"Likely overassistance" during invasive pressure support ventilation in patients in the intensive care unit: a multicentre prospective observational study

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Abstract

Objective: To evaluate the prevalence of "likely overassistance" (categorised by respiratory rate [RR] ≤ 17 breaths/min or rapid shallow breathing index [RSBI] ≤ 37 breaths/min/L) during invasive pressure support ventilation (PSV), and the additional prevalence of fixed ventilator settings.

Design: Multicentre prospective observational study of invasive PSV practice in six general Victorian intensive care units with blinding of staff members to data collection.

Patients: At each hospital, investigators collected data between 11 am and 2 pm on all invasive PSV-treated patients on 60 sequential days, excluding weekends and public holidays, between 22 February and 30 August 2017. Each patient was included for maximum of 3 days.

Main results: We studied 231 patients, with a total of 379 observations episodes over the study period. There were 131 patients (56.7%) with at least one episode of RR ≤ 17 breaths/min; 146 patients (63.2%) with at least one episode of RSBI ≤ 37 breaths/min/L, and 85 patients (36.8%) with at least one episode of combined RR ≤ 17 breaths/min and RSBI ≤ 37 breaths/min/L. Moreover, the total number of observations with "likely overassistance" (RR ≤ 17 or RSBI ≤ 37 breaths/min/L) was 178 (47%) and 204 (53.8%), respectively; while for both combined criteria, it was 154 (40.6%). We also found that 10 cmH_2O pressure support was delivered on 210 of the observations (55.4%) and adjusted in less than 25% of observations. Finally, less than half (179 observations) of all PSV-delivered tidal volumes (V_T) were at the recommended value of 6–8 mL/kg predicted body weight (PBW) and more than 20% (79 observations) were at ≥ 10 mL/kg PBW.

Conclusion: In a cohort of Victorian hospitals in Australia, during invasive PSV, "likely overassistance" was common, and the pressure support level was delivered in a standardised and unadjusted manner at 10 cmH_2O, resulting in the frequent delivery of potentially injurious V_T.

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Australia and New Zealand intensive care units (ICUs) admit 150 000 patients per year, of whom 45–58% require mechanical ventilation.[1,2] Liberation from mechanical ventilation is uncomplicated for most patients;[3] however, almost a quarter of patients require extended weaning from the ventilator.[4] Weaning is a complex, nuanced process that may take up to 50% of the total time a patient spends on ventilatory support.[4,5]

Pressure support ventilation (PSV) is the most commonly used ventilation mode in Australian ICUs,[1] and it is also commonly used as a weaning mode. It is a spontaneous mode of ventilation that provides titratable inspiratory pressure during a triggered inspiratory effort and a set positive end-expiratory pressure level on expiration.[6] There is no consensus recommendation for titrating pressure support and there are little data about its use in Australia. However, studies performed in other countries have suggested that variables such as respiratory rate (RR),[7,8] tidal volume (V_T),[7-9] minute volume[10] or rapid shallow breathing index (RSBI)[11,12] may be used to titrate such pressure support. In particular, there has been concern that inappropriately high levels of pressure support may lead to so called overassistance.

Overassistance during PSV may occur frequently[13,14] and can lead to excessive V_T and decreased respiratory drive.[15,16] It may also lead to patient–ventilator dyssynchrony,[15] diaphragmatic atrophy,[17] sleep disorders[18] and ventilator-associated lung injury.[19] Some observational data showed that these side effects may prolong the duration of mechanical ventilation and even mortality.[20,21] The incidence of such overassistance remains uncertain because it is difficult to diagnose at the bedside. A recent study defined ventilator overassistance as the "occurrence of work of breathing less than 0.3 J/L or 10% or more of ineffective inspiratory effort".[22] Using oesophageal balloon manometry to measure the work of breathing in 27 patients with 211 measurements in a single centre, these investigators found that RR ≤ 17 breaths/min and/or RSBI (defined as RR/min divided by V_T in litres) ≤ 37 breaths/min/L helped diagnose overassistance at the bedside, with an area under the receiver operating characteristic curve of 0.92 and 0.84, respectively. It also found that RR ≤ 12 breaths/min had 100% specificity for overassistance, and that overassistance occurred in 37–48% of their study patients.[22] However, the prevalence of such overassistance in other centres or health care settings is uncertain. In this regard, there may be considerable heterogeneity in PSV use,[23] and, in particular, there is little information on how PSV is used outside of clinical trial settings, whether it is titrated and whether "likely overassistance" does occur and, if so, how often.

We hypothesised that, in a representative cohort of Australian hospitals, "likely overassistance" (defined as RR ≤ 17 breaths/min, RSBI ≤ 37 breaths/min/L, and a combination of both parameters) would occur in at least one-third of such patients or observations, that PSV would be stereotypically set, and that PSV would remain unadjusted in at least half of the treated patients or observations. We conducted a multicentre prospective observational study to test these hypotheses.

