Spontaneous breathing trials: how and for how long?

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Purpose of review
Guidelines recommend systematic performance of a spontaneous breathing trial (SBT) before extubation in ICUs, the objective being to reduce the risk of reintubation. In theory, a more challenging SBT performed with a T-piece may further reduce the risk of reintubation, whereas a less challenging SBT performed with pressure-support ventilation (PSV) may hasten extubation.

Recent findings
Recent findings show that a more challenging SBT with a T-piece or for a prolonged duration do not help to reduce the risk of reintubation. In contrast, a less challenging SBT with PSV is easier to pass than a T-piece, and may hasten extubation without increased risk of reintubation. Although SBT with PSV and additional positive end-expiratory pressure is indeed a less challenging SBT, further studies are needed to generalize such an easy trial in daily practice. Earlier screening for a first SBT may also decrease time to extubation without increased risk of reintubation. Lastly, reconnection to the ventilator for a short period after successful SBT facilitates recovery from the SBT-induced alveolar derecruitment.

Summary
Several recent clinical trials have improved assessment of the most adequate way to perform SBT before extubation.

Keywords
airway extubation, pressure-support ventilation, spontaneous breathing trial, ventilator weaning

INTRODUCTION

Guidelines recommend systematic performance of a spontaneous breathing trial (SBT) before extubation in patients intubated at least 24 h in ICUs [1]. The main objective of the SBT is to mimic the postextubation physiological conditions, the objective being to reduce the risk of reintubation. While the overall rate of reintubation in ICUs is around 10–15%, it may exceed 20% in patients at high risk of extubation failure [2]. SBTs are usually performed with a T-piece by simply disconnecting the patient from the ventilator and providing additional oxygen, or by using low levels of pressure-support ventilation (PSV) approximating 7–8 cm H_2O, without disconnecting the patient from the ventilator. SBTs with a T-piece accurately reflect postextubation physiologic conditions, and work of breathing measured after extubation is similar to work of breathing measured using a T-piece [3,4]. Indeed, due to transient upper airway edema or to laryngeal lesions, immediately after extubation upper airway resistance remains high, and work of breathing does not decrease despite removal of the endotracheal tube. In contrast, SBTs performed with PSV are easier to pass, with work of breathing significantly lower than when using a T-piece [4,5]. Low levels of PSV were initially justified to reduce the work imposed by the ventilator circuit/valve and endotracheal tube [6]. However, due to technological improvements the work load has decreased considerably [7], and work of breathing is lower than after extubation. Work of breathing during a SBT without any assistance (PSV 0 cmH_2O) and without positive end-expiratory pressure (PEEP 0) is exactly the same as when using a T-piece [4]. By activating automatic tube compensation, work of breathing becomes lower than with a T-piece; but it usually remains higher than with PSV of 7–8 cmH_2O [8]. Although SBTs performed with PSV underestimate the work of

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Curr Opin Crit Care 2025, 31:86–92

DOI:10.1097/MCC.0000000000001227

KEY POINTS

- A more challenging spontaneous breathing trial with a T-piece or for a prolonged duration do not help to reduce the risk of reintubation.
- A less challenging spontaneous breathing trial with pressure-support may hasten extubation without increased risk of reintubation.
- Earlier screening for a first spontaneous breathing trial may decrease time to extubation without increased risk of reintubation.
- Reconnection to the ventilator for a short period could allow recovery from the alveolar derecruitment induced by spontaneous breathing trial.

breathing needed to breathe after extubation, no study has shown increased risk of reintubation as compared to T-piece. In contrast, a less challenging SBT with PSV may facilitate extubation decision-making.

In 1997, a large-scale randomized controlled trial (RCT) compared SBT performed with PSV (7 cmH_2O) or with a T-piece in 484 patients intubated for at least 48 h [9]. In accordance with physiologic results, the proportion of patients who passed the first SBT was higher with PSV than with a T-piece. However, the proportion of patients extubated after one SBT and not reintubated within the 48 h following extubation did not significantly differ, and the two SBTs were subsequently considered as equivalent. In 2019, another large-scale RCT compared SBTs performed with PSV (8 cmH_2O) for only 30 min or with a T-piece for 2 h in 1153 patients intubated for at least 24 h [10]. This time, the proportion of patients extubated after one SBT and not reintubated within the 72 h following extubation was significantly higher with PSV than with a T-piece. These findings once again confirm that an SBT with PSV is easier to pass than with a T-piece that may hasten extubation without increased risk of reintubation. However, these clinical trials included a majority of patients at low risk of extubation failure, and their findings might not be extrapolable to patients at high risk.

