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Influence of invasive ventilation modes on weaning and extubation evolution of critical patients

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ABSTRACT. The aim of this research was to analyze the influence of invasive ventilation modes on weaning and extubation process. It is a prospective cohort study that assessed patients admitted to the Intensive Care Unit (ICU) using Invasive Mechanical Ventilation (IMV). The following aspects were considered: ventilation mode used, days until evolution to weaning and extubation, its success/failure, hospitalization period, and ICU outcome (discharge/death). Sixty patients were assessed, 48 of which were admitted on volume-controlled ventilation (VCV), three on pressure-controlled ventilation (PCV), and nine on spontaneous mode. A total of 79% of VCV individuals and 67% of PCV went into spontaneous mode. There was no significant difference between modes for time until evolution to spontaneous breathing, neither between that and weaning and extubation. Among possible factors responsible for weaning and extubation success, only days on spontaneous mode influenced these outcomes, so individuals who breathed spontaneously for more days were 1.5% more likely to succeed at weaning and 1.3% more likely to succeed at extubation. The ventilation mode used at admission did not influence weaning and extubation process. Longer time on spontaneous breathing mode predicted the patients' greater chances of weaning and extubation success.

Keywords: artificial respiration; ventilator weaning; extubation; intensive care units; physiotherapy.

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Introduction

Invasive Mechanical Ventilation (IMV), or better referred to as Invasive Ventilation Support, is one of the therapeutic pillars of Intensive Care Units (ICUs) and a major tool for treating critical patients. Recent studies show that 30% to 50% of people admitted to these units use this support at some point. Another study conducted in 40 Brazilian ICUs showed that a little over half of the patients were on IMV. The purpose of the latter is to adjust oxygen supply and demand, decreasing muscle work and reducing respiratory discomfort; therefore, it can be defined as an artificial way to ventilate patients unable to breath spontaneously, replacing their ventilatory activity (Borges et al., 2016; Medeiros, Silva & Bastos, 2015; Damasceno et al., 2006; Melo et al., 2015).

However, it is not exempt from risks and, despite its benefits, is associated with high morbidity and mortality rates due to its connection with some complications, whether psychological or physiological, besides resulting in high costs for institutions, making it of paramount importance that patients return as quickly as possible to spontaneous breathing. Moreover, increased mortality in ICUs is closely related to a patient's prolonged time on IMV (Santos, 2015; Melo et al., 2017; Muniz et al., 2015).

The 2013 Mechanical Ventilation Brazilian Guideline of the Pneumology and Tisiology Brazilian Society [*Sociedade Brasileira de Pneumologia e Tisologia*] (SBPT) and the Intensive Medicine Brazilian Association [*Associação de Medicine Intensiva Brasileira*] (AMIB) recommends that patients should be admitted and ventilated on volume-controlled mode (VCV) or pressure-controlled mode (PCV). It also suggests that the preferable spontaneous mode should be pressure support ventilation (PSV) and that its use should start as early as possible. It also recommends that using synchronized intermittent mandatory ventilation (SIMV) should be avoided, as it proved to be associated with longer time for IMV withdrawal (Barbas, Ísola & Farias, 2013).

Therefore, patient survival rates do not depend only on factors present at the beginning of ventilation support, but also on development and handling of these factors throughout hospitalization. For this reason, proper conduct associated with a thorough clinical assessment by medical teams is required and must

always be up to date (Martins, Botti, Castro, Aguiar & Sleutjes, 2005; Teixeira, Gomes & Coelho, 2013; Moreira, Teixeira, Savi & Xavier, 2015).

Weaning is a process that should be performed individually and may occur rapidly or gradually. It consists of transition from artificial to spontaneous breathing in patients that stay more than 24 hours on IMV. Weaning is considered successful when the patient, still connected to the ventilator, succeeds on the spontaneous breathing test (SBT) (Goldwasser et al., 2007; Santos, 2015; Barbas et al., 2013).

It may pose a challenge when there is no clinical and careful judgement and bedside follow-up, since its prolongation is linked to higher mortality. For this reason, daily assessments and identifications of patients with possibility of discontinuing ventilation should be carried out along with suspension, also daily, of sedation so that the patient's spontaneous breathing capacity can be checked (Tallo, Sandre, Lopes, Simone & Lopes, 2014; José et al., 2013).

