ESSAYS ON APS CLASSIC PAPERS

The significance of the blood gas analyzer

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This essay looks at the historical significance of an APS classic paper that is freely available online: Severinghaus JW and Bradley AF. Electrodes for blood PO\textsubscript{2} and PCO\textsubscript{2} determination. J Appl Physiol 13: 515–520, 1958 (http://jap.physiology.org/cgi/reprint/13/3/515).

ONE OF THE MOST RAPID and significant transformations in clinical practice that evolved from physiological research is the development of the modern, integrated blood gas analyzer (1, 2, 4). We take for granted the ability to measure PO\textsubscript{2}, PCO\textsubscript{2}, and pH in blood samples quickly and reliably. The significance of this technology has had wide-ranging effects in physiological research and clinical medicine.

Severinghaus (Fig. 1) has described the seminal work his team performed in the 1950s to develop what is now modern blood gas analysis (3). In deference to his modesty, I will briefly comment on the importance of this applied physiological tour-de-force in both basic research and clinical medicine.

The current analyzers are incredibly sophisticated, stable, and fast. There are no water baths to fill or leak, and the electrode membranes last for months rather than days (or even hours!). They have accurate, fast calibration without the necessity of tedious tonometry, and little drift. Modern analyzers have computer interfaces and internal algorithms to calculate pertinent parameters. For example, correction for body temperature, and calculations of oxygen saturation, base excess, and bicarbonate concentration are now done automatically rather than by the tedious hand calculations that used to be done. Ironically, because of this, many of our medical trainees and young physicians do not understand the principles involved in the direct measurements and in the calculation of associated parameters. An example is the difference between an O\textsubscript{2} saturation and content calculated from blood gas measurements and a measured O\textsubscript{2} saturation and content. This becomes apparent when confronted with a patient with carbon monoxide poisoning whose calculated O\textsubscript{2} saturation is normal (because PO\textsubscript{2} is normal) but measured O\textsubscript{2} content is significantly decreased. Most of us love modern computer technology, but the disconnection from the actual techniques does have a downside!

We can now analyze literally hundreds of blood gas samples a day in minimal volumes of blood. The ability to measure PO\textsubscript{2}, PCO\textsubscript{2}, and pH in one small sample very quickly and with high throughput has made physiological research much better. Many of you are probably familiar with the spectacular set of experiments done by John West and his group in which blood gases were measured at their base camp laboratory at an elevation of 6,300 m (20,700 ft) on an expedition to Mount Everest (6)!

Even more dramatic is the many orders of magnitude advancement in clinical care that has resulted from the modern, integrated blood gas analyzer. It has allowed the scientific management of the weaning of ICU patients from a ventilator; this process used to involve considerable guesswork and luck. A set of blood gases can now be obtained faster than virtually any other clinical laboratory measurement, allowing rapid and efficient adjustments in ventilator settings. In the past, most patients with acute respiratory distress syndrome died, but care has improved partly because of the ability to allow permissive hypercapnia (i.e., with low tidal volumes) to minimize pulmonary stress. This is a result of the ability to rapidly measure blood PCO\textsubscript{2} and pH. Point-of-care devices can now provide blood gas analysis at the bedside. These highly portable devices also allow physiological studies of blood gases in the field.

Even more dramatic is the ability to care for neonates with cardiopulmonary problems. When I was a student in the 1970s, the number of blood gas measurements in neonates was kept to

Fig. 1. J. W. Severinghaus.
the bare minimum because of the relatively large blood volume required. Now, a set of blood gases can be done from a capillary tube. An extremely significant byproduct of the miniaturization of blood gas analysis is the ability to do basic cardiopulmonary research in very small animals. Furthermore, pulse oximetry arose in part out of the improvement in the $O_2$ electrode that was part and parcel of the improvement in blood gas analysis (1, 5). Finally, modern anesthesiology and thoracic surgery, particularly in patients with complicated cardiopulmonary problems, would not be possible without simultaneous blood $P_{O_2}$, $P_{CO_2}$, and pH measurements.

It is important that young physiologists and physicians understand the incredibly hard work that went into development of this wonderful technology, and, as a result, the classic paper of J. W. Severinghaus is truly deserving of this recognition.

REFERENCES