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Feedback and education improve physician compliance in use of lung-protective mechanical ventilation

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Abstract *Objective:* Use of lung-protective mechanical ventilation (MV) by applying lower tidal volumes is recommended in patients suffering from acute lung injury (ALI) or acute respiratory distress syndrome (ARDS). Recent data suggest that lung-protective MV may benefit non-ALI/ARDS patients as well. This study analyzed tidal volume settings in three ICUs in The Netherlands to determine the effect of feedback and education concerning use of lung-protective MV. *Design and setting:* Observational study in one academic and two nonacademic "closed format" ICUs. *Patients:* Intubated mechanically ventilated subjects. *Interventions:* Feedback and education concerning lung-protective MV with special attention to the importance of closely adjusting tidal volumes to predicted body weight (PBW). *Results:* Tidal volumes declined significantly within 6 months after intervention (from 9.8±2.0 at baseline to 8.1±1.7 ml/kg PBW) as the percentage of undesirable ventilation data points, defined as tidal volumes greater than 8 ml/kg PBW (84% vs. 48%). There were no differences between patients meeting the international definition criteria for ALI/ARDS and those not. Only four patients received tidal volumes less than 6 ml/kg PBW. Lower tidal volumes were still used after 12 months. Tidal volumes in patients on mandatory MV and patients breathing on spontaneous modes were similar. *Conclusions:* Feedback and education improve physician compliance in use of lung-protective MV.

Keywords Respiration, artificial · Respiratory distress syndrome, adult · Tidal volume

Introduction

Mechanical ventilation (MV) is routinely applied in critically ill patients. However, life-saving MV frequently induces injury to the lungs, known as ventilator-induced lung injury. Alveolar overdistension and repetitive opening and closing of atelectatic lung units are thought to play a causal role of ventilator-induced lung injury in patients with acute lung injury (ALI) or acute respiratory distress syndrome (ARDS) [1]. To test this hypothesis investigators have used lung-protective MV strategies in patients with ALI/ARDS, applying lower tidal volumes [2] and/or sufficient levels of positive end expiratory pressure (PEEP) [3]. The ARDS Network trial confirmed that MV with lower tidal volumes significantly decreases mortality and increases the number of ventilator-free

Table 1 Patient characteristics in an academic ICU (Academic Medical Center) and two nonacademic ICUs (Gelre Hospital, Medical Center Leeuwarden), before and after education (*APACHE II* Acute Physiology And Chronic Health Evaluation II, *SAPS II* Simplified Acute Physiology Score II, *IQR*, interquartile range; *ABW* actual body weight, *PBW* predicted body weight)

	Academic ICU		Nonacademic ICUs	
	Before (*n*=30)	After (*n*=45)	Before (*n*=20)	After (*n*=19)
Gender: M/F	18/12	27/18	13/7	10/9
Age (years), mean ±SD	55±21	62±15.1	66±10.6	68±13.4
ALI/ARDS (%)	43	27	55	47
APACHE II, mean ±SD	21.4±8.9	20.1±7.4	21±6.2	20±4.7
SAPS II, mean ±SD	44.1±17.5	44.4±16.4	48±12.1	45±13.2
PaO_2/FIO_2, median (IQR)	264 (201–314)	251 (188–334)	215 (179–277)	268 (214–286)
Height (cm), mean ±SD	168±12.4	173±8.2*	171±8.7	171±9.2
ABW (kg), mean ±SD	77.7±14.3	77.0±17.9	73±8.3	74±13.5
PBW (kg), mean ±SD	62.1±12.7	66.8±9.0*	65±9.2	65±9.6

$^*p<0.05$

days. Recently published data also suggest that non-ALI/ARDS patients benefit from lower tidal volumes [4].

Many medical advances enter clinical practice only slowly. Although clinicians in teaching hospitals are often early supporters of new medical advances, several reports show reluctant use of lung-protective MV [5, 6, 7]. One reason for not using lower tidal volumes in non-ALI/ARDS patients is poor physician recognition of patients with ALI/ARDS [8, 9]. Other barriers to the use of lung-protective MV include concerns over patient discomfort and tachypnea as well as hypercapnia, acidosis, and hypoxemia [8]. In addition, the importance of using *predicted* body weight (PBW) instead of *actual* body weight (ABW) may have been neglected [10].