Extubation, in its turn, refers to removing the endolaryngeal prosthesis from the patient's airway, and its success depends on the need, or lack of, to reintubate the patient within 48 hours after the procedure. Therefore, the recommendation is to withdrawal the patient from invasive ventilation as quickly as possible when clinically viable. However, withdrawing the patient may be harder than keeping him or her on invasive ventilation because this process takes around 40% of mechanical ventilation total time (Goldwasser et al., 2007; Barbas et al., 2013).

Thus, due to the importance of ICU critical patients' prognosis, a more detailed study about the influence of ventilation modes employed on time until evolution to weaning and extubation becomes vital. In this sense, the study guiding question was: Does the ventilation mode employed in the treatment of critical patients interfere with weaning and extubation evolution time? The hypothesis, based on studies and guidelines already present in the literature, is that, depending on the ventilation mode used, there is some delay in weaning and extubation evolution.

In light of the foregoing, the objective of the present study was to analyze the relationship between invasive ventilation modes and their influence on ICU critical patients' weaning and extubation processes.

Methodology

The project was accepted by the University of Western São Paulo (UNOESTE) Ethics and Research Committee (CAAE No 79507317.3.0000.5515) and Presidente Prudente Regional Hospital (HRPP) Medical Ethics Committee according to Resolution 466/2012 CONEP.

This is a prospective cohort study. All patients selected were hospitalized in the HRPP general ICU from October 01 to November 02, 2017. Patient inclusion depended on Free and Informed Consent Form (FICF) signing after the patient's or responsible family member's agreement.

The inclusion criteria were: all patients who remained hospitalized in the HRPP general ICU, on IMV, for a period equal to and/or longer than 24 hours, and who were aged above 18, both genders. The exclusion criteria were: patients who were hospitalized but did not require IMV, those in palliative care determined by the medical team, and those who used IMV or were hospitalized in that unit but for a period shorter than 24 hours.

After inclusion, data referring to the patients' mechanical ventilation were recorded and divided into three groups: group I (GI) for volume-controlled ventilation mode (VCV), group II (GII) for pressure-controlled ventilation mode (PCV), and group III (GIII) for spontaneous breathing mode (PSV).

For each patient selected, the following information was duly noted: ventilation mode used at ICU admission and total days on it, the day when he or she began to breath spontaneously and total days on this mode, time from spontaneous breathing until evolution to weaning and extubation and their outcomes (success or failure). Then, gender, age, admission diagnostic hypothesis, the patient's comorbidities, type of treatment performed (clinical or surgical) were recorded as well, and a score system was adopted to quantify the gravity of the patient's disease at their admission moment (SAPS III). Finally, data referring to ICU hospitalization outcome were checked, such as total days in the unit and outcome (discharge or death).

Successful weaning was identified in those patients who, while still connected to the ventilator, succeeded on the SBT. Extubation success, in its turn, was considered when, after removal of the endolaryngeal prosthesis, the patients remained longer than 48 hours without needing reintubation; failure in this regard was identified when, in a period shorter than 48 hours, they were reintubated (Goldwasser et al., 2007; Barbas et al., 2013). The mechanical ventilators used in the HRPP ICU were Drager brand – model

Savina, version 03.04, and ventilator Nellcor Puritan Bennetti – Ventilation System 840.

Results were analyzed on electronic database. Then, statistical analysis was run by means of absolute and relative frequencies for qualitative variables, considering median and a 25-75% interquartile range for quantitative variables, since data were found to be non-parametric as per the Kolmogorov-Smirnov test. Differences between modes according to days since admission, days on spontaneous mode, weaning and extubation success, and ICU outcome were verified through the Kruskal-Wallis test with Dunn's *post hoc* for quantitative variables, or through the chi-squared test for qualitative variables. Assessments as to influence of sex, diagnostic hypothesis, likelihood of death, and days on admission mode and spontaneous mode on weaning and extubation success was conducted by means of binary logistic regression, observing the odds ratio (Exp(B)) and a 95% confidence interval (95% CI). All tests were carried out using SPSS 15.0 statistical software. The significance for all of them was set at $p < 0.05$.

