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Driving Pressure or Tidal Pressure: What a Difference a Name Makes

To the Editor:

In a recent article in this Journal, Baldomero et al[1] provided, for the first time, data on actual ranges of driving pressure for a variety of patients during mechanical ventilation. This is a well-written and useful article, and our intent is not to criticize it but to point out how the common use of the term driving pressure may lead to confusion.

In the Quick Look section of the article, driving pressure (ΔP) is defined as "the difference between P_{plat} [plateau pressure] and end-expiratory pressures."[1] This is not a generally true statement (despite

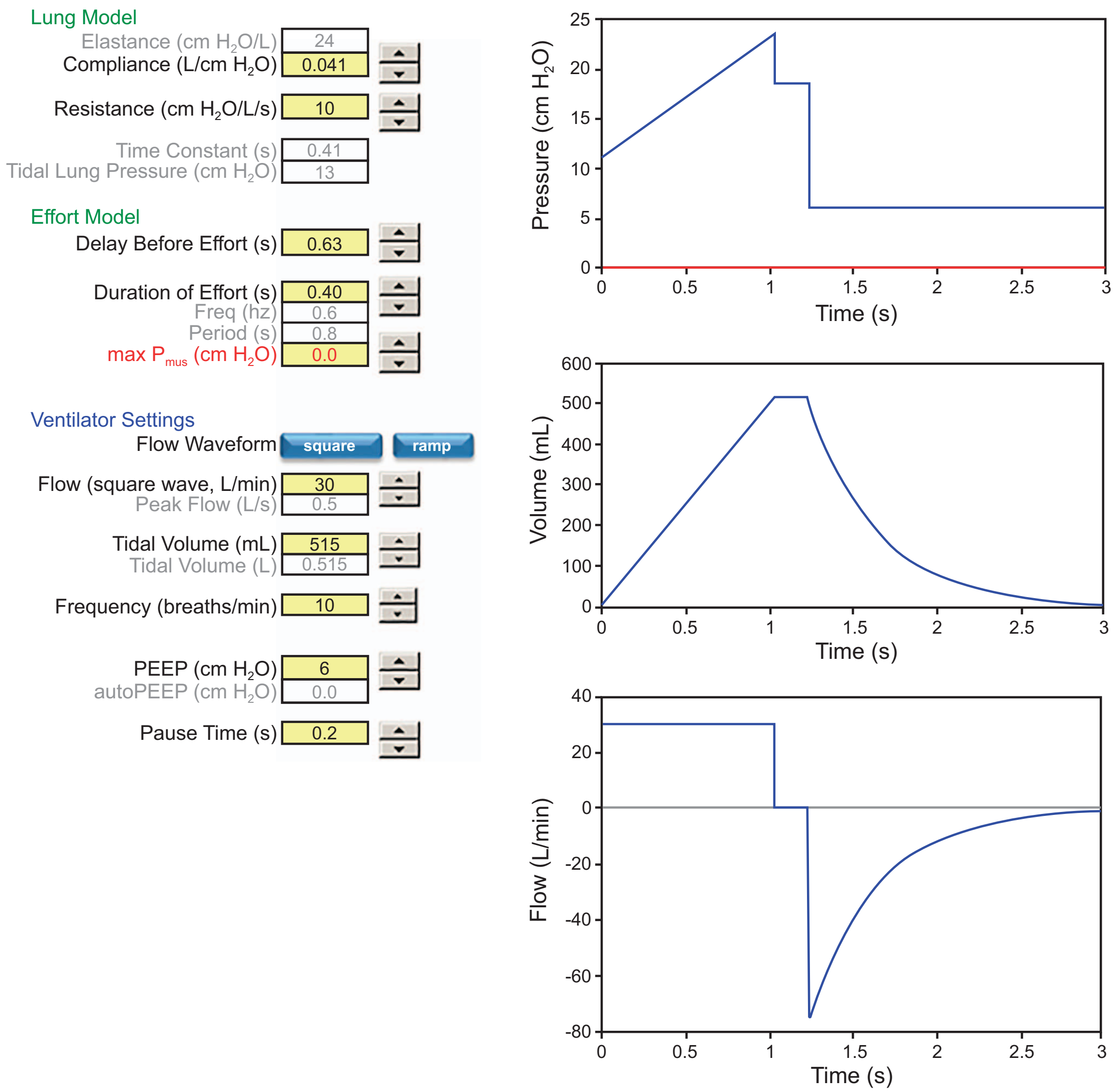

Fig. 1. Volume control breath with inspiratory hold, no inspiratory effort and no auto-PEEP.