The aim of this observational study, the preliminary findings of which we have presented previously [11] was to analyze tidal volume settings in MV patients in three "closed format" intensive care units in The Netherlands. To determine the effect of feedback and education concerning use of lung-protective MV we studied tidal volume settings after 6 months in the same centers. In addition, to determine the long-term effect of our intervention we studied tidal volumes in an additional set of patients 1 year later in one center.

Methods

Study centers

We studied MV settings in one academic ICU [Academic Medical Center (AMC) in Amsterdam, The Netherlands] and two nonacademic ICUs [Gelre Hospital (GH) location Lukas in Apeldoorn, The Netherlands; Medical Center Leeuwarden (MCL) in Leeuwarden, The Netherlands]. The AMC is a large teaching hospital where the ICU is a 28-bed "closed format" department in which medical/surgical patients (including cardiothoracic and neurosurgical patients) are under the direct care of the ICU team. As part of the team nurses can make ventilator therapy recommendations, but unit policy mandates that all changes in MV settings be ordered by physicians. The ICU team comprises 8 full-time intensivists, 8 subspecialty fellows, 12 residents, and occasionally one intern. The GH is an affiliated teaching hospital where the ICU is a 10-bed "closed format" department. In this hospital nurses can make ventilator therapy recommendations and changes. Here, in contrast to the ICU of the AMC, physicians are only present at night on request. The ICU team consists of 2 full-time intensivists, 5 part-time intensivists who participate in duty shifts, and one resident. The MCL is a large general teaching hospital in the north of The Netherlands, with a 13-bed "closed format" mixed ICU. Here nurses can make ventilator therapy recommendations, although unit policy mandates that changes in MV settings be ordered by physicians. The ICU team comprises 6 full-time intensivists, 2 residents, and occasionally interns.

MV protocol

In the AMC a written MV protocol is available for all ICU members, both on the intranet and in printed form. Briefly, this protocol advises pressure-controlled (PC) MV or pressure-support (PS) MV in all patients. Levels of positive end-expiratory pressure (PEEP) are adjusted to PaO_2 levels. Use of prone positioning is recommended in patients requiring injurious FIO_2 levels (>0.6). There is a clear recommendation on tidal volume settings that tidal volumes be between 6 and 8 ml/kg PBW in all patients, irrespective of the presence of ALI/ARDS (the upper limit of 8 ml/kg PBW was chosen based on the ARDS Network protocol [2], in which tidal volumes were allowed the be as high as 8 ml/kg PBW in some circumstances). The protocol states that "mild hypercapnia" is accepted in patients with ALI/ARDS (but no limits for $PaCO_2$ are given). In the case of PS MV the level of support is set to reach a respiratory rate between 10 and 20 breaths/min or a level at which the patient is comfortable breathing, according to patient and/or physician vision. However, use of lower tidal volumes takes precedence over respiratory rate, allowing higher respiratory rates. No written MV protocol is available in the other two hospitals.

Patients and data collection

The study included 114 consecutive, intubated MV subjects aged 18 years or over, divided into two groups: 50 before intervention (31 men, 19 women) and 64 after (37 men, 27 women; (Table 1). In a third data collection period 12 months after intervention 103 patients were examined at the AMC. MV settings were collected over a period of 2 weeks at three different times during the day (8 a.m., 2 p.m., 8 p.m.) and were recorded by one intensivist in each hospital and one of the authors (E.W.); other intensivists, fellows, and residents were unaware of the collection of data. Measurements were performed directly before and approximately 6 months after an educational program; data were collected at the AMC in June 2003 and January 2004, at the GH in October 2003 and April 2004, and at the MCL in November 2003 and May 2004. The third data-collection period was in September 2004 at the AMC; tidal volume settings were analyzed to determine long-term effects of the intervention.

