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Impact of pressure support ventilation duration after a spontaneous breathing trial on reintubation rates in critically ill subjects: a retrospective study

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Abstract

Background To investigate the effect of different durations of pressure support ventilation (PSV) after a spontaneous breathing trial (SBT) on 48-hour reintubation rates in critically ill subjects.

Methods This single-center retrospective cohort study included adult subjects who received mechanical ventilation for over 48 h, successfully completed SBT, and were scheduled for extubation in the intensive care unit of a tertiary hospital between January and December 2023. Subjects were divided into three groups based on PSV duration after SBT: direct extubation (DE, ≤ 30 min), short-term PSV (SP, 30 min–3 h), and long-term PSV (LP, 3–12 h). The primary outcome was the 48-hour reintubation rate. The secondary outcomes included intensive care unit length of stay and 28-day mortality.

Results A total of 982 subjects were included (638, 235, and 109 in the DE, SP, and LP groups, respectively). The 48-hour reintubation rates were 18.34%, 14.04%, and 16.51% in the DE, SP, and LP groups, respectively ($P=0.298$). Multivariate logistic regression showed no significant difference in reintubation risk for SP (OR = 0.73, $P=0.141$) and LP groups (OR = 0.88, $P=0.643$) compared with the DE group. Age (OR = 1.18, $P=0.003$) and APACHE II score (OR = 1.07, $P<0.001$) were identified as independent risk factors for reintubation. The median intensive care unit length of stay was 16 days in the DE group, 18 days in the SP group, and 19 days in the LP group ($P=0.033$). The 28-day mortality did not differ significantly among groups (12.85%, 11.91%, and 14.68%, respectively; $P=0.690$).

Conclusions PSV duration after SBT did not significantly affect reintubation rates in the overall population. While short-term PSV showed potential benefits in specific subgroups, particularly COPD patients, direct extubation after successful SBT appears safe for most patients and may reduce ICU length of stay. These findings suggest that extubation strategies should be individualized based on patient characteristics rather than applying extended PSV periods universally.

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Keywords Mechanical ventilation, Spontaneous breathing trial, Pressure support ventilation, Critical care, Oxygen therapy modality, Reintubation

Introduction

Mechanical ventilation is a cornerstone therapy in intensive care units (ICU), with approximately 40–60% of critically ill subjects requiring this intervention for respiratory support [1, 2]. While essential for maintaining adequate gas exchange and reducing work of breathing, prolonged mechanical ventilation is associated with various complications, including ventilator-associated pneumonia, respiratory muscle weakness, and increased mortality [3–6]. Therefore, timely and safe liberation from mechanical ventilation remains a crucial challenge in critical care medicine. Spontaneous breathing trials (SBTs) are suggested by the American Thoracic Society as a key assessment tool for evaluating readiness for extubation [7]. However, even after successful SBTs, more than 10% of subjects require reintubation within 48 h [8], a scenario associated with significantly increased mortality rates [6, 9, 10]. Although SBTs are widely accepted for assessing extubation readiness [11], controversy remains regarding their optimal implementation, including trial duration and methodology [12–14].

In clinical practice, various factors may delay extubation after a successful SBT, including organizational factors and patient-specific considerations [15–17]. Pressure support ventilation (PSV) has been established as an effective method for conducting SBTs, with multiple studies demonstrating advantages over T-piece trials [14, 18–20]. The success of ventilator weaning is closely related to respiratory muscle function [21, 22], and insufficient muscle strength or fatigue can lead to weaning failure [23, 24]. Some researchers have hypothesized that a rest period after SBT might facilitate respiratory muscle recovery and reduce reintubation rates. A recent study demonstrated that reconnecting subjects to the ventilator for one hour after SBT resulted in lower reintubation rates among subjects with prolonged mechanical ventilation [25]. Additionally, studies have shown that post-SBT ventilator support may aid in alveolar recruitment [26]. Despite these promising findings, evidence regarding the optimal duration of PSV after SBT remains limited, particularly concerning its benefits in specific patient populations [27].

This study aimed to investigate whether different durations of PSV after SBT affect reintubation rates in critically ill subjects, with particular attention to specific patient subgroups and different oxygen therapy modalities. We hypothesized that short-term PSV after SBT might reduce reintubation rates by allowing respiratory muscle recovery and optimizing alveolar recruitment, particularly in high-risk subjects. Our study specifically examines the post-SBT period using an intermediate level of pressure support - higher than during SBT but lower than pre-weaning support levels - to balance respiratory muscle recovery with maintained readiness for extubation [28, 29].

Methods

Study design and participants

This study was conducted at the Department of Critical Care Medicine of a tertiary hospital in southwestern China. We included adults (≥18 years) who received MV > 48 h, successfully completed an SBT, and were scheduled for extubation in 2023. Patients with tracheostomy, non-standard weaning, controlled ventilation after SBT, or incomplete data were excluded. Patients were categorized into three groups: Direct Extubation (DE, ≤30 min of PSV after SBT), Short-term PSV (SP, 30 min–3 h), and Long-term PSV (LP, 3–12 h). The study was approved by the hospital's ethics committee (S20240233-02) with waived informed consent.

Standardized weaning process and group classification

Following the hospital's established weaning protocol implemented in 2021 (Supplementary Material 1), all subjects underwent standardized weaning using PSV method for SBT. Daily weaning readiness was assessed using criteria including resolution of acute disease phase, adequate oxygenation (PaO2/FiO2 > 200 mmHg with PEEP ≤ 5 cmH2O), hemodynamic stability, adequate mental status, and cough strength [30–32]. The SBT was conducted using low-level pressure support (PS 5–8 cmH2O with PEEP 5 cmH2O), with initial durations of 30, 60, or 120 min.

After successful completion of SBT, subjects in SP and LP groups continued to receive individualized intermediate levels of pressure support ventilation, with support levels higher than during SBT but lower than pre-weaning levels (typically ranging from 8 to 12 cmH_2O with PEEP maintained at 5 cmH_2O). The pressure support levels were adjusted based on work of breathing parameters including rapid shallow breathing index (RSBI) and respiratory rate [33, 34], to ensure patients maintained stable respiratory patterns while allowing for adequate spontaneous breathing. Clinicians adjusted pressure support levels in real-time according to the patient's work of breathing, aiming to achieve a balance between maintaining adequate ventilation and preventing respiratory muscle fatigue. Patients requiring controlled ventilation after a successful SBT were excluded from the study, as

this typically indicates clinical deterioration or significant patient-ventilator asynchrony.

