 17) and O_2 desaturation (4%, n = 6).

In the univariate analysis, respiratory distress on admission, maximum inspiratory pressure (MIP) prior to SBT, and the higher proportion of SBT using a TT were predictors of negative trials (*Tables 1 and 2*). In the multivariate analysis of patient characteristics (*Table 3*) and SBT-related variables (*Table 4*), this association persisted for respiratory distress as a reason for admission, higher pre-trial IMV respiratory rate, and TT SBT modality.

Patients who presented negative SBT during the weaning process had a longer stay in IMV and in the PICU (*Table 1*).

Finally, the EF rate for the period, included UEs, was 14% (52/372).

DISCUSSION

SBT is a critical element of the IMV weaning process, although its results have been scarcely reported in the pediatric setting. With this objective, we conducted the present study and documented that, in our practice, positive SBT resulted in a high percentage of successful extubations.

There is a discrepancy in the way in which SBT is done. The supported options aims to increase sensivity in search of more chances of successfull extubation, but carries a risk of failure. The pediatric weaning guidelines and epidemiological studies support this practice. A survey of 555 pediatric intensivists (380 PICUs) reported that SBT with total support was the most frequent approach (80%), and half of the respondents configured PS about the size of the TET.[7,11] Nationwide, a survey in 80 PICUs reported the use of total support at 58%.[8]

In our PICU, the weaning process is protocolized, with the TT as the SBT preferred, while the modality with total support is reserved for those patients at risk of extubation failure. It is still being determined whether SBT should include PS; EET avoids natural upper airway resistance. On the other hand, resistance is a flow function, so when the flow is kept within limits related to the age and size of the EET, the increase in artificial airway resistance is minimal.[12,13] Under these premises, our choice of TT as the first choice is supported.

Khemani determined respiratory effort by esophageal manometry in four scenarios on 409 patients: PS 10 over 5 cmH_2O, CPAP 5 cmH_2O and spontaneous breathing 5 and 60 minutes post-extubation and reported that PS and CPAP underestimated the post-extubation effort in 126-147% and 17-25%, respectively, for all ETT subgroups.[5]

In our study, SBT in TT was used in a higher proportion in the SBT-negative group.

Table 1. Comparison of patients with negative spontaneous breathing trial in the extubation process versus patients without negative spontaneous trial

Variables	Patients with no negative SBT in the process (n = 201)	Patients with negative SBT in the process (n = 103)	*p*
Demographic characteristics			
Age (months)	10 (3-36)	8 (3-24)	0.303*
Weight (kg)	8.25 (6-14)	8 (5-14)	0.409*
Male	60% (120)	58% (60)	0.790#
PIM III	0.91 (0.51-3.66)	0.88 (0.55-3.17)	0.519*
Reason for respiratory admission	81% (163)	92% (95)	**0.008#**
Comorbidities	26% (52)	21% (22)	0.411#
Failure of previous extubation	13.2% (26)	19.4% (20)	0.150#
Results			
Days in IMV (total)	7 (4-10)	9 (7-12)	<0.0001*
Days in PICU	9 (7-12)	11 (9-15)	<0.0001*

Percentage (number); median (interquartile range).
** Wilcoxon rank-sum test (Mann-Whitney).*
 # Pearson chi-square test.
SBT: spontaneous breathing trial; PIM III: Paediatric Index of Mortality 3; IMV: invasive mechanical ventilation; PICU: pediatric intensive care unit.

