

Adoption of Lower Tidal Volume Ventilation Improves With Feedback and Education

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OBJECTIVE: To determine whether feedback and education improve adoption of lung-protective mechanical ventilation (ie, with lower tidal volume [V_T]). **METHODS:** We conducted a retrospective study of ventilator settings; we used data from 3 consecutive studies of patients with acute lung injury and/or acute respiratory distress syndrome, in the intensive care units of 2 university hospitals in the Netherlands. At site 1 we conducted a time series study of before and after education and feedback about lung-protective mechanical ventilation, and we compared the results from site 1 to the ventilation strategies used at site 2, which did not undergo the education and feedback intervention. Feedback and education consisted of presentations of actual ventilator settings, advised ventilator settings, and discussions on potential reasons for not using lower V_T . **RESULTS:** Two studies were performed at site 1, in 1999–2000 (Study 1, $n = 22$) and in 2002 (Study 2, $n = 12$). In 2003–2004, Study 3 was performed simultaneously at site 1 ($n = 8$) and site 2 ($n = 17$). At site 1, the mean \pm SD V_T was 10.9 mL/kg predicted body weight (PBW) (95% CI 10.3–11.6) in Study 1 and 9.9 mL/kg PBW (95% CI 9.0–10.8) in Study 2 (difference not significant). After the feedback and education intervention at site 1, V_T declined to 7.6 mL/kg PBW (95% CI 6.5–8.7) in Study 3 ($p = 0.003$). At site 2, where no feedback or education were given, V_T was 10.3 mL/kg PBW (95% CI 9.5–11.0) in Study 3 ($p < 0.001$ vs Site 1). **CONCLUSIONS:** Adoption of a lower- V_T ventilation strategy in patients with acute lung injury or acute respiratory distress syndrome is far from complete in the Netherlands. Adoption of a lower- V_T strategy improves after feedback and education. *Key words:* mechanical ventilation, acute lung injury, acute respiratory distress syndrome, ARDS, tidal volume. [Respir Care 2007;52(12):1761–1766. © 2007 Daedalus Enterprises]

Introduction

One major advance in the field of mechanical ventilation has been the clear demonstration that use of lower

tidal volume (V_T) (6 mL/kg predicted body weight [PBW]) significantly reduces mortality in patients with acute lung injury (ALI) and its more severe form, acute respiratory distress syndrome (ARDS).¹ Although guidelines support the use of lower V_T in patients with ALI/ARDS,² physicians have been reluctant to adopt lung-protective ventilation.^{3–5} Poor recognition by physicians of ALI/ARDS,⁶ concerns over hypercapnia, acidosis, and hypoxemia,⁷ as well as fear of increased need for sedation to maintain ventilator synchrony and comfort are several of the barriers to the use of lower V_T .^{8,9} In addition, the importance of using PBW (ie, weight based on patient's height, instead of actual body weight) may have been neglected.¹⁰

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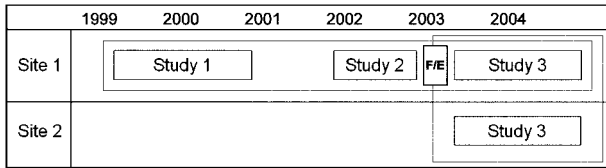


Fig. 1. Chronology of our 3 studies on ventilator settings, and the feedback and education sessions. Three consecutive studies were performed during a 6-year period. Study 1, Study 2, and Study 3 were all performed at site 1. Study 3 was also performed at site 2. Ventilator settings of patients recruited in Study 1 and Study 2 at site 1 were compared to Study 3. Ventilator settings of patients in Study 3 at site 1 and site 2 were also compared. The box labeled F/E represents the feedback and education sessions at site 1.

In this investigation we determined ventilator settings in 3 consecutive ALI/ARDS studies performed in the Netherlands before and after publication of the landmark study by the ARDS Network.¹ We focused on the effect of feedback and education on the use of lung-protective (lower- V_T) ventilation at one intensive care unit (ICU) (Academic Medical Center, Amsterdam, site 1). Feedback and education was given not because of one of the above-mentioned studies, but because ICU team members did not follow the recommendations in the local ventilation guideline, in particular the recommendation on lower V_T , several years after the local guideline became effective.

Methods

We collected data on ventilator settings of patients recruited in 3 consecutive randomized controlled ALI/ARDS studies in the ICUs of 2 university hospitals. site 1 was the Academic Medical Center, University of Amsterdam, Amsterdam, the Netherlands. site 2 was the University Medical Center, University of Utrecht, Utrecht, the Netherlands.