Another question is whether or not PEEP should be added during SBTs. A large-scale international observational study showed that SBTs were most commonly performed using PSV with additional PEEP [11]. Addition of PEEP may further decrease work of breathing and may also mask weaning-induced pulmonary edema, as it has been shown that PEEP decreases left ventricular filling pressures by decreasing both preload and afterload [5,12]. Therefore, addition of PEEP may further hasten extubation compared with no PEEP, but it could render the SBT too easy to pass, thereby leading to an increased risk of postextubation respiratory failure. Several recent studies shed light on these questions, especially as regards reintubation rates according to the difficulty of the SBT.

WHEN TO PERFORM A FIRST SPONTANEOUS BREATHING TRIAL?

Guidelines on weaning have emphasized that the first SBT must be performed as soon as the patient meets the following criteria [13]: patient awake, hemodynamic stability with no need for vasopressors (or minimal doses), respiratory rate $\leq$ 35 breaths/minute, adequate oxygenation defined as PaO_2/FiO_2 >150 mmHg on PEEP $\leq$ 8 cmH_2O and $FiO_2 \leq$ 40%, and adequate cough.

A multicenter, prospective, observational cohort study recently reported the factors independently associated with delayed initiation of the first SBT among 5869 patients under invasive ventilation [14▪]. In addition to patient-related factors such as frailty, severity and reason for admission (trauma and neurological events), deep sedation levels and use of continuous neuromuscular blockade were potentially modifiable factors independently associated with delayed weaning process. As a result, avoidance of excessive sedation whenever possible is likely to be a major decision that may hasten extubation.

To hasten extubation, a multicenter RCT recently compared earlier screening to initiate the first SBT with PaO_2/FiO_2 >180 mmHg on PEEP 10 cmH_2O and FiO_2 50% vs. usual screening with PaO_2/FiO_2 >150 mmHg on PEEP 8 cmH_2O and FiO_2 40% [15▪▪]. In the same study, they compared an easy SBT with PSV 8 cm H_2O and PEEP 5 cm H_2O vs. a standard SBT with PSV 5 cmH_2O and no PEEP for 30 min. In this trial, which included 940 patients at low risk of extubation failure, the main finding was that earlier screening with standard SBT or usual screening with an easy SBT were both associated with decreased time to extubation without increased risk of reintubation as compared to usual screening and standard SBT. However, early screening with an easy SBT was potentially harmful and this strategy was discontinued for safety reasons due to reintubation rates as high as 20%. Whereas this study rather favors early screening to initiate the first SBT, the objective being to decrease time to extubation (this strategy was associated with the shortest time to extubation), performing less challenging SBT using PSV and additional PEEP maybe another way to hasten extubation without increased risk of reintubation.

In addition to the usual criteria, the rapid shallow breathing index (RSBI), calculated as the ratio of respiratory frequency divided by tidal volume, is frequently used to decide on SBT initiation, high RSBI being associated with an increased risk of weaning failure. However, RSBI is calculated using tidal volumes expressed in milliliters, which may be markedly influenced by patient size and sex. A posthoc analysis of a multicenter RCT showed that despite higher RSBI, females were at lower risk of reintubation than males [16▪]. In fact, females had higher RSBI due to lower tidal volumes than males when expressed in milliliters while tidal volumes were similar when expressed in milliliters of predicted body weight. Based on a meta-analysis showing that RSBI had poor specificity for predicting extubation success [17], the guidelines proposed by the American Association for Respiratory Care suggested that RSBI was not needed to determine readiness for a SBT (conditional recommendation; moderate certainty) [18▪].

HOW SHOULD TO SPONTANEOUS BREATHING TRIALS BE PERFORMED?