Table 2. Comparison between positive and negative spontaneous breathing trial

Variables		Positive SBT (n = 348)	Negative SBT (n = 145)	*p*
Previous conditions to SVT				
IMV	PC mode	76% (265)	79% (115)	0.504 #
	MIP	19.2 (3.6)	20.2 (3.3)	**0.002** **
	PEEP	5.4 (0.6)	5.3 (0.6)	0.713**
	RR	21 (4)	22 (4)	0.061 **
	FiO_2	0.37 (0.09)	0.38 (0.09)	0.297 **
	eTV/kg	7.8 (1.6)	7.6 (1.9)	0.377 **
ABG	pH	7.45 (0.06)	7.45 (0.05)	0.935 **
	PCO_2	42 (8)	42 (8)	0.864 **
	PO_2	107 (34)	100 (33)	0.158 **
	HCO_3	29.2 (6.5)	29.2 (5.9)	0.797 **
	PO_2/FiO_2	309 (129)	279 (120)	0.078 **
Spontaneous breathing trial				
IMV days to SBT		7 (5-10)	7 (5-10)	0.515 *
SBT in TT		77% (268/348)	89% (127/145)	**0.0001#**
SBT with PS		23% (80/348)	11% (16/145)	**0.005#**
SBT duration (min)		50 (30-60)	30 (30-50)	**<0.0001** *

Percentage (number); means (standard deviation).
 # Pearson chi-square test.
** Wilcoxon rank-sum test (Mann-Whitney).*
*** Student's t-test.*
IMV, invasive mechanical ventilation; PC, pressure control; MIP, maximal inspiratory pressure; PEEP, positive end-expiratory pressure; RR, respiratory rate; FiO_2, fraction of inspired oxygen; eTV, exhaled tidal volume; ABG, arterial blood gas; PCO_2, partial pressure of CO_2; PO_2, partial pressure of oxygen; HCO_3, bicarbonate;
SBT: spontaneous breathing trail; TT: T-piece; PS: pressure support.

Table 3. Multivariate analysis of patient characteristics as risk factors for presenting at least one negative spontaneous breathing trial

Variables	OR	95%CI	*p*
PIM III	1.01	0.98-1.04	0.37
Reason for respiratory admission	2.78	1.09-7.11	**0.033**
Comorbidities	0.98	0.36-1.32	0.26
Weight (kg)	0.99	0.97-1.01	0.82
Previous extubation failures	1.3	0.67-2.5	0.42

PIM III: Pediatric Index of Mortality 3; OR: odds ratio; 95%CI: 95% confidence interval.

Table 4. Multivariate analysis of the conditions before the spontaneous breathing trial and the characteristics related to the spontaneous breathing trial as risk factors for presenting a negative trial

Variables	OR	95%CI	*p*
IMV PC mode	1.5	0.77-3.21	0.20
MIP	1.07	0.98-1.16	0.11
Respiratory rate in IVM	1.10	1.02-1.20	**0.013**
PO_2/FiO_2	0.99	0.99-1.00	0.85
SBT in T-tube	3.11	1.02-9.48	**0.045**
Duration of SBT	0.96	0.94-0.97	**<0.0001**

OR, odds ratio; 95%CI, 95% confidence interval; MIP, maximal inspiratory pressure; PC: pressure control; SBT: spontaneous breathing trial; IMV, invasive mechanical ventilation; FiO_2, fraction of inspired oxygen; PO_2, partial pressure of oxygen.

There are few studies in pediatrics that evaluate outcomes of SBT in general and one SBT over another. Chavez et al. analyzed an SBT using a T-piece/CPAP system; 92% (59 of 64 patients) were successfully extubated after a positive SBT, being the SBT specificity 37% with a negative predictive value of 50%.[14] Farias et al. observed no difference in reintubation rate (15.1% vs. 12.7%) in 257 children with IMV ≥48 h randomized to an SBT with PS vs. TT.[15] Vishwa et al. compared 2-h SBT with PS + CPAP (n = 121) vs. CPAP (n = 123), with successful IMV weaning after the first SBT in 80.2% of the PS group and 75.6% of the CPAP group.[16]

A recent meta-analysis compared the performance of PS over TT in 14 studies and 4459 adult and pediatric patients, reporting that patients were no more likely to pass an SBT with PS compared to TT; excluding one of these studies with discordant results, that probability was 9% higher for SBT in PS, which was associated with higher extubation success (7%), being 18 the number needed to treat.[17]

In our series, there were 7 days of IMV until the realization of the SBT; and there were 8 days in total of IMV.

