Editorials

Measuring Dead Space: Does It Really Matter? or, What Are We Waiting For?

This issue of the Journal features 2 valuable papers on different aspects of the ratio of physiologic dead space to tidal volume (VD/VT). The study by Raurich and colleagues demonstrates that elevated VD/VT during both the early phase (within 3 days of lung injury onset) and the intermediate phase (from 8–10 days) of acute respiratory distress syndrome (ARDS) is associated with greater mortality risk. They found that the mean VD/VT in survivors was < 0.55, in contrast to non-survivors, in whom the mean VD/VT was > 0.60, and at both time points higher VD/VT was independently associated with greater mortality risk. The paper by McSwain et al reveals data that show a strong correlation between the arterial carbon dioxide (PaCO₂) and end-tidal carbon dioxide [PETCO₂] difference and all VD/VT ranges they measured in pediatric patients (age range 0–17 years).

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These works contribute to the growing body of knowledge that demonstrates the importance of assessing and measuring VD/VT, which is linked to mortality risk in ARDS and to other important clinical indices. VD/VT correlates with the severity of lung injury, and may help predict successful extubation in pediatric and adult patients, and may be useful in diagnosing and assessing the severity of pulmonary embolism.

The findings by Raurich et al both support and extend the importance of the results of previous studies. In the original study by Nuckton et al, an early VD/VT elevation was independently associated with mortality, whereas in a subset of the patients who survived to ARDS day 6, a sustained VD/VT increase of > 0.55 also distinguished survivors from non-survivors. What is unique in the study by Raurich and colleagues is the finding that the mortality risk increased markedly from the early to the intermediate phase of ARDS, with odds ratios (OR) of 1.59 and 2.87, respectively. Furthermore, these results support the findings of both Cepkova et al and Lucangelo et al in that elevated VD/VT was associated with mortality in the era of lung-protective ventilation. This is important because VD/VT might be expected to lose some of its specificity as a mortality predictor because of a relative increase in anatomic deadspace volume when smaller VT and shorter inspiratory times are used.

In the study by Nuckton et al, VD/VT originally was measured daily for the first 3 days of ARDS, and every third day thereafter until day 21 in patients who still required continuous mechanical ventilation. Ultimately, these measurements were abandoned because of the relatively small number of patients available for study. At that time, however, VD/VT already had been measured in 34 patients on ARDS day 9. Coincidentally, Raurich and colleagues also made their intermediate measurements at an average of ARDS day 9. Because we had access to the database of Nuckton et al, we compared those measurements to the findings of Raurich and colleagues. In the 34 patients in the Nuckton et al study, VD/VT (corrected for compression volume contamination) measured on ARDS day 9 was significantly different between survivors and non-survivors (0.53 ± 0.09 vs 0.68 ± 0.07, P < .001 via unpaired t test). Likewise, the OR and 95% confidence interval (95% CI) for mortality (via Fisher’s exact test), based on a VD/VT cut-off value of 0.60, similarly increased over the course of ARDS from day 1 (OR = 1.63, 95% CI 1.05–2.51, P = .03) to day 3 (OR = 2.50, 95% CI 1.39–4.50, P = .008) and day 9 (OR = 3.41, 95% CI 1.19–9.85, P = .007). It is important to emphasize that this subset of patients from the Nuckton et al study consisted of all the patients who had survived until day 9 and had measurements at each of the protocol-stipulated time points.

These findings are consistent with the results of Raurich and colleagues published in this issue of the Journal. Raurich and colleagues have reaffirmed the prognostic value of VD/VT measurements in ARDS, both in the early and, now, in the intermediate phase of the disease.

The study by McSwain et al in this issue of the Journal shows a strong correlation of the relationship between PaCO₂ and PETCO₂, across ranges of VD/VT in pediatric patients, and, more importantly, validates previous findings of the clinical utility of the PaCO₂-PETCO₂ difference as a surrogate for measured VD/VT. Over 20 years ago, Yamanaka...
and Sue\textsuperscript{19} demonstrated that the $P_{acO_2}$-$P_{ETCO_2}$ difference correlated closely with $V_T/V_I$ in adult patients with respiratory failure, and suggested that calculation of the $P_{acO_2}$-$P_{ETCO_2}$ difference was the most appropriate use of end-tidal CO\textsubscript{2} monitoring, which could be easily adapted for expedient measurement of $V_T/V_I$.

In 1984, a study by Murray and colleagues\textsuperscript{20} suggested that the $P_{acO_2}$-$P_{ETCO_2}$ difference may be a more sensitive indicator of appropriate positive end-expiratory pressure (PEEP) than are changes in shunt or $P_{aO_2}$. In that study, in dogs with oleic-acid-induced lung injury, the $P_{acO_2}$-$P_{ETCO_2}$ difference was smallest at, or close to, the lowest shunt fraction and the highest $P_{aO_2}$. Murray and colleagues concluded that monitoring the $P_{acO_2}$-$P_{ETCO_2}$ difference would permit rapid titration of PEEP by indicating when the perfusion and distribution of blood flow to ventilating gas-exchange units is optimized during lung recruitment.

More recently, Tussman and associates\textsuperscript{21} demonstrated that the $P_{acO_2}$-$P_{ETCO_2}$ difference was useful for detecting the point of lung collapse and for establishing open-lung PEEP after a recruitment maneuver. In their model with surfactant-depleted pigs, a decremental PEEP trial was performed after a recruitment maneuver. $V_D$ variables were compared with the volumetric state of the lungs with computed tomography and gas exchange via calculation of shunt fraction. Tussman et al found that alveolar $V_D$, the ratio of alveolar $V_D$ to alveolar $V_T$, and the $P_{acO_2}$-$P_{ETCO_2}$ difference were the variables that most closely correlated with the development of lung collapse on computed tomogram, as well as with changes in arterial oxygenation. Of importance to note, the $P_{acO_2}$-$P_{ETCO_2}$ difference and the ratio of alveolar $V_D$ to alveolar $V_T$ had the highest sensitivity and specificity in detecting early lung collapse, with an area of 0.99 under the receiver operating characteristic curve. Based on these results, Tussman et al concluded that, since the ratio of alveolar $V_D$ to alveolar $V_T$ (as opposed to $V_D/V_T$) agreed well with lung recruitment observed via computed tomography, the ratio of alveolar $V_D$ to alveolar $V_T$ should replace the classical $V_D/V_T$ ratio whenever alveolar aeration is to be optimized.

The confluence of readily available bedside measurement of $V_D/V_T$ (via volumetric capnography\textsuperscript{22-24} and the growing body of evidence demonstrating its broad clinical value strongly supports the widespread adoption of $V_D/V_T$ measurement and assessment into routine clinical practice. Volumetric capnography provides both clinicians and investigators with a robust measure of pulmonary function, which remains largely underutilized. Given the relative ease of determining the $P_{acO_2}$-$P_{ETCO_2}$ difference, use of this physiologic variable may be an even better and more cost-effective way to evaluate changes in $V_D/V_T$, to assess lung recruitment, and to optimize gas exchange.

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Mr Kallet has disclosed a relationship with Phillips Respironics. Mr Siobal has disclosed no conflicts of interest.

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