Several clinical trials have recently compared patient extubation outcomes according to type of SBT, i.e. between an easy SBT or a more challenging SBT in terms of work of breathing. A large-scale multicenter RCT including 969 patients at high risk of extubation failure (age >65 years, or with any underlying cardiac or chronic respiratory disease), compared SBTs performed with PSV 8 cmH_2O and no PEEP or with a T-piece [19▪▪]. Although ventilator-free days at day 28 (primary outcome) did not significantly differ between groups, the proportion of patients who had weaning simple (i.e. extubated within the 24 h following the first SBT) was significantly higher with PSV than with a T-piece, while reintubation rates at day 7 were similar between groups. After this new study tending to favor of SBTs with PSV as opposed to a T-piece, we have now 3 large-scale clinical trials showing that SBTs performed with PSV may hasten extubation without increased risk of reintubation, even in patients at high risk of extubation failure (Figs. 1 and 2). Additionally, SBT with PSV is easier to perform than a T-piece since it involves no ventilator disconnection, requires no additional materials, and that allows continuous monitoring of tidal volumes and respiratory rate on a ventilator screen.

A recent network meta-analysis of RCTs (6196 patients) assessing reintubation rates according to type of SBT did not detect any significant difference between a SBT performed with PSV or a T-piece

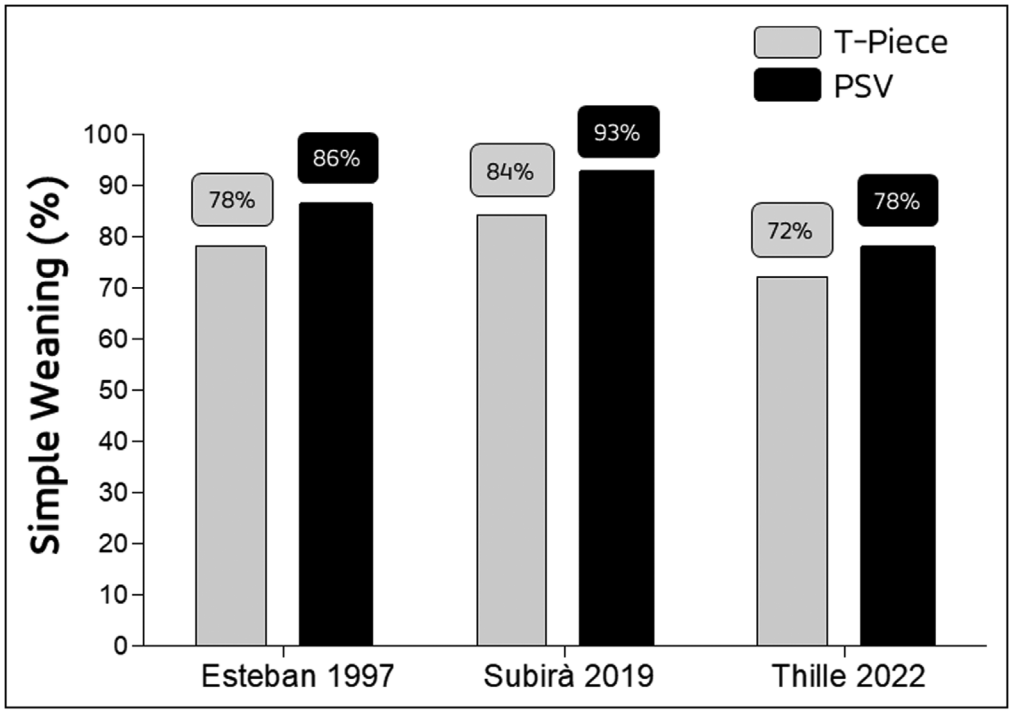

FIGURE 1. Bars comparing the proportion of patients with simple weaning, i.e. extubated after only one SBT or within the 24 h following the first SBT, between a first SBT performed with PSV or with a T-piece. In the first seminal randomized controlled trial published by Esteban and colleagues in 1997 (484 patients), and in the two more recent large-scale randomized controlled trials published by Subira *et al.* in 2019 (1153 patients) and Thille *et al.* in 2022 (969 patients), the proportion of patients with simple weaning was significantly higher using SBTs with PSV than with a T-piece.