Table 1. Study patients' characteristics

Patient characteristics	Values (***n*** = 231)
Male	146 (63.2%)
Age (years), mean (SD)	60 (17.2)
Patient weight, (kg), mean (SD)	83 (22)
Patient height (cm), mean (SD)	169 (11.5)
PBW (kg), mean (SD)	62.7 (15.4)
Elective admission	32 (13.9%)
Medical admission	115 (49.8%)
Premorbid restrictive lung disease	9 (3.9%)
Premorbid obstructive lung disease	41 (17.7%)
Premorbid mixed lung disease	6 (2.6%)
Fluid overload	49 (21.2%)
Acute pulmonary oedema	11 (4.8%)
Pneumonia	68 (29.4%)
Atelectasis	24 (10.4%)
Pleural effusion	65 (28.1%)
APACHE II score, mean (SD)	21.1 (8.34)
Hospital stay before data collection (days), mean (SD)	6.8 (5.9)
ICU stay before data collection (days), mean (SD)	3.5 (5.5)
V_T (mL), mean (SD)	509 (143)
V_T/PBW (mL/kg), mean (SD)	7.8 (6.57)
PEEP, mean (SD)	7.81 (6.57)
Pressure support, median (IQR)	10 (10–10)
Respiratory rate, mean (SD)	17.9 (6.1)
Spo_2, mean (SD)	96.3 (2.61)
Fio_2, mean (SD)	30.9 (7.9)
pH, mean (SD)	7.4 (0.073)
Pao_2, mean (SD)	95.4 (43.5)
$Paco_2$, mean (SD)	40.1 (7.8)
HCO_{3-}, mean (SD)	24.9 (4.99)

APACHE = Acute Physiology and Chronic Health Evaluation. Fio_2 = fraction of inspired oxygen. HCO_{3-} = bicarbonate ion. ICU = intensive care unit. IQR = interquartile range. Pao_2 = arterial partial pressure of oxygen. $Paco_2$ = arterial partial pressure of carbon dioxide. PBW = predicted body weight. PEEP = positive end-expiratory pressure. SD = standard deviation. Spo_2 = oxygen saturation measured by pulse oximetry. V_T = tidal volume.

Methods

Study design

We conducted a multicentre prospective observational audit of PSV practices in six mixed medical–surgical adult ICUs in Victoria, Australia. Four ICUs were located in tertiary hospitals and two in regional hospitals. This study was classified as low risk, with all information being recorded as part of usual care, and was approved by all ethics committees of the participating institutions with a waiver of informed consent (ethics approval no. LNR/17/Austin/265).

Inclusion criteria

All consecutive adult patients (aged ≥ 18 years) admitted to the participating ICUs during the study period who received invasive mechanical ventilation on PSV mode with either an endotracheal tube, or a nasotracheal tube or a tracheostomy were included in the study.

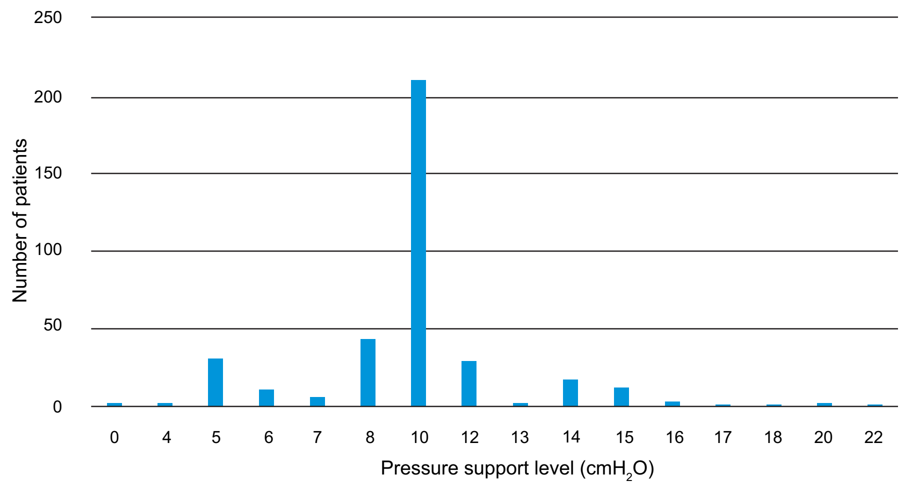
Exclusion criteria

Patients who received extracorporeal membrane oxygenation, mechanical ventilation but not pressure support ventilation, heart and/or lung transplant, or palliative care were excluded from the study.

Data collection

At each hospital, between 11 am and 2 pm, investigators collected data on patients meeting the inclusion criteria

Figure 1. Distribution of the pressure support level for all observations



on 60 sequential days (excluding weekends and public holidays) between 22 February and 30 August 2017. Each patient was included for maximum of 3 days. The variables recorded were all available at the bedside or on the computer-based ICU system. We only used data pertaining to the patient's index (first) ICU admission. Using existing ICU-based electronic databases and an electronic medical record review, we recorded all arterial blood gas results and documented chest x-ray reports for all patients involved in the study.

The attending clinical staff, including all medical and nursing staff, were blinded to the conduct and purpose of the study to avoid changes in practice. Data collection included patients' demographics, APACHE (Acute Physiology and Chronic Health Evaluation) II score, past medical history and admitting diagnosis, ventilator settings and variables.