We conducted 3 separate studies. Study 1 (performed in 1999–2000) and Study 2 (in 2002) were performed at site 1 (Fig. 1). Study 3 (in 2003–2004) was performed simultaneously at site 1 and site 2. The education and feedback intervention on lung-protective ventilation occurred at site 1, but not at site 2.

The study subjects met the standard definition of ALI/ARDS.¹¹ The 3 ALI/ARDS studies tested the safety and efficacy of instillation of surfactant versus standard therapy (these 3 studies are as yet unpublished).

Study Centers

The ICU at site 1 is a 28-bed department. The ICU at site 2 is a 32-bed department. Both ICUs are so-called “closed-format” units (ie, all patients are under the direct care of the members of the ICU team). As part of the ICU

team, nurses can make ventilator therapy recommendations, but unit policy mandates that all changes in ventilator settings be ordered by ICU physicians. However, since pressure-controlled ventilation was used in all patients, ICU nurses were allowed to change the applied airway pressure to assure the use of the correct V_T at all times.

The ICU team at site 1 comprises 5–8 full-time intensivists, 6–8 subspecialty fellows, 12 residents, and occasionally 1 intern. The ICU team at site 2 comprises 6–8 full and part-time intensivists, 3–4 subspecialty fellows, 15 residents, and 3 interns.

Intervention: Feedback and Education

At site 1, in between Study 2 and Study 3, the intervention consisted of:

1. A concise presentation to all ICU physicians on results from several animal studies^{12,13} and clinical studies of lung-protective ventilation with lower V_T in patients with ALI/ARDS.^{1,14–19}

2. A recall on what was stated in the local ventilation guideline on V_T (should be 6–8 mL/kg PBW; the upper limit of 8 mL/kg PBW was chosen based on the ARDS Network protocol,¹ in which V_T was allowed to be as high as 8 mL/kg PBW in some circumstances), and a recall that we all agreed on use of lower V_T when this guideline was made effective.

3. Presentation of data on actual V_T before this intervention (“feedback”); for this, two of us (EKW and MJS) collected all ventilator settings of all patients during a 2-week period.

4. A discussion on potential reasons for not using lower V_T , including the importance of using PBW instead of actual body weight to set V_T , and fear of increased need for sedation to maintain ventilator synchrony and comfort (“education”).

The same intervention strategy was applied with the ICU nurse team at site 1. This was repeated 3 times. Finally, the patient data management system (Metavision, iMDsoft, Sassenheim, Netherlands) was equipped with a special tool that automatically calculated the ideal V_T from the patient’s height, after which the V_T target was automatically visible in the “respiratory tab” (ie, for all patients it was easy to check whether V_T was 6–8 mL/kg PBW).

Mechanical Ventilation Protocols

During conduct of the first 2 studies, no specific recommendations were made on V_T in the study protocols other than to follow local ventilation guidelines. The protocol of Study 3, however, contained a recommendation on V_T settings: V_T was advised to be 6–8 mL/kg PBW.

At site 1 and site 2 the local ventilation guidelines recommended using pressure-controlled or pressure-support ventilation. Positive end-expiratory pressure (PEEP) was to be adjusted to the P_{aO_2} level (at site 1 the algorithm advised higher PEEP than did the algorithm at site 2). Prone positioning was recommended for patients who required a fraction of inspired oxygen (F_{IO_2}) > 0.6. Mild hypercapnia was accepted in patients with ALI/ARDS, but no P_{aCO_2} limits were given.

Patients and Data Collection

The following data were extracted from the trial record files at 0, 4, 8, 12, 16, 20, 24, 30, 36, 40, 48, 60, and 72 hours after randomization: V_T , respiratory rate, PEEP, peak inspiratory pressure (PIP), F_{IO_2} , P_{aO_2} , P_{aCO_2} , and arterial pH. V_T was expressed in mL/kg PBW.

Statistical Analysis

All ventilator settings (including V_T) and blood gas analysis results were similar between patients in the different treatment arms of the studies. Therefore, the data from each study were pooled, and further analysis compared settings between the 3 consecutive studies, and between the 2 sites. To detect differences in baseline data in the studies we used an analysis of variance test and post hoc analysis with Tukey's test. These data are presented as mean \pm SD or median and interquartile range. Ventilator data from the studies were all statistically analyzed with a linear mixed model analysis. The fixed effects included in the regression model were study, sample time, and the interaction between study and sample time. Patient was modeled as a random effect. These data are all presented as mean and 95% confidence interval (CI). For categorical data the chi square test was used. Data in the figures are presented as mean \pm SD. A p value < 0.05 was considered significant. The analysis was performed with statistics software (SPSS 12.0, SPSS, Chicago, Illinois).