While variation in SBT duration introduces some heterogeneity, this practice reflects our institutional protocol based on clinical risk stratification, where longer durations were used for patients with previous extubation failure, prolonged ventilation (>7 days), or uncertain clinical stability [35–37]. To account for this potential confounder, we included SBT duration as a variable in our analysis. For successful SBT completion, a cuff leak test was performed, and extubation decisions were made jointly by physicians and respiratory therapists [38, 39]. Subjects were divided into three groups based on PSV duration after SBT: Direct Extubation (DE, ≤30 min), Short-term PSV (SP, 30 min–3 h), and Long-term PSV (LP, 3–12 h) (Figs. 1, 2, 3, 4, 5 and 6).

Post-extubation support and data collection

After extubation, subjects received either conventional oxygen therapy, high-flow nasal cannula oxygen therapy(HFNC), or noninvasive ventilation(NIV) based on respiratory parameters and clinical needs. Trained research personnel collected data including demographics, Acute Physiology and Chronic Health Evaluation II (APACHE II) and Sequential Organ Failure Assessment (SOFA) scores, comorbidities, ventilation parameters, and outcome indicators using standardized forms. High-risk extubation failure criteria included age>65 years, COPD, cardiac failure, multiple comorbidities, prolonged ventilation (>7 days), previous extubation failure, upper airway issues, APACHE II score>12, copious secretions, or BMI>30 kg/m². Subjects with ≥1 risk factor were classified as high-risk [40–43]. Subjects were classified as high-risk if they exhibited one or more of the identified risk factors. To address the potential cumulative impact of multiple risk factors, we also conducted a secondary analysis comparing outcomes between high-risk (≥1 risk factor) and low-risk (no risk factors) groups across the three PSV durations (DE, SP, and LP). This analysis aimed to determine whether the effect of PSV duration differed based on patients' risk profile.

Statistical analysis

Continuous variables were presented as medians (interquartile ranges) and categorical variables as frequencies (percentages). Between-group comparisons used chi-square tests for categorical variables and Kruskal-Wallis tests for continuous variables. Multivariate logistic regression and Cox proportional hazards analyses were performed to assess reintubation risk, adjusting for age, APACHE II score, COPD status, surgical status, and post-extubation oxygen therapy. Pre-specified subgroup analyses focused on COPD subjects and different oxygen therapy modalities. All analyses were performed using R software version 4.4.0, with $P<0.05$ considered statistically significant.

Results

Subject characteristics

A total of 982 subjects were included (638, 235, and 109 in the DE, SP, and LP groups, respectively). Table 1 shows the baseline characteristics. The median age ranged from

