# WHAT IS A "SAFE" PLATEAU PRESSURE IN ARDS?

*by John Marini MD*

Considerable attention has been focused on the causative roles of tidal volume and airway pressure in the generation of ventilator-induced lung injury (VILI). To this point, tidal volume has received the lion's share of recognition, fueled by the successful NIH-sponsored ARDSnet clinical trial comparing small vs. large tidal volumes (ARMA). Quite appropriately, however, further analyses have shifted emphasis toward limiting the static end-inspiratory pressure that distends the lung's alveoli and surrounding chest wall. More specifically, current practice is to monitor end-inspiratory plateau pressure (Pplat), which corresponds to the point of maximal tissue stress that is reached repeatedly with every tidal cycle. Whatever the explanation, this readily measured value appears to relate directly (and almost linearly) to all-cause mortality in some clinical trials of lung protective strategies in ARDS. Indeed, the inference has been made that there is no threshold for injury induced by ventilating pressure exists and no Pplat that is "safe" to apply. If correct, such an idea would suggest that tidal volume and PEEP, the controllable drivers of Pplat in ARDS patients, should be reduced to the lowest values consistent with a well tolerated physiological response. But is apparently logical advice really valid, or is there another better explanation for the correlation? The answer lies in a closer examination of the underlying mechanisms of ventilator-induced injury.

The pressure-volume relationship of the normal respiratory system inflated under passive conditions suggests that total lung capacity is typically reached at a static airway pressure of approximately 30 cmH2O. Any pressures greater than that value are almost certainly overstretch vulnerable portions of the lung. At that pressure, the transpulmonary (or transalveolar) pressure distending the lung is about 15-20 cmH2O. This estimate derives from the fact that the fraction of the static alveolar pressure that transmits to the pleural space is described by the expression: _Ppl =_Paw (Cl/(Cl+Cw)), where Cl and Cw are the respective compliance values for the lung and chest wall. Because the normal chest wall is about as compliant as the lung over the usual tidal range, the transmission fraction is normally about 0.5. It is important to note that some alveoli are already over distended as TLC is approached, however, as many non-dependent alveoli reach their limit of distension at lower values. Were the injured lung comprised dichotomously of stiff and normally compliant units, as the "baby lung" concept would imply, then a plateau value of 30 cmH2O would be an excellent guess for the upper limit pressure that just avoids over distention of those that remain viable. In apparent vindication of this concept, ventilator induced lung injury cannot be induced in anesthetized animals with plateau pressures lower than this value. In work from our own laboratory, for example, we could define an injury threshold value in large animals of about 30 cmH2O, with no edema forming after hours of ventilation in animals ventilated with lower pressures. During vigorous exercise, trans-alveolar pressures frequently exceed 20 cmH2O for lengthy periods, without apparent damage or inflammation. (Consider a 4-hour marathon.)

Unfortunately, the situation is not so simple. In the heterogeneous injured lung, overstretching is not the only—or perhaps even the primary—injury mechanism in play; amplified forces at the junctions of open and closed lung units ups the ante associated with any given airway pressure and advises caution in setting specific targets based only on a global measurement such as Pplat. Moreover, the inflamed gas-blood membrane is not a normal one, and may be predisposed to undergo further injury at lower plateau values, in light of the ancillary factors that enhance its sensitivity. Experimental animal data suggest that these cofactors include high microvascular pressure on the arterial side of the alveolus, low vascular pressure on the downstream (venous) side of the capillary, high body temperature, and high pH. There are likely to be more. Perhaps more importantly, the ventilating lung is often not passively inflated, but rather assisted by the efforts of the patient. The plateau pressure is only the airspace component of the trans pulmonary pressure; pleural pressure is the other. A plateau pressure that might be safe to apply under control conditions corresponds to a transalveolar pressure that is much higher during vigorous efforts in volume or pressure assist-control ventilation. The underestimate increases with the vigor of patient effort. At the bedside this false reassurance of the 'acceptable' plateau is illustrated by the major jump in Pplat that occurs in delivering the same tidal volume after silencing the breathing efforts of a dyspneic patient.

There are other explanations as to why a threshold value for safety cannot be identified in clinical trials. The first is that no defi-

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# ON A LIGHTER SIDE with Andy Rooney

Life is best when it's filled with small pleasures. The big ones don't last. I was thinking what a good day Saturday was for me.

I have a light that shines the time in red on the ceiling above my bed, so if I'm on my back I can read it without doing anything more strenuous than opening my eyes. I awoke before it was really light out and, glancing at the ceiling, took snug comfort from seeing that it was only 6:30. Because it was Saturday, I didn't have to get up for an hour and a half, so I went back to sleep. I didn't have to get up all day if I didn't want to.