The following MV data were recorded: MV mode, FIO_2, applied tidal volume, PEEP level, maximum airway pressure (Pmax) in PC-MV or plateau pressure in volume-controlled ventilation, and respiratory rate (breaths/min). Tidal volumes were not corrected for ventilator tubes or ventilator types, and only exhaled volumes were recorded. Patient's height was measured, and weight was taken from the medical record; if no weight was recorded, weight used by the nursing team was taken as ABW. Arterial blood gases were recorded; the sample closest to the observation was taken for each set. ALI/ARDS (at any time during the MV episode) was diagnosed by one intensivist in every hospital and one of the authors (E.W.) using consensus criteria for ALI/ARDS: acute onset of respiratory failure, ratio of partial pressure of arterial oxygen to the fraction of inspired oxygen (PaO_2/FIO_2) of 300 mmHg or less, and bilateral infiltrates on chest radiography [12].

Definitions

Actual body weight was defined as the body weight of patient measured before admission to the hospital or ICU. *Predicted* body weight (PBW) was calculated by the following formula: in men, PBW (kg)=50+0.91 (centimeters of height−−152.4); in women, PBW (kg)=is 45.5+0.91 (centimeters of height−−152.4) [13]. Applied tidal volume was defined as expiratory volume measured by the ventilator. The tidal volume, expressed as milliliters/kilogram PBW, was calculated by dividing applied tidal volume by PBW for each patient.

Feedback and education

At the AMC the intervention consisted of: (a) a presentation of the results of the first data collection to all ICU-physicians ("feedback" on current practice); (b) a discussion on studies using lower tidal volumes and on potential reasons for not using lower tidal volumes, including the importance of using PBW instead of ABW to set tidal volumes ("education"); and (c) a demonstration of the results of the first data collection to all ICU nurses. At the GH a similar intervention took place, and a MV protocol was introduced stating that tidal volumes should be between 6 and 8 ml/kg PBW. At the MCL only feedback to the physicians of the first data collection took place, and the importance of using PBW to set tidal volumes was emphasized, but no written protocol was introduced.

Statistical analysis

After we determined that MV settings on day 1 did not differ from average data for all respiratory variables we chose to use the mean of all respiratory variables per patient for analysis and presentation of data. Statistical analysis of continuous data used the Kruskal-Wallis test and post-hoc analysis with the Mann-Whitney *U* test; for categorical data the χ^2 test was used. Data are presented as mean ±SD or as median (with interquartile range). Differences with a *p* value less than 0.05 were considered significant.

Results

Tidal volumes

Patients *without ALI/ARDS* showed a decline in tidal volumes from 9.7±1.9 ml/kg PBW before the intervention to 8.0±1.7 ml/kg PBW thereafter (p<0.0001; Fig. 1). The proportion of non-ALI/ARDS patients with tidal volumes above 8 ml/kg PBW declined from 88% to 49% at the AMC (p=0.007) and from 78% to 40% at the GH and the MCL (p=0.011). The proportion of patients with tidal volumes above 10 ml/kg PBW declined from 41% only 9% at the AMC (p=0.008) and from 33% to 10% at the GH and the MCL (p=0.023). Patients *with ALI/ARDS* showed a decline from 9.9±2.2 ml/kg PBW before the intervention to 8.2±1.8 ml/kg PBW thereafter (p=0.013; Fig. 2). The number of observations in which tidal volumes were above 8 ml/kg decreased from 85% to 42% at the AMC (p=0.03) and from 82% to 67% at the GH and the MCL (p=0.45). The percentage of patients with tidal volumes above 10 ml/kg PBW declined from 39% to 8% at the AMC (p=0.08) and from 73% to 22% at the GH and the MCL (p=0.028).

