Brief Communication

# A complete audit cycle to assess adherence to a lung protective ventilation strategy

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**Abstract**

There is clear evidence for the use of a protective ventilation protocol in patients with acute respiratory distress syndrome (ARDS). There is evidence to suggest that protective ventilation is beneficial in patients at risk of ARDS. A protective ventilation strategy was implemented on our intensive care unit in critical care patients who required mechanical ventilation for over 48 h, with and at risk for ARDS. A complete audit cycle was performed over 13 months to assess compliance with a safe ventilation protocol in intensive care. The ARDS network mechanical ventilation protocol was used as the standard for our protective ventilation strategy. This recommends ventilation with a tidal volume ($V_t$) of 6 ml/kg of ideal body weight (IBW) and plateau airway pressure of ≤30 cm $H_2O$. The initial audit failed to meet this standard with $V_t$'s of 9.5 ml/kg of IBW. Following the implementation of a ventilation strategy and an educational program, we demonstrate a significant improvement in practice with $V_t$'s of 6.6 ml/kg of IBW in the re-audit. This highlights the importance of simple interventions and continuous education in maintaining high standards of care.

**Keywords:** Intensive care, protective, respiratory, tidal volume, ventilation

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## Introduction

There is clear evidence for the use of a protective ventilation protocol in patients with acute respiratory distress syndrome (ARDS). The hallmark ARDS network (ARDSNet) trial of 2000 showed a significant mortality benefit in patients ventilated with a protective ventilation strategy with low tidal volume ($V_t$) of 6 ml/kg of ideal body weight (IBW) and plateau pressure of 30 cm $H_2O$ or below.[1] Ventilator induced lung injury (VILI) through large $V_t$s, volutrauma, high airway pressures, barotrauma, and sheer stress from repetitive opening and closing of alveoli, atelectotrauma, can cause lung damage in normal lungs.[2,3]

Protective ventilation strategies for patients with noninjured lungs remains controversial and large randomized studies are needed. A number of studies have shown that protective ventilation is beneficial in patients at risk of developing ARDS. For instance in patients who have undergone a primary physiological insult such as critically ill patients with sepsis, pneumonia, trauma or high risk surgical patients requiring intensive care unit (ICU) care postoperatively. In these patients, it is sensible to implement a protective ventilation strategy to minimize the risk of developing ARDS.

A multicenter randomized trial in 2013 showed improved clinical outcomes with fewer respiratory complications in patients ventilated with a lung-protective ventilation strategy undergoing major abdominal surgery.[4] In an observational study Gajic *et al*. assessed risk factors for the development of VILI in mechanically ventilated ICU patients. They concluded that high $V_t$s (>6 ml/kg IBW) were associated with the development of acute lung injury (ALI).[5] In another study by Gajic *et al*., over 3000 ICU patients without ARDS were mechanically ventilated for 48 h or more. High $V_t$s were associated with ARDS with an odds ratio of 2.6 for a $V_t$ over 700 ml.[6] Determann *et al*. performed a randomized trial comparing traditional

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and protective $V_t$s in 152 critically ill-patients. The trial was stopped early as more patients in the conventional group developed ALI (13.5% vs. 2.6% $P = 0.01$).[7]

We recommend a protective ventilation strategy in critical care patients who require mechanical ventilation for over 48 h and have or are at risk for ARDS. This is in line with current opinion and recent evidence.[8]

### Aim

The aim of this audit was to assess compliance with a safe ventilation strategy for mechanically ventilated patients on ICU with or at risk of ARDS. The mechanical ventilation protocol set out by ARDS clinical network was used as the standard for both audits in the management of patients requiring mechanical ventilation. These recommend a $V_t$ of 6 ml/kg of IBW and a plateau airway pressure of ≤30 cm $H_2O$.

The survey was carried out alongside the initial audit. This aimed to establish the level of knowledge amongst ICU nursing staff surrounding ARDS.

## Methods

Data were collected prospectively for both phases of the audit over an 8-week period, data collection were anonymous and only nonidentifiable information was used. The audit was registered with the hospitals audit board. The initial audit was carried out from December 2010 to January 2011, and the re-audit was carried out from January 2012 to February 2012. Data was collected from a nine bedded general ICU. All critical care patients who were mechanically ventilated for over 48 h and who were at risk of developing ARDS were included in the audit. Risk factors for ARDS included: Sepsis, trauma, high-risk surgery, pneumonia, aspiration, and blood transfusion. Exclusion criteria were: Patients ventilated for <48 h, patients' breathing spontaneously and patients' using noninvasive ventilation. There were no patients with head injury in our audit.

