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 (V_D/V_T). The study by Raurich and colleagues[1] demonstrates that elevated V_D/V_T 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 V_D/V_T in survivors was < 0.55, in contrast to non-survivors, in whom the mean V_D/V_T was > 0.60, and at both time points higher V_D/V_T was independently associated with greater mortality risk. The paper by McSwain et al[2] reveals data that show a strong correlation between the arterial carbon dioxide (P_{aCO_2}) to end-tidal carbon dioxide [P_{ETCO_2} difference and all V_D/V_T ranges they measured in pediatric patients (age range 0–17 years).

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These works[1,2] contribute to the growing body of knowledge that demonstrates the importance of assessing and measuring V_D/V_T, which is linked to mortality risk in ARDS[3-6] and to other important clinical indices. V_D/V_T correlates with the severity of lung injury,[7-11] can be useful as an indicator of lung recruitment versus overdistention in patients with acute lung injury,[12-14] may help predict successful extubation in pediatric[15] and adult patients,[16] and may be useful in diagnosing and assessing the severity of pulmonary embolism.[17,18]

The findings by Raurich et al[1] both support and extend the importance of the results of previous studies.[3,4] In the original study by Nuckton et al,[3] an early V_D/V_T elevation was independently associated with mortality, whereas in a subset of the patients who survived to ARDS day 6, a sustained V_D/V_T increase of > 0.55 also distinguished survivors from non-survivors.[4]

What is unique in the study by Raurich and colleagues[1] 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[5] and Lucangelo et al,[6] in that elevated V_D/V_T was associated with mortality in the era of lung-protective ventilation. This is important because V_D/V_T might be expected to lose some of its specificity as a mortality predictor because of a relative increase in anatomic dead-space volume when smaller V_T and shorter inspiratory times are used.

In the study by Nuckton et al,[3] V_D/V_T 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, V_D/V_T already had been measured in 34 patients on ARDS day 9. Coincidentally, Raurich and colleagues[1] also made their intermediate measurements at an average of ARDS day 9. Because we had access to the database of Nuckton et al,[3] we compared those measurements to the findings of Raurich and colleagues.[1]

In the 34 patients in the Nuckton et al study,[3] V_D/V_T (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 V_D/V_T 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[3] 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[1] published in this issue of the Journal. Raurich and colleagues[1] have reaffirmed the prognostic value of V_D/V_T measurements in ARDS, both in the early and, now, in the intermediate phase of the disease.

The study by McSwain et al[2] in this issue of the Journal shows a strong correlation of the relationship between P_{aCO_2} and P_{ETCO_2} across ranges of V_D/V_T in pediatric patients, and, more importantly, validates previous findings of the clinical utility of the P_{aCO_2}-P_{ETCO_2} difference as a surrogate for measured V_D/V_T. Over 20 years ago, Yamanaka and Sue[19] demonstrated that the P_{aCO_2}-P_{ETCO_2} difference correlated closely with V_D/V_T 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_2 monitoring, which could be easily adapted for expedient measurement of V_D/V_T.

In 1984, a study by Murray and colleagues[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[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[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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