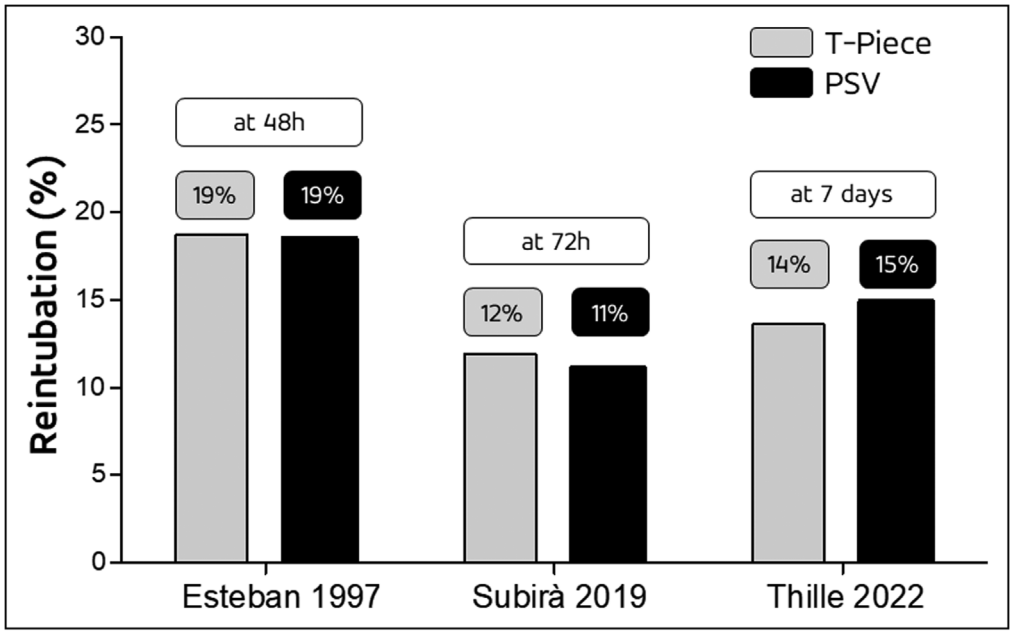

FIGURE 2. Bars comparing the rates of reintubation (at 48 h, 72 h or 7 days following extubation according to the study) between a first SBT performed with PSV or with a T-piece. In the first seminal randomized controlled trial published by Esteban and colleagues in 1997 (484 patients), and in the two more recent large-scale randomized controlled trial published by Subira *et al.* in 2019 (1153 patients) and Thille *et al.* in 2022 (969 patients), reintubation rates were similar regardless the type of SBT.

[20▪▪], meaning that a more challenging SBT in terms of work of breathing does not help to reduce the risk of reintubation. In contrast, another network meta-analysis (6716 patients) confirmed that an easy SBT performed with PSV facilitated extubation decision-making [21▪]. In this study, a higher proportion of patients passed the first SBT and were successfully extubated using SBTs performed with PSV rather than with a T-piece.

SBTs with PSV and additional PEEP represent less challenging trials that could further hasten extubation. In the above-mentioned meta-analysis [20▪▪], reintubation rates did not significantly differ between SBTs performed with PSV and additional PEEP or with a T-piece. These findings should nevertheless be interpreted with caution because only small-scale clinical trials have compared these two types of SBT, and no study has included a specific population at high risk of extubation failure. In a recent single-center RCT including 98 patients who had failed a first SBT with a T-piece, the risk of reintubation was not higher with PSV (7 cmH_2O) and PEEP (5 cmH_2O) than with a T-piece [22▪]. However, time to extubation was not significantly reduced in patients having undergone SBTs with PSV and PEEP compared to a T-piece, and a less challenging SBT might be more effective for the first SBT than in patients with weaning difficulties. Lastly, a less challenging SBT performed with PSV 8 cmH_2O and PEEP 5 cmH_2O reduced time to extubation compared to standard SBT with PSV 5 cmH_2O and no PEEP when the first SBT was initiated according to usual screening [15▪▪]. In contrast, the process was harmful when initiated with earlier screening, and further studies are needed to generalize such an easy trial with PSV and PEEP in daily practice.

WHAT IS THE OPTIMAL LENGTH OF SPONTANEOUS BREATHING TRIALS?