Results

A total of 60 patients admitted to the ICU and who required IMV were assessed. Their ages ranged from 19 to 89 years old, with a median of 59.5 years. It is also noteworthy that 41 (68%) of the 60 individuals assessed were males, 47 (78%) had never smoked, and 33 (55%) came from the first-aid post. Diagnostic hypotheses were divided into three types: extrapulmonary (30%), pulmonary (35%) and surgical (35%); the most frequent comorbidities were related to cardiovascular diseases, 22 (36.6%), and metabolic ones, 19 (31.06%).

As for type of treatment undergone, 39 (65%) of the 60 patients investigated received clinical treatment, and 21 (35%) were subjected to surgical treatment. SAPS III was adopted, which quantifies the gravity of the patient's disease at ICU admission moment, as well as his or her likelihood of death, with the latter being considered high as per its score in statistical analyses (54.5 (34.1-74.3)). About total ICU hospitalization period and total OTI period, the median was 7 and 4 days, respectively. Table 1 displays these general characteristics of the study population.

Table 1. Study sample characterization (n=60).

Age (years), median (IQR)	59.5 (43.3-70.0)
Sex (F/M), n	19/41
Tobacco smoking history, n	
Not a tobacco smoker	47
Tobacco smoker	11
Former tobacco smoker	2
Origin n	
Nursing Ward	9
Surgical Center	18
First-Aid Post	33
ICU hospitalization days, median (IQR)	7.0 (3.0-12.8)
OTI days, median (IQR)	4.0 (2.0-9.0)
Diagnostic hypothesis, n	
Extrapulmonary	18
Pulmonary	21
Surgical	21
Comorbidity n	
Cardiovascular	22
Respiratory	7
Mental	12
Metabolic	19
Type of treatment, n	
Clinical	39
Surgical	21
Disease gravity (SAPS III), median (IQR)	69.0 (59.3-80.5)
Likelihood of death, median (IQR)	54.5 (34.1-74.3)

Legend: F/M: female/male; OTI: Orotracheal Intubation; Quantitative data expressed as median and 25-75% interquartile range (IQR); Qualitative data expressed as frequency (n).

The patients were subdivided into three groups, according to ventilation mode used at their ICU admission: VCV (GI); PCV (GII) and PSV (GIII). Information collected comprehended the total days that they

remained on admission mode before going into spontaneous mode, the total days that they remained on spontaneous mode before progressing to weaning and extubation, whether the latter were successful or failed, and ICU outcome.

GI included 48 patients, 38 of which progressed to spontaneous mode, and 10 passed away after sustaining it. Among the 38 patients, 21 succeeded at extubation, and only 19 had a successful weaning, as there were two accidental extubations without SBT. Eight patients evolved to tracheostomy (TCT), eight died before progressing to weaning and extubation, two of which progressed to brain death and were organ donators, and one patient was transferred to the Coronary ICU due to their diagnostic hypothesis. Finally, out of the 48 patients in this group, 29 were discharged from the ICU, 18 died and one was transferred to another ICU.

GII admitted three patients, two of which evolved to spontaneous mode, and one passed away before sustaining it. Of those two patients, one had successful weaning and extubation, and the other one progressed to TCT. Finally, two of the three patients in this group were discharged from the ICU, and one progressed to death.

GIII comprehended nine patients; because they had already admitted on spontaneous mode, all stayed this way. Among them, three succeeded at weaning, and four at extubation, as there was one accidental extubation without SBT. Two patients progressed to TCT, one of which had gone through a failed attempt of extubation, and three died before managing to progress to weaning and extubation. Finally, six of the nine patients were discharged from the ICU, and three passed away. Table 2 presents data collected from the three groups into which the patients were divided.

Table 2. Admission mode days, spontaneous mode days, weaning and extubation success, and outcome according to ventilation mode.

