**Learning Objectives**

After reading this chapter, you will be able to:
- Define key terms related to neurologic assessment.
- Describe the functional anatomy of the nervous system.
- Explain the cortical function of the different lobes of the brain.
- Describe the functions of the brainstem, the cerebellum, and 12 pair of cranial nerves.
- Describe common techniques used to assess the mental status.
- Identify the parameters necessary to obtain a Glasgow Coma Scale and be able to interpret the results.
- Describe the importance of assessing sedation and delirium in the intensive care unit.
- Describe common techniques used to assess the cranial nerves, the sensory system, the motor system, coordination, and gait.
- Describe common techniques used to assess deep, superficial, and brainstem reflexes.
- Explain the relationship between vital signs and neurologic status.
- Identify the importance of intracranial pressure monitoring and the value of assessing cerebral perfusion pressure.

**Key Terms**

<table>
<thead>
<tr>
<th>Afferent</th>
<th>Deep Tendon Reflexes</th>
<th>Oculocephalic Reflex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anosognosia</td>
<td>Doll's eyes</td>
<td>Oculovestibular Reflex</td>
</tr>
<tr>
<td>Anisocoria</td>
<td>Efferent</td>
<td>Patellar Reflex</td>
</tr>
<tr>
<td>Apneustic</td>
<td>Gag Reflex</td>
<td>Perrla</td>
</tr>
<tr>
<td>Ataxia</td>
<td>Glasgow Coma Scale</td>
<td>Persistent Vegetative State</td>
</tr>
<tr>
<td>Ataxic Breathing</td>
<td>Graphesthesia</td>
<td>Phrenic Nerves</td>
</tr>
<tr>
<td>Autotopagnosia</td>
<td>Intracranial Pressure</td>
<td>Plantar Reflex</td>
</tr>
<tr>
<td>Babinski's Sign</td>
<td>Level of Consciousness</td>
<td>Pneumotaxic</td>
</tr>
<tr>
<td>Botulism</td>
<td>Lower Motor Neuron</td>
<td>Pronator Drift</td>
</tr>
<tr>
<td>Cerebral Perfusion Pressure</td>
<td>Mini-Mental State Examination</td>
<td>Proprionception</td>
</tr>
<tr>
<td>Cheyne-Stokes Respiration</td>
<td>Miosis</td>
<td>Pupillary Reflex</td>
</tr>
<tr>
<td>Cough反射</td>
<td>Myasthenia Gravis</td>
<td>Sensory Dissociation</td>
</tr>
<tr>
<td>Cushing's Triad</td>
<td>Mydriasis</td>
<td>Stereognosis</td>
</tr>
<tr>
<td>Decerebrate Posture</td>
<td>Nystagmus</td>
<td>Upper Motor Neuron</td>
</tr>
<tr>
<td>Decorticate Posture</td>
<td></td>
<td>Westphal's Sign</td>
</tr>
</tbody>
</table>
Neurologic assessment is a method of obtaining specific data in relation to the function of a patient’s nervous system and is typically performed by the attending physician. Since injuries that involve the nervous system often affect the patient’s respiratory system and the ability of the patient to cooperate with respiratory care procedures, the respiratory therapist (RT) should become familiar with the key components of the neurologic assessment. The challenges of examining an intubated, restrained, and often-sedated patient in the intensive care unit (ICU) makes neurologic assessment difficult in many patients.

Proper clinical assessment of the nervous system emphasizes the neurologic history and examination. Obtaining historical information from critically ill patients, particularly those with altered states of consciousness can be difficult. However, attempting to obtain a history by speaking with the patient or family members can provide extremely useful information in the ICU. Whereas the history usually indicates the nature of the dysfunction, the neurologic examination localizes and quantifies its severity.

The neurologic examination is often brief if initial interactions with the patient are normal (e.g., the patient responds appropriately to verbal stimuli) and the patient has no symptoms suggesting neurologic disease. This initial interaction with the patient could provide insights about the patient that could possibly impact adherence to respiratory care and coordination to use devices such as a pressurized metered-dose inhaler (pMDI). A more extensive examination is performed when abnormalities are suspected and may involve the expertise of a neurologist. The neurologic examination is a comprehensive evaluation that covers several areas: mental status, cranial nerve function, motor system, coordination, sensory system, and muscle stretch reflexes. This initial examination establishes baseline data with which to compare subsequent assessment findings. Neurologic observations allow monitoring and evaluation of changes in the nervous system that aid in the diagnosis and treatment that later impact patient prognosis and rehabilitation.

