The need to evaluate a patient's response to anesthetics has existed from the very beginning. John Snow recognized certain signs as guidelines for the administration of ether or chloroform. As early as January of 1847, Plomley had described three stages of anesthesia; later Snow added a fourth. To facilitate teaching during World War I, Guedel codified a system that had been used clinically for ether administration for nearly 70 years. He clearly defined the four stages of anesthesia and described the respiratory changes, pupillary alterations, eye movements, and swallowing and vomiting responses that allow estimation of depth of ether anesthesia in any one specific patient. In 1943, Gillespie added reflex responses as additional signs; that is, laryngeal and pharyngeal reactivity, lacrimation, and the respiratory response to surgical incision.

The Guedel system applied only to the unpremedicated patient allowed to breathe spontaneously during ether anesthesia, a situation that no longer exists in modern practice. Most patients receive either opioid or anticholinergic drugs as premedicants, and both alter the reliability of pupillary changes. Ether, cyclopropane, and fluoroxyne, which stimulate the sympathetic nervous system, cause a dose-related dilation of the pupils that is absent with halothane, enflurane, and isoflurane. The latter drugs cause a dose-related depression of blood pressure and hardly alter pulse rate, but ether, cyclopropane, and fluoroxyne in general demonstrate no consistent related changes in these variables. The signs proposed by Guedel and Gillespie still may be observed, but the variability among anesthetics is so great that no uniform system to evaluate depth of anesthesia is likely to evolve. Cardiovascular alterations, widely used by clinicians to evaluate the patient's response to anesthetics, are not included in Guedel's scheme. Respiratory signs, the keystone of Guedel's system, are usually invalid in today's practice of controlled ventilation and use of neuromuscular
blockers. Nevertheless, evaluation of the patient's physiologic response is an important guide to anesthetic dose requirements. Guedel's system will be described first, followed by a discussion of modifications of his approach required to assess depth of anesthesia in current practice.

GUEDEL'S SIGNS AND STAGES OF ETHER ANESTHESIA

A graphic presentation of the signs and stages of ether anesthesia is given in Figure 16–1 as taken from Gillespie's chart, which emphasizes reflex alterations. The converging lines indicate progressive loss of reflex activity as anesthesia deepens.

STAGE I—AMNESIA AND ANALGESIA

Stage I is defined as lasting from the beginning of anesthesia to the loss of consciousness. Those parts of the brain of most recent phylogenetic development seem to be depressed first. This results in obtundation of intellect, memory, integrative functions, and perception of time and space. Although this is commonly called the stage of analgesia, sensation of pain is not absent and the pain threshold is apparently unchanged, but the patient's reaction to pain is altered. If warned, the patient will usually tolerate procedures that normally would not be accepted, that is, minor operations or the pain of the second stage of labor. As pointed out by Snow more than a century ago and more recently confirmed by Artusio (1954), analgesia is more profound upon emergence from ether anesthesia.

Unfortunately, an objective sign has not yet been found to indicate the transition to stage II, in which stimuli may cause the patient to react violently. Kaye states that eyelid closure in response to stroking of the eyelashes disappears at the end of stage I and this is often used as a guide.