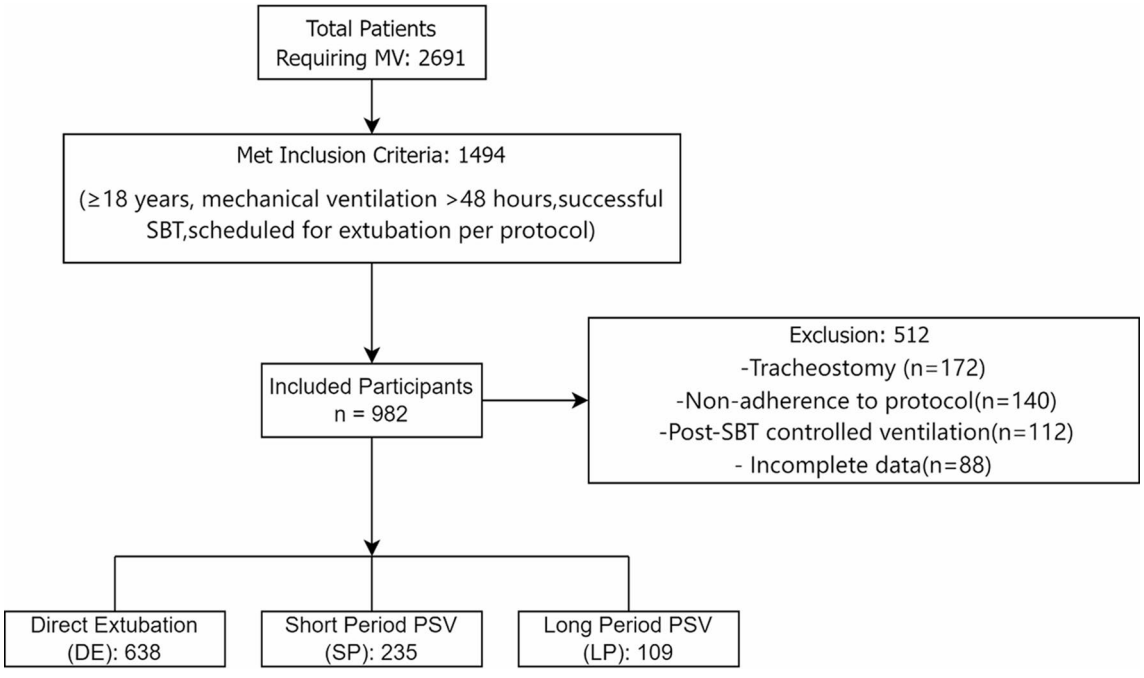

Fig. 1 Patient screening process diagram

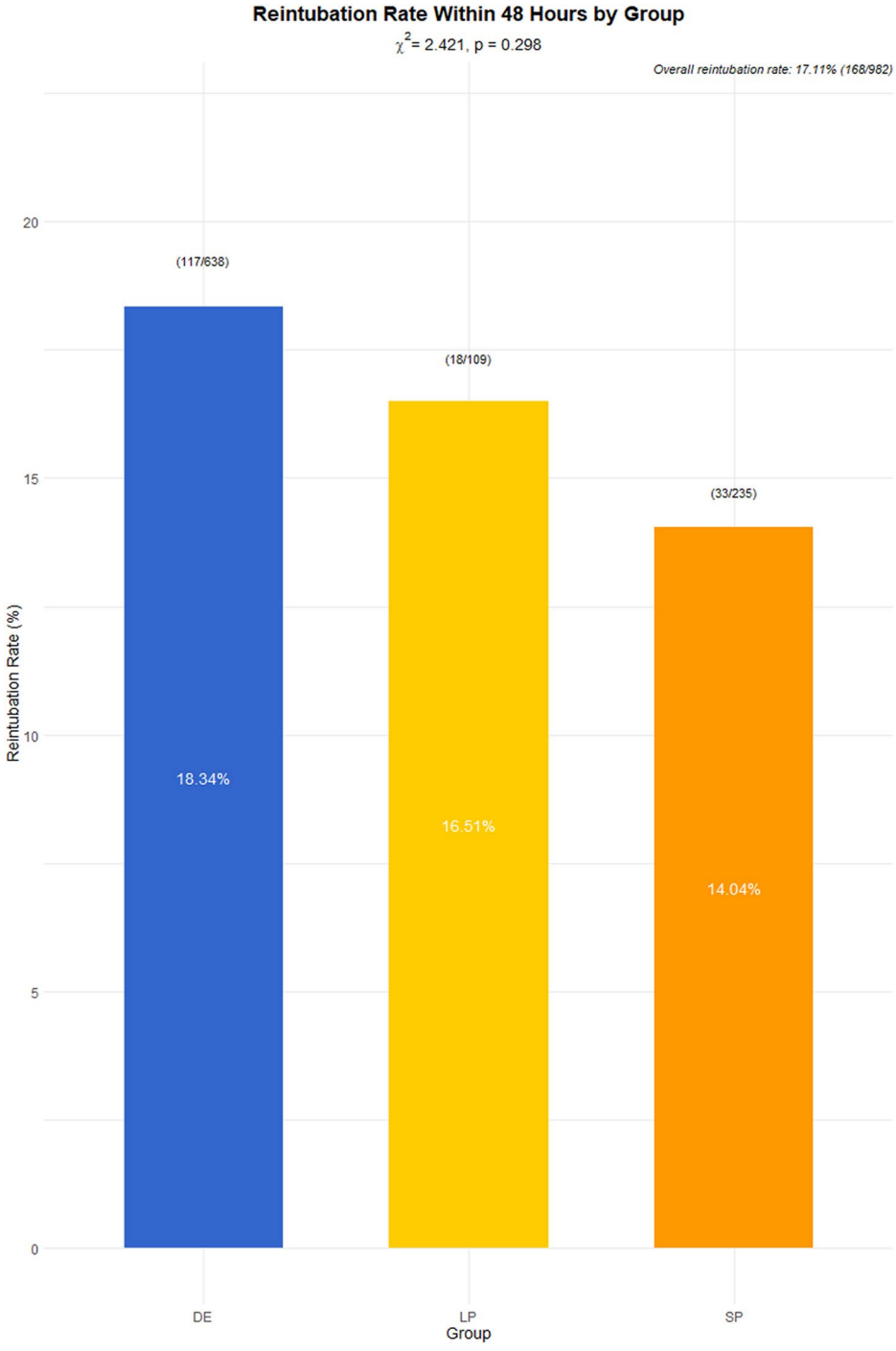

Fig. 2 Reintubation rate within 48 h for three groups of patients

55 to 59 years, with males accounting for 61.3% of the population. Medical subjects comprised 63.2% (621/982) of the cohort, while surgical subjects accounted for 36.8% (361/982). The median APACHE II score was 34 points (interquartile range [IQR]: 28–39), and the median SOFA score was 11 points (IQR: 8–14). The median duration of mechanical ventilation was 6.5 days (IQR: 4.0-9.5). These characteristics showed no significant differences among the three groups (all $P > 0.05$).

The top three primary reasons for intubation were acute respiratory failure (51.4%), post-operative respiratory support (29.4%), and coma (19.2%). Common comorbidities included hypertension (50.6%) and diabetes (19.3%). COPD prevalence differed significantly among the groups (DE: 14.9%, SP: 11.5%, LP: 31.19%,