Modes	GI - VCV, (n=48)	GII - PCV, (n=3)	GIII - PSV (n=9)	p
Admission mode days, median (IQR)	2.0 (1,0-4,0)	3.0 (2.0-5.0)	3.0 (1.0-6.5)	0.461
Spontaneous mode	PSV (n=38)	PSV (n=2)	PSV (n=9)	
Spontaneous mode days, median (IQR)	3.0 (0.0-6.0)	8.0 (0.0-16.0)	4.0 (1.5-12.5)	0.461
Weaning success, n	19	1	3	0.420
Extubation success, n	21	1	4	0.654
ICU outcome, n				
Discharge	29	2	6	
Death	18	1	3	0.461
Transfer	1	0	0	

Legend: VCV: Volume-Controlled Ventilation; PCV: Pressure-Controlled Ventilation; PSV: Pressure Support Ventilation; ICU: Intensive Care Unit; Quantitative data expressed as median and 25-75% interquartile range (IQR); Qualitative data expressed as frequency (n). Kruskal-Wallis Test; *p < 0.05.

Concerning admission days on each ventilation mode, there was no difference as to total days on each one, but the largest number of individuals was found on VCV mode (80%). Following days on admission mode, the patients went into spontaneous mode, but there was no significance difference between modes in relation to total days on spontaneous mode either. Weaning and extubation success did not differ between admission modes, that is, the preceding ventilation mode did not influence weaning and extubation success or these patients' outcomes.

Table 3 indicates possible factors responsible for weaning and extubation success in the individuals assessed.

Table 3. Binary logistic regression for weaning and extubation success according to sex, diagnostic hypothesis, SAPS III, likelihood of death, and days on admission mode and spontaneous mode.

	Weaning Success			Extubation Success		
Variables	Exp (B)	95%CI	p	Exp (B)	95%CI	p
Sex	1.789	0.269-11.898	0.548	1.880	0.369-9.585	0.477
Diagnostic hypothesis	0.508	0.148-1.748	0.283	0.761	0.256-2.260	0.622
SAPS III	1.395	0.948-2.054	0.091	1.141	0.876-1.484	0.328
Likelihood of death	0.812	0.640-1.031	0.087	0.917	0.774-1.087	0.318
Admission mode days	1.488	0.899-2.462	0.122	1.415	0.924-2.167	0.111
Spontaneous mode days	1.479	1.046-2.092	0.027*	1.274	1.014-1.601	0.038*

**Legend: Exp (B): odds ratio; 95%CI: 95% confidence interval; *** p < 0.05.

It is worth highlighting that sex, diagnostic hypothesis, SAPS III and likelihood of death, and days on admission mode before days on spontaneous mode had no influence on the success of both weaning and extubation. Nevertheless, number of days on spontaneous mode influenced these outcomes, since

individuals who remained more days on spontaneous mode were 1.5% more likely to being successful at weaning, and 1.3% more likely of succeeding at extubation.

Discussion

IMV is key to maintaining and supporting a patient's life, but prolonging its time compromises post-discharge quality of life due to risk of specific complications, such as pneumonia associated with mechanical ventilation, barotrauma, tracheal lesions, and others. Taking them into account, weaning and extubation are extremely important tasks and must be started and performed as early as possible (Basto et al., 2014). This study analyzed the influence of ventilation modes on critical patients' weaning and extubation time.

OTI characterizes the beginning of IMV use, and when it is maintained for a period equal and/or longer than 24 hours, the removal of this type of prothesis from the patient can already be considered as weaning and extubation. All individuals included in the present study had this characteristic, which gives homogeneity to the population studied. This research also observed that the age median of all 60 patients investigated was 59.5 years, which differs from the study conducted by Melo et al. (2015), in which the patients' mean age was greater. However, this does not allow for a real comparison because that study restricted its mean age, differently from this research, which used statistics of greater reliability (Melo et al., 2015). As for patients' gender, our research had a higher predominance of males, which corroborates with a research showing the profile of patients admitted to ICUs, in which literature data reveal a predominance of males among ICU patients (Moreira, Nunes, Santos & Calles, 2013).

The most frequent diagnostic hypotheses for ICU admission found in our patients were pulmonary and extrapulmonary diseases, and surgical interventions, with prevalence of treatment of non-surgical, clinical patients. Other authors have also analyzed the frequency of these diagnostic hypotheses in intensive care environments and the prevalence of treatment of clinical patients that characterizes the profile of Brazilian ICUs (Silva et al., 2012; Ferreira, Machado, Martins & Sampaio, 2017).