STAGE II—DELIRIUM

Stage II, or the stage of delirium, lasts from the time of loss of consciousness to onset of a regular pattern of breathing and disappearance of the lid reflex, here meaning the normal attempt of eyelids to close when passively opened. This is the state of unconsciousness with uninhibited reaction. Patients should not undergo stimulation of any kind during this stage because the response may be injurious. This is why the prophylactic use of restraints is routine. Respiration may be irregular, and the pupils often are dilated and reactive to light. Pharyngeal and laryngeal reflexes, swallowing and laryngeal closure in response to stimulation, are obtunded at the lower limits of this stage, although vomiting can occur through plane 1 of stage III. The chief reason for rapidly increasing the inhaled concen-
<table>
<thead>
<tr>
<th>Stage</th>
<th>Respiration</th>
<th>Ocular Movements</th>
<th>Pupils</th>
<th>Eye Reflexes</th>
<th>Pharynx Reflexes</th>
<th>Lacrimation</th>
<th>Muscle Tone</th>
<th>Resp. Response / Incision</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Voluntary</td>
<td>O</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>Tense</td>
<td>Struggle</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>III</td>
<td></td>
<td></td>
<td>lid tone</td>
<td>swallow</td>
<td>retch vomit</td>
<td>Tense</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plane 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plane 2</td>
<td></td>
<td></td>
<td>corneal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plane 3</td>
<td></td>
<td></td>
<td>pupillar</td>
<td>light reflex</td>
<td>glottis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plane 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage IV</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 16-1. The signs and reflex reactions of the stages of anesthesia. (Reproduced with permission from Gillespie NA: Anesth Analg Curr Res 22:275, 1943.)
tration of anesthetic is to pass through this stage quickly. It is unwise to begin operation before the ensuing third stage has been reached because of the possibility of inducing movement or excitement. To paraphrase John Snow, "The surgeon wishes to know whether the patient will lie still under the knife."

STAGE III—SURGICAL ANESTHESIA

Stage III, or the stage of surgical anesthesia, lasts from the onset of a regular pattern of breathing to cessation of respiration. Most surgical procedures are performed at one of the levels of this stage. For more accurate estimation of depth of anesthesia, the third stage is arbitrarily divided into four planes.

Plane 1

Plane 1 is entered when the lid reflex is abolished and respiration becomes regular. In this plane duration of inspiration is usually longer than expiration, although this is not easily detected.

In plane 1 the eyes may oscillate and not infrequently are eccentrically fixed. Movement may not be apparent immediately when the eyelids are passively opened, especially if only one eye is inspected; it is better to examine both simultaneously. Movements may cease if the lids are kept open too long but usually return after they have been closed for a few seconds. If the extraocular muscles are tonically active, the abdominal muscles may be assumed to be in the same state. Gross ocular movement is minimal or absent during halothane anesthesia, in all planes.

Pupillary dilation may persist for a while but the pupils become distinctly smaller when well into the first plane. Reaction to light is present with ether, cyclopropane, and fluroxene and absent with halothane, enflurane, and isoflurane. The pupils tend to persist in the dilated state during cyclopropane and fluroxene anesthesia but are constricted with other agents.

During plane 1 the vomiting reflex in response to insertion of an oral airway is gradually abolished. It is interesting that swallowing, retching, and vomiting reflexes tend to disappear in that order during induction and reappear in the same order during emergence from anesthesia. The reasons for this are not clear.

Secretion of tears decreases through plane 1. The tendency for the respiratory rate and depth to increase in response to skin incision decreases. In many instances onset of peripheral venous dilation and increased cutaneous blood flow signify entry into the first plane.

Plane 2

Plane 2 lasts from the time the eyes cease to move and become concentrically fixed to the beginning of a decrease in intercostal muscle activ-
ity or thoracic respiration. Although true with ether, not infrequently with cyclopropane the eyes will not be centrally fixed, though all other signs indicate that anesthesia is in plane 2 or 3. Respirations remain regular but tidal volume is diminished, the rate tending to rise. Duration of inspiration and expiration may become equal or expiration may be slightly prolonged.

The pupils begin to dilate in plane 2 with ether, cyclopropane, and fluoroxyene, remaining constricted with the other agents. A rise in $P_{aCO_2}$ tends to produce pupillary dilation. On the whole, pupillary size is an unreliable indicator in patients given excessive amounts of premedication. Morphine tends to constrict the pupils, whereas belladonna derivatives produce dilation, with the effects of morphine generally overshadowing those of atropine or scopolamine. Whether the pupillary change is a peripheral or central influence on the autonomic nervous system has not been established. Pupillary signs are less reliable in patients over the age of 50. The best approach is to regard the dilated pupil as a sign of overdose or hypoxia until proved otherwise, except in the second stage.

Reflex closing of the vocal cords or laryngospasm begins to disappear in plane 2. The conjunctivae become lusterless and the respiratory response to skin incision disappears.