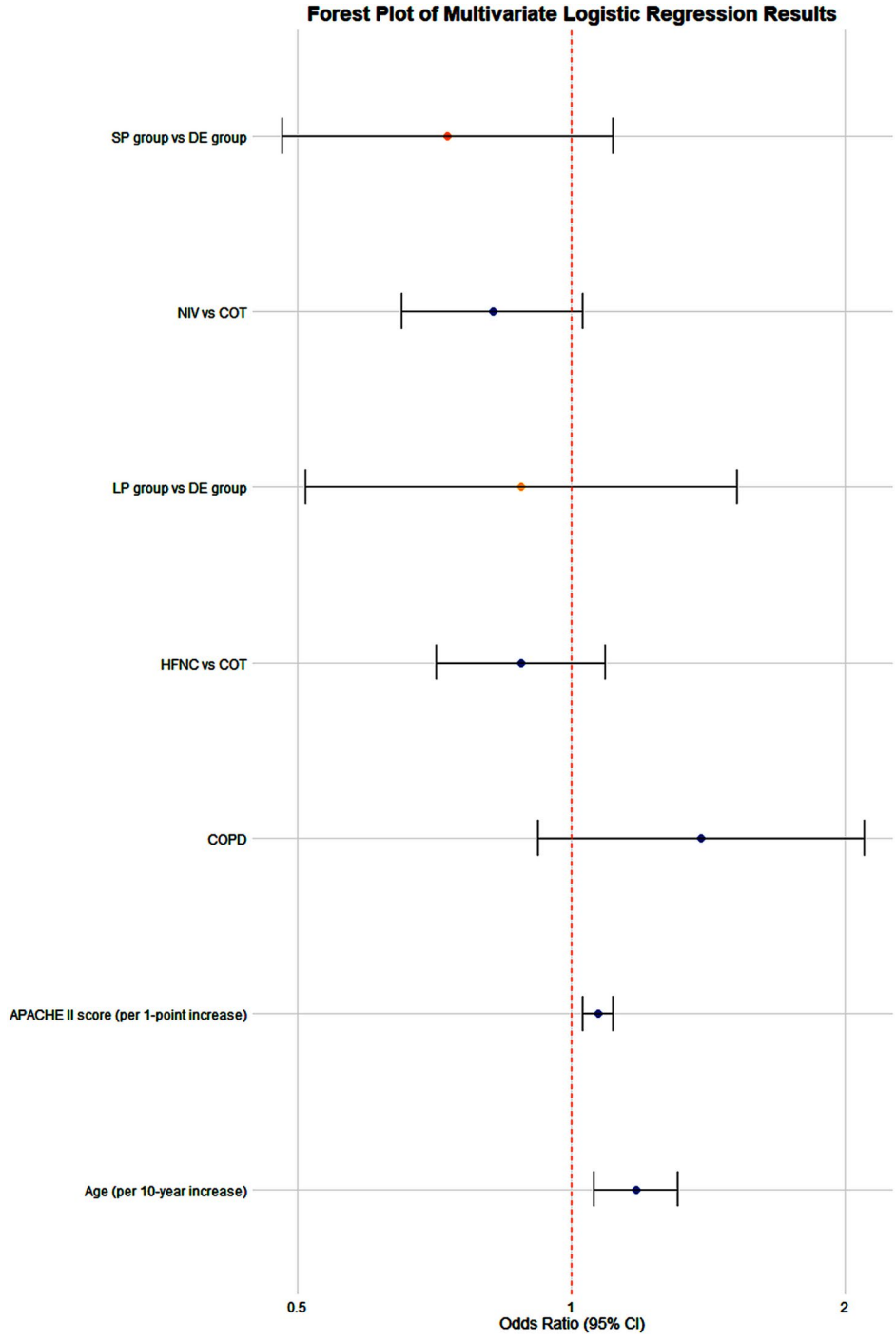

Fig. 3 Forest plot of multivariate logistic regression analysis

$P = 0.03$). The proportion of high-risk subjects (defined as having at least one high-risk criterion) was similar across groups (DE: 75.2%, SP: 76.1%, LP: 75.8%, $P = 0.87$).

Primary outcome

Analysis of our primary endpoint showed that the overall 48-hour reintubation rate was 17.1% (168/982), with no statistically significant difference between groups (DE: 18.34%, SP: 14.04%, LP: 16.51%; $\chi^2 = 2.421$, $P = 0.298$). Multivariate logistic regression analysis, adjusting for age, APACHE II score, COPD status, surgical status, and post-extubation oxygen therapy modality, showed no significant difference in reintubation risk for SP (OR = 0.73, 95% CI: 0.48–1.11, $P = 0.141$) and LP groups (OR = 0.88, 95% CI: 0.51–1.52, $P = 0.643$) compared with the DE