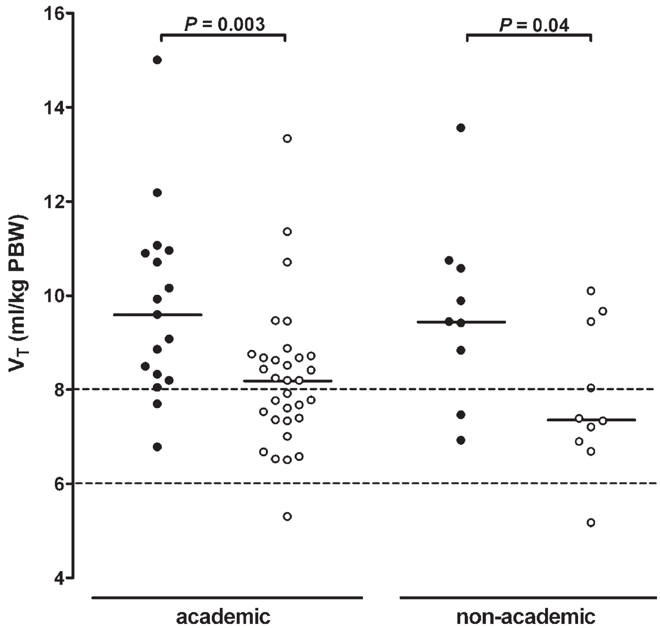

Fig. 1 Tidal volumes declined in non-ALI/ARDS patients after intervention. Tidal volumes measured before (*closed symbols*) and after intervention on the use of lung-protective mechanical ventilation (*open symbols*) in one academic and two nonacademic centers. *Each dot* mean tidal volume of an individual patient; tidal volumes were collected three times per day for 2 weeks; *horizontal lines* median tidal volumes; *area between dotted lines* target tidal volume (as described in the mechanical ventilation protocol)

Tidal volume based on predicted and actual body weight (before intervention)

Mean PBW (63.6±10.6 kg) was 15% less than mean ABW (76.4±14.2 kg). When tidal volumes were adjusted to ABW instead of PBW, tidal volumes were above 8 ml/kg in 43% of cases at the AMC and in 81% at the GH and

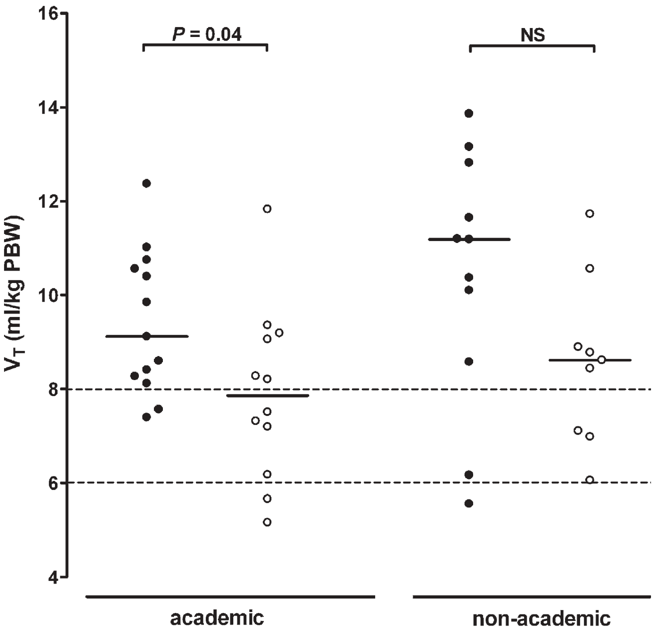

Fig. 2 Tidal volumes declined in ALI/ARDS patients after intervention. *Each dot* mean tidal volume of an individual patient; tidal volumes were collected three times per day for 2 weeks; *horizontal lines* median tidal volumes

the MCL, and above 10 ml/kg in 17% at the AMC and in 38% at the GH and the MCL.

Ventilator modes, PEEP and P-max

PC or PS modes of MV were most often used in all centers; adaptive support ventilation (as provided by Hamilton Galileo) was used in a significant number of patients at MCL (Table 2). Levels of PEEP, Pmax, respiratory rate, and ventilator mode are presented in Table 2. Pmax was higher than 30 cmH_2O in 19% of observations before education, with no difference between ALI/ARDS and non-ALI/ARDS patients, and in 8% after the intervention (p=0.1).

pH and $PaCO_2$ levels

Before the intervention pH and $PaCO_2$ levels in ALI/ARDS and non-ALI/ARDS patients did not differ; hypercapnia ($PaCO_2 \geq 50$ mmHg) occurred in only 2% of patients. After the intervention hypercapnia occurred in 13% of patients (p=0.04), with no difference between ALI/ARDS patients and non-ALI/ARDS patients

Relationship between mode of ventilation and tidal volume

To determine whether tidal volumes vary with the MV mode used in the ICU we differentiated those were receiving MV with PS and those receiving it with PC. No differences in tidal volumes were seen between the two groups, either before or after the intervention (Fig. 3).