Outcomes

The primary outcome was the prevalence of "likely overassistance" (defined as presence of RR ≤ 17 breaths/min and RSBI ≤ 37 breaths/min/L), as previously described.[20]

The secondary outcomes were the percentage of patients and/or observations with the level of pressure support set at a fixed unadjusted value, defined by the absence of any changes during the observation period. The other secondary outcome was the percentage of patients and observations with V_T > 8 mL/kg predicted body weight (PBW) and > 10 mL/kg PBW. PBW was calculated using the criteria from the National Institutes of Health–National Heart, Lung, and Blood Institute Acute Respiratory Distress Syndrome (ARDS) Network.[24]

Data analysis

All data were initially assessed for normality. Group comparisons were performed using χ^2 test for equal proportion (or Fisher exact test when numbers were small), Student *t* test for normally distributed data, and Wilcoxon rank sum otherwise, with results reported as numbers (%), means ± standard deviation or median (interquartile range [IQR]), respectively. To increase the robustness of this analysis, a two-sided $P = 0.01$ has been chosen to indicate statistical significance. All analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC, USA).

Results

Patient characteristics

We studied 231 patients, including a total of 379 observation points in six ICUs over the study period. Overall, 146 patients were male (63%), the mean patient age was 60 ± 17 years and the average PBW was 62.7 ± 15.4 kg. The average APACHE II score was 21.1 ± 8.3, and patients were assessed at a median of Day 3 (IQR, 1–7) of ICU stay (Table 1). Nine patients had pre-morbid restrictive lung disease, and 41 had chronic obstructive pulmonary disease. One in five patients was diagnosed as having fluid overload, and one in four as having pneumonia (Table 1). The median level of pressure support was 10 cmH_2O (IQR, 10–10) (Table 1). The total number of all observations in the study patients was 379, and a pressure support level 10 cmH_2O was applied in 210 patients (55%) (Figure 1).

Patiens with "likely overassistance"

Overall, of 231 patients, 131 (56.7%) had the first marker of "likely overassistance" (at least one episode of RR ≤ 17 breaths/min) (online Appendix, Table S1, available at cicm.org.au/Resources/Publications/Journal). These patients had significantly higher V_T and higher V_T/PBW ratios, and a significantly lower RR. One-hundred and forty-six patients (63.2%) had the second marker of "likely overassistance" (at least one episode of RSBI ≤ 37 breaths/min/L). They were more likely to be male, had higher actual and predicted body weight and higher V_T and V_T/PBW ratios (online Appendix, Table S2).

There were 85 patients (36.8%) with both markers of "likely overassistance" (online Appendix, Table S3). Their

Table 2. Summary of the total observations for different respiratory variables

Variable	Total number of observations	Number (%)
RR ≤ 17 (breaths/min)	379	178 (47%)
RR ≤ 12 (breaths/min)	379	71 (18.7%)
RSBI ≤ 37 (breaths/min/L)	379	204 (53.8%)
RR ≤ 17 (breaths/min) and RSBI ≤ 37 (breaths/min/L)	379	154 (40.6%)
V_T/PBW > 8 (mL/kg)	378	172 (45.5%)
V_T/PBW > 10 (mL/kg)	378	79 (20.9%)

PBW = predicted body weight. RR = respiratory rate. RSBI = respiratory shallow breathing index. V_T = tidal volume.

characteristics replicated those in each of the two separate "likely overassistance" groups, including a shorter time in the ICU and hospital before the first measurement.

Observations with "likely overassistance"

The study had a total of 379 observations episodes (Table 2). The total number of observations with a marker of "likely overassistance" (RR ≤ 17 or RSBI ≤ 37 breaths/min/L) was 178 (46.9%) and 204 (53.8%), respectively; while for both combined criteria it was 154 (40.6%) (Table 2). Moreover, 71 observations (18.7%) had RR ≤ 12 breaths/min.

Response to "likely overassistance"

There were 148 observations in which a follow-up observation was available the next day (Table 3). Sixty-one observations had RR ≤ 17 breaths/min, 36 (59%) had no changes in their pressure support levels and 28 (45.9%) remained at an unadjusted pressure support level of 10 cmH_2O the next day. Moreover, 11 (18%) had their pressure support level increased, and only 14 (22.9%) had a decrease in pressure support levels. Among those with RSBI ≤ 37 breaths/min/L at the first observation and those with both "likely overassistance" markers, the findings were similar (Table 3) (online Appendix, Figure S1). Finally, such pattern of limited adjustment applied even to patients with RR ≤ 12 breaths/min (Table 3).

Tidal volume to predicted body weight ratio

Almost half of the observation episodes (172/378 observations) had V_T in excess of 8 mL/kg PBW (Table 2). A total of 148 observations were followed up the next day; 71 of these observations (48%) had V_T > 8mL/kg PBW the next day. Forty-seven of 71 observations (66.2%) continued to have the same level of pressure support the subsequent day, with V_T levels remaining above 8 mL/kg PBW. Pressure support level was decreased only in 13 observations (18.3%) and, interestingly, 11 observations (15.5%) had their pressure support level increased despite V_T/PBW > 8 mL/kg (Table 3).

Thirty-five out of 148 observations (23.6%) remained ventilated with V_T > 10mL/kg PBW the subsequent day. Of these, 17 observations (48.6%) had no change in pressure support level, and 11 (31.4%) remained at a pressure support level 10 cmH_2O (Table 3).