Data collection for each patient included: Admission diagnosis, age, sex, height, and IBW. Patients' height was measured on admission and recorded on the ICU chart; this along with the patient's sex, was used to calculate IBW [Table 1].[1] A reference sheet with IBW calculated using this formula was available for a range of heights at each ICU bed space. IBW was then used to calculate a $V_t$ of 6 ml/kg as part of a protective ventilation strategy.

Ventilation parameters collected included mean daily $V_t$, plateau airway pressure and the lowest partial pressure of arterial oxygen ($P$)/fraction of inspired oxygen ($F$) ratio ($P/F$ ratio) for each ventilated day recorded.[2] The $P/F$ ratio is used as an indicator of disease severity in ARDS. Data were collected from ICU charts in each bed space. Data were collected on a spreadsheet using Microsoft Excel for Windows and analyzed using Statistical package for the social sciences (SPSS). Data were tested for normality. Student's $t$-test was used for continuous data and Fischer's exact test for categorical data.

An anonymous survey in the form of a short questionnaire was carried out prospectively over a 2-day period in January 2011 alongside the initial audit. This assessed knowledge of ARDS among critical care nurses. The questionnaire was distributed to a random sample of 30 nurses working at our critical care unit. Questions assessed their understanding regarding definitions of ARDS, and their knowledge of how to calculate IBW and the ideal $V_t$ for patients with or at risk of ARDS.

Following the initial audit, an education program targeted at junior doctors and ICU nurses were introduced, this aimed to improve compliance to a protective ventilation strategy. Education focused on the importance of using safe ventilation parameters in patients at risk of ARDS, how to calculate IBW and deliver $V_t$'s of 6 ml/kg of IBW at the bedside. Laminated cards were placed on the intensive care ventilators as a reminder. These displayed recommended ventilation parameters including IBW for a range of heights and ideal $V_t$'s for a range of IBW's.

## Results

Data were collected for a total of 141 ventilated days in the first audit and 125 ventilated days in the re-audit. There were no differences between the two audit cohorts at baseline [Table 2]. The main ventilation mode used was pressure-synchronized intermittent mandatory ventilation. Overall mean $V_t$'s was 9.5 ml/kg of IBW in the initial audit compared to 6.6 ml/kg IBW ($P < 0.0001$) following the implementation of the intervention [Figure 1]. No difference was seen in mean plateau airway pressures between the two phases of the audit (29.5 cm $H_2O$ vs. 30.2 cm $H_2O$). The lowest mean $P/F$ ratio for the initial and re-audit were 131 and

**Table 1: IBW calculated using a patient's sex and height in the following formula**

| Sex | IBW (kg) |
|---|---|
| Male | 50+ (0.91×height (cm) -152.4) |
| Female | 45.5+ (0.91×height (cm) -152.4) |

IBW: Ideal body weight

173 mmHg, respectively ($P < 0.0002$) [Table 2]. Outcome measures included 30 days mortality, which was the same in both cohorts, 5 (35.7%) patients died in each cohort [Table 2].

The nursing survey was distributed to 30 nurses, of whom 24 (80%) responded. About 16 (67%) of the nurses in the survey were a band five, 4 (17%) were band six, and 3 (13%) were a band seven. The average number of years of critical care experience was 7 years. 20 (83%) responders knew the meaning of ARDS, and 22 (92%) used the hospitals ventilation protocol for patients with or at risk of ARDS. The majority of nurses in the survey 16 (70%) stated they were aware of how to calculate a safe $V_t$ for patients' with ARDS. 10 (42%) of the nurses surveyed calculated IBW. 10 (42%) of the nurses surveyed knew the ideal $V_t$ for patients with ARDS.

## Discussion

This completed audit cycle demonstrated a significant improvement in clinical practice through the implementation of a simple education program aimed at junior doctors and nursing staff through increased awareness surrounding a protective ventilation strategy on ICU. The standards of this audit were to comply with a protective ventilation strategy for patients at risk of ARDS, in accordance with evidence based guidelines set out by ARDSNet. The initial and re-audit both met the standards for pressure limited ventilation as part of a protective ventilation strategy; however, the initial audit failed to meet standards for a protective volume ventilation strategy. Patients were ventilated with large $V_t$'s similar to conventional ventilation strategies of 10 ml/kg/IBW. Following implementation of interventions, the re-audit demonstrated a significant improvement in compliance to this standard.