Long-term results

In the data collected at the AMC 1 year after intervention tidal volumes were 7.8±1.3, compared to 8.1±1.7 ml/kg PBW 6 months previously (p=0.27). These tidal volumes 6 and 12 months after the intervention were significantly lower than those before intervention (p<0.0001). Tidal volumes were 7.5±1.1 and 7.9±1.3 ml/kg PBW in those with and without ALI/ARDS patients, respectively (Fig. 4).

Table 2 Mechanical ventilation data in an academic ICU (Academic Medical Center) and two nonacademic ICUs (Gelre Hospital, Medical Center Leeuwarden) before and after education (*ASV* adaptive-support ventilation, *VCV* volume-controlled ventilation, *PSV* pressure-support ventilation, *PCV* pressure-controlled ventilation, *Pmax* maximum airway pressure, *Pplat* plateau airway pressure)

	Academic ICU		Nonacademic ICUs	
	Before (n=30)	After (n=45)	Before (n=20)	After (n=19)
Ventilator mode (%)				
ASV	0	0	16.4*	4.9
VCV	2.2	6.6	2.4*	0
PSV	60.4	65.9	27.3	59*
PCV	37.4	27.5	53.9*	36.1
Ventilator settings, median (IQR)				
Respiratory rate (breaths/min)	17.9 (15.7–23.1)	17 (14–24.2)	19.4 (17.5–21.8)	21 (19–23)
PEEP (cmH_2O)	6.3 (5.0–9.2)	7.5 (6–12.9)*	10 (9.1–13)	8.7 (7.8–11)
Pmax or Pplat (cmH_2O)	20.5 (15.8–25)	21 (17.8–23.3)	27.3 (20.9–32.4)	22 (19.7–27)
Blood gas analysis, median (IQR)				
pH	7.44 (7.4–7.45)	7.42 (7.4–7.45)	7.38 (7.33–7.44)	7.42 (7.37–7.45)
PaCO2 (mmHg)	36.3 (34.0–40.0)	39.4 (34.7–43)	38 (33.4–45)	37.2 (33.6–43.3)

*p<0.05

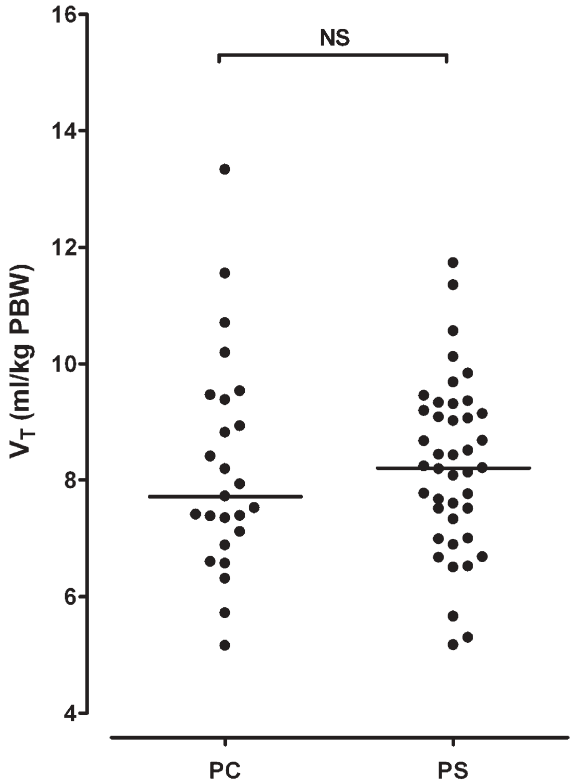

Fig. 3 Tidal volumes during spontaneous mechanical ventilation (pressure support, *PS*) or mandatory mechanical ventilation (pressure control, *PC*) were similar after intervention. *Each dot* mean tidal volume of an individual patient; *horizontal line* median tidal volume per group; *NS* not significant