Discussion

Key findings

In a multicentre prospective observational study of current PSV practice in six Australian hospitals, we found that "likely overassistance" (defined as RR ≤ 17 breaths/min or RSBI ≤ 37 breaths/min/L) was widespread and involved more than 50% of all patients and observations. Moreover, we found that a standard pressure support level of 10 cmH_2O was delivered during more than half of the observation episodes. In addition, we also found that less than half of the total observations were at the recommended V_T/PBW ratio of 6–8 mL/kg, and that more than 20% of observations were at a V_T/PBW ≥ 10 mL/kg (Table 2). Finally, the subsequent day, most patients had no adjustment in pressure support levels despite "likely overassistance" and high V_T delivery, even for patients with RR ≤ 12 breaths/min or V_T/PBW ≥ 10 mL/kg (Table 3).

Relationship to previous studies

PSV is one of the most commonly used ventilation strategies in Australia, but the optimum pressure support level is not well defined or studied. This is problematic because an unadjusted pressure support level may result in high V_T and overassistance, both of which can cause harm, such as ventilator-induced lung injury,[25,26] prolonged ventilation,[16] hyperinflations,[26] diaphragmatic atrophy[17] and patient–ventilator dyssynchrony.[15,27]

Despite the wide use of PSV,[1] overassistance has not been studied widely — the majority of the studies have evaluated underassistance.[13,14] Pletsch-Assuncao and colleagues[22] found a rate of overassistance between 37% and 48% at baseline in a cohort of 27 patients with 211 observations. Our findings are similar, identifying "likely overassistance" in 40–53% of all observations. This is despite several observations in the literature that suggest harm from overassistance. For example, Leung et al[28] compared associated ventilator modes on triggering, patient effort and

Table 3. Summary of the data for the next day follow-up

Respiratory variables	Total observations (n = 148)	Percentage of observations: Pressure support level decreased	Pressure support level unchanged	Pressure support level increased	Pressure support level remained at 10 cmH_2O
RR ≤ 17 (breaths/min)	61 (41.2%)	14 (22.9%)	36 (59%)	11 (18%)	28 (45.9%)
RR ≤ 12 (breaths/min)	22 (14.9%)	4 (18.1%)	14 (63.6%)	4 (18.1%)	10 (45.4%)
RSBI ≤ 37 (breaths/min/L)	70 (47.3%)	13 (18.6%)	45 (64.3%)	12 (17.1%)	32 (45.7%)
RR ≤ 17 (breaths/min) and RSBI ≤ 37 (breaths/min/L)	52 (35.1%)	12 (23%)	32 (61.5%)	8 (15.3%)	25 (48%)
V_T/PBW > 8 (mL/kg)	71 (48%)	13 (18.3%)	47 (66.2%)	11 (15.5%)	31 (43.7%)
V_T/PBW > 10 (mL/kg)	35 (23.6%)	9 (25.7%)	17 (48.6%)	9 (25.7%)	11 (31.4%)

PBW = predicted body weight. RR = respiratory rate. RSBI = respiratory shallow breathing index. V_T = tidal volume.

dyspnoea and showed that adding high pressure support increased the rate of ineffective triggering and wasted inspiratory effort. Moreover, high levels of pressure support produced large V_T and prolonged inspiratory time.[29] Large V_T can decrease the neural inspiratory time and inspiratory effort.[30] Thille and colleagues[15] showed that aiming for 6 mL/kg during PSV can eliminate ineffective triggering and reduce patient–ventilator dyssynchrony. A meta-analysis performed by Serpa Neto et al[31] showed that among patients without ARDS lung-protective ventilation with lower V_T could have better outcomes.[31] PBW is more reliable than actual body weight to estimate lung size because actual body weight can produce excessive V_T in patients with obesity and inadequate V_T in underweight patients. In mandatory mode of ventilations, patients with ARDS who are ventilated > 8 mL/kg PBW[32] can have ventilator-induced lung injury. It is possible that PSV at similarly high volumes may also be injurious.[9] A retrospective analysis study by Amato et al,[33] indicated that patients with ARDS who are on mandatory mode of ventilation benefit from reductions in V_T only if associated with a decrease in driving pressure (calculated by plateau pressure minus driving pressure), as low driving pressure can reduce the stress on lungs with low compliance. Similarly, in PSV, a decrease in driving pressure by lowering pressure support level in order to achieve a low V_T might also lead to a decrease in lung stress in spontaneously ventilated patients.[22]

Implications of study findings

Our findings imply that in patients treated in Victorian ICUs "likely overassistance" is common. PSV is delivered in a stereotypical manner at 10 cmH_2O. Finally, they imply that despite "likely overassistance" and high V_T/PBW ratios in the likely injurious range, the level of PSV is typically unadjusted toward a safer and more physiological level.

Strengths and limitations

To our knowledge, this is the only multicentre study to address pressure support levels and the occurrence of "likely overassistance", as recently defined.[20] Our study included six different ICUs, making our findings likely representative of both Victoria and Australia. We studied PSV strategies in ICUs ranging from tertiary to regional hospitals which included trauma, liver transplant, cardiothoracic, neurosurgical and medical ICU patients. The total number of patients included in the study was > 200 and the number of observations almost 400, thus likely to reliably represent overall daily PSV practice. Finally, all ICU staff were blinded to the purpose and conduct of the study at the time of the data collection, preventing a Hawthorne effect.