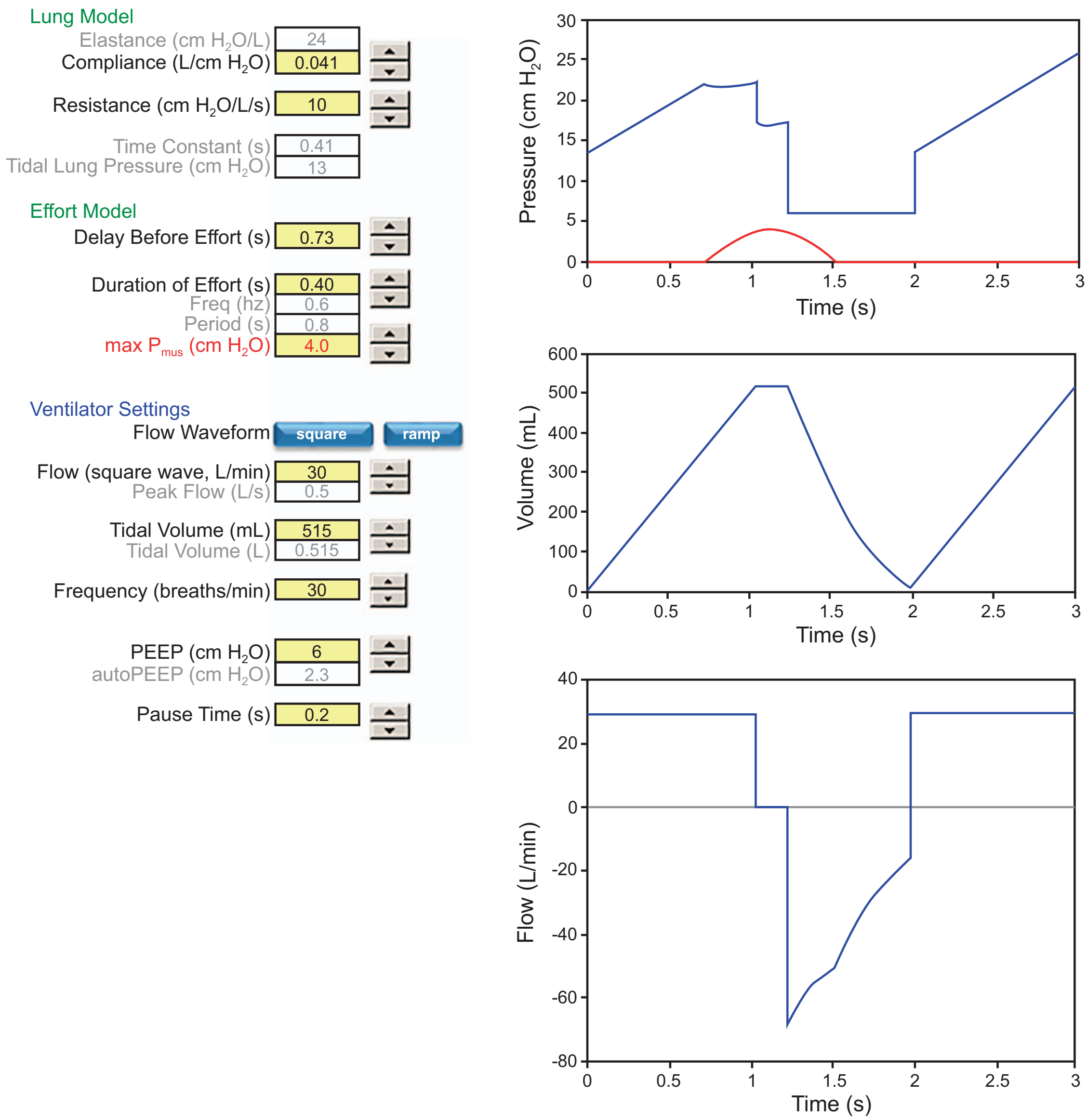

Fig. 2. Volume control breath with inspiratory hold, no auto-PEEP but with inspiratory effort of 4 cm H_2O.

