Monitoring Lung Mechanics

New Applications for Established Tools

Pressures measured at the various boundaries of the respiratory system include the pressure at the airway opening (Paw), alveolar pressure (considered equal to Paw if there is no gas flow and the glottis remains open), and pleural pressure (Ppl). During static and dynamic respiratory maneuvers, it is possible to measure the pressure across the lung (transpulmonary pressure [Ptp]) by measuring the difference between Paw and Ppl. The latter has been measured with needles, trocars, catheters, and most commonly balloons. Only a few direct comparisons of Ppl and esophageal pressure (Pes) have been made.1 These generally show good agreement, except that pressure swings recorded by the balloon technique are larger in the lower third of the esophagus, near the diaphragm. Monitoring total respiratory mechanics (as a reflection of lung mechanics) in patients with acute lung injury or labile airway obstruction (by recording tidal volume and Paw) assumes that the chest wall (ie, rib cage plus abdominal) component remains constant. In fact, this may not be the case in patients with ascites, pregnancy, peritonitis, pleural effusions, or the abdominal compartment syndrome, which result in a reduction of chest wall and, hence, total respiratory compliance. Thus, separately recording Ppl and deriving Ptp from this value allow one to determine if changes in total respiratory compliance are due to changes in lung or chest wall elasticity. In addition, measurement of work of breathing can only be accomplished by recording Ppl (or a reasonable surrogate).

Being able to measure changes in Ppl by taking advantage of other routes already available, such as central venous or bladder catheters, can provide a means to measure lung compliance (separate from total respiratory compliance) in patients receiving mechanical ventilation or those who have experienced abdominal trauma. Femal and colleagues2 discovered that changes in central venous pressure (ΔPcvp) during inspiratory efforts against an occluded airway closely approximated changes in Pes (ΔPes). In this issue of CHEST, Chieveley-Williams and colleagues (see page 533) compared changes in bladder pressure (ΔPblad) and ΔPcvp with changes of gastric pressure (ΔPga) and ΔPes, respectively, in patients receiving mechanical ventilation and various levels of inspiratory pressure support. They found that the concordance between ΔPes and ΔPcvp was within ±10% of unity in 5 of 10 patients, similar to results reported by Walling and Savege3 and Femal et al.2 Divergences between the two pressure
changes could, in part, be explained on the basis of the underlying diseases and their effects on alveolar gas compression or decompression,4–5 nonuniform pleural surface pressure changes, the position of the catheter within the esophagus, cardiogenic oscillations, and differences between the behavior of fluid-filled catheter systems and air-filled esophageal systems (a minor factor).6

While measurements of absolute values of Pes as an estimate of Ppl are problematic in patients in a supine posture (thought to be due to the weight of the mediastinal contents on the esophagus), use of the “occlusion test”7 should avoid this problem; it is possible to find a spot in the esophagus in which ΔPes is the same as Paw swings (ΔPaw) recorded during inspiratory efforts made against a closed airway. Likewise, Fimleale et al,8 using similar water-filled catheter systems and the occlusion test, showed that in 8 of 10 supine normal volunteers, ΔPes/ΔPaw was within 10% of unity; in 3 of their subjects, however, there was much discordance between ΔPes and ΔPcvp (with ΔPes/ΔPcvp as high as 176% in 1 subject). The overall discrepancies were even greater in the study of Walling and Savege,9 where ΔPes exceeded ΔPcvp by as much as 112% in one subject. These authors did not, however, make use of the occlusion test to find the proper position of their esophageal catheter, and they compared air-filled with fluid-filled systems of different lengths and diameters, so that the frequency response characteristics were different and could distort the pressure signals.

What about the validity of ΔPblad? The stomach and bladder, when partially filled, are both distensible and compressible bags lying within the abdominal cavity. It might be thought that intra-abdominal pressure should be transmitted to both viscera equally. Decramer et al,9b showed in dogs, however, that surface pressures on the abdominal side of the diaphragm may not be uniform. Since transdiaphragmatic pressure (Pdi) is conventionally determined as the difference between gastric pressure (Pga) and Pes (Pdi = Pga − Pes),9 this difference may not be truly representative of actual Pdi. By the same token, inhomogeneous surface pressures on the abdominal side of the diaphragm might also contribute to discordance between ΔPga and ΔPblad. Collee et al10 compared only static end-expiratory Pga and bladder pressure (Pblad) in 26 patients who had undergone abdominal surgery. While they found a mean concordance of within ± 0.2% of unity, there was considerable variability; in one patient, Pga exceeded Pblad by 63%. Also, their measurements did not include dynamic respiratory efforts. What is important is the concordance of not so much the respective static pressures at zero flow, but their swings during inspiratory efforts over physiologic tidal ranges. In 5 of their 10 patients, Chieveley-Williams et al found that the concordance between Pdi and (Pblad − Pcvp) was within ±10% of unity. Again, variabilities among subjects were most likely related to the use of different catheter systems, as well as to nonuniform abdominal surface pressures. Interestingly, in patients with fluid-filled abdomens, ΔPga/ΔPblad may approach unity, as pressure swings throughout the abdomen become more homogeneous.8 Chieveley-Williams et al did not indicate, however, if any of their five patients with ΔPga/ΔPblad values within ±10 of unity had abdominal ascites, although one patient had pancreatitis and another had abdominal sepsis.

