Problems With Forehead Reflectance Pulse Oximetry

In this issue of Respiratory Care, Berkenbosch and Tobias present a study of a "new" forehead reflectance pulse oximetry sensor in pediatric patients.[1] The Nellcor Max-Fast forehead sensor has actually been on the market since early 2003, but this is the first clinical study to compare pulse oximetry (S_{pO_2}) readings taken on the forehead to oxygen saturation measurements made via CO-oximetry of arterial blood in pediatric patients under 10 kg. The subjects were a mixed group of surgical and intensive-care patients, all of whom had indwelling arterial cannulas for blood sampling and analysis. The study was sponsored by Nellcor.

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Berkenbosch and Tobias gathered 116 data sets from 28 patients, including S_{pO_2} readings from the Max-Fast forehead sensor and a finger sensor, paired with CO-oximetry measurements from arterial blood samples (S_{aO_2}). They found the bias and precision of the forehead sensor to be comparable to those of the finger sensor, and concluded that the Max-Fast "provided as accurate an estimation of S_{aO_2} as did a commonly used. . . digit-based transmittance sensor."[1] This conclusion may be correct when applied to the limited data of this study, but there are problems with the unstated implication that forehead sensors can perhaps replace finger sensors.

First, Berkenbosch and Tobias present no data on what is commonly called "signal dropout" rate, which is the percentage of time during which the oximeter gives no reading at all or gives a reading with some sort of signal-quality alarm. Berkenbosch and Tobias state that "some data suggest that perfusion to the forehead region is better maintained during conditions of poor perfusion," but most of the clinical experience with reflectance sensors suggests a marginal signal-noise ratio and a high incidence of dropout. This experience dates back to the late 1980s, when I performed volunteer and clinical studies with a forehead-reflectance sensor made by Sentinel (which was later acquired by Ciba-Corning). Our conclusion was that these sensors were not clinically acceptable because of a dropout rate of roughly 20%.[2] Those results are 15 years old, and the technology has undoubtedly been greatly improved since then, but it is still vital that accuracy data on forehead pulse oximetry be accompanied by data on dropout rate. Berkenbosch and Tobias state that "these studies are underway," but my point is that accuracy data should not be presented without corresponding dropout data. There is no benefit in having a new sensor with low uncertainty (low bias and precision values) when that sensor only works 80% of the time. For comparison, multiple studies have shown that the dropout rate for finger sensors in various clinical settings averages about 1–2%.

The second problem with forehead pulse oximetry is the high incidence of erroneously low S_{pO_2} values, apparently caused by venous congestion under the sensor. This issue was recognized with the earlier generation of reflectance sensors.[2] This S_{pO_2} "under-reading" occurs most frequently during mechanical ventilation, in Trendelenburg position, and during surgical procedures in which venous drainage from the neck may be impeded. Because of this known limitation, I performed, in 2003, a clinical study of the Max-Fast with a mixed group of 24 adult surgical patients.[3] The Max-Fast showed an error greater than 7% during 28% of the monitoring time, compared with 2.5% of the time with a finger sensor. Almost all of these large errors were under-reads. In one case (an operation on the anterior neck), the Max-Fast read an S_{pO_2} of 60–70% during the entire procedure, while both earlobe pulse oximetry and blood-gas analysis indicated saturation values in the mid-90s. Comparing Figures 1 and 2 in the paper by Berkenbosch and Tobias, we see a relatively large number of under-read S_{pO_2} values (data points with negative errors) from the Max-Fast, compared to the finger sensor. This is evidence of the same problem in pediatric patients.

The final important issue regarding forehead pulse oximetry is the time required for the sensor to respond to changes in pulmonary oxygenation. Severinghaus et al found, in healthy volunteers, that sudden hypoxia at the level of the lungs was not detected by a finger-sensor for approximately 1 min.[4] Earlobe sensors consistently detected these changes within 10–20 seconds. Similar unpublished experiments in my own laboratory found that, in volunteers with cool hands, this detection-time delay could be up to 2 min. There is no question that a sensor on the head (eg, forehead, earlobe, or lips) will detect changes in central oxygenation sooner than a finger sensor. This is an effect of circulatory physiology, and thus cannot be removed by refinements in oximetry. Therefore, we must eagerly pursue the development of alternative sensor sites, particularly those on the head. On the other hand, we cannot afford to sacrifice the excellent reliability of current-generation pulse oximeters—the fact that today's instruments function well in patients who are either moving or poorly perfused,[5] including pediatric patients.[6,7] In view of the above documented problems with forehead reflectance pulse oximetry, the paper by Berkenbosch and Tobias[1] has not yet convinced me that the Max-Fast represents an important advance in technology. Clearly, more clinical evidence is needed, particularly on the incidence of under-reads and dropouts.

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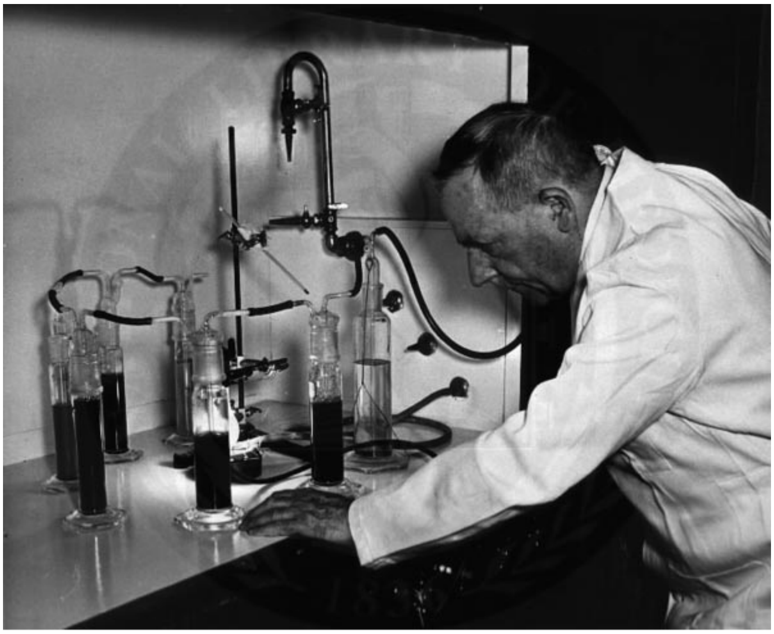

Chemist, physician, and Nobel Prize winner Otto H Warburg
with the Warburg manometer,
a device for measuring changes in gas exchange, 1949
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