I awoke again in less than an hour, though, and remembered I had bought some good hard rolls and a jar of jam the day before. I decided I'd had enough sleep, so I got up. As luck would have it, I had finished a can of coffee the day before, so I opened a new can. If I had more money than I knew what to do with, I'd open a new can of coffee every morning and throw the old one out.

The newspaper was outside my door. The paper is better some days than others and this was a good day. I start with the least important news which interests me most: sports. After I've found out who won, I turn the pages to what really matters in the news, which seldom matters to me.

There were several important stories on page one but I didn't read them. What can they tell me about Iraq that I don't know and want to hear? The stock market was up and I don't pay a lot of attention to it, but I own a small amount of six stocks. When the market is up, I look at where they are. This gives me a feeling of financial well-being. If the market is down, I don't look.

After breakfast and the newspaper, I took a shower. My shower seems better some days than others and Saturday it was just right — not too hot, not too cold. I took the paper wrapper off a new cake of soap. If I had enough money to start a new can of coffee every morning, I'd start a new cake of soap, too. These are among the small pleasures that add up to a good day.

My laundry had come back the day before and after breakfast I put on clean underwear, a clean shirt and clean socks. After dressing, I got my car out of the garage and drove to the office to do some weekend work. I like the feeling I'm getting ahead of everyone who's taking Saturday off. Off what? As I drove to work, it was a pleasure to note that I'd bought gas Friday and my tank was full. There are few minor pleasures that exceed a full tank of gas.

There was mail I hadn't read at the office and I started going through it. Getting a lot of mail makes me feel good even when there isn't anything much good about it. Mail is almost always more of a pleasure to anticipate than to open and read. I enjoy getting mad and it made me mad to think about the nerve people have using mail to sell something. That isn't what mail, is for. Mail that's trying to sell something ought to cost the sender twice what a personal letter costs. The postal service reverses that and charges less to deliver commercial mail than personal letters.

I had an idea for a "60 Minutes" piece, so I wrote that. I'll probably change it before I do it on camera, but at least I have a start. Sometimes I have the feeling I'll never have another idea.

One of the best things about my job is that I have a couch in my office. I feel sorry for all the people in the world who work all day without being able to lie down to take a nap. I'd rather have a nap than a raise. I get more rest in 10 minutes on the couch than in seven hours in bed. Today hasn't been as good as Saturday was.

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nition including a mechanics element has been incorporated into the "official" American-European Consensus Conference definition used for identifying ARDS in virtually all trials. The resulting patient samples are therefore comprised of patients with widely varying compliance characteristics. In the ARMA trial, for example, the linear correlation extended all the way down to 10 cmH2O-a pressure that included PEEP. (Do such values conjure up the image of a patient with ARDS?) Against the background of diverse sampling and disease labeling, a given plateau pressure in one patient might represent overstretching, whereas the same value does not carry the same injury potential in another whose respiratory system distends less easily. Another key point is that for the same lung, the plateau pressure associated with a given tidal volume is considerably higher if the chest wall is stiff. Without more precise definitions and more careful measurement of the key variables that characterize mechanics, the inferences for management of the individual that can be drawn from population-based clinical trials is limited indeed. What about the strong correlations between Pplat and observed mortality mentioned earlier? Higher plateau pressures are usually needed in lung-injured patients who are sicker, and in my view this accounts for much of the correlation. In fact, once minute ventilation, PEEP levels, illness severity scores, and other important drivers are factored in, it is not easy to find any residual relationship between Pplat and mortality until pressures exceed 35 cmH2O, as illustrated in a recently published and well executed analysis.

In the end, what useful statements can be made regarding the task of identifying a safe and appropriate plateau value to set? First, it is not likely to be true that with regard to plateau pressure "the lower the better". Both volume and pressure targeted ventilation can be falsely reassuring, especially if imposing less ventilating pressure (e.g., low level pressure targeting) elicits stronger patient effort. A sharp distinction must be drawn, however, between vigorously triggered and quiescent breathing. Under controlled ventilation conditions (or when the patient's inspiratory efforts entirely cease before the end of the inflation period) we are unlikely to be causing lung damage with plateau pressures less than 25 cmH2O. If the chest wall is stiff (e.g., obesity, ascites, abdominal surgery), plateaus considerably higher than that value may be tolerable. Conversely, we cannot think of a plateau of <30 cmH2O to be safe under all conditions; during vigorous breathing transpulmonary pressures may be dangerously elevated even though the measured Pplat seems acceptable. Finally, we must understand and always consider underlying mechanistic principles when attempting to guide ventilator management at the bedside. Not to do so places a dangerous instrument in the hands of the clinical provider and positions the vulnerable patient directly in harm's way.

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