It also gauges the patient’s response to the clinician’s interventions. Once a thorough evaluation is done on admission or at the beginning of each shift, subsequent assessments should be tailored to the patient’s condition. The frequency of these assessments will depend on the patient’s diagnosis, acuity of condition, and on how rapidly changes are occurring or expected to occur. Neurologic assessment should start with minimal verbal stimulus and progress to maximal tactile stimulus as the condition warrants. A meaningful neurologic assessment requires adequate stimulation.

**FUNCTIONAL NEUROANATOMY**

To perform or understand a neurologic assessment, the examiner needs a basic understanding of anatomy and function of the nervous system. The neurologic system is made up of two major parts: the central and peripheral nervous systems. The central nervous system (CNS) contains the brain and spinal cord (Figure 6-1), whereas the peripheral
The nervous system is composed of the 12 cranial nerves and the 31 spinal nerves. The brain consists of three parts: the cerebrum, which contains two hemispheres; the brainstem (midbrain, pons, and medulla); and the cerebellum.

The nervous system is also organized according to its function into sensory (afferent) and motor (efferent) divisions. This functional organization allows the clinician to understand how signals are transmitted towards and from the CNS (Figure 6-2).

The cerebrum is the largest part of the brain and is made up of two hemispheres and areas that control specific intellectual or motor functions (Figure 6-3). Lesions
in the cerebrum can lead to abnormalities in functions such as movement, level of consciousness, ability to speak and write, emotions, or memory.

The brainstem is the lower part of the brain where it connects to the spinal cord. It consists of the midbrain, pons, and the medulla oblongata (Figure 6-4). The brainstem is the pathway for all fiber tracts passing up and down from peripheral nerves and spinal cord to the highest parts of the brain. Most of the cranial nerves originate in the brainstem.

Many neurologic functions of particular importance to the RT, such as regulation of heart rate, blood pressure, and breathing, are located in the brainstem. In addition, the brainstem contains reflex centers for certain cranial nerve functions such as the pupillary reflex, which is discussed later in this chapter. Lesions in the brainstem can cause a wide range of breathing problems from hyperventilation to apnea.

**SIMPLY STATED**

Many neurologic functions of particular importance to the RT, such as regulation of heart rate, blood pressure, and breathing, are located in the brainstem.

The cerebellum is located in the posterior part of the brain and is responsible for controlling equilibrium, muscle tone, and coordination of muscle movements. Lesions in the cerebellum cause characteristic symptoms such as loss of muscle coordination (ataxia), tremors, and disturbances in gait and balance.

The spinal cord lies within the center of the vertebral bodies and extends from the base of the brain down to the level of the first lumbar vertebra. It spans a distance of approximately 45 cm in the average adult. It serves the purpose of connecting the brain to the various parts of the body for motor and sensory function. It is an oval cylinder that has two tapering bulges: one in the cervical region and one in the lumbar region.

Two sets of nerve fibers called spinal nerves project from both sides of the spinal column at 31 locations along the spine. Posterior or dorsal (sensory) and anterior or ventral (motor) nerve roots separate as they exit the spinal cord until their fibers combine at the level of the dorsal root ganglion. The dorsal nerve root consists of posterior nerve fibers that carry sensory information into the spinal cord. The ventral nerve root consists of anterior nerve fibers that conduct motor impulses out of the spinal cord. Because all spinal nerves contain both motor and sensory fibers, they are called mixed nerves. Each has the ability to provide sensory input to the brain (e.g., feel pain) and the ability to cause muscle movement (e.g., extend the arm on command) (Figure 6-5).

These spinal nerves have no specific name but rather are numbered according to the level of the vertebral column at which they exit the spinal column. There are eight cervical (C1 to C8), twelve thoracic (T1 to T12), five lumbar (L1 to L5), five sacral (S1 to S5), and one coccygeal pair of spinal nerves.