Our study has some limitations. It was performed in Victorian hospitals and may not apply to hospitals in other countries. However, our results are very similar to the study by Pletsch-Assuncao and colleagues[22] in Brazil, suggesting that our findings may apply beyond the Australian context. Moreover, the study hospitals had a twice daily ward round by an ICU specialist, giving ample opportunity for adjustment of pressure support levels. The data collection was not based on continuous data recordings and, for pragmatic reasons, was performed as a single data collection point per day. Nevertheless, the follow-up data showed that the changes in pressure support level occurred uncommonly and the rate of "likely overassistance" remained overall unchanged. For "likely overassistance" identification, we relied on the findings of a previous study.[20] Therefore, we used the qualifier "likely" because we did not conduct detailed invasive assessment of work of breathing. However, our findings are similar to those obtained with such measurements, have face validity and, even when our criteria were made stricter by using RR ≤ 12 breaths/min, and more specific by using both RR and RSBI, the results were not significantly different. The group of patients with RR > 17 breaths/min, RSBI > 37 breaths/min/L and the combination of both markers (online Appendix, Table S2, Table S3 and Figure S1) had an average stay in the ICU before data collection of several days more than the patients with "likely overassistance". However, APACHE score, premorbid conditions and diagnosis were similar. Hence, the longer stay of patients before data collection is unlikely to have a significant implication on the study results.

Conclusion

In a multicentre prospective observational study in Australia, we found that, during PSV, "likely overassistance" was widespread, a standard level of pressure support of 10 cmH_2O was delivered most of the time and, with little follow-up adjustment, despite low RR and low RSBI, most observations were at V_T/PBW ratios in the potentially injurious range, also with little adjustment. These observations raise concerns about the quality and safety of invasive PSV in Australian ICUs.

Competing interests

None declared.

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Appendix

This appendix was part of the submitted manuscript and has been peer reviewed. It is posted as supplied by the authors.

Table S1. Patients characteristics for RR less or equal to 17 versus more than 17

	RR ≤ 17[1] (n = 131)	RR > 17[2] (n = 100)	
Patient Characteristics	(% or SD)[3]	(% or SD)[3]	p value
Male	87 (66.4%)	59 (59%)	0.25
Age	60 (17)	60 (17.5)	0.99
Patient weight (KG)	83.8 (23.1)	82 (20.4)	0.55
Patient height (cm)	170 (10.7)	168 (12.4)	0.25
PBW[4] (KG)	64.3 (11.1)	60.8 (19.5)	0.09
Elective admission	81 (13.7%)	14 (14%)	0.96
Medical admission	62 (47.3%)	53 (53%)	0.39
Premorbid restrictive lung disease	5 (3.8%)	4 (4%)	0.95
Premorbid obstructive lung disease	21 (16%)	20 (20%)	0.43
Premorbid mixed lung disease	4 (3.1%)	2 (2%)	0.7
Fluid overload	26 (20%)	23 (23%)	0.58
APO[5]	7 (5.4%)	4 (4%)	0.63
Pneumonia	30 (23.1%)	38 (38%)	0.014
Atelectasis	15 (11.5%)	9 (9%)	0.53
Pleural effusion by CXR	40 (30.8%)	25 (25%)	0.36
APACHE II score	20.1 (8.06)	22.4 (8.55)	0.035
Hospital days before data collection	6.6 (13.3)	7.7 (8.35)	0.01
ICU days before data collection	2.7 (4.2)	5.2 (7.4)	0.001
VT[6] (ml)	546 (147)	461 (123)	<0.0001
VT/PBW[7] (ml/kg)	8.7 (2.5)	7.8 (5.7)	<0.0001
PEEP[8]	8 (8.46)	7.6 (2.47)	0.65
PS[9]	10 [8-10]	10 [10-10]	0.08
RR[10]	14.3 (4.34)	22.7 (4.61)	<0.0001
SpO_2[11]	96.5 (2.43)	96 (2.82)	0.14
FiO_2[12]	30.4 (7.7)	31.5 (8.2)	0.3
pH[13]	7.39 (0.076)	7.42 (0.066)	0.003
PaO2[14]	97.3 (47.9)	92.9 (37.2)	0.46
PaCO2[15]	41.2 (7.5)	38.8 (8.2)	0.015
HCO3[16]	24.7 (4.8)	25.1 (5.25)	0.53

1- (% or SD) = Percentage or standard deviation
2- RR ≤ 17 = Respiratory rate less or equal to 17
3- RR > 17 = Respiratory rate more than 17
4- PBW = Predicted body weight
5- APO = Acute pulmonary oedema
6- VT = Tidal volume
7- VT/PBW = Tidal volume on predicted body weight
8- PEEP = Positive end expiratory pressure
9- PS = Pressure support
10- RR = Respiratory rate
11- SpO2 = Oxygen saturation
12- FIO2 = Fractional of inspired oxygen
13- pH = Scale of acidity
14- PaO2 = Partial pressure of oxygen
15- PaCO2= Partial pressure of carbon dioxide
16- HCO3 = Bicarbonate ion