Whereas guidelines recommend performance of a SBT lasting from 30 min to 2 h [13], what matters is to know whether the SBT should last closer to 30 min than to 2 h, or vice versa. In a recent study assessing time to SBT failure in 100 pediatric patients having undergone 305 SBTs with continuous positive airway pressure of 5 cm H_2O for 2 h, SBT failure occurred subsequent to the first 30 min in around 40% of cases [23▪]. Therefore, the authors concluded that a 30-min SBT would probably be too short to detect potential SBT failure. However, SBT failure is partly based on subjective criteria with a high grade of variation due to the clinical assessor. Moreover, while patients were monitored with esophageal catheters to assess inspiratory effort, most SBT failures were based on excessive work of breathing, which is not among of the usual criteria for failure at the bedside. Lastly, the study did not assess extubation outcome and it is possible that some patients who failed the SBT between 30 min and

2 h may nonetheless have been successfully extubated. A previous study showed that in adults, around one third of SBT failures occurred between 30 min and 2 h [24]. Despite these findings, an old RCT assessing extubation outcomes showed no difference between a SBT performed with a T-piece for 30 min or for 2 h, and reintubation rates were exactly the same (13%), regardless of SBT duration [25]. A more recent RCT compared a SBT with PSV for 30 min or with a T-piece for 2 h, and once again, no difference was found in terms of reintubation [10]. In contrast, a higher proportion of patients were promptly and successfully extubated using a short rather than a prolonged SBT. Therefore, even though it has been shown that SBT failure may occur late subsequent to the first 30 min, no study has demonstrated that SBT lasting as long as 2 h may help to decrease the risk of reintubation.

WHAT CAN BE RECOMMENDED IN CLINICAL PRACTICE?

As several recent clinical trials have shown that SBT performed with PSV 8 cm H_2O and no PEEP decreased time to extubation without increased risk of reintubation as compared to T-piece [10,19▪▪], SBT with PSV should be preferred as a first option (Fig. 3). Although SBT performed with a T-piece indeed reflects work of breathing after extubation, no study has shown that a more challenging trial with a T-piece of for prolonged duration led to decreased risk of reintubation [20▪▪]. In fact, reintubation is often multifactorial and may be influenced by noninvasive respiratory supports initiated after extubation. Prophylactic noninvasive ventilation decreases the risk of reintubation in patients at high risk of extubation failure [26,27], and this strategy has probably more impact that the challenge proposed by the SBT. However, SBT with a T-piece for a prolonged period might be useful in patients with neuromuscular disease such as myasthenia gravis or Guillain-Barré syndrome, which are characterized by respiratory muscle fatigue. By contrast, an even less challenging SBT with PSV 8 cmH_2O and PEEP 5 cmH_2O may further hasten extubation without increased risk of reintubation. However, no large-scale clinical trials ensure safety regarding the risk of reintubation, especially in patients at high risk of reintubation. Combined with early screening to initiate a first SBT, SBT with PSV and PEEP may increase the risk of reintubation. Lastly, the actual usefulness of a SBT could be questioned, especially in patients at low risk of extubation failure. In a large-scale international study on weaning practices, more than 20% of patients were directly extubated without prior SBT [11]. However, no study has