A herniated vertebral disk is the most common nerve root pathology that results in compression on the nerve roots. This usually results in pain with radiation into the affected area of skin (dermatome) supplied with afferent nerve fibers by a single posterior spinal root (Figure 6-6).

**SIMPLY STATED**

A herniated vertebral disk is the most common nerve root pathology, and it causes pain with radiation into the affected area of skin (dermatome) supplied with afferent nerve fibers by a single posterior spinal root.
The involvement of multiple nerve roots suggests the presence of inflammatory processes such as Guillain-Barré syndrome. Because of the proximity of dorsal and ventral roots, motor involvement is also common. The hallmark of selective nerve root involvement is a pattern of unilateral symptoms limited to the distribution of that nerve root. The involvement of multiple nerve roots suggests the presence of inflammatory (Guillain-Barré syndrome, amyloidosis, or vasculitis), neoplastic (carcinomatous meningitis) or infectious (syphilis or Lyme disease) processes.

Two spinal nerves important for respiratory function are the right and left phrenic nerves that innervate the diaphragm to control breathing. The phrenic nerves arise from the cervical spine roots of C3 to C5. Damage to this portion of the spinal cord or both phrenic nerves can result in complete paralysis of the diaphragm and make the patient dependent on a ventilator for life. Figure 6-7 illustrates the typical outcome after spinal cord or root injury.

MENTAL STATUS EXAMINATION AND LEVEL OF CONSCIOUSNESS

The cerebral hemispheres represent the highest and most complex level of neurologic function. Although a great deal of the mental status reflects integration of cortical function, it can still be divided into functional areas that correspond to anatomic regions of the cerebral hemispheres (Figure 6-8). Table 6-1 gives a brief overview of areas of cortical function that can be assessed by components of the mental status examination.

Evaluation of patient’s orientation allows the clinician to evaluate if the patient is aware of himself/herself as a person. Anosognosia is being unaware that one is ill. Autotopagnosia is the inability to locate one’s own body parts. Time is typically the first out of the three areas of orientation that is lost when brain injury is present, followed by place and person.

Level of Consciousness

Evaluation of level of consciousness (LOC) and mentation are the most important parts of the neurologic examination. A change in either is usually the first clue to CNS dysfunction. The initial goals of the examination...
of a patient with altered mental status are to determine if
the patient is conscious and then to determine awareness. Altered awareness is associated with either reticular system
dysfunction or bilateral hemispheric dysfunction. Testing
anatomic structures surrounding these structures provides
the major clues regarding the etiology and level of dysfunc-
tion. Table 6-2 shows the major findings on assessment of
the LOC and their expected anatomic correlates.

Assessment of mentation begins when you first encoun-
ter the patient. A neurologically healthy patient will be
awake and interacting with those around. If asleep, the
patient can be easily aroused to an awake, alert state.
Different levels of consciousness from full alertness to
coma have been defined (Box 6-1). Since these and other
terms used to categorize the LOC are frequently used
imprecisely, it is often recommended to avoid using them.
Instead, a brief description of the applied stimulus and
arousal pattern is preferred.

A condition in which a patient’s eyes may be open, but
the patient cannot be aroused is known as a persistent
vegetative state or prolonged postcoma unresponsiveness
and typically indicates irreversible brain damage. Breathing
may not be affected if the brainstem is unaffected by the
injury.

**SIMPLY STATED**

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important parts of the neurologic examination. A change in
either is usually the first clue to CNS dysfunction.

A condition in which a patient’s eyes may be open, but
the patient cannot be aroused is known as a persistent
vegetative state or prolonged postcoma unresponsiveness
and typically indicates irreversible brain damage. Breathing
may not be affected if the brainstem is unaffected by the
injury.
Compromise of the LOC may be due to a generalized dysfunction (e.g., drug overdose) or an abnormality in a specific area of the brain. When an abnormality that affects a local area of the brain causes loss of consciousness, it usually does this by increasing pressure over the brainstem. When excessive pressure is applied, brainstem functions are lost in a predictable sequence. The loss of function starts from the top of the midbrain and extends sequentially down through the medulla (Table 6-3).