The main lesson to be learned from the elegant study of Chieveley-Williams et al is that indwelling central venous and bladder catheters already in place can be used to at least record trends in respiratory effort pressures while monitoring patients who are being weaned off ventilation. Careful attention to uniformity of central venous and bladder catheter systems should help reduce discrepancies in pressure changes between these systems and the more conventionally used esophageal and gastric catheter systems. This would then enable the estimation of lung mechanics and work of breathing by the respiratory muscles and the ventilator in a more convenient manner without resorting to additional catheters. Clearly, more studies comparing these catheter systems in patients with a variety of medical and surgical conditions and in those receiving different modes of ventilation are needed to validate them.

Ahmet Baydur, MD, FCCP
Los Angeles, CA

Dr. Baydur is a member of the Division of Pulmonary and Critical Care Medicine, University of Southern California School of Medicine.

Correspondence to: Ahmet Baydur, MD, FCCP, University of Southern California, Keck School of Medicine, 2025 Zonal Ave, GNH 11-900, Los Angeles, CA 90033

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Benchmarking in Critical Care

The Road Ahead

In this issue of CHEST (see page 539), Sirio et al compare critical care outcomes in the United States and Japan after accounting for differences in severity of disease and case mix using APACHE (acute physiology and chronic health evaluation) III. One of the objectives of international comparisons of critical care delivery systems is to determine if differences in resource use translate into differences in health-care outcomes. This study found that the observed and expected mortality rates in the Japanese cohort were identical. This finding is notable given the fact that hospital length of stays in Japan are significantly longer than they are in the United States due to differences in discharge policies. The authors point out that longer hospital length of stays are usually associated with higher hospital mortality rates, inferring that the aggregate outcomes in the Japanese data set may be better than expected. However, this study does not include information on the processes of care that may have led to improved outcomes relative to the American cohort. This study reminds us that one of the primary goals of outcomes information is to identify high-performance hospitals or health-care delivery systems so that we can uncover the “best practices” responsible for their superior outcomes and then implement them in other settings. Although there is little evidence to suggest that we are making significant progress toward accomplishing this goal, the work of O’Connor et al in the Northern New England Cardiovascular Disease Study Group demonstrates the potential for improving mortality rates through quality-improvement initiatives grounded in outcomes information. Furthermore, following the publication of the Institute of Medicine report on patient safety, there now exists a national mandate to search for processes of care that will minimize medical errors and improve patient outcomes.

The question then arises: How do we formulate an agenda that will help translate research on ICU outcomes into improvements in the quality of care for ICU patients? First, we need a national contemporary population-based ICU outcomes database; Project IMPACT, a multicenter outcomes database sponsored by the Society of Critical Care Medicine, may be an excellent starting point. Second, we need to examine the comparative performance characteristics of existing ICU prediction models within this database to determine which model is best, or alternatively, to develop a better model in order to have a “single yardstick” against which to measure ICU performance. Third, the use of a fixed end point such as 30-day or 90-day mortality should be substituted for hospital mortality. Fourth, we need to look at other outcomes besides mortality. Fifth, once we have identified high-performance ICUs, we must use these centers of excellence as data laboratories in order to identify best practices. Finally, and most importantly, we must insure that these best practices are widely disseminated and adopted in other centers.

A national database is necessary in order to better understand the connection between medical interventions, processes of care, costs, and health-care outcomes in the ICU. Increasingly, third-party payers and purchasers are pressing health-care systems to collect data on health-care outcomes. Clinical performance data will be used as one of the criteria for accreditation by the Joint Commission, the National Committee on Quality Assurance, and the Health Care Financing Administration. The decision by the critical-care community to collect and utilize outcomes data on a national scale can either originate and be directed by physicians, or can be mandated and directed by government agencies, payers, and accreditation bodies. We propose that all ICUs participate in the formation of a national ICU-outcomes database. Universal participation will eliminate the possibility of selection bias, in contrast to voluntary participation that may result in a non-representative group of ICUs. Adequate funding is necessary for the success of such a national data set. One potential source of seed money is the Agency for Healthcare Research and Quality. Further funding might be obtained by charging third-party payers for the cost of data collection and analysis. The creation of a national data repository, as opposed to numerous regional databases, is critical to the formation of a broadly representative data set so that research findings based on this database can be generalized to other ICUs in this country.

At present, there is no consensus on which ICU...