Results

Study Subjects

There were 22 patients in Study 1, and 12 patients in Study 2. Study 3 included 8 patients at site 1, and 17 patients at site 2. Table 1 shows the subjects' baseline characteristics. There were significantly fewer women in Study 3 at site 1 than in the other studies ($p < 0.001$ vs Study 1 and Study 2 and Study 3 at site 2). Height and PBW values were significantly lower in Study 1 and Study 2 than in Study 3. Acute Physiology and Chronic Health Evaluation II scores were lower in Study 1 than in Study 2

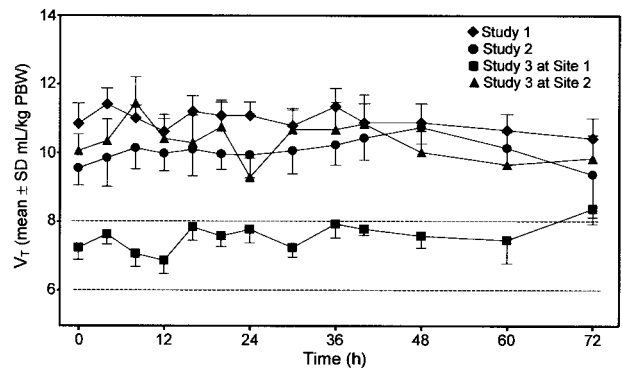


Fig. 2. Tidal volume (V_T) in 3 consecutive trials, in the first 72 hours after inclusion. The area between the dotted lines indicates the target V_T explicitly stated in the mechanical ventilation protocol during Study 3.

or Study 3 ($p = 0.013$ vs Study 2, $p = 0.004$ vs Study 3 at site 1, and $p < 0.001$ vs Study 3 at site 2).

Tidal Volume and Respiratory Rate

All patients in all 3 studies were initially ventilated with pressure-controlled ventilation. In addition, prone positioning was used in all patients in the first few days after the start of ventilation. During weaning, pressure-support ventilation was used.

The mean V_T in Study 1 and Study 2 were similar: 10.9 mL/kg PBW (95% CI 10.3–11.6) and 9.9 mL/kg PBW (95% CI 9.0–10.8), respectively (difference not significant).

In Study 3, at site 2 the mean V_T was 10.3 mL/kg PBW (95% CI 9.5–11.0), as compared to 7.6 mL/kg PBW (95% CI 6.5–8.7) at site 1 ($p < 0.001$ vs Study 3 at site 2, and $p < 0.001$ and $p = 0.003$ vs Study 1 and Study 2, respectively) (Fig. 2).

The percentage of data points with $V_T > 10$ mL/kg PBW declined from 62% and 49% in Study 1 and Study 2, respectively, to 3% in trial Study 3 at site 1 ($p < 0.001$). At site 2 the percentage of data points with $V_T > 10$ mL/kg PBW was 48%. The number of observations with $V_T > 8$ mL/kg PBW decreased from 95% and 86% in Study 1 and Study 2, respectively, to 28% in Study 3 at site 1 ($p < 0.001$). At site 2 the number of observations with $V_T > 8$ mL/kg PBW was 81%.

With the use of lower V_T , the respiratory rate increased from 15.6 breaths/min (95% CI 16.6–20.1) and 18.3 breaths/min (95% CI 16.5–20.2) in the first 2 studies (difference not significant between Study 1 and Study 2) to 20.4 breaths/min (95% CI 18.1–22.7) in Study 3 at site 1 ($p = 0.001$ vs Study 1). At site 2, respiratory rate was significantly lower: 17.1 breaths/min (95% CI 15.5–18.6) ($p = 0.002$ vs Study 3 at site 1).

Table 1. Baseline Characteristics of Patients in the Studies

	Study, Study Location, and Number of Patients			
	Study 1 Site 1 <i>n</i> = 22	Study 2 Site 1 <i>n</i> = 12	Study 3	
			Site 1 <i>n</i> = 8	Site 2 <i>n</i> = 17
Sex (M, F)	15, 7	9, 3	8, 0*	13, 4
Age (mean ± SD y)	59 ± 14	59 ± 15	60 ± 11	56 ± 18
APACHE II (mean ± SD)	17.1 ± 5.7†	19.2 ± 6.8	19.8 ± 8.6	19.9 ± 6.3
Mortality at day 28 (<i>n</i> , %)	4 (18.2)	2 (16.7)	1 (12.5)	2 (11.8)‡
Cause of ALI/ARDS				
Sepsis	6	4	3	3
Pneumonia	6	3	0	6
Trauma	1	1	0	3
Shock	8	3	5	4
Other	1	1	0	1
P _{aO₂} /F _{IO₂} (median and IQR mm Hg)	191 (41–242)†	107 (86–158)§	150 (136–220)	150 (124–213)
Height (mean ± SD cm)	173 ± 9.9	171 ± 8.1	178 ± 7.2	177 ± 11.7
Actual body weight (mean ± SD kg)	73.1 ± 12.5†	77.6 ± 17.2¶	80.5 ± 18.7	84.9 ± 13.7
Predicted body weight (mean ± SD kg)	67.2 ± 9.6	65.9 ± 8.0	73.6 ± 6.6	70.5 ± 12.5