**Glasgow Coma Scale**

The **Glasgow Coma Scale** (GCS) was published in 1974 by Graham Teasdale and Bryan J. Bennett to assess the LOC after head injury. It is the most widely used instrument...
for quantifying neurologic impairment. The GCS is used to test best motor response, best verbal response, and eye opening. Although it is easy to perform and readily reproducible, it is poorly suited for patients who have impaired verbal responses caused by aphasia, hearing loss, or tracheal intubation. A scale that goes from 3 (deep coma or death) to 15 (fully awake) is useful for rapid triage (Table 6-4).

Patients with GCS scores of 12 to 15 often are admitted to a non-ICU observational unit unless neurologic examination or a diagnostic test reveals a lesion or abnormality that warrants ICU admission. Scores of 9 to 12 on the GCS indicate a significant insult with a moderate coma. Patients with GCS scores less than 9 have a severe coma and typically require endotracheal intubation. Since endotracheal intubation makes it impossible to test the patient’s verbal response, the letter “T” is often attached to the GCS score to indicate the presence of the tube (e.g., GCS ST).

**SIMPLY STATED**

The GCS is the most widely used instrument for quantifying neurologic impairment. Patients with GCS scores less than 8 have a severe coma and typically require endotracheal intubation.

---

**TABLE 6-1**

<table>
<thead>
<tr>
<th>Cerebral Lobe</th>
<th>Cortical Function</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frontal</td>
<td>Attention: working memory</td>
<td>Digit span, spelling backward, and naming months of the previous year backward</td>
</tr>
<tr>
<td></td>
<td>Judgment: abstract reasoning</td>
<td>Problem solving, verbal similarities, and proverbs</td>
</tr>
<tr>
<td>Temporal</td>
<td>Orientation, memory</td>
<td>Verbal fluency and the ability to generate a set of items</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Questions about month, date, day of week and place</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Three-word recall (recent memory)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Naming Presidents (remote memory)</td>
</tr>
<tr>
<td>Frontal-temporal</td>
<td>Receptive language</td>
<td>Follow commands (spoken and written language)</td>
</tr>
<tr>
<td></td>
<td>Expressive language</td>
<td>Fluency and correctness of content and grammar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reading comprehension</td>
</tr>
<tr>
<td>Parietal (dominant)</td>
<td>Gnosis</td>
<td>Identify objects placed in their hand and numbers written on their hand with eyes closed</td>
</tr>
<tr>
<td></td>
<td>Constructional</td>
<td>Attending to the contralateral side of the body</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Drawing a face, clock, or geometric figures</td>
</tr>
<tr>
<td>Parietal (nondominant)</td>
<td>Praxis</td>
<td>Perform skilled motor tasks without any nonverbal prompting</td>
</tr>
<tr>
<td>Occipitotemporal</td>
<td>Visual recognition</td>
<td>Recognition of colors and faces</td>
</tr>
</tbody>
</table>

---

**Occipital lobe**
- Interpretation of written language (left hemisphere).

**Parietal lobe**
- Recognition of right/left differentiation, sensation, recognition of body parts.
- Recognition of right/left differentiation, sensation, recognition of body parts.

**Frontal lobe**
- Judgment, humor, social mores, affect, personality, motor movement, expressive speech (Broca, left hemisphere), spatial and perceptual information (right hemisphere).
- Set generation
- Problem solving, verbal similarities, and proverbs
- Verbal fluency and the ability to generate a set of items
- Questions about month, date, day of week and place
- Three-word recall (recent memory)
- Naming Presidents (remote memory)
- Follow commands (spoken and written language)
- Fluency and correctness of content and grammar
- Reading comprehension

**Temporal lobe**
- Hearing, comprehension of spoken and written language (Wenecke, left hemisphere), long-term memory.
- Recognition of colors and faces
TABLE 6-2
Clinical Findings with Different Levels of Central Nervous System Dysfunction