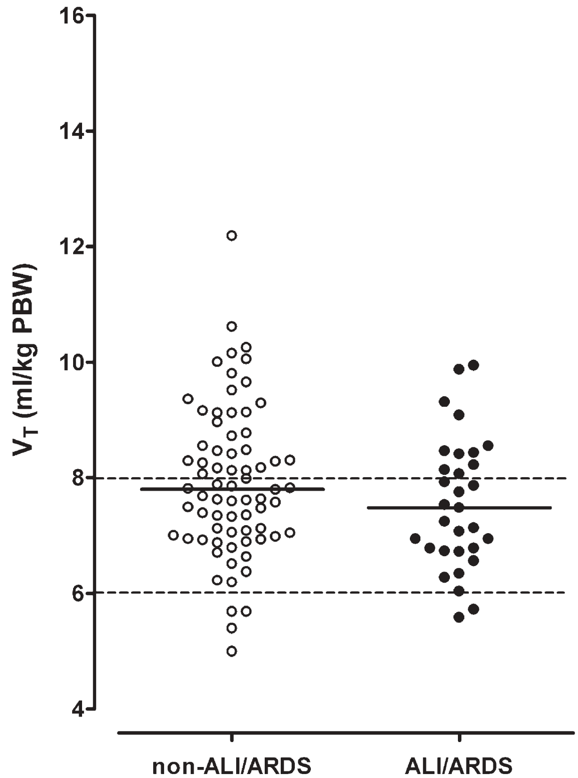

Fig. 4 Long-term results. Tidal volumes 12 months after intervention in the academic center. *Open symbols* non-ALI/ARDS patients; *closed symbols* ALI/ARDS patients; *each dot* mean tidal volume of an individual patient; *horizontal lines* median tidal volumes per patient group

Discussion

A valuable advance in the field of MV has been the clear demonstration that use of lower tidal volumes, rather than conventional MV using higher tidal volumes, significantly reduces mortality in patients with ALI/ARDS [2]. Other so-called lung-protective MV approaches such as use of PC MV, optimal PEEP, recruitment maneuvers, prone positioning, high-frequency oscillation, and permissive hypercapnia have not proven effective. Although guidelines support the use of lower tidal volumes in ALI/ARDS patients [14], physicians have been slow to adopt lung-protective MV using lower tidal volumes. The present study shows that an educational program showing actual daily practice to all ICU team members, emphasizing the use of PBW instead of ABW to set tidal volumes, can significantly reduce tidal volumes.

The results of our study are in accord with those of other investigators. Several published and unpublished studies have shown the reluctance of physicians and respiratory therapists in applying lung-protective MV using lower tidal volumes [6, 7, 15]. Reported reasons for not using lower tidal volumes are diagnostic uncertainty [9] and unwillingness to use lower tidal volumes [8]. Importantly, many ICU physicians believe that normal tidal volumes are greater than they actually are [16]. In addition, use of ABW instead of PBW to calculate tidal volumes may result in excessively high tidal volumes [10]. Our results highlight the importance of using PBW instead of ABW to calculate tidal volumes. Indeed, we found a substantial difference between ABW and PBW values. Tidal volumes were significantly lower when applied tidal volumes were expressed as milliliters/kilogram ABW. Others have reported various strategies to influence MV practices [17, 18]. Roche and coworkers [18] successfully used an intensive educational program encouraging an active role for ICU nurses and simple protocols written to support increased involvement of nursing staff in the set-up and adjustment of mechanical ventilators. It must be mentioned, however, that the report of these findings did not state whether tidal volumes were adjusted to PBW (i.e., if ABW was used for calculation of tidal volumes, these volumes may still have been too high).

Providing feedback on previous practice has been shown to be more effective than simple education [19]. Recently Cook and coworkers [20] have emphasized the importance in improving daily practice of using an environment scan (to establish the extent to which a prescribed strategy is being used) and understanding current behavior (to determine why a strategy is not used). We performed an environment scan by analyzing current MV settings in our ICUs (showing underutilization of lung-protective MV, using lower tidal volumes) and tried to understand why this happened (discussion on potential reasons for not using lower tidal volumes, illuminating that ABW instead of PBW was used to calculate tidal volumes). We then, successfully, targeted behavior by emphasizing the significance of use of lower tidal volumes, as well as the importance of using PBW to set the ventilator. Using this approach, within 6 months tidal volumes declined significantly. Importantly, after 12 months lower tidal volumes were still being used.