its common usage in the literature) because end-expiratory pressure must be measured under 2 specific conditions. One condition is the requirement for the absence of any inspiratory effort that could cause underestimation of P_{plat} (or overestimation if the patient actively exhales). The article's introduction includes this in its definition of ΔP: "the difference between P_{plat} and end-expiratory airway pressures *assessed under passive conditions* . . ." (emphasis ours)[1]; however, this definition fails to mention the other specific criterion, the requirement of a total PEEP measurement (total PEEP = set PEEP + auto-PEEP) by means of an end-expiratory hold. total PEEP = positive end expiratory pressure during an occlusion (aka, intrinsic PEEP), set PEEP = PEEP set on the ventilator, auto-PEEP = additional end expiratory pressure above set PEEP due to gas trapping (aka autoP-EEP).

The authors, of course, understand the true definition, as indicated by the equation they describe in the Methods section: $\Delta P = (P_{plat} - \text{total PEEP})$, and they explicitly note that "The algorithm of these ventilators for determining and displaying P_{plat} requires the absence of overt effort or instability during end-inspiratory circuit occlusion, but it does not assure entirely passive inflation . . ."[1]

These considerations indicate problems with the term ΔP. Confusion increases when talking about pressure control ventilation.[2] For example, from the ventilator's point of view, driving pressure (ie, the pressure associated with inflation) could be $\Delta P_{elastic}$ = elastance × Δvolume, or $\Delta P_{resistive}$ = resistance × flow, or $\Delta P_{total} = \Delta P_{elastic} + \Delta P_{resistive}$, where the Δ denotes a change in time for $\Delta P_{elastic}$ and ΔP_{total}, and a difference in space for $\Delta P_{resistive}$. From the patient's point of view, driving pressure