* Adjusted *p* values: *p* < 0.001 versus Study 1, 2 and Study 3 at site 2

† *p* < 0.05 versus Study 2 and 3

‡ *p* < 0.05 versus Study 1, 2 and Study 3 at site 1

§ *p* < 0.001 versus Study 1 and 3

|| *p* < 0.01 versus Study 3

¶ *p* < 0.05 versus Study 1 and Study 3 at site 2

See text for exact *p* values.

APACHE II = Acute Physiology and Chronic Health Evaluation II

ALI = acute lung injury

ARDS = acute respiratory distress syndrome

F_{IO₂} = fraction of inspired oxygen

IQR = interquartile range

PEEP and PIP

Individual PEEP decreased significantly over time in all patients in the 3 studies (*p* < 0.001). The mean PEEP in Study 3 at site 2 (9.5 cm H₂O [95% CI 8.5–10.5]) was lower than the mean PEEP in Study 1, Study 2, or Study 3 at site 1 (11.2 cm H₂O [95% CI 10.3–12.1], 13.7 cm H₂O [95% CI 12.5–14.9] and 14.1 cm H₂O [95% CI 12.6–15.6], respectively) (*p* = 0.059 vs Study 1, *p* < 0.001 vs Study 2 and Study 3 at site 1).

Similarly, individual PIP decreased over time in all patients in the 3 studies (*p* < 0.001). The mean PIP in Study 2 (31.4 cm H₂O [95% CI 28.7–34.0]) was higher than in Study 3 at site 1 (26.8 cm H₂O [95% CI 23.5–30.1], *p* = 0.034). In the other 2 studies the mean PIP was 28.1 cm H₂O (95% CI 26.1–30.0) and 28.3 cm H₂O (95% CI 26.1–30.5) in Study 1 and Study 3 at site 1, respectively.

F_{IO₂}, P_{aO₂}, P_{aCO₂}, and pH

Data for F_{IO₂}, P_{aO₂}, P_{aCO₂}, and pH are given in Table 2. There were no significant F_{IO₂} or pH differences between

the studies. P_{aCO₂} was significantly lower in Study 1 and Study 2 than in Study 3 at site 2 (*p* = 0.011 and 0.021, respectively), but this difference was clinically unimportant. P_{aCO₂} was not significantly different between site 1 and site 2 in Study 3. P_{aO₂} was significantly higher in Study 1 and Study 2 than in Study 3 at site 2 (*p* = 0.013 and *p* = 0.01, respectively). P_{aO₂} was not different between site 1 and site 2 in Study 3.

Discussion

Use of lung-protective lower-V_T ventilation is recommended for patients suffering from ALI/ARDS.² This study demonstrates, similar to a growing number of other published studies,^{3–5} the poor penetration of the use of lower V_T for patients with ALI/ARDS. Indeed, no adoption of lower V_T was found in the first years after publication of the ARDS Network trial.¹ Although adoption of lower-V_T ventilation improved after feedback and education on lung-protective mechanical ventilation, the number of observations with V_T > 8 mL/kg PBW was still 28%.

Table 2. Blood Gas Analysis Values*

	Study, Location, and Number of Patients			
	Study 1	Study 2	Study 3	
	Site 1 <i>n</i> = 22	Site 1 <i>n</i> = 12	Site 1 <i>n</i> = 8	Site 2 <i>n</i> = 17
F _{IO₂}	0.50 (0.47–0.54)	0.52 (0.47–0.56)	0.46 (0.41–0.52)	0.51 (0.47–0.55)
P _{aO₂} (mm Hg)	140 (128–151)†	140 (125–155)†	122 (104–140)	110 (98–122)
P _{aCO₂} (mm Hg)	36.9 (35.3–38.6)†	37.8 (35.6–40.1)†	41.1 (38.3–44.0)	40.4 (38.6–42.3)
pH	7.40 (7.38–7.42)	7.40 (7.37–7.43)	7.38 (7.35–7.42)	7.41 (7.39–7.44)

*Values in parentheses are 95% confidence intervals.

