# Encyclopedia of the Mind

## Anesthesia and Awareness

10.4135/9781452257044.n12

*University of California, San Diego*
The purpose of anesthesia is to render a surgical patient insensitive to pain. Regional and local anesthesia act on the specific sensory nerves and tracts of the skeletal nervous system and spinal cord, leaving the patient conscious and able to communicate and cooperate with the surgical team. General anesthesia, by contrast, operates at the level of the central nervous system, abolishing pain by rendering the patient totally unconscious, in a sort of "controlled coma." For this reason, research on general anesthesia provides an avenue for investigating fundamental aspects of consciousness. This entry provides a brief overview of modern anesthetic technique and the monitoring of anesthetic depth, and discusses issues pertaining to surgical awareness and memory.

# Anesthetic Technique

The first successful use of ether by William Morton on October 16, 1846, is still celebrated as "Ether Day" by anesthesiologists worldwide. Chloroform was introduced in 1847 and gained popularity when used by Queen Victoria during the birth of her eighth child. Modern anesthetic practice, known as *balanced anesthesia*, employs a "cocktail" of different drugs to achieve three different end points: sedation, loss of consciousness, and muscle relaxation. Commonly employed sedatives include diazepam and midazolam. Typical anesthetic agents include inhalants such as nitrous oxide and oxygen, isoflurane, or sevoflurane, and intravenous drugs such as sufentanil or propofol. Muscle relaxation is typically achieved with a drug such as tubocurarine. Because the neuromuscular blockade induces a total paralysis of the skeletal musculature, the patient must be artificially respirated during the procedure, until the blockade is reversed by a drug such as neostigmine. For the same reason, the patient is unable to communicate with the surgical team or respond behaviorally to requests; this situation raises the question of how anyone knows that the patient is really unconscious.

# Monitoring Anesthetic Depth

Clinically, the success of general anesthesia is shown by the patient's lack of response to verbal commands or to what is euphemistically referred to as "surgical stimulation." Moreover, postoperatively, the patient will report no sensation of pain during the operation; nor will the patient recall any events that took place during the operation. By these standards, far less than 1% of surgical patients report any surgical awareness. Still, a postoperative interview is a little late to determine that a patient was not adequately anesthetized, and so considerable effort has been made to develop means of monitoring the patient's state of consciousness, as well as vital functions, during anesthesia. One "on line" measure, based on presumed autonomic signs of conscious awareness, is the PRST score, which takes into account the patient's blood *p*ressure, heart *r*ate, *s*weating, and secretion of *t*ears. Another standard simply relies on biochemical measures of anesthetic concentration in the lungs or bloodstream. A common measure is MAC, which is the *minimum alveolar concentration* of inhalant anesthetic, measured through the respirator, which eliminates motor response to surgical stimulation in 50% of patients. A weaker concentration, *MAC-aware*, also known as *MAC-awake*, typically about 0.3 to 0.5 MAC, is sufficient to eliminate awareness (measured by response to a verbal request), without necessarily eliminating all reflexive motor responses. A stronger concentration, MAC-BAR (1.7–2.0 MAC) is required to block autonomic as well as skeletal reflexes. Including muscle relaxants in balanced anesthesia, then, allows administration of lower doses of anesthetic agents. Similar standards, based on blood plasma levels, have been determined for intravenous anesthetic agents. Because the operational definition of MAC means that 50% of patients will respond to surgical events, **[p. 31 ↓ ]** anesthesiologists generally administer a dose equivalent to approximately 1.3 MAC to ensure adequate anesthesia.

Most modern methods for monitoring the depth of anesthesia involve measures of central nervous system function, such as the *event-related potential* (ERP, or simply EP) observed in the electroencephalogram (EEG), elicited by somatosensory or auditory stimulation (ERPs can be elicited by visual stimulation, too, but surgical patients' eyes are closed). The ERP consists of three major components: early (appearing in the first 10 msec after the stimulus), reflecting brain stem activity; middle

(10–100 msec), reflecting subcortical activity; and late (100–1000 msec), reflecting cortical activity. As a general rule, adequate anesthesia reduces the amplitude of the various peaks and troughs in the ERP subcomponents, as well as their latency with respect to the stimulus. A frequently employed *AEP index* of consciousness reflects the degree to which three midlatency subcomponents of the auditory ERP are delayed with respect to normal.