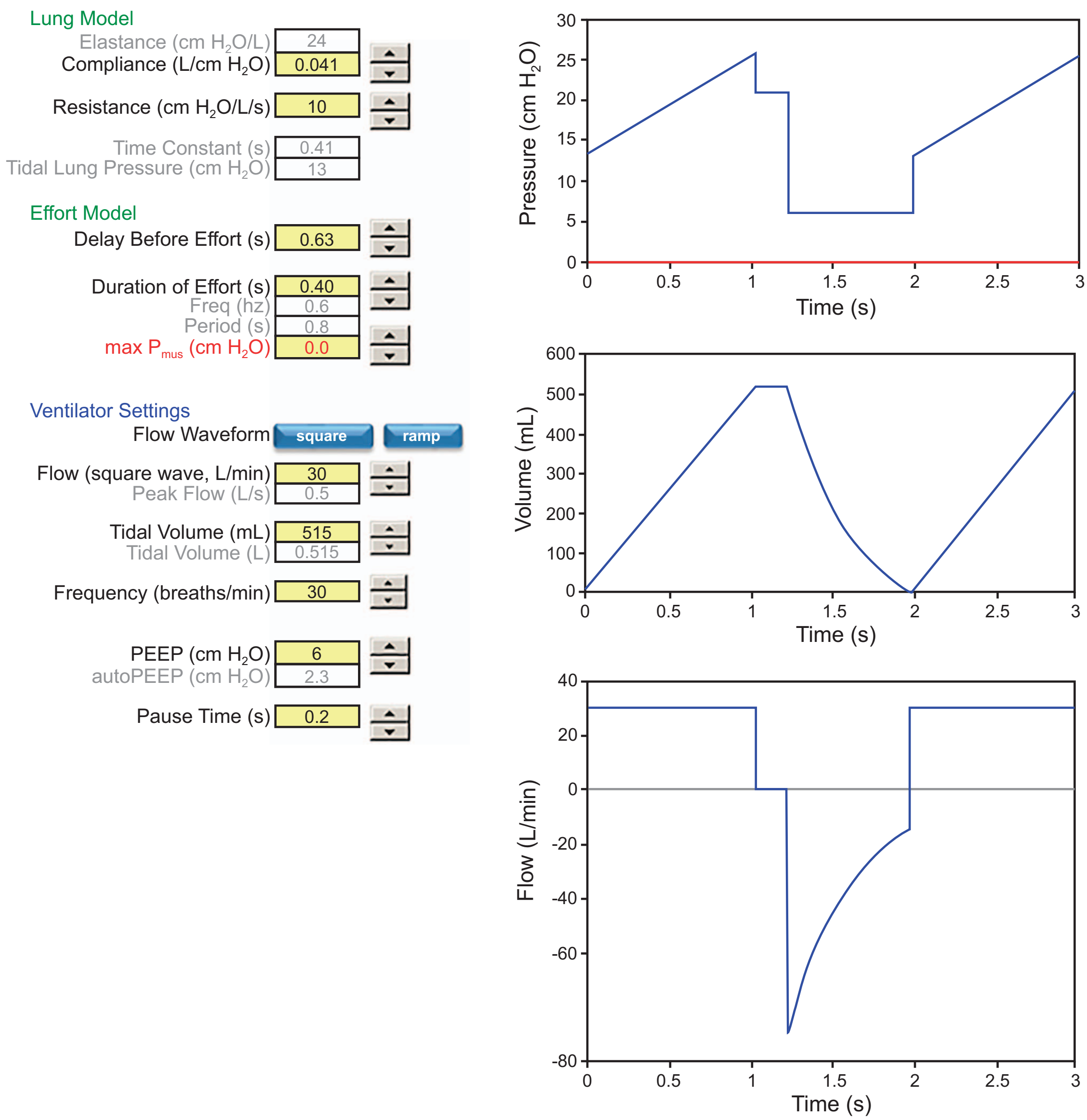

Fig. 3. Volume control with inspiratory hold, no inspiratory effort, but with 2.3 cm H_2O of auto-PEEP.

could be any form of pressure that is driving inspiration[3] or the pressure that is driving expiration. In pressure control modes, clinicians often refer to *inspiratory pressure* above PEEP as the driving pressure[4-8] perhaps because they see a constant inspiratory pressure and often assume that to be equal to P_{plt} (and set PEEP is equal to total PEEP). But this is only true if the inspiratory and expiratory time is long enough for inspiratory and expiratory flow to decay to zero.

There is a more subtle problem with ΔP: what does the Δ stand for? The symbol itself is borrowed from mathematics and represents either a difference or a change in some variable. A *difference* in pressure can be between 2 points in space, as in the calculation of transrespiratory system pressure (eg, $P_{TR} = P_{AO} - P_{BS}$, where AO is airway opening and BS is body surface). A *change* in pressure can be measured at 2 points in time or a measurement made relative to a reference value (eg, pressure measured relative to atmospheric pressure, called gauge pressure). Driving pressure, as defined above, is actually a change in a pressure difference. The pressure *difference* is P_{TR} (or alternatively transpulmonary pressure, $P_{tp} = P_{AO} - P_{PL}$, where P_{PL} is pleural pressure). The pressure *change* is P_{TR} at end-inspiratory hold relative to P_{TR} at end-expiratory hold.

All of this complexity vanishes if we simply use a different term, tidal pressure, P_T. Tidal pressure is related to tidal volume by the simple equation: $P_T = E \times V_T$ or $P_T = V_T/C$, where V_T is tidal volume, E = elastance, and C = compliance. This definition is independent of both inspiratory effort and auto-PEEP. It is interpreted the same as ΔP, the change in the pressure difference across the system required to deliver the V_T. The pressure difference can be either transrespiratory pressure or transpulmonary pressure.