Muscle tone lessens as anesthesia deepens, but this is not always a reliable measure of depth of anesthesia. Abdominal muscle tone varies enormously among individuals, as does apparent flaccidity of the peritoneum. These phenomena are influenced by age, physical status, and the degree of intestinal or gastric distention. The tone of a flaccid muscle may be increased by a stimulus. Thus, a gentle surgeon will obtain as good abdominal exposure in the second plane as a rough surgeon in the third plane. Lack of oxygen or excess of carbon dioxide enhances muscle rigidity.

**Plane 3**

Plane 3 is entered when intercostal activity begins to decrease; the upper intercostals seem to become less active before the lower. Some interpret intercostal activity as secondary to diaphragmatic movement; as the diaphragm weakens, so does thoracic movement. Contraction of intercostal muscles lags behind that of the diaphragm, causing a rocking movement; to detect this lag one should observe both diaphragmatic and intercostal activity and establish the time relationship. Complete intercostal paralysis occurs in lower plane 3 while respiration is carried on solely by the diaphragm. As a consequence, tidal volume is reduced. Inspiration is now shorter than expiration and the pause between them is longer than in lighter planes of anesthesia. Some individuals, particularly men, exhibit only abdominal movement with respiration even in lighter planes of anesthesia. When the intercostals become paralyzed, passive retraction of the chest on inspiration usually occurs, giving a false impression of intercostal activity unless the time relationship is analyzed. It is unwise and unnecessary to maintain plane 3 for very long.

In mid to lower plane 3, reactivity of the pupils to light is gradually lost.
Plane 4

Plane 4 extends from the time of paralysis of the intercostal muscles to cessation of spontaneous respiration. As anesthesia deepens through this plane, diaphragmatic activity and respiratory exchange become progressively reduced until breathing stops. The pupils dilate and no longer react to light. There is little muscle tone, even in the robust person.

Tracheal tug often appears in association with deep anesthesia and intercostal paralysis. Respiratory obstruction or the actions of the accessory muscles of ventilation may produce tracheal tug, and the phenomenon is frequently observed as the diaphragm begins to regain function after use of a neuromuscular blocker. We believe that "tug" represents an unopposed action of the diaphragm, displacing the hilum of the lung and therefore increasing traction on the trachea.

STAGE IV

Stage IV lasts from the time of cessation of respiration to failure of the circulation, where respiration fails first because of a high concentration of anesthetic in the central nervous system. This is not to be confused with the apnea caused by breath-holding; nor should it be confused with the reflex breath-holding sometimes seen in lighter planes of anesthesia following manipulation of thoracic or abdominal organs, as with periosteal, pharyngeal, laryngeal, or bronchial stimulation; such breath-holding usually takes place at end inspiration and the glottis is closed. Less frequently, a prolonged expiratory effort is made or cough results.

In stage IV, which is premortem, most reflexes are absent and the circulation is about to fail, a plane of anesthesia arrived at only in error. Steps should be taken promptly to lighten anesthesia, as even brief maintenance in this plane leads to circulatory failure. The concentration of anesthetic in the blood and alveoli should be lowered by manual ventilation of the lungs with high flows of oxygen and repeated emptying of the reservoir bag.

CLINICAL ASSESSMENT OF ANESTHETIC REQUIREMENTS

Currently, anesthetists use a more logical approach than that proposed by Guedel to evaluate the effects of anesthetics. His was a static system: ether at a given dose (although then unknown) produces a given effect. He neglected the patient as a responsive organism in whom graded stimuli produce graded responses. Anesthetics alter patient reactivity, allow application of a large magnitude of stimuli, yet limit the resulting response. To evaluate fully the effect of an anesthetic, the anesthetist must evaluate both the stimulus and response. Gillespie recognized this concept when he
added response to surgical incision to Guedel’s scheme. Today’s anesthesi- 
tists use a stimulus-response assessment to classify adequacy of anesthetic 
level; it is less well defined than Guedel’s scheme but more operational.

