# The Search for the Optimal Tidal Volume: Why Do We Use Body Weight?

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The tidal volumes used during mechanical ventilation can be a contributing factor to lung injury in the perioperative period.[1] Tidal volumes are only one of multiple factors that have been shown to interact in a complex fashion to potentially injure a patient's lungs.[2] Among these other potential factors are driving pressure,[3] positive end expiratory pressure (PEEP)[4] recruitment,[5] $FIO_2$, inflammation, anti-inflammatories (including some anesthetics),[6] blood products, and other fluids.[7] However, among the multiple factors that enter in the equation of lung injury, tidal volumes are the most studied factor, both in healthy and in previously injured lungs. The reasons that tidal volumes have been scrutinized so closely are not completely obvious. It could be due to the availability of data for retrospective studies or due to the ability to control this variable in prospective studies.

One factor that is common to essentially all studies of tidal volume and lung injury is that some measure of the patient's body weight (actual, predicted, or ideal) is used to choose the tidal volumes to be studied.[8,9] This approach in research is not unreasonable, because I believe that, in practice, most clinicians are probably thinking of body weight, at least as 1 factor, when they dial-in the settings on their ventilator. In this issue of *Anesthesia & Analgesia*, Hoftman et al[10] use forced vital capacity (FVC) to predict lung compliance and to help select an optimal tidal volume during intraoperative mechanical ventilation. A major question raised by this study is as follows: why do we usually use body weight to choose tidal volumes?

Body weight is recognized as a poor predictor of lung function and volumes. Chest physicians have known for a long time that to compare measured pulmonary function among normal individuals, it is necessary to correct for height, age, sex, and race/ethnicity[11] (not weight). Although equations to develop predicted body weights (PBW) include sex and height, there is very little correction for other factors. For example, a 25-year-old Caucasian male, 165 cm (5 ft 4 in) height, has a PBW of approximately 61 kg.[12] During pulmonary function testing, his predicted FVC is 4.7 L. A 70-year-old Caucasian female, 170 cm (5 ft 7 in) height, has an identical PBW of 61 kg but a predicted FVC of 3.3 L (30% less). Why do we assume that the optimal tidal volume is the same for both?

In the study by Hoftman et al,[10] data from 130 patients in the supine position during volume-controlled 2-lung ventilation after the induction of anesthesia were studied retrospectively. Since these patients were scheduled for thoracic surgery, full pulmonary function testing and computed tomography (CT) scans were available for all patients. Total lung capacity from pulmonary function testing ($TLC_{PFT}$) was compared to PBW, spirometric FVC, and total lung capacity derived from 3D CT scans ($TLC_{CT}$). Not surprisingly, PBW was poorly correlated with $TLC_{PFT}$ when compared to FVC. $TLC_{CT}$ was better correlated to $TLC_{PFT}$ than PBW but not as highly correlated as FVC. It is understandable that 1 pulmonary function test (FVC) was more significantly correlated with another pulmonary function test ($TLC_{PFT}$) than a static radiographic assessment of lung volume ($TLC_{CT}$). This is because lung volumes and capacities are the product of the dynamic interaction of 2 springs: the chest-wall/diaphragm mechanical spring and the pulmonary parenchyma. Changes in the mechanical properties of either of these 2 springs affect both lung volumes and capacities.

Hoftman et al[10] then examined the ratios of tidal volume/FVC plotted against peak inspiratory pressure to find an optimal tidal volume to adequately ventilate all patients while avoiding high-peak airway pressures in those with decreased compliance. The formula they developed was tidal volume = FVC/8. This formula will give clinical tidal volumes that are not importantly different from tidal volumes derived from common weight-based formulas in the majority of healthy middle-age adults. However, for patients with abnormal pulmonary function, the clinical difference in tidal volume may be very important.

Essentially all anesthesiologists know that the use of excessive tidal volumes in patients with obstructive pulmonary diseases contributes to breath-stacking and auto-PEEP.[13] What is less appreciated is the risk of lung injury in patients with restrictive lung disease secondary to pulmonary fibrosis. In a study of pulmonary resection surgery for lung cancer, a small subgroup (n = 22) of patients with pulmonary fibrosis had an incidence of postoperative lung injury of 21%, significantly higher than patients without pulmonary fibrosis (3.7%).[14] However, the risks of excessive tidal volumes in patients with restrictive lung diseases due to chest-wall or skeletal restrictive processes such as obesity

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or kyphoscoliosis are less clear. In these patients, it is probably not possible to isolate tidal volume as a single risk factor for lung injury and driving pressure, and the other "usual suspects" come into play.

Patients with healthy lungs are normally tolerant of the subclinical lung injury caused by several hours of mechanical ventilation. We have at least 70 years of anesthesia practice to validate the safety of our standard protocols for intraoperative ventilation. However, in patients at an increased risk of perioperative lung injury, we need to continually examine all factors under the control of the anesthesiologist that may exacerbate or ameliorate lung injury. I believe that there are 4 groups of patients at increased risk that clinicians may commonly encounter: patients receiving large-volume transfusions,[15] patients undergoing cardiopulmonary bypass,[16] patients who receive 1-lung ventilation,[17] and patients with restrictive lung disease.[13]

In these high-risk groups, perhaps, we should consider using tidal volumes based on FVC not weight. The data to predict normal FVC (height, age, and ethnicity) are as readily available as body weight for almost all patients. They could easily be programmed into our anesthetic machines to give us a predicted normal FVC and an optimal tidal volume for each patient. This is not to say that the formula developed by Hoftman et al[10] (FVC/8) is the last word. But it is a very useful starting point for further research in perioperative lung injury. Studies using intraoperative static compliance versus dynamic compliance, as used in this current study, may modify the formula.

While pulmonary function testing is not available for most patients presenting for anesthesia, measuring FVC does not require an appointment to the Pulmonary Function Laboratory. It can be measured inexpensively with simple spirometry in the anesthesiology preadmission clinic or even at the bedside. Perhaps we should consider it in any patient with moderate or severe pulmonary disease who is scheduled for surgery that will involve several hours of mechanical ventilation.

Going forward, the work by Hoftman et al[10] has raised an excellent question: why do anesthesiologists use a patient's weight to choose the tidal volume for intraoperative ventilation? This question deserves a better answer.

## DISCLOSURES

**Name:** Peter D. Slinger MD, FRCPC.
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