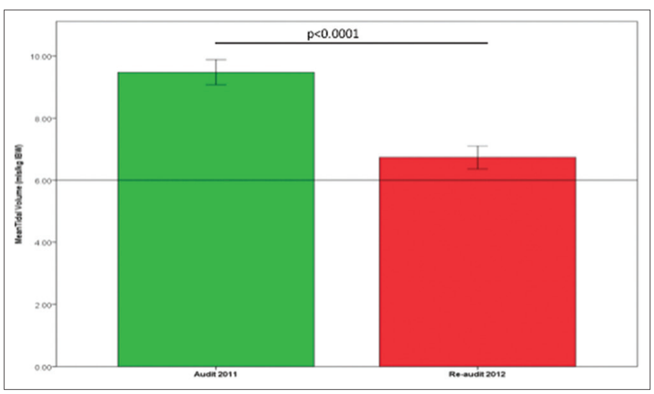


**Figure 1:** Mean Tidal Volumes between the two audits. Error bars represent 95% CI of the mean. *$t$-test

**Table 2: Demographics and data between the two audit groups**

| | Audit 2010 ($n$=14) (%) | Audit 2012 ($n$=14) (%) | $P$ |
|---|---|---|---|
| Age* | 49.2 (17.7) | 63.6 (19.1) | 0.1139 |
| Sex, female | 9 (64.3) | 8 (42.9) | 0.7388 |
| Mortality | 5 (35.7) | 5 (35.7) | 1.0 |
| Length of stay* | 21.50 (10.9) | 31.64 (21.5) | 0.1283 |
| Lowest $P/F$ ratio (mmHg)* | 130.8 (69.7) | 172.9 (106.5) | 0.0002 |
| APACHE II* | 19.2 (6.7) | 20.6 (4.0) | 0.4828 |
| Tidal volume (ml/kg IBW)* | 9.5 (2.4) | 6.6 (2.0) | 0.0001 |

*Values represent mean and standard deviation. $P/F$: Partial pressure of arterial oxygen/fraction of inspired oxygen; APACHE II: Acute physiology and chronic health evaluation II; IBW: Ideal body weight

There is good evidence from both animal and human studies to suggest that a high $V_t$ strategy can cause volutrauma and is associated with a significant risk of VILI. Lower $V_t$ of 6 ml/kg improves clinical outcome in patients with and at risk of ARDS.[1,3-7] This evidence is further enhanced by a randomized controlled trail by Pinheiro de Oliveira *et al*. This suggests that high $V_t$ may induce lung injury in mechanically ventilated patients' with normal lungs.[9] Reasons for high $V_t$ include poor nurse education on how to implement a safe ventilation protocol in these patients as highlighted in the survey and a failure to recognize patients at risk of ARDS amongst intensive care staff. Many of the junior doctors were foundation level or medical core trainees with limited ICU experience.

The lowest mean $P/F$ ratio was significantly lower in the initial audit than the re-audit; this may have contributed to higher observed $V_t$s in this group. We recognize the importance of implementing protective ventilation in these patients. Larger $V_t$ observed in patients with lower $P/F$ ratios suggests that these patients may be particularly difficult to ventilate using a safe ventilation strategy. However, the $P/F$ ratio for both audits met ARDS criteria.

The nursing survey identified an educational need amongst nursing staff regarding ARDS and appropriate ventilation strategies for these patients. Most responders claimed to use the ARDS ventilation protocol and were aware of how to calculate a safe $V_t$ for these patients. However, the survey demonstrated that most nurses did not calculate IBW. The majority of responders did not know the ideal $V_t$ value of 6 ml/kg, without this knowledge, the ventilation protocol cannot be implemented. Our survey found that most nurses had not undergone formal training on ARDS and its management, and when questioned, most felt they would benefit from further training.

There are many challenges to the effective implementation of a protective ventilation strategy on ICU. This audit demonstrated that simple interventions in combination with a targeted education program can improve compliance with a safe ventilation protocol. These changes have improved our management of patients at risk of, and with established ARDS at the bedside. We hope that a simple education program can be implemented across other ICU's to help optimize the management of patients with or at risk of ARDS.

### *Recommendations*

A mandatory half day training session on ARDS and lung-protective ventilation for critical care nursing staff and regular teaching on ARDS for junior doctors at the start of each rotation. More consultant led focus on safe ventilation strategy during ward rounds. This should include a $V_t$ prescription box on the bedside chart of every patient, to be filled out on the daily consultant ward round. Ventilation strategy to be assessed as part of the protocol when setting up ventilation for a new ICU admission, and to be recorded in the notes with a sticker. Increased tolerance of permissive hypercapnia.

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