Analyses of the EEG power spectrum (derived by a "fast Fourier transform" of the raw EEG signal) show that adequately anesthetized patients typically have a median EEF frequency of 2 to 3 Hz or less (corresponding to the "delta" activity observed in slow-wave sleep), with a *spectral edge frequency* at the very high end of the EEG frequency distribution, within or below 8 to 12 Hz (alpha activity). Another derivative of the raw EEG is provided by *bispectral analysis* (BIS), a popular monitoring technique based on a complicated and proprietary set of transformations based on the amount of high-frequency activity (14–30 Hz), synchronization of the EEG at low frequencies, and the presence of a "flat line" EEG. BIS ranges from close to 100 in patients who are normally awake to values well under 60 in patients who are adequately anesthetized by clinical criteria. In one study, a BIS score of 86 was associated with a 50% reduction in recall of material presented during anesthesia and a score of 64 with a 95% reduction.

# Awareness and Memory

Adequate general anesthesia abolishes conscious recollection of surgical events by definition, raising the question of whether there is any *unconscious* perception of these events, outside of conscious awareness but nonetheless encoded in memory. This question has been addressed by looking for evidence of priming, which occurs when processing of one stimulus facilitates the processing of a later stimulus (in negative priming, the first stimulus inhibits processing of the second). For example, subjects who have recently read the word *assassin* are more likely to successfully complete the fragment *a__a__in* with an English word than those who have not.

In fact, some research has found evidence of spared priming for information presented during general anesthesia—at least with some anesthetic agents, and especially at BIS levels above 60. BIS levels below 60 appear to abolish both explicit and implicit

memory for surgical events. But even when implicit memory is spared, the effect appears to be limited to repetition priming rather than semantic or conceptual priming. Because the patient is presumably unconscious of surgical events at the time they occur, spared priming, usually construed as an expression of implicit memory, is, in this case, better interpreted as an expression of implicit or unconscious perception. This implicit perception, when it occurs, appears to be analytically limited, in that it permits the analysis of the sound but not the meaning of the stimulus. For that reason, preserved priming during general anesthesia does not justify administering therapeutic suggestions intended to facilitate the patient's postoperative recovery.

Even when there is some sparing of implicit perception, that does not mean that the anesthetized patient is consciously aware of surgical events as they occur. Still, it would be useful to have an "on line" index of conscious awareness that does not depend on inferences from physiology. One possibility is suggested by the *isolated forearm technique*, in which an inflated blood-pressure cuff is used to restrict the flow of blood to the patient's forearm while the muscle relaxant is being administered. As a result, the patient is free to communicate manually with the anesthetist. One study of awareness during cesarean section found that although patients might respond to instructions delivered during the first minute or so, response quickly drops to zero thereafter, indicating that the patient is, after all, unaware of what is taking place.

John F. Kihlstrom and Randall C. Cork

10.4135/9781452257044.n12

*See also*

Further Readings

Fenster, J. M. (2001). Ether Day: The strange tale of America's greatest medical discovery and the haunted men who made it . New York, NY: HarperCollins.

Kihlstrom, J. F., & Cork, R. C. (2007). Anesthesia . In M. Velmans, ed. & S. Schneider (Eds.), A companion to consciousness (pp. pp. 628–639). Oxford, UK: Blackwell. http://dx.doi.org/10.1002/9780470751466.ch50

Mashour, G.A. (Ed.). (2010). Consciousness, awareness, and anesthesia . Cambridge, UK: Cambridge University Press.

Merikle, P. M., & Daneman, M. (1996). Memory for unconsciously perceived events: Evidence from anesthetized patients . Consciousness and Cognition, vol. 5 , pp. 525–541. http://dx.doi.org/10.1006/ccog.1996.0031

SAGE knowledge