**STIMULUS-RESPONSE ASSESSMENT**

The stages of amnesia and analgesia and of delirium (Guedel’s stages I 
and II) are usually not seen during induction of anesthesia at present 
because of the nearly routine use of intravenous induction techniques. 
Even during inhalation induction the two stages are not differentiated but 
are regarded as a single level, that of presurgical anesthesia. Excitement 
may occur during this stage and precautions to avoid patient stimulation 
during induction are still applicable. Three signs generally identify passage 
from the presurgical to a surgical level of anesthesia: loss of lid reflex, 
onset of muscle relaxation, and onset of rhythmic respiration. If these have 
not occurred, then the patient is at a presurgical level and stimulation must 
be avoided. When they are present, surgical anesthesia exists.

Three levels of anesthetic depression are recognized: presurgical anes- 
thesia, surgical anesthesia, and overdose. Three planes of surgical anesthesia are accepted: too light, adequate, and too deep (Fig. 16–2). The thoughtful anesthetist follows a specific method in judging a patient’s status. First, evaluation of afferent input to the nervous system; second, estimation of observable physiologic responses; and finally, the interaction among patient, stimulus, and anesthetic is considered and the level of surgical anesthesia deduced.

![Figure 16–2](image-url)  
*Figure 16–2. Schematic representation of evaluation of anesthetic requirements.*
Stimulus Assessment

Stimulus intensity is arbitrarily classified somewhere between strong and weak. Strong stimulation results from a skin incision, anal or cervical dilation, periosteal stimulation, fracture manipulation, visceral or peritoneal traction, diaphragmatic stimulation, manipulation of the cornea, and excessive distention of the bladder. Weak stimulation results from uterine curettage, retroperitoneal dissection, wound debridement, mild distention of the bladder, and manipulation of fascia or muscle if without traction. No appreciable stimulation occurs during surgical dissection of brain, muscle, and connective tissue, bowel section and suturing, or lung resection and suturing. Inflammation usually enhances the intensity of the stimulus. Careful surgical manipulation may diminish the stimulus and the patient’s age or physical status may influence the response.

Anesthetists must continuously monitor surgical activity if they are to have the information required to evaluate the anesthetized patient adequately.

Response Evaluation

Woodbridge, recognizing the large number of subtle observations the anesthetist must make, cited four components of the anesthetic state: sensory, motor, mental, and reflex functions. Table 16–1 attempts to classify the intensity of responses that may be observed in reference to Woodbridge’s components. Note that observations made to evaluate depression in any one component involve nearly all body systems. Moreover, a single response may relate to several components. For example, if a patient takes a deep breath, turns the head, and develops tachycardia and hypertension when an incision is made, it is obvious that sensory depression is inadequate. Whether motor depression is inadequate depends upon the site of operation. The low intensity responses listed are undesirable in virtually every case and most anesthetists avoid drug doses that result in such responses. Utilization of this system permits logical evaluation of specific drug effects in each of Woodbridge’s components.

**Depth of Anesthesia and Arterial Pressure.** Arterial hypotension is the chief clinical sign of depth of anesthesia with halothane and oxygen and the more common combination of halothane, nitrous oxide, and oxygen. Hypercarbia, although not to be condoned, counteracts hypotension, and with time during administration of halothane the arterial pressure rises. Both effects probably are related to increased sympathetic nervous activity. Pain perception during light anesthesia causes arterial pressure to rise. Enflurane, isoflurane, and methoxyflurane resemble halothane in their actions on blood pressure.