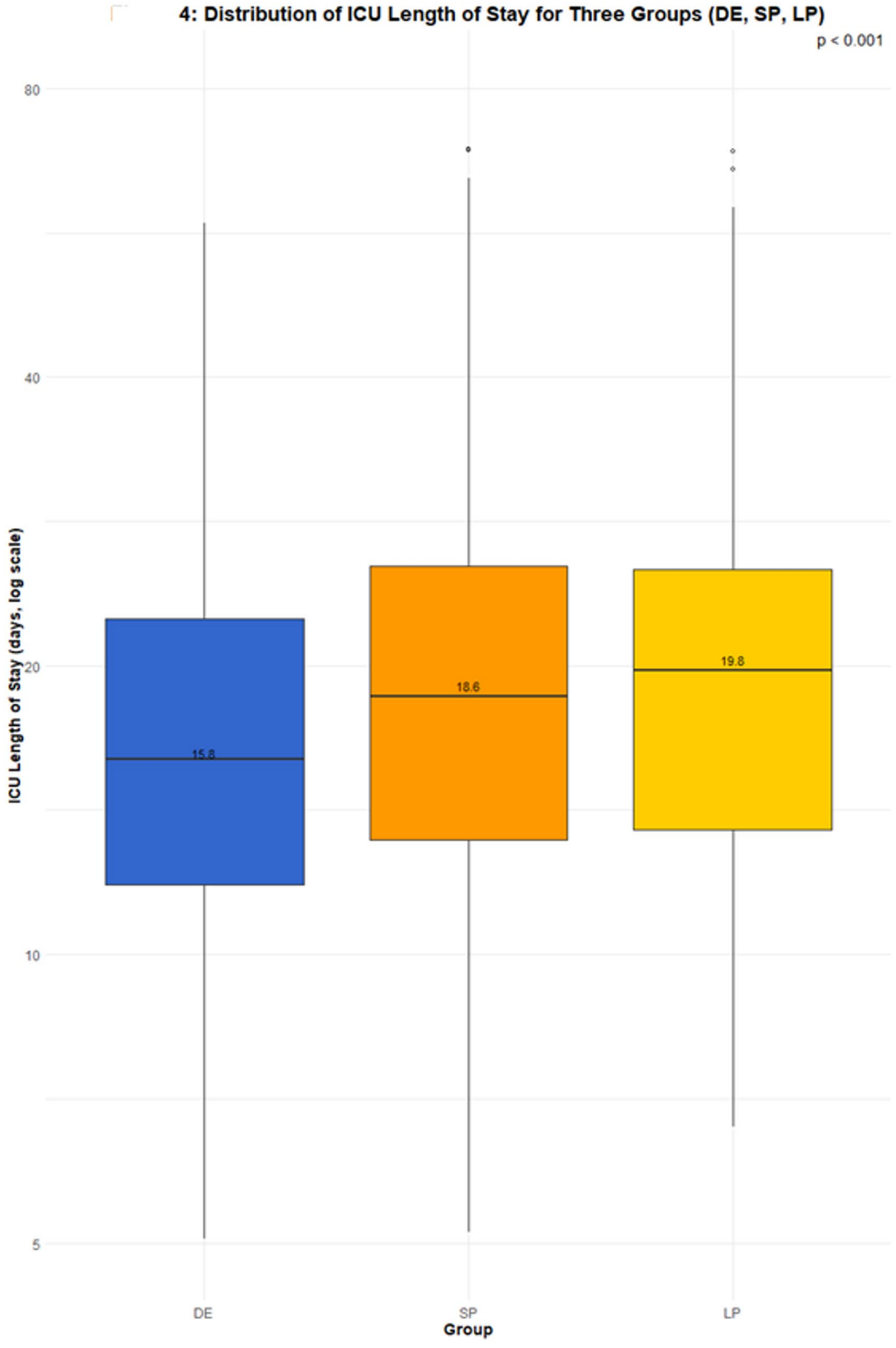

Fig. 4 ICU length of stay

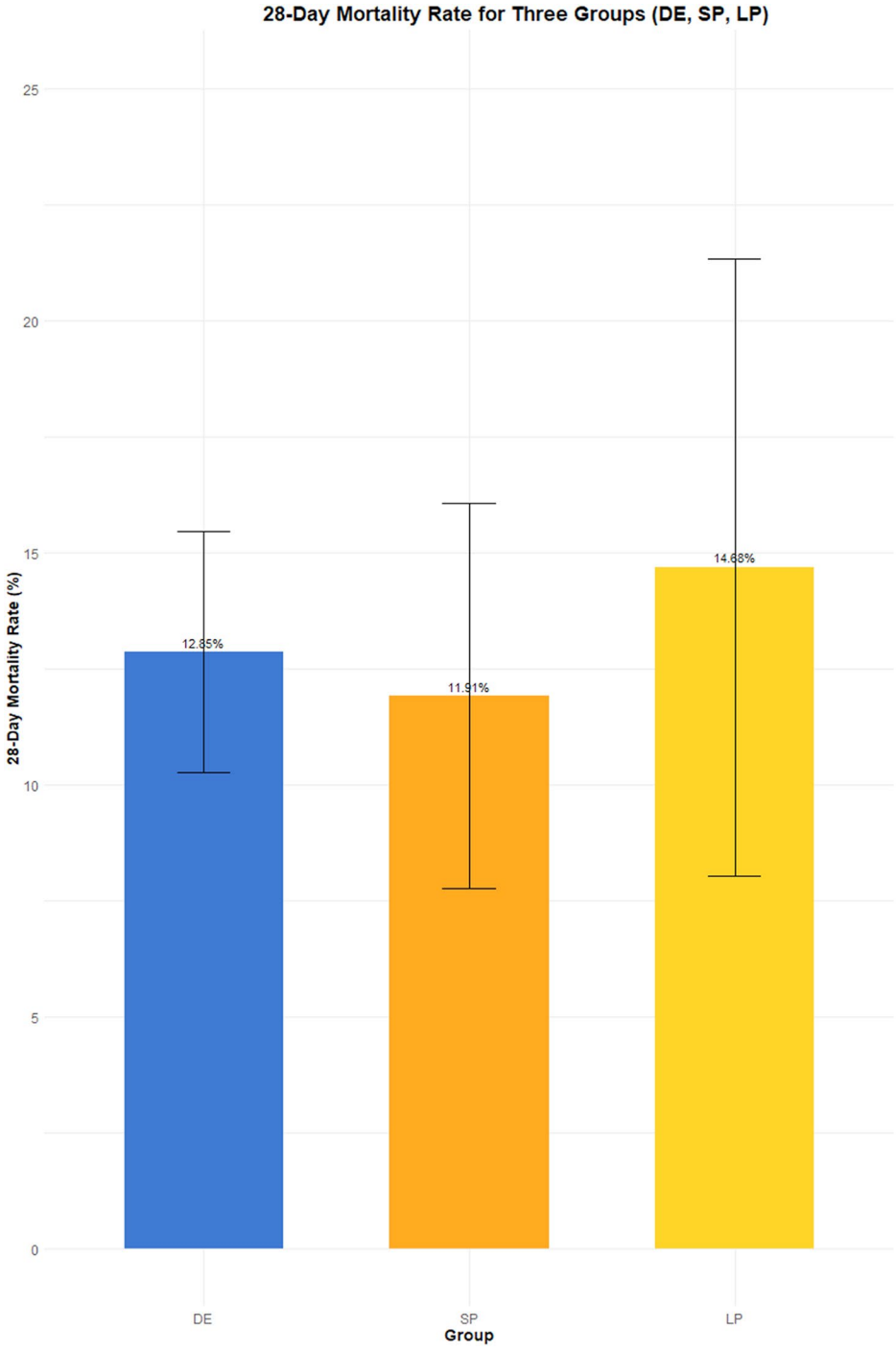

Fig. 5 28-day mortality rate of three groups of patients

group. Surgical status was not associated with reintubation risk (OR = 1.12, 95% CI: 0.78–1.61, $P = 0.542$).

Regarding oxygen therapy modalities, compared with conventional oxygen therapy, both NIV (OR = 0.82, 95% CI: 0.65–1.03, $P = 0.089$) and HFNC (OR = 0.88, 95% CI: 0.71–1.09, $P = 0.237$) showed trends toward lower reintubation risk, though not reaching statistical significance. Age (per 10-year increase, OR = 1.18, 95% CI: 1.06–1.31, $P = 0.003$) and APACHE II score (per point increase, OR = 1.07, 95% CI: 1.03–1.11, $P < 0.001$) were identified as independent risk factors for reintubation.

Analysis of different SBT durations showed reintubation rates of 16.9% (97/573), 16.3% (33/202), and 18.4% (38/207) for 30-minute, 60-minute, and 120-minute SBTs, respectively ($\chi^2 = 0.42$, $P = 0.81$), indicating no