Table S2. Patient characteristics for RSBI less than or equal to 37 versus RSBI more than 37

Patient characteristics	**RSBI ≤ 37[1](n=146)** (% or SD)[3]	**RSBI> 37[2] (n=85)** (% or SD)[3]	**pvalue**
Male	108 (74%)	38 (44.7%)	<0.0001
Age	59.1 (16.5)	61.7 (18.3)	0.26
Patient weight (KG)	86 (22.6)	77.8 (19.9)	0.007
Patient Height (cm)	171 (10.4)	166 (12.5)	<0.0001
PBW[4] (KG)	65.7 (10.6)	57.6 (20.2)	<0.0001
Elective admission	23 (15.8%)	9 (10.6%)	0.27
Medical admission	72 (49.3%)	43 (50.6%)	0.85
Premorbid restrictive lung disease	5 (3.4%)	4 (4.7%)	0.64
Premorbid obstructive lung disease	23 (15.8%)	18 (21.2%)	0.30
Premorbid mixed lung disease	4 (2.7%)	2 (2.4%)	1.00
Fluid overload	29 (19.9%)	20 (23.8%)	0.48
APO[5]	6 (4.1%)	5 (6%)	0.53
Pneumonia	35 (24%)	33 (39.3%)	0.01
Atelectasis	13 (8.9%)	11 (13.1%)	0.32
Pleural effusion	40 (27.6%)	25 (29.8%)	0.73
APACHE II score	20.5 (8.23)	22.2 (8.47)	0.13
Hospital days before data collection	5.9 (10.4)	8.3 (13)	0.005
ICU days before data collection	3.1 (5.6)	5 (6.3)	<0.0001
VT[6] (ml)	575 (129)	397 (84.2)	<0.0001
VT/PBW[7]	9 (2.5)	7.1 (6)	<0.0001
PEEP[8]	7.92 (8.09)	7.64 (2.28)	0.75
PS[9]	10 [8-10]	10 [10-12]	0.001
RR[10]	15 (4.52)	22.9 (5.15)	<0.0001
SpO2[11]	96.4 (2.43)	96.2 (2.91)	0.52
FiO2[12]	3.05 (7.9)	31.4 (8.1)	0.41
pH[13]	7.4 (0.074)	7.41 (0.071)	0.13
PaO2[14]	94.7 (45.5)	96.5 (40)	0.76
PaCO2[15]	40 (7.77)	40.3 (8.19)	0.80
HCO3[16]	24.4 (4.79)	25.6 (5.27)	0.08

1- (% or SD) = Percentage or standard deviation
2- RSBI ≤ 37 = Rapid shallow breathing index less or equal to 37
3- RSBI > 17 = Rapid shallow breathing index more than 17
4- PBW = Predicted body weight
5- APO = Acute pulmonary oedema
6- VT = Tidal volume
7- VT/PBW = Tidal volume on predicted body weight
8- PEEP = Positive end expiratory pressure
9- PS = Pressure support
10- RR = Respiratory rate
11- SpO2 = Oxygen saturation
12- FIO2 = Fractional of inspired oxygen
13- pH = Scale of acidity
14- PaO2 = Partial pressure of oxygen
15- PaCO2= Partial pressure of carbon dioxide
16- HCO3 = Bicarbonate ion

Table S3. Patients characteristics for combination of RR less or equal to 17 and RSBI less or equal to 37 versus RR more than 17 and RSBI more than 37

Patients characteristics	**RR ≤ 17and RSBI ≤37**[1] (% or SD)[3]	**RR > 17and RSBI >37**[2] (% or SD)	**pvalue**
Male	85 (73.3%)	61 (53%)	0.001
Age	59.8 (16.4)	60.2 (18)	0.87
Patient weight (KG)	85.8 (23.4)	80.3 (20.2)	0.06
Patient height (cm)	171 (10.5)	167 (12.2)	0.01
PBW[4] (KG)	65.3 (10.8)	60.2 (18.6)	0.005
Elective admission	17 (14.7%)	15 (13%)	0.72
Medical admission	55 (47.4%)	60 (52.2%)	0.47
Premorbid restrictive lung disease	5 (4.3%)	4 (3.5%)	0.73
Premorbid obstructive lung disease	18 (15.5%)	23 (20%)	0.37
Premorbid mixed lung disease	4 (3.4%)	2 (1.7%)	0.68
Fluid overload	23 (19.8%)	26 (22.8%)	0.58
APO[5]	6 (5.2%)	5 (4.4%)	0.78
Pneumonia	26 (22.4%)	42 (36.8%)	0.02
Atelectasis	11 (9.5%)	13 (11.4%)	0.63
Pleural effusion	33 (28.7%)	32 (28.1%)	0.92
Apache II score	20.2 (8.29)	22 (8.33)	0.10
Hospital days before data collection	5.8 (10.6)	7.8 (12.2)	0.008
ICU days before data collection	2.7 (4.4)	4.8 (6.9)	0.001
VT[6] (ml)	571 (136)	447 (121)	<0.0001
VT/PBW[7] (ml/kg)	9 (2.5)	7.6 (5.3)	<0.0001
PEEP[8]	8 (8.95)	7.54 (2.46)	0.53
PS[9]	10 [8-10]	10 [10-10]	0.09
RR[10]	13.8 (4.33)	22 (4.77)	<0.0001
SpO_2[11]	96.6 (2.48)	96.1 (2.73)	0.14
FiO_2[12]	30.8 (7.9)	30.9 (8)	0.94
pH[13]	7.39 (0.076)	7.42 (0.068)	0.004
PaO_2[14]	95.3 (46.2)	95.5 (40.8)	0.98
$PaCO_2$[15]	41.1 (7.7)	39.2 (7.9)	0.06
HCO_3[16]	24.6 (4.91)	25.1 (5.08)	0.42