<table>
<thead>
<tr>
<th>Dysfunction</th>
<th>Response to Noxious Stimuli</th>
<th>Pupils</th>
<th>Eye Movements</th>
<th>Breathing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Both cortices</td>
<td>Withdrawal</td>
<td>Small, reactive</td>
<td>Spontaneous conjugate horizontal movements; if none, cervicoocular or vestibuloocular reflexes can be elicited.</td>
<td>Posthyperventilation apnea or Cheyne-Stokes respiration.</td>
</tr>
<tr>
<td>Thalamus</td>
<td>Decorticate posturing</td>
<td>Same as above, unless the optic tracts also damaged</td>
<td>Same as above.</td>
<td>Same as above.</td>
</tr>
<tr>
<td>Midbrain</td>
<td>Decorticate or decerebrate posturing</td>
<td>Midposition, fixed to light</td>
<td>Loss of ability to adduct. Both eyes may be deviated laterally (wall-eyed; CN III damaged).</td>
<td>Usually same as above; potential for central reflex hyperpnea.</td>
</tr>
<tr>
<td>Pons</td>
<td>Decerebrate posturing</td>
<td>Usually small; may exhibit bilateral pinpoint pupils (especially with midline pontine hemorrhage); Horner’s syndrome with lateral lesions</td>
<td>Loss of conjugate horizontal movements with retained vertical movements and accommodation. Often eyes are deviated medially (CN VII damage).</td>
<td>May exhibit central reflex hyperpnea, cluster (Biot’s) breathing, or apneustic breathing.</td>
</tr>
<tr>
<td>Medulla</td>
<td>Weak leg flexion (or none)</td>
<td>Usually small; Horner’s syndrome with lateral lesions</td>
<td>Usually no effect on spontaneous eye movements. May interfere with reflex responses. Rarely, nystagmus.</td>
<td>Rarely, ataxic respiration; apnea if respiratory centers involved.</td>
</tr>
</tbody>
</table>


Box 6-1 Levels of Consciousness

**Full consciousness:** The patient is alert, attentive, follows commands, responds promptly to external stimulation if asleep, and once awake, remains attentive.

**Lethargy:** The patient is drowsy but partially awakens to stimulation; patient will answer questions and follow commands but will do so slowly and inattentively.

**Obtundation:** The patient is difficult to arouse and needs constant stimulation to follow a simple command. Although there may be verbal response with one or two words, the patient will drift back to sleep between stimulation.

**Stupor:** The patient arouses to vigorous and continuous stimulation; typically, a painful stimulus is required. The only response may be an attempt to withdraw from or remove the painful stimulus.

**Coma:** The patient does not respond to continuous or painful stimulation. There are no verbal sounds and no movement, except possibly by reflex.

TABLE 6-3
Sequence of Loss of Brainstem Function

<table>
<thead>
<tr>
<th>Highest Level of Brainstem Function</th>
<th>Breathing</th>
<th>Oculocephalic Reflex</th>
<th>Pupils</th>
<th>Pain Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>High midbrain</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
<td>Withdrawal</td>
</tr>
<tr>
<td>Mid-midbrain</td>
<td>Cheyne-Stokes</td>
<td>Present</td>
<td>Small but reactive</td>
<td>Decorticate</td>
</tr>
<tr>
<td>Pons</td>
<td>Hyperventilation</td>
<td>Minimal</td>
<td>Mid-Fixed</td>
<td>Decerebrate</td>
</tr>
<tr>
<td>Medulla</td>
<td>Ataxic</td>
<td>None</td>
<td>Mid-Fixed</td>
<td>None</td>
</tr>
</tbody>
</table>
If the patient does not have spontaneous movements of the eyes or limbs or does not have a verbal response, the examiner should attempt to arouse the patient with a loud voice such as calling his/her name. If the patient is still unresponsive after verbal stimuli, a response to pain can be assessed by using central stimulation techniques as explained later in the chapter.

**Mini-Mental State Examination**

The Mini-Mental State Examination (MMSE), or Folstein test, is a brief 30-point quantitative questionnaire used to assess cognition. It can be used to screen for cognitive impairment, to estimate the severity of cognitive impairment at a given point in time, to follow the course of cognitive changes in an individual over time, and to document an individual’s response to treatment. It samples various functions, including arithmetic, memory, and orientation. It was introduced by Folstein et al in 1975 and is widely used with small modifications. Any score over 27 (out of 30) is normal; between 20 and 26 indicates mild dementia; 10 to 19 indicates moderate dementia, and below 10 indicates severe dementia. The normal value is also corrected for degree of schooling and age.

**Assessment of Sedation and