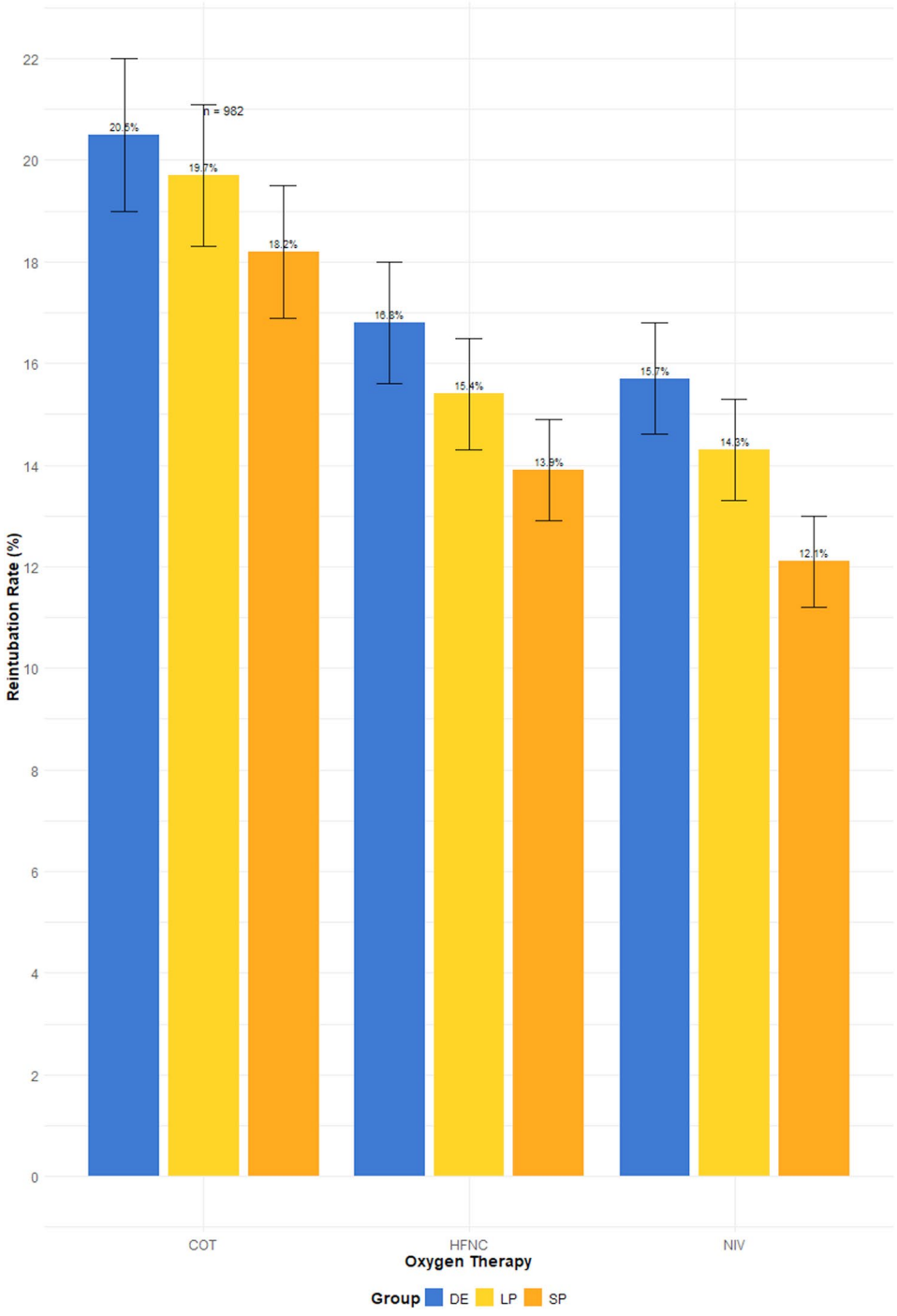

Fig. 6 Reintubation rates for three groups under different oxygen therapies

significant association between SBT duration and extubation outcomes.

Cox proportional hazards regression analysis, adjusting for age, APACHE II score, COPD status, surgical status, mechanical ventilation duration, and post-extubation oxygen therapy modality, showed no significant effect of PSV duration on reintubation risk (SP group: HR = 0.78, 95% CI: 0.53–1.14, $P = 0.198$; LP group: HR = 0.92, 95% CI: 0.56–1.51, $P = 0.741$). Mechanical ventilation duration was independently associated with reintubation risk (per day increase, HR = 1.11, 95% CI: 1.05–1.17, $P = 0.001$), with age (per 10-year increase, HR = 1.12, 95% CI: 1.01–1.24, $P = 0.032$) and APACHE II score (per point increase, HR = 1.04, 95% CI: 1.01–1.08, $P = 0.021$) as additional risk factors.

Table 1 Basic characteristics of included patients

Characteristics	DE (*n* = 638)	SP (*n* = 235)	LP (*n* = 109)	χ^2	*P*
Age, y, median (Q_1, Q_3)	57 (38, 76)	59 (40, 75)	55 (37, 74)	0.89	0.64
Sex (Male), n (%)	382 (59.87)	142 (60.43)	64 (58.72)	0.35	0.84
Admission type, n (%)				0.42	0.81
Medical	403 (63.17)	148 (62.98)	70 (64.22)		
Surgical	235 (36.83)	87 (37.02)	39 (35.78)		
BMI, kg/m^2, mean ± SD	25.3 ± 5.2	25.1 ± 5.0	25.4 ± 5.3	0.71	0.7
APACHE II score, median (Q_1, Q_3)	34 (18, 50)	35 (19, 52)	33 (17, 49)	0.83	0.66
SOFA score, median (Q_1, Q_3)	11 (6, 18)	12 (7, 19)	10 (5, 17)	0.96	0.62
Mechanical ventilation before SBT, d, median (Q_1, Q_3)	6 (5, 8)	7 (5, 9)	6 (4, 8)	0.80	0.67
Reason for intubation, n (%)					
Acute respiratory failure	325 (50.94)	121 (51.49)	57 (52.29)	2.34	0.31
Coma	122 (19.12)	46 (19.57)	20 (18.35)	2.70	0.26
Other reasons	86 (13.48)	31 (13.19)	15 (13.76)	2.92	0.23
Shock	65 (10.19)	23 (9.79)	11 (10.09)	3.03	0.22
Cardiac arrest	40 (6.27)	14 (5.96)	6 (5.50)	2.69	0.26
Comorbidities, n (%)					
Arterial hypertension	324 (50.78)	120 (51.06)	55 (50.46)	0.47	0.79
Diabetes mellitus	123 (19.28)	46 (19.57)	20 (18.35)	0.60	0.74
COPD	95 (14.89)	27 (11.49)	34 (31.19)	7.02	0.03
Neurologic disease	48 (7.52)	23 (9.79)	12 (11.01)	1.31	0.52
Cancer	45 (7.05)	22 (9.36)	11 (10.09)	0.71	0.7
Renal failure	71 (11.13)	25 (10.64)	13 (11.93)	0.50	0.78
Heart disease	98 (15.36)	37 (15.74)	16 (14.68)	0.69	0.71
Liver disease	47 (7.37)	18 (7.66)	8 (7.34)	0.33	0.85
High-risk patients, n (%)*	485 (76.02)	179 (76.17)	82 (75.23)	0.40	0.82
High-risk criteria, n (%)					
Age > 65 y	383 (60.03)	141 (60.00)	65 (59.63)	0.80	0.67
Comorbidities > 1	287 (44.98)	106 (45.11)	49 (44.95)	1.78	0.41
Prolonged MV (> 7 days)	305 (47.81)	115 (48.94)	52 (47.71)	0.62	0.73
Upper airway problems	115 (18.03)	42 (17.87)	20 (18.35)	0.40	0.82
COPD	95 (14.89)	27 (11.49)	22 (20.18)	6.25	0.04
APACHE II > 12	102 (15.99)	38 (16.17)	17 (15.60)	0.42	0.81
> 1 failed SBT	57 (8.93)	21 (8.94)	10 (9.17)	0.74	0.69
Copious secretions	115 (18.03)	42 (17.87)	20 (18.35)	2.05	0.36
BMI > 30 kg/m^2	121 (18.97)	45 (19.15)	21 (19.27)	1.17	0.56
Cardiac insufficiency	38 (5.96)	14 (5.96)	7 (6.42)	0.17	0.92

Abbreviations: DE, Direct Extubation; SP, Short-term PSV; LP, Long-term PSV; COPD, chronic obstructive pulmonary disease; APACHE II, Acute Physiology and Chronic Health Evaluation II; SBT, spontaneous breathing trial; BMI, body mass index; SD, standard deviation; Q_1, first quartile; Q_3, third quartile

*High-risk patient defined as having at least one high-risk criterion

Secondary outcomes

The median intensive care unit length of stay was 16 days (IQR: 10–25) in the DE group, 18 days (IQR: 12–27) in the SP group, and 19 days (IQR: 13–29) in the LP group ($P = 0.033$). Twenty-eight-day mortality rates were 12.9%, 11.9%, and 14.7% in the DE, SP, and LP groups, respectively ($P = 0.690$).

