Monitoring Tissue Blood Flow and Oxygenation

A Brief Review of Emerging Techniques

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KEYWORDS

• Physiologic monitoring • Near-infrared spectroscopy • Laser Doppler flowmetry
• Videomicroscopy • Oximetry • Tissue oxygen tension
• Tissue carbon dioxide tension • Lactic acid

KEY POINTS

- Emerging technology should be carefully evaluated prior to implementation and end users should carefully consider the validity of the measurement prior to altering patient therapy.
- Near-infrared spectroscopy, laser Doppler flowmetry, and videomicroscopy may be used to assess perfusion in the microcirculation although each technique has inherent limitations due to their regional nature.
- Tissue oxygen and carbon dioxide levels seem to reflect the extent of tissue metabolism but are also regional in nature.
- Increased lactate levels usually reflect abnormal metabolism but may increase in the absence of cellular hypoxia under certain circumstances.

INTRODUCTION

Understanding the technology that produces physiologic data in terms of its accuracy and precision is an important part of clinical practice. As new technology emerges, it is incumbent on the bedside clinician to understand not only its scientific basis but also the principles of measurement application specific to the new technology. However, technological accuracy and precision will not prevent operator error in the application of devices or the misinterpretation of displayed results. In the clinical setting, operator error is the primary cause of error in measurement.[1]

Measurement issues in clinical practice have been well described. A common example of an operator error is incorrect selection of cuff size or cuff placement during noninvasive oscillometric blood pressure (NIBP) measurement, clearly affecting the accuracy and precision of the measurement value. In addition, NIBP values

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significantly and clinically differ from invasive measures of blood pressure due to patient and disease factors including low systolic pressure, intra- and postoperative instability, atrial fibrillation, or low birth weight.[2–8] Despite the limitations of this ubiquitous technology, NIBP remains a mainstay of patient management in many critical situations. It therefore remains a high priority for bedside clinicians to remain vigilant about the appropriate selection, application, and interpretation of data received from physiologic monitors.

This article describes some of the most promising emerging technologies developed for measuring tissue-level oxygenation or perfusion. Each technique, like all measurement techniques, has its own inherent limitations that should be carefully considered. The end user must understand what the instrument measures and how to interpret the readings. Optical monitoring using near-infrared spectrometry, the Doppler shift, and videomicroscopy are discussed in terms of their application at the tissue level. Assessment of the metabolic state of the extracellular space with existing technology applied in a novel way (oxygen and carbon dioxide electrodes) and proxy indicators of metabolic status (lactate) are discussed. The article also addresses the sources of variation in each measurement and how operator error in the application of these methods can influence patient outcomes.

MEASUREMENT IN CLINICAL PRACTICE

When a novel technology enters the clinical arena, providers are charged with understanding the specifications and limitations of the new instrument. Of particular importance are the accuracy and precision of the device and across what measurement range these specifications apply. The specifications for new technology should be reviewed and evaluated before initiating a new technique in clinical practice (**Box 1**).

Devices used to measure a physiologic variable should meet minimum standards in terms of accuracy and precision, have acceptable sensitivity and specificity, and operate with a clearly defined maximum permissible measurement error.[9]

Box 1
Definitions related to measurement

- *Accuracy* is the closeness of agreement between a measured value and a "true" value
- *Precision* is the closeness of agreement between measured values on the same objects with repeated measurement; also known as measurement reproducibility
- *Sensitivity* communicates the test's ability to identify a positive result; the probability that the test is positive when the patient has the disorder
- *Specificity* communicates a test's ability to identify a negative result; the probability that the test is negative when the patient does not have the disorder
- *Error* is the difference between the measured value and a reference value (used in quality-control procedures)
- *Maximum permissible measurement error* is the extreme value of measurement error, with respect to a known reference value, permitted by specification or regulations for a measuring instrument
- *Calibration error* may occur when a measured value is compared with a known but incorrect standard
- *Offset or zero error* occurs when a device is zeroed against an incorrect value
- *Drift* is a gradual change in the reported measurement when the measured value has not actually changed