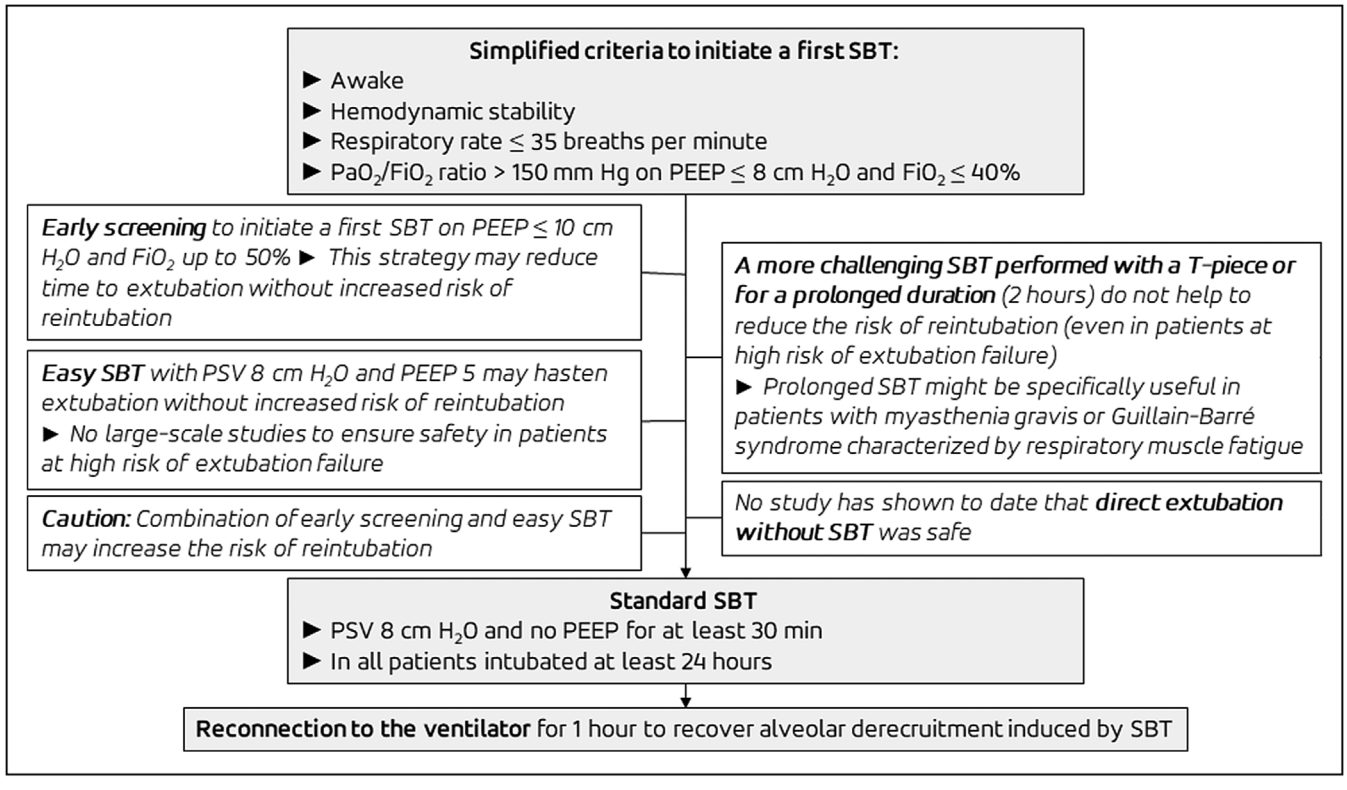

FIGURE 3. Figure summarizing the timing to perform a first spontaneous breathing trial (SBT), how and for how long SBTs should be performed, and what can be recommended in clinical practice.

demonstrated that reintubation rates were similar in patients extubated without SBT as compared to patients extubated after successful SBT, and SBT remains recommended before extubation of all patients mechanically ventilated for at least 24 h [1].

RECONNECTION TO THE VENTILATOR BEFORE EXTUBATION

It has been shown that reconnection to the ventilator for one hour after successful SBT may decrease the risk of reintubation, especially when SBT is performed with a T-piece [28]. While these findings were confirmed in a second clinical trial, it was only in the subgroup of patients extubated after more than 72 h of mechanical ventilation [21▪]. The physiologic mechanisms leading to this effect are unclear. An old physiological study demonstrated that even in case of SBT failure, patients did not exhibit fatigue of respiratory muscles at the end of SBT. However, reconnection to the ventilator could allow recovery from the alveolar derecruitment induced by SBT. A recent physiological study compared end-expiratory lung volumes at the end of a SBT performed with PSV or a T-piece, and after reconnection to the ventilator for one hour in 25 patients who passed the SBT [29▪▪]. Alveolar derecruitment at the end of the SBT was markedly more pronounced after a T-piece than with PSV. Reconnection to the ventilator for 1 h allowed complete recovery from SBT-induced alveolar derecruitment induced and may prevent respiratory failure after extubation. After a SBT performed with PSV, 10 min of reconnection to the ventilator was enough to completely recover volumes lost at the end of the SBT. A short period of reconnection to the ventilator should therefore be advocated before extubation with the aim of completely recovering pulmonary volumes.

CONCLUSION

Recent findings show that earlier screening for a first SBT may decrease time to extubation without increased risk of reintubation. A more challenging SBT with a T-piece or for a prolonged duration do not help to reduce risk of reintubation. In contrast, a less challenging SBT with PSV is easier to pass than with a T-piece, and may hasten extubation without increased risk of reintubation. Reconnection to the ventilator for a short period after successful SBT allows recovery from SBT-induced alveolar derecruitment.

Acknowledgements

We would like to thank Jeffrey Arsham, American translator at the University hospital of Poitiers, for English editing of the manuscript.

Financial support and sponsorship

None.

Conflicts of interest

A.W.T. received personal fees and travel expense coverage to attend scientific meetings from Fisher & Paykel, outside the topic of manuscript. The remaining authors have no conflicts of interest.

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