According to the WIND classification, weaning processes are classified into four groups according to the duration of weaning after the first separation attempt: no separation, short weaning (<24 h), difficult weaning (24 h-7 days) and prolonged weaning (>7 days).[18]

This segmentation applied to the pediatric setting. It is associated with higher mortality for the non-separation and prolonged weaning groups.[19] Our serie is set in a difficult weaning process.

Regarding the duration of the SBT, in our study, it was 45 minutes; it was shorter in negative SBT. Recommendations suggest an extension between 30 and 120 minutes.[4]

Knox et al. analyzed 100 pediatric patients and 305 SBT, of which 42% were successful, 32% failed within 30 minutes, and 25% failed between 30 and 120 minutes. In the group of the patients with successful SBT within 30 minutes, 40% failed within 120 minutes, so the 30-minute could not be reliable.[20] Loberger compares 1-h SBT versus 2-h in 305 and 218 patients, respectively; he reports no difference in EF rate or the need for rescue NIV. The passing rate was higher in the 1-h trial (71% vs. 51%).[21]

In the present study, 29% of the SBT were negative. The leading causes were increased work of breathing, tachypnea, and tachycardia, and their predictors were respiratory distress on admission and higher programmed respiratory frequency prior to SBT and its modality in TT. Knox´s study found that patients with negative SBT were younger and had a lower weight, more hours of IMV, and a higher MIP prior to SBT; the clinical triggers for SBT failure were increased respiratory rate (77%), moderate or severe retractions (60%), and increased end-tidal CO_2 (16%).[20] Miller documented the conditioning factors of SBT over 720 events in 320 patients with congenital heart disease; 528 SBT were positive, and 58% (n = 306) resulted in extubation with 9.4% failure. Significant differences were in the SBT pass rate for ventilator mode, MIP, driving pressure, mean airway pressure, and dead space to tidal volume ratio.[22] In the Loberger study, the three leading causes of negative SBT were tidal volume ≤5 ml/ kg (23.6%), increased respiratory rate >30% (21%) and oxygen saturation <92%.[21]

A meta-analysis analyzed the different trials and predictor indexes of extubation on 41 publications and 8111 pediatric patients, the CROP index (which considers distensibility and dynamic, respiratory frequency, oxygenation index, and maximal inspiratory pressure) obtained the highest sensitivity and SBT the highest specificity, arguing that the low sensitivity of SBT could be because in most studies supported SBT were performed.[23]

All the above is intended to emphasize that there is no SBT or indicators that guarantee the success of extubation, but the standardization of SBT, its stratification according to risk factors, and its management by a respiratory therapist is a good practice; this was stated in a recent publication that analyzed the implementation of the different recommendations.[24]

In the present study, the EF rate was 14%, in the upper range of the rates traditionally reported (3% to 22%).[25] One possible explanation is that our work, by selecting patients with more than 48 h in IMV, segmented the cohort to a more complex weaning process; on the other hand, the cohort consisted mainly of patients with respiratory compromise as the cause of admission.

The main limitation of the present study is that it was carried out in a single center, so the population studied may have characteristics that make it impossible to extrapolate the results. Its design arises from a secondary analysis of a before-and-after study, which makes it impossible to establish causality. Although the study evaluates the result of the SBT, it does not allow the calculation of operational validity parameters since this would imply subjecting individuals with a negative trial to extubation. Its strength lies in the large number of cases and in exploring a variable that is scarcely documented, allowing us to diagnose the situation regarding the results of SBT in our routine practice.

CONCLUSION

Positive SBT was associated with successful extubation in a high proportion. Respiratory distress as a cause of admission, programmed respiratory rate prior to SBT, and a higher proportion of TT modality were negative predictors for the trial. Negative SBT in the weaning process was associated with a more extended stay in IMV and PICU. ■

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