†Adjusted *p* < 0.05 versus Study 3 at site 2. See text for *p* values.

F_{IO₂} = fraction of inspired oxygen

Our analysis has several limitations. First, we analyzed different treatment groups within each study together, because the study protocols did not prescribe different ventilator settings for the 2 arms, and no differences were found regarding respiratory variables between the 2 arms. We are uncertain, however, whether changes in the pulmonary condition as a result of the differences in treatment may have resulted in a change in ventilator settings. The groups may be too small to identify this.

Second, as with any secondary subset analysis from a large trial, this report may have important inherent flaws due to its retrospective design, small sample size, and focus on individual study sites, where the ventilation practices might not represent the norm.

Third, a study makes clinicians aware that patients meet criteria for ALI/ARDS, which may change clinical behavior (such as use of lung-protective ventilation); in other words, V_T practice may not have changed at all in patients not recruited into the studies.

An alternative explanation for the change in ventilator settings is trends in care during the study period. Indeed, one could argue that this V_T decline was (also) an effect of time (ie, the result of improved awareness about the benefit of lower V_T, less disagreement about the evidence, and more motivation to apply lower V_T). For several reasons we consider this less likely, however. First, although there was a trend toward lower V_T between Study 1 and Study 2, the difference was small and not statistically significant. Second, ventilator settings in Study 3 did not show a trend during the study period at site 1 or site 2. Third, if a V_T practice change during the study period explained the change in ventilator settings at site 1, why did ventilator settings at the other site remain unchanged? Providing feedback on previous practice is more effective than simple education.²⁰ Recently, Cook and co-workers emphasized the importance of an environmental scan and understanding of current behavior to improve daily practice.²¹

In a previous report we demonstrated the effect of a feedback and education program that targeted a lower-V_T strategy in all mechanically ventilated ICU patients.²² We found that V_T declined significantly within 6 months in our ICU, and, more importantly, after 12 months lower V_T was still used. In the present study the use of lower-V_T ventilation improved at the center that received feedback and education, whereas in a neighboring university hospital, where neither feedback nor education had taken place, V_T remained larger than is presently recommended for patients with ALI/ARDS.

Of course, other, yet unrecognized differences between the 2 sites may account for this difference. However, the 2 ICUs are very similar, both being closed-format units, and had no changes in staffing over time. The only difference between the 2 centers was the lower PEEP at site 2 in Study 3 than at site 1 in all 3 studies, but the sites' ventilation guidelines contained different PEEP recommendations, which completely explains this difference.

Clinicians in teaching hospitals only slowly adopted the lower-V_T strategy several years after publication of the ARDS Network study.³ Although significant V_T reductions in patients with ALI/ARDS were described in another study, wide variation in ventilator practice persisted, and the proportion of patients who received V_T within the recommended limit (≤ 8 mL/kg PBW) remained modest.⁴ In contrast, physicians at ARDS Network centers prescribed significantly lower V_T after completing the study (1999–2002) than they had during the study (1996–1999).²³

In an international observational study on 198 European ICUs, which included over 393 patients with ALI/ARDS, in more than half of cases the ventilator settings were other than the ARDS Network lung-protective ventilation strategy.⁵ Our data are in line with that report. Indeed, several years after publication of the ARDS Network trial, V_T was still large and not different from the V_T values before the benefits of lower V_T in ALI/ARDS became clear.

Various reasons for the slow adoption of low V_T were recently summarized.²⁴ Physicians may choose to control plateau pressure (or PIP in pressure-controlled ventilation) instead of V_T , despite the clear benefit of using lower V_T at every plateau pressure (ie, also at lower levels). Physicians may have concerns about the initial worsening of P_{aO_2} and P_{aCO_2} when V_T is lowered, despite the demonstration that the initial deterioration in P_{aO_2}/F_{IO_2} is short-lived.¹ The ARDS Network study demonstrated that low- V_T patients had a lower F_{IO_2} by the 3rd day than did patients who received conventional V_T . Similarly, although low- V_T ventilation increases P_{aCO_2} initially, there is no difference in pH by day 7. Finally, many physicians may worry that a low- V_T strategy increases ventilator asynchrony. Two retrospective analyses, however, found no difference either in the number of patients receiving benzodiazepine sedatives or opioid analgesics or the dosages of those medications.^{25,26}

Conclusions

From the present analysis we conclude that adoption of lower V_T as a standard of care in patients with ALI/ARDS is still poor, but may improve with feedback and education.

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