Although tidal volumes declined after intervention, in a number of observations levels were still above 8 ml/kg PBW. In addition, after intervention there was still residual variation. Several factors may explain these findings. First, in our experience, a number of patients have tidal volumes above 8 ml/kg PBW with the lowest level of pressure support (i.e., <5 cmH_2O). Second, there may have been reasons for applying larger tidal volumes (e.g., severe acidosis). A wide variation in tidal volumes has also been noted by others [4, 7]. Results of scientific trials show that unwanted variation remains common in clinical care, and in our study it may also have been caused by unwillingness of the ICU team members to strictly apply to the MV protocol. However, our current analysis does not provide sufficient data to confirm this. Nevertheless, we do think that improving MV settings is a continuous process: new (probably similar) interventions are needed to bring about a further decline in tidal volumes.

It may seem surprising that we advocate the use of lower tidal volumes in all MV patients irrespective of the presence of ALI/ARDS. A recent study, however, shows that patients admitted for other reasons than ALI/ARDS and ventilated with higher tidal volumes have an increased incidence of late-onset ALI/ARDS [4]. In addition, animal studies have shown that lung overdistension induces lung injury [21]. Indeed, MV with relatively high tidal volumes can induce ventilator-induced lung injury in animals with healthy lungs [22, 23]. Although additional studies must be performed to determine whether lower tidal volumes truly benefit patients without ALI/ARDS, at present we also use lower tidal volumes in these patients.

The only two clinical trials reporting mortality benefit from lung protective ventilation in ALI targeted either tidal volumes less than 6 ml/kg PBW [2], with the allowance of using tidal volumes up to 8 ml/kg PBW in some circumstances, or tidal volumes less than 6 ml/kg ABW [3]. However, our protocol prescribed tidal volumes between 6 and 8 ml/kg PBW, and therefore, at least in patients with ALI/ARDS, our intervention may not be sufficient to improve lung-protective MV.

From the present findings it cannot be concluded which part of the intervention had the greatest impact. Although we consider feedback on current practice and discussions on new insights on MV and potential barriers to introduce results from trials of importance, it may be that simply a discussion on MV would have caused a change in practice. Further, one must bear in mind that any change observed may have been due to other factors than the intervention. It can be suggested that enough time had passed with further debate in the literature, and locally that tidal volumes would have been declined in any case.

In conclusion, after feedback and education ICU physicians prescribed lower tidal volumes more frequently. Our findings underscore the use of PBW instead of ABW to calculate tidal volumes.

References

1. Slutsky AS (1999) Lung injury caused by mechanical ventilation. Chest 116:9S-15S
2. Acute Respiratory Distress Syndrome Network (2000) Ventilation with lower tidal volumes as compared with traditional tidal volumes for acute lung injury and the acute respiratory distress syndrome. N Engl J Med 342:1301–1308
3. Amato MB, Barbas CS, Medeiros DM, Magaldi RB, Schettino GP, Lorenzi-Filho G, Kairalla RA, Deheinzelin D, Munoz C, Oliveira R, Takagaki TY, Carvalho CR (1998) Effect of a protective-ventilation strategy on mortality in the acute respiratory distress syndrome. N Engl J Med 338:347–354
4. Gajic O, Dara SI, Mendez JL, Adesanya AO, Festic E, Caples SM, Rana R, St Sauver JL, Lymp JF, Afessa B, Hubmayr RD (2004) Ventilator-associated lung injury in patients without acute lung injury at the onset of mechanical ventilation. Crit Care Med 32:1817–1824
5. Brower RG, Thompson BT, Ancukiewicz M (2004) Clinical trial of mechanical ventilation with traditional versus lower tidal volumes in acute lung injury and acute respiratory distress syndrome: effects on physicians' practices. Am J Respir Crit Care Med 169:A256
6. Weinert CR, Gross CR, Marinelli WA (2003) Impact of randomized trial results on acute lung injury ventilator therapy in teaching hospitals. Am J Respir Crit Care Med 167:1304–1309
7. Young MP, Manning HL, Wilson DL, Mette SA, Riker RR, Leiter JC, Liu SK, Bates JT, Parsons PE (2004) Ventilation of patients with acute lung injury and acute respiratory distress syndrome: has new evidence changed clinical practice? Crit Care Med 32:1260–1265
8. Rubenfeld GD, Cooper C, Carter G, Thompson BT, Hudson LD (2004) Barriers to providing lung-protective ventilation to patients with acute lung injury. Crit Care Med 32:1289–1293