To illustrate this, consider Figure 1, which shows the pressure, volume, and flow waveforms of a patient-ventilator simulator based on the equation of motion[9]:

$$P_{AO} + P_{mus} = V/C + R\dot{V} + \text{total PEEP}$$

where P_{AO} is gauge pressure at the airway opening (eg, the displayed pressure on a ventilator), P_{mus} = muscle pressure (ie, the force of inspiratory effort), C is compliance, V is volume, $\dot{V}$ is flow, and total PEEP is end-expiratory airway pressure during an expiratory hold. The simulator is set with respiratory system mechanics similar to those reported in the article by Baldomero et al.[1] There is no auto-PEEP and no inspiratory effort ($P_{mus} = 0$). In Figure 1, $\Delta P = P_{plat} - PEEP = 18.6 - 6 = 12.6$ cm H_2O. This is the same value as $P_T = V_T/C = 515/41 = 12.6$ cm H_2O.

Shown in Figure 2 is the same model as in Figure 1 except with an inspiratory effort late in the inspiratory phase (eg, reverse triggering[10]), which decreases the P_{plat}. Now $\Delta P = P_{plat} - PEEP = 16.9 - 6 = 10.9$ cm H_2O. However, tidal pressure has not changed: $P_T = V_T/C = 515/41 = 12.6$ cm H_2O.

Shown in Figure 3 is the same model as in Figure 1 except with a higher ventilator frequency, which causes a auto-PEEP level of 2.3 cm H_2O. The $\Delta P = P_{plat} - PEEP = 20.8 - 6 = 14.8$ cm H_2O. But again, tidal pressure has not changed: $P_T = V_T/C = 515/41 = 12.6$ cm H_2O.

These results are summarized in Table 1. It shows that, under ideal conditions (passive inflation and no auto-PEEP), ΔP is equivalent to P_T. But, with inspiratory effort, ΔP underestimates P_T; with auto-PEEP, ΔP overestimates P_T.

One might argue that using V_T is not really a simplification because C (or E) must be calculated with the same caveats (ie, passive conditions and regard for auto-PEEP), as indicated in the Methods section of the article by Baldomero et al.[1] However, C (or E) can be estimated without an inspiratory hold maneuver during inspiratory flow by fitting pressure, volume, and flow data points to the equation of motion by using linear regression.[11] Indeed, the ventilator used in the study by Baldomero et al[1] can do this (ie, dynamic vs static mechanics). Hence, given only one automatic, maneuver-free estimation of mechanics, multiple, unambiguous determinations of P_T can be made over a relatively long period of ventilation.

Table 1. Examples of How Driving Pressure Is Underestimated in the Presence of Inspiratory Effort and Overestimated If Auto-PEEP Is Not Considered; These Factors Do Not Affect Tidal Pressure

Factor	P_T	ΔP
$P_{mus} = 0$	12.6	12.6
$P_{mus} = 4$	12.6	10.9
Auto-PEEP = 0	12.6	12.6
Auto-PEEP = 2.3	12.6	14.8

In conclusion, the paper by Baldomero et al[1] defines driving pressure as P_{plat} − total PEEP. This is not the same force that drives inspiratory or expiratory flow. On the contrary it is a different metric related to a different concern, ie, lung stretch, and not peak flow. Hence it deserves a different name. We suggest the name tidal pressure, P_T, defined as $V_T \times E = V_T/C = P_{plat}$ − total PEEP. It follows that from the perspective of lung injury, the important concept is tidal pressure, not driving pressure. If we are going to adopt a new metric for use in monitoring the risk of ventilator induced lung injury, we should use a term for it that has the lowest chance of misunderstanding. In that regard, tidal pressure is preferable to driving pressure.

Robert L Chatburn
Respiratory Institute
Cleveland Clinic
Cleveland, Ohio

Matthias van der Staay
Department of Engineering
IMT AG
Buchs, Switzerland

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Correspondence: Robert L Chatburn MHHS RRT RRT-NPS FAARC, Respiratory Therapy Department – M56, Cleveland Clinic, 9500 Euclid Ave, Cleveland, OH 44195. E-mail: chatbur@ccf.org.

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