Post-extubation oxygen therapy distribution differed among groups, with higher NIV use in LP group (37.6%) compared to DE (19.9%) and SP (20.9%) groups (Table 2). When examining the interaction between PSV duration and post-extubation oxygen therapy, we observed consistent patterns across the three PSV groups. Within each oxygen therapy modality, the SP group demonstrated the lowest reintubation rates, though these differences did not reach statistical significance. The reintubation rates for conventional oxygen therapy were 20.5% (56/273), 18.2% (18/99), and 19.7% (7/35) for DE, SP, and LP groups, respectively ($P = 0.875$). For HFNC, the reintubation rates were 16.8% (40/238), 13.9% (8/57), and 15.4% (5/33) ($P = 0.721$), and for NIV, the rates were 15.7% (20/127), 12.1% (6/49), and 14.6% (6/41) ($P = 0.638$), respectively.

The significant difference in ICU length of stay among groups (median 16, 18, and 19 days for DE, SP, and LP groups, respectively, $P = 0.033$) raises important questions about the clinical impact of extended PSV duration. While prolonged PSV periods might provide physiological benefits for certain patients, our data suggest this practice may be associated with extended ICU stays. In resource-limited intensive care environments, this extension has substantial clinical and economic implications. Prolonged ICU stays not only increase healthcare costs but may also elevate the risk of hospital-acquired infections and other ICU-related complications. Notably, despite longer ICU stays in the SP and LP groups, reintubation rates were not significantly reduced in these groups, further questioning the clinical value of extended PSV periods.

This finding aligns with our primary conclusion that direct extubation after successful SBT completion may be safe for most patients without requiring extended PSV periods. Only in specific patient subgroups, such as

Table 2 Post-extubation oxygen therapy modalities and reintubation rates by PSV duration

Oxygen Therapy Modality	DE (*n* = 638)	SP (*n* = 235)	LP (*n* = 109)	*P*
Conventional Oxygen				
n (% of group)	273 (42.8)	99(42.1)	35 (32.1)	0.125
Reintubation, n (%)	56 (20.5)	18(18.2)	7 (19.7)	0.875
HFNC				
n (% of group)	238 (37.3)	87(37)	33(30.3)	0.324
Reintubation, n (%)	40 (16.8)	12(13.9)	5 (15.4)	0.721
NIV				
n (% of group)	127 (19.9)	49(20.9)	41 (37.6)	< 0.001
Reintubation, n (%)	20 (15.7)	6(12.1)	6(14.6)	0.638

DE: Direct Extubation; SP: Short-term PSV; LP: Long-term PSV; HFNC: High-Flow Nasal Cannula; NIV: Non-Invasive Ventilation

those with COPD, might short-term PSV provide some benefit, but even in these scenarios, the potential negative impacts of prolonged ICU stays should be considered. Therefore, we recommend clinicians consider the balance between resource utilization and clinical benefit when deciding on PSV duration, adopting more aggressive extubation strategies for most patients who complete SBT successfully.

Subgroup analyses

In the COPD subgroup ($n = 156$), reintubation rates did not significantly differ between DE (19.0%, 18/95), SP (14.8%, 4/27), and LP (16.7%, 6/34) groups ($P = 0.842$). Further analysis stratified by post-extubation oxygen therapy revealed that among COPD patients receiving NIV, the SP group demonstrated the lowest reintubation rate (0%, 0/2), compared to 14.8% (4/27) in DE and 9.1% (1/11) in LP, though subgroup sizes limited statistical power. This potential advantage of short-term PSV (SP) was counterbalanced by its association with prolonged ICU stays (median 18 days [IQR:12–27] vs. 16 days [IQR:10–25] in DE, $P = 0.033$). Notably, despite higher NIV utilization in the LP group (37.6% vs. 19.9% in DE), its reintubation rate in COPD-NIV patients (9.1%) remained statistically indistinguishable from DE (14.8%), suggesting extended PSV duration may not confer additional clinical benefits.

Among high-risk patients (≥ 1 risk factor, $n = 746$), reintubation rates were 18.8% (DE), 14.5% (SP), and 17.1% (LP) ($P = 0.364$), with similar trends observed in low-risk cohorts (17.0% vs. 12.7% vs. 14.8%, $P = 0.684$). Patients with ≥ 3 risk factors ($n = 295$) exhibited numerically higher reintubation rates (19.3% vs. 16.5% in those with 1–2 factors, $P = 0.317$), yet the SP group maintained the lowest rate (15.8% vs. 20.1% in DE). However, these marginal advantages in SP/LP groups were attenuated by their extended ICU stays (18–19 days vs. 16 days in DE) and comparable 28-day mortality (11.9% and 14.7% vs. 12.9% in DE, $P = 0.690$). Collectively, the analysis supports that direct extubation following successful SBT (DE) achieves clinical safety comparable to PSV-based strategies, while the modest reintubation reductions in select subgroups (e.g., SP in COPD-NIV patients) must be weighed against the increased ICU resource utilization associated with prolonged ventilator support.

Discussion

Our analysis yielded three principal findings. First, PSV duration after SBT did not significantly affect 48-hour reintubation rates, while mechanical ventilation duration emerged as an independent risk factor (11% increased risk per day). Second, the short-term PSV group showed numerically lower reintubation rates, particularly in COPD patients, though not reaching statistical significance. Third, this pattern remained consistent across different oxygen therapy modalities, suggesting potential value in individualized post-SBT support strategies [44–46]. The severity of illness in our study population deserves emphasis. With median APACHE II and SOFA scores of 34 and 11 points respectively, our cohort represents high-acuity critically ill patients. The notably high severity scores observed may reflect the evolving COVID-19 management policies and associated resource allocation priorities during the study period. The substantial ICU length of stay (median 16–19 days) and 28-day mortality (11.9–14.7%) further illustrate this point. Our finding that extended PSV periods did not reduce reintubation rates even in these vulnerable patients suggests direct extubation after successful SBT may be safe across a spectrum of critically ill patients. Our approach of using intermediate pressure support levels after SBT differs from previous studies that did not specify the post-SBT ventilatory mode. The intermediate support strategy we adopted aims to strike a balance between preventing respiratory muscle fatigue and maintaining weaning momentum. This may explain why our results differ from previous studies examining post-SBT ventilator support. Our findings differ from recent studies exploring post-SBT ventilator support. Fernandez et al. [25]. reported that 1-hour post-SBT ventilation significantly reduced reintubation rates (5% vs. 14%, $P < 0.001$) in their multicenter trial. Similarly, Dadam et al. [27]. found significant benefits in subjects ventilated for > 72 h (12.7% vs. 22.6%, $P = 0.04$). Several factors might explain these disparate results. It is noteworthy that because we used PSV (PS 5–8 cmH_2O with PEEP 5 cmH_2O) instead of a T-piece trial during SBT, the subjects had already received a certain level of support during the SBT. This might have diminished the additional benefits of prolonged PSV on respiratory muscle recovery and alveolar recruitment after SBT, leading to no significant differences observed among the groups. First, our study's broader population likely introduced greater heterogeneity. Second, our PSV