1- (% or SD) = Percentage or standard deviation
2- RR ≤ 17 and RSBI ≤ 37 = RR less or equal to 17 and rapid shallow breathing index less or equal to 37
3- RR > 17 and RSBI > 37= RR more than 17 and rapid shallow breathing index more than 17
4- PBW = Predicted body weight
5- APO = Acute pulmonary oedema
6- VT = Tidal volume
7- VT/PBW = Tidal volume on predicted body weight
8- PEEP = Positive end expiratory pressure
9- PS = Pressure support
10- RR = Respiratory rate
11- SpO2 = Oxygen saturation
12- FIO2 = Fractional of inspired oxygen
13- pH = Scale of acidity
14- PaO2 = Partial pressure of oxygen
15- PaCO2= Partial pressure of carbon dioxide
16- HCO3 = Bicarbonate ion

Appendix Figure S1

All Patients 231
Likely over assistance

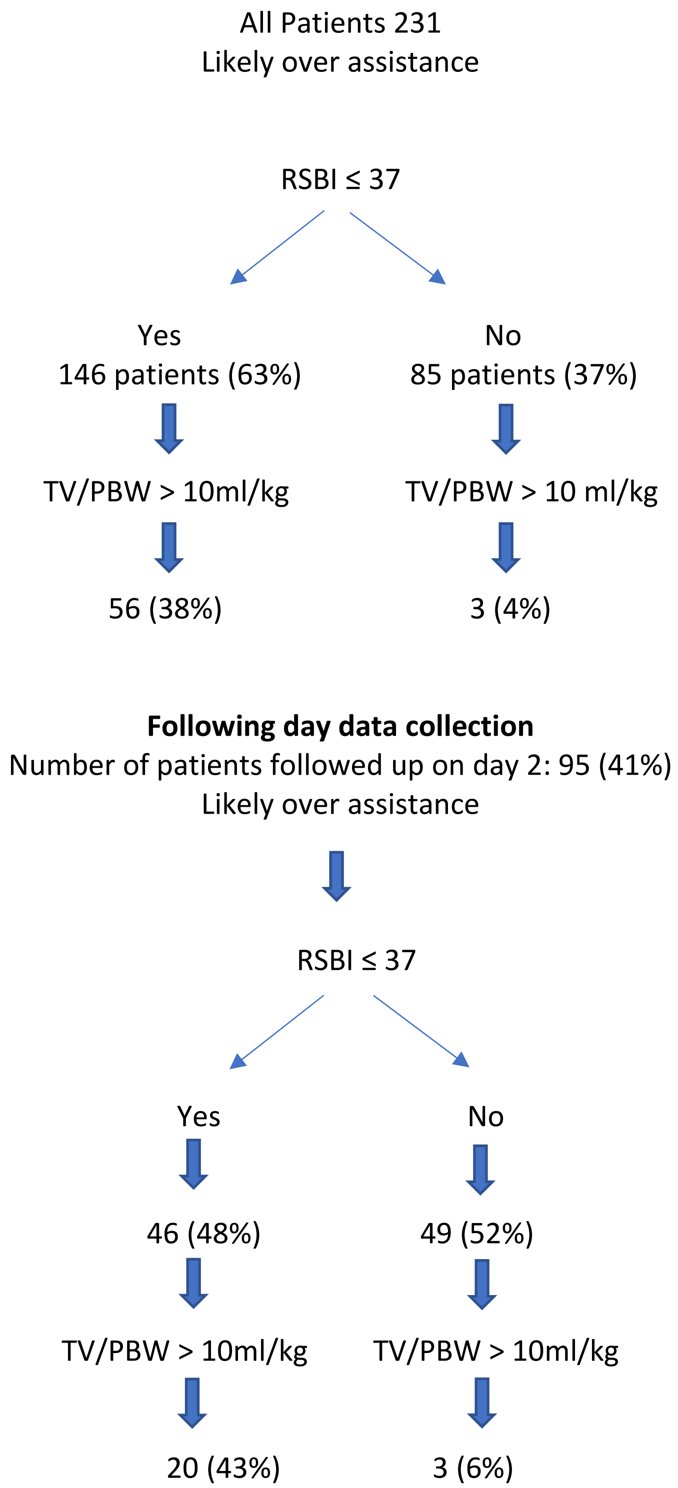
RR ≤ 17

Yes	No
131 patients (57%)	100 patients (43%)
TV/PBW > 10ml/kg	TV/PBW > 10 ml/kg
45 (34%)	14 (14%)

Following day data collection
Number of patients followed up on day 2: n=95 (41%)
Likely over assistance

