ABSTRACT. When we ask, what renders essential a particular monitoring approach during routine anesthesia for a healthy patient, perplexing questions, rather than satisfying answers, are raised. I have examined these questions with the help of three lenses that focus on the relationship between the outcome of anesthesia and the detection, and thus correction, of abnormalities during anesthesia. The first lens looks at whether the monitoring modalities accepted by anesthesiologists as "minimal" and "essential" have been scientifically proven to affect outcome from routine anesthesia. A second lens views how well monitors reveal the integrity of the organism and its components. Currently available monitors describe the output of cells or organs but relay little information about the viability of cells. Thus, they describe the symptoms rather than the causes of the pathophysiology related to anesthesia. Today's monitors also measure input, for example, the supply of oxygen, perhaps the most routinely measured of all the variables. The third lens looks at whether there are nonclinical influences on monitoring practice. This lens views the gap between recognizing monitoring possibilities and adopting them clinically; it also views geographic differences in monitoring, as well as social pressures exerted through legal proceedings. Finally, currently recognized essential monitors such as blood pressure measurement, electrocardiography, and oxygen analysis are mentioned, and candidates for inclusion in the list of essential monitors, such as oximeters, capnographs, and the automated record, are discussed.

KEY WORDS. Equipment: computers, monitors; Measurement techniques; Monitoring; Records, anesthesia

Monitoring can be classified under two headings. Monitors are aids in clinical management for example, when they are used to titrate drugs (e.g., to induce hypotension) or to adjust a mechanical ventilator to attain a desired level of alveolar carbon dioxide (e.g., for hyperventilation in neurosurgical anesthesia). Generally, however, monitors are considered devices that assist the clinician in detecting and diagnosing physiologic aberrations. I shall concentrate on this second heading and on monitors as they are used for simple, routine anesthesia, which represents the bulk of anesthesia practice. It is for this routine application that the rationale for designating monitors as essential for safe anesthesia must be defined.

A common definition of "essential monitoring," or "minimal monitoring," relies on the prevalence of use of a specific monitor. Once a monitoring practice has been adopted by the majority of anesthesiologists—and no one can say whether this is 51% or 99%—that practice becomes a standard. When we ask what specific rationale led anesthesiologists to adopt a particular monitoring modality, perplexing issues arise. I focus on
three of these issues and thus view monitoring through three different lenses, as it were.

**THE FIRST LENS: DO WE SELECT MONITORS BECAUSE THEY AFFECT OUTCOME?**

"Outcome" as used here refers to the consequence of anesthesia. Since anesthesia is not given for its own sake but for the patient's comfort and to facilitate the surgeon's work, postanesthetically, the outcome of anesthesia per se should be unremarkable and uneventful. An outcome is remarkable when the consequences of anesthesia impair postoperative well-being or require diagnostic or therapeutic measures that prolong hospitalization.

Adverse outcome can be classified as acute in onset and either transient or prolonged, or as delayed in onset and prolonged. Intraoperative atelectasis leading to postoperative pneumonia that responds to therapy represents an example of an acute and transient adverse outcome. An example of a particularly feared acute and prolonged adverse outcome is an intraoperative cardiac arrest leading to brain damage. A slowly ascending urinary tract infection that becomes symptomatic weeks or months after an unsterile catheterization in the operating room is a delayed complication that may last for years and may eventually lead to chronic pyelonephritis and even death.

**Identifying an Endpoint**

Now we must ask how monitoring can prevent adverse outcomes. We can propose that respiratory monitoring may detect the collapse of alveoli and intrapulmonary shunting and thus enable us to treat atelectasis and prevent pneumonia. Monitoring arterial pressure could enable us to correct developing hypotension that might precipitate cardiac arrest and brain damage. I cannot propose how to monitor the sterility of catheters in the operating room to prevent bladder infection.

When we monitor blood pressure or the electrocardiogram (ECG), these variables become descriptors of a state of well-being or ill-being.* These descriptors are included to provide quantifiable data that guide the physician in protecting or improving the patient's state. Within these statements lie issues in monitoring that have not been well addressed, namely how do we define the point at which well-being slips into ill-being? Can we prove that a given measurement reflects either state?

Inherent in these questions is an uncertainty about the urgency, intensity, and effectiveness of therapy. These questions seem contrived when we treat a patient whose blood pressure has become unmeasurable. Who would deny that detecting the absence of blood pressure and reestablishing it by cardiopulmonary resuscitation can restore a patient to good health? But this example represents one extreme on a scale. Where is the line between normotension and hypotension and at what degree of hypotension does a state of ill-being begin?

In the 1940s, anesthesiologists were taught to administer vasopressors if intraoperative blood pressure fell much below 120/80 mm Hg. Supposedly a "low pressure" did not represent a state of well-being, yet the harm of intraoperative hypotension was known only in the extreme case, such as shock. Maintaining the patient's blood pressure in a range that was classified as normal in textbooks was considered prudent because, it was argued, if severe hypotension caused severe damage, then modest hypotension was likely to produce modest damage, a defensible thesis.

In the 1950s and 1960s the profession learned to induce hypotension by various means. Thus the clinical wisdom of the 1940s gave way to the clinical wisdom of the 1960s. The unacceptable hypotension of the 1940s became the acceptable hypotension of the 1960s. While the endpoints shifted, the borders remained ill defined.

**The Correlation Between Outcome and Monitored Variables**

In a study largely ignored in the general anesthesia literature, Gruvstad et al [1] correlated intraoperative arterial pressure with postoperative psychological function in matched groups of patients. For the same type of operation, normotension was maintained in one group and hypotension in the other. More and longer lasting psychological deficits were detected after hypotension than after normotension during anesthesia. Another less exhaustive study failed to demonstrate such differences [2].

Schneider and coworkers [3] examined whether deviations from normal blood pressure during anesthesia correlated with deviations from the expected outcome of operation and anesthesia. Extensive statistical analysis of preoperative and intraoperative blood pressure data showed that highly variable intraoperative arterial pressure correlated with a postoperative course fraught with more complications than did stable intraoperative pressure. Unfortunately the study did not address whether regulating the blood pressure or keeping it stable would prevent postoperative complications. The authors surmised, and properly so, that sick patients have labile

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*I use the natural pair ill-being and well-being to avoid the term illness, which implies a specific diagnosis, and to contrast better the two concepts.