protocol during SBT differs from the T-piece method used in previous studies [11]. The use of PSV during SBT may better maintain alveolar recruitment [20, 47], potentially reducing the additional benefit of extended post-SBT support. Recent evidence suggests shorter SBT durations may be as effective as longer trials [12]. Our analysis showed comparable reintubation rates across 30-minute, 60-minute, and 120-minute SBTs, suggesting optimal approach may depend more on patient characteristics than standardized duration.

The duration of SBT itself remains controversial. While traditional protocols advocate for 30–120 min trials [48, 49], recent evidence suggests that shorter durations might be equally effective. Subirà et al. [12]. demonstrated comparable outcomes between 30-minute and 2-hour trials. Our findings extend this discussion by examining various post-SBT PSV durations, suggesting that the optimal approach might depend on patient characteristics rather than a standardized duration.

Our subgroup analyses revealed particularly interesting patterns in COPD subjects. The trend toward lower reintubation rates in the short-term PSV group (14.8% vs. 19.0% in DE) aligns with physiological principles. COPD subjects often experience increased work of breathing and are susceptible to respiratory muscle fatigue [50, 51]. The combination of short-term PSV with appropriate post-extubation support (particularly NIV) might provide a crucial window for respiratory muscle recovery while maintaining adequate ventilation [52, 53].

The interaction between PSV duration and post-extubation oxygen therapy modalities deserves special attention. Our data showed consistently lower reintubation rates with HFNC and NIV compared to conventional oxygen therapy across all PSV duration groups. This observation supports recent guidelines recommending these advanced oxygen delivery methods for high-risk subjects [54, 55]. The similar patterns across PSV durations suggest that the choice of post-extubation support might be more crucial than PSV duration itself. Interestingly, the lowest reintubation rates were consistently observed in the SP group regardless of the post-extubation support modality, suggesting a potential additive effect of short-term PSV combined with appropriate post-extubation respiratory support. This finding aligns with the physiological principle that a brief period of respiratory muscle recovery followed by adequate ventilatory support might optimize extubation outcomes. The trends were particularly notable in COPD subjects receiving NIV, where the combination of short-term PSV and NIV yielded the lowest reintubation rates, although the small sample sizes in these specific subgroups limit the statistical power of these observations.

The significant difference in ICU length of stay among groups (median 16, 18, and 19 days for DE, SP, and LP groups, respectively) raises important practical considerations. While extended PSV might provide physiological benefits for some subjects, it could potentially delay ICU discharge and increase healthcare costs. In our center, like many ICUs in China, the practice of weaning has evolved to emphasize both safety and efficiency. The standardized use of PSV during SBT, rather than T-piece trials, reflects this balanced approach and aligns with recent international trends [56, 57].

Our study has several limitations. As a single-center retrospective study, selection bias and unmeasured confounding factors may have influenced our results [58], while the absence of standardized criteria for PSV duration extension potentially introduced practice variation. Though our overall sample size was substantial, some subgroup analyses (particularly COPD patients with different oxygen therapies) had limited statistical power. Important physiological measurements such as respiratory muscle function [58, 59] and ICU-acquired weakness [60, 61] were not systematically documented, limiting mechanistic insights. Additionally, findings from our tertiary Chinese hospital may not fully generalize to settings with different weaning practices or resource availability.

Future research should address these limitations through prospective studies with standardized protocols, incorporating physiological assessments (e.g., diaphragmatic ultrasound [62]) and electrical impedance tomography [63, 64], and cost-effectiveness analyses to better inform individualized weaning strategies.

Conclusions

Although our study did not demonstrate a statistically significant effect of PSV duration on reintubation rates, we observed interesting trends, particularly in certain subgroups. This emphasizes the importance of adopting individualized strategies during the extubation process for critically ill subjects. In clinical practice, physicians should comprehensively consider subjects' individual characteristics, underlying diseases, and oxygen therapy requirements to formulate optimal extubation strategies. Future research should focus on more precisely defining the subject groups most likely to benefit from extended PSV and explore the potential synergistic effects of combining PSV with other supportive measures.

Abbreviations

ICU	Intensive Care Unit
PSV	Pressure Support Ventilation
SBT	Spontaneous Breathing Trial
HFNC	High-Flow Nasal Cannula Oxygen Therapy
NIV	Noninvasive Ventilation
APACHE II	Acute Physiology and Chronic Health Evaluation II
SOFA	Sequential Organ Failure Assessment
COPD	Chronic Obstructive Pulmonary Disease
DE	Direct Extubation
SP	Short-term PSV

LP	Long-term PSV
RSBI	Rapid Shallow Breathing Index
OR	Odds Ratio
HR	Hazard Ratio
CI	Confidence Interval
BMI	Body Mass Index

Supplementary Information

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Supplementary Material 1

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Author contributions
Jinlong Xu: conceptualisation, methodology, formal analysis, writing-original draft and visualization. Zefang Liu: conceptualisation, methodology, writing-original draft, writing-reviewing & editing. Simei Wang: methodology, data curation, resources, validation reviewing & editing and supervision. Zhenghua Liang: conceptualisation, software, reviewing & editing, methodology, visualization, and formal analysis. Qiuyu Liu: methodology, data curation, software, writing-original draft and writing-reviewing and editing. Zhihua Xu: data collection, literature review, reviewing initial draft. Pingzhen Wu: clinical data collection, data entry, reviewing initial draft. Lijun Liang: supervision, methodology, visualization, writing-reviewing and editing.

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Data availability
Data are available upon request from the authors.

Declarations

Ethics approval and consent to participate
This study was approved by the Ethics Committee of Mianyang Central Hospital (approval number: S20240233-02). The requirement for informed consent was waived due to the retrospective nature of the study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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