**Evaluation of Anesthetic Requirement.** A comparison of strength of surgical stimulus and observation of intensity of response allows for evaluation of specific anesthetic requirements. If the response is excessive in a
<table>
<thead>
<tr>
<th>Woodbridge Component</th>
<th>Sensory</th>
<th>Motor</th>
<th>Mental</th>
<th>Reflexes</th>
<th>Circulatory</th>
<th>Respiratory</th>
<th>Gastrointestinal</th>
</tr>
</thead>
<tbody>
<tr>
<td>High intensity response</td>
<td>Breath-holding, Deep breathing, Stiff chest, Phonation, Laryngospasm, Tachycardia, Rise or fall in BP, Movement with stimulus, Pupillary dilation, Sweating, Coughing</td>
<td>Fine or gross movement, Abdominal tightness, Muscle potentials on EKG</td>
<td>Movement upon stimulation, Delirium, Uninhibited speech or actions</td>
<td>Bradycardia and hypotension or Tachycardia and hypertension Arrhythmias</td>
<td>Bradycardia and hypotension or Tachycardia and hypertension Arrhythmias</td>
<td>Spasm: laryngeal bronchiolar chest wall Salivation</td>
<td>Nausea, Retching, Vomiting, Swallowing</td>
</tr>
<tr>
<td>Acceptable response</td>
<td>Minimal response to painful stimuli followed by accommodation, Stability of cardiovascular respiratory systems</td>
<td>Quiet surgical field, Relaxation of muscle</td>
<td>Amnesia, Ataxia, Sleep</td>
<td>Absence of troublesome CV, respiratory, and gastrointestinal reflexes</td>
<td>Absence of troublesome CV, respiratory, and gastrointestinal reflexes</td>
<td>Absence of troublesome CV, respiratory, and gastrointestinal reflexes</td>
<td>Absence of troublesome CV, respiratory, and gastrointestinal reflexes</td>
</tr>
<tr>
<td>Low intensity response</td>
<td>No response</td>
<td>Muscle flaccidity, Inability to re-establish normal ventilatory function at end of anesthesia</td>
<td>Prolonged obtundation in pre- or postanesthetic period</td>
<td>Bradycardia, Tachycardia, Hypotension, Arrhythmias, Intolerance to position change</td>
<td>Bradycardia, Tachycardia, Hypotension, Arrhythmias, Intolerance to position change</td>
<td>Respiratory arrest*</td>
<td>Respiratory arrest*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Intestinal atony, Postoperative ileus</td>
</tr>
</tbody>
</table>

*In the absence of neuromuscular blockers or hypocarbia.
specific area, compensatory adjustments are needed. A higher concentration of inhalation anesthetic may be administered with full recognition that this may increase depression in all areas; alternately, a specific drug, a neuromuscular blocker, may be chosen to correct the defect. Observations are repeatedly made and adjustments instituted. Occasionally, the system is disturbed by design to test the resulting response; the anesthetist may increase or reduce the inhaled concentration of anesthetic in order to observe the effect. In fact, as anesthesia progresses, the anesthetist should gradually reduce the inhaled concentration and observe the effect in order to prevent overdose as body tissues become saturated.

**APPRaisal**

In many ways, this procedural assessment is a restatement of what the good clinician has always done. As powers of observation improve and experience increases, the beginner will find that a combination of signs provides a satisfactory guide to anesthetic depth. It is well known, for example, that reactivity to stimuli diminishes with age and is always less marked in the critically ill. The anesthetist must be all the more alert and observant to prevent overdose.

General anesthesia usually appears to be deeper than it actually is. It is usually easier to lighten than to deepen anesthesia. Therefore, induction should be carried a little further than seems necessary for the incision, so that the difficulties associated with inadequate anesthesia are not encountered. A middle course must be steered between light and unnecessarily deep anesthesia.

**Additional Observations**

A correlation of the clinical signs of anesthesia with the arterial level of the anesthetic has been attempted. Although for any one individual the depth of anesthesia may correlate closely with the arterial concentration of anesthetic, the same concentration of anesthesia in a population of individuals gives wide deviations in depth. For this reason, and because arterial concentration of anesthetic is ascertained only after some delay, it is only rarely used as a clinical guide to depth.

The electroencephalogram (EEG) also has limited usefulness as a monitor of anesthetic depth. Each anesthetic differs in the EEG alterations it produces (see Chapter 11). Other factors such as tensions of oxygen or carbon dioxide and level of blood pressure can alter the EEG and thus the EEG response to anesthetics. Moreover, each anesthetic interacts differently with these modifying factors. As a result, the EEG is seldom used as a monitoring device in anesthesia.
REFERENCES