9. Dedhiya P, Mikkelsen R, Kalhan R, Caughan C, Lanken B (2004) Early clinician recognition of acute lung injury may increase use of lung protective ventilation. Am J Respir Crit Care Med 169:A17
10. Kam EP, Eslick GD, James A, Benson JP (2004) Acute respiratory distress syndrome (ARDS) and low tidal volume ventilation: the debate about weight. Intensive Care Med 30:1502
11. Wolthuis E, Spronk P, Kuiper M, Vroom M, Schultz M (2004) Dutch intensivists do not use small tidal volumes (Vt) in mechanical ventilation (MV). Crit Care 8 [Suppl 1]:P26
12. Bernard GR, Artigas A, Brigham KL, Carlet J, Falke K, Hudson L, Lamy M, Legall JR, Morris A, Spragg R (1994) The American-European Consensus Conference on ARDS. Definitions, mechanisms, relevant outcomes, and clinical trial coordination. Am J Respir Crit Care Med 149:818–824
13. Devine B (1974) Gentamicin therapy. Drug Intell Clin Pharm 8:650–655
14. Dellinger RP, Carlet JM, Masur H, Gerlach H, Calandra T, Cohen J, Gea-Banacloche J, Keh D, Marshall JC, Parker MM, Ramsay G, Zimmerman JL, Vincent JL, Levy MM (2004) Surviving sepsis campaign guidelines for management of severe sepsis and septic shock. Crit Care Med 32:858–873
15. Rubenfeld GD, Caldwell E, Hudson L (2001) Publication of study results does not increase use of lung protective ventilation in patients with acute lung injury. Am J Respir Crit Care Med 163:A295
16. Tobin MJ, Chadha TS, Jenouri G, Birch SJ, Gazeroglu HB, Sackner MA (1983) Breathing patterns. 1. Normal subjects. Chest 84:202–205
17. Hunter J, Rothwell M (2004) New method to evaluate the practice of positive pressure ventilation in intensive care units. Br J Anaesth 92:296–297
18. Roche RJ, Mackinlay C, McLaughlin A, Panikkar K, Young JD (2003) New method to evaluate the practice of positive pressure ventilation in intensive care units. Br J Anaesth 91:419–420
19. Bero LA, Grilli R, Grimshaw JM, Harvey E, Oxman AD, Thomson MA (1998) Getting research findings into practice: closing the gap between research and practice: an overview of systematic reviews of interventions to promote the implementation of research findings. BMJ 317:465–468
20. Cook DJ, Montori VM, McMullin JP, Finfer SR, Rocker GM (2004) Improving patients' safety locally: changing clinician behaviour. Lancet 363:1224–1230
21. Dreyfuss D, Soler P, Basset G, Saumon G (1988) High inflation pressure pulmonary edema. Respective effects of high airway pressure, high tidal volume, and positive end-expiratory pressure. Am Rev Respir Dis 137:1159–1164
22. Belperio JA, Keane MP, Burdick MD, Londhe V, Xue YY, Li K, Phillips RJ, Strieter RM (2002) Critical role for CXCR2 and CXCR2 ligands during the pathogenesis of ventilator-induced lung injury. J Clin Invest 110:1703–1716
23. Wilson MR, Choudhury S, Goddard ME, O'Dea KP, Nicholson AG, Takata M (2003) High tidal volume ventilation upregulates intrapulmonary cytokines in an in vivo mouse model of ventilator-induced lung injury. J Appl Physiol 95:1385–1393