RR ≤ 17

Yes	No
41 (43%)	54 (57%)
TV/PBW > 10ml/kg	TV/PBW > 10ml/kg
15 (37%)	8 (15%)


All Patients 231
Likely over assistance
RSBI ≤ 37
Yes
146 patients (63%)
No
85 patients (37%)
TV/PBW > 10ml/kg
TV/PBW > 10 ml/kg
56 (38%)
3 (4%)
Following day data collection
Number of patients followed up on day 2: 95 (41%)
Likely over assistance
RSBI ≤ 37
Yes
No
46 (48%)
49 (52%)
TV/PBW > 10ml/kg
TV/PBW > 10ml/kg
20 (43%)
3 (6%)

All observations 379
Likely over assistance

RR ≤ 17

Yes
178 patients (47%)

TV/PBW > 10ml/kg

51 (29%)

No
201 patients (53%)

TV/PBW > 10 ml/kg

28 (14%)

Following day data collection
Number of observations followed up next day (148)
Likely over assistance

RR ≤ 17

Yes

61 (41%)

TV/PBW > 10ml/kg

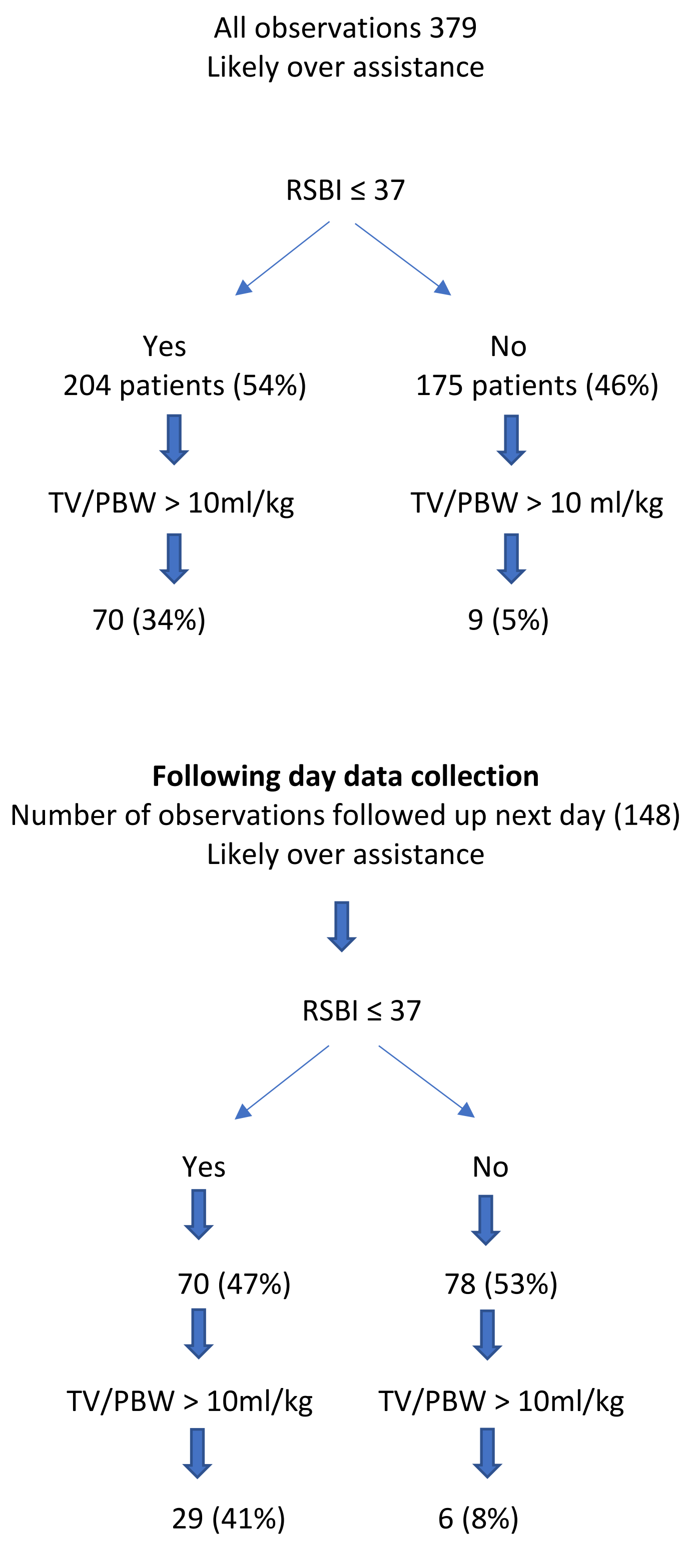
20 (33%)

No

87 (59%)

TV/PBW > 10ml/kg

15 (17%)


All observations 379
Likely over assistance
RSBI ≤ 37
Yes
204 patients (54%)
No
175 patients (46%)
TV/PBW > 10ml/kg
TV/PBW > 10 ml/kg
70 (34%)
9 (5%)
Following day data collection
Number of observations followed up next day (148)
Likely over assistance
RSBI ≤ 37
Yes
No
70 (47%)
78 (53%)
TV/PBW > 10ml/kg
TV/PBW > 10ml/kg
29 (41%)
6 (8%)