Most critical patients have one or more pathologies associated with physiological disorders, such as Systemic Arterial Hypertension (SAH), Diabetes Mellitus (DM), Alcoholism, Kidney Failure, Tobacco Smoking, and others. Researches have been showing that the most frequent comorbidities found in ICU patients are SAH and DM (Silva et al., 2012), which corroborates with our study, as it revealed that the most frequent comorbidities were related to cardiovascular disorders (e.g., SAH) and metabolic disorders (e.g., DM).

In the present study, all patients admitted to the ICU on IMV came from other hospital sectors, with predominance of those coming from the First-Aid Post (FAP), followed by the Surgical Center (SC), and lastly from Nursing Wards. This characteristic is different from what other authors have presented, as they have shown an inverse situation compared to our study (Ferreira et al., 2017). This difference can be explained by the fact that the hospital where this study was conducted is a reference institution and receives the most serious cases from the whole region.

For treatment of critical patients, IMV is required most of the times. In our research, the patients' median of days on OTI was four, with IQR between 2.0-9.0 days, a result similar to that presented in another study showing that most patients remained on mechanical ventilation for up to ten days, with a median of two days (Lisboa, Medeiros, Alegretti, Badalotto & Maraschin, 2012).

About this study patients' ICU stay period, hospitalization ranged from one to 29 days, with a median of seven days and IQR of 3.0-12.8 days. In another research, hospitalization time stood at 11-30 days, with a permanence of 26.5 days. This, as already mentioned, cannot be taken into account for real comparison, since the statistical analyses run are different. Still in that research, the authors also addressed the patients' clinical evolution, with most of them progressing to death, differing from results found in our study, which observed a higher number of discharges. This shows the multidisciplinary work performed in our ICU and the problem-solving capacity with patients hospitalized in it (Melo et al., 2015).

Regarding the ventilation mode used for admission of patients to the ICU, the VCV mode was predominant in our study, differing from a retrospective study in a university hospital where the prevalent ventilation mode was PCV (Cruz, Tufanin & Gardenghi, 2015). This is due to the fact that any of these modalities can be used in the beginning of ventilation support, without recent evidence of superiority or greater effectiveness or safety of one over the other. Furthermore, the benefits of each one depend on countless other factors, such as the clinic, the comorbidities presented by the patient, and even on available mechanical ventilator (Araújo, Leão & Ferreira, 2014; Cunha, 2013).

When it comes to the influence of ventilation modes on weaning and extubation processes, our study, in a first analysis, showed no difference between ventilation modes used at admission as to total days before switching ventilation to spontaneous mode and total days before progressing to weaning and extubation among the patients. This can be explained by the fact that the SIMV mode was not used in any patient, which is considered in the literature as a predictor of increased time for withdrawal from MV, which leads to a larger number of complications (Barbas et al., 2013).

Running another type of statistical analysis (binary logistic regression), it was possible to find that patients who stayed longer on spontaneous breathing mode were more likely to have a successful weaning and extubation. This differs from what has been said about the need to with drawing the patient as early as possible from mechanical ventilation, which is explained by the fact that a thorough assessment is required from the multiprofessional team and that it should be performed only when all criteria are met, showing the importance of a physiotherapist throughout this process (Tallo et al., 2014; Barbas et al., 2013; Goldwasser et al., 2007). Additionally, according to the 3rd Mechanical Ventilation Brazilian Consensus, published in 2007, the PSV mode can be used for gradual weaning of IMV patients, a strategy that has been proved by means of random clinical trials as effective to reduce ventilation weaning failure (Goldwasser et al., 2007). A study assessing inspiratory muscle strength (IPmax) on weaning process also proved the effectiveness of gradual weaning, mainly in neurological patients; with five days, the patients began to show significant gains in respiratory muscle strength, and around ten days they were already capable of breathing spontaneously (Passarelli, Tonella, Souza & Gastaldi, 2011).

The study limitations involve difficulties of information collection, since the patients' treatment is carried out by many physiotherapists with different shifts, which may have resulted in different treatments and interpretation means for each patient. It was also necessary to exclude patients who did not meet the study inclusion criteria, as well as those who did not sign the FICF.

Conclusion

The ventilation mode used at admission of critical patients to the ICU did not influence their weaning and extubation process. Longer time on spontaneous breathing mode predicted these patients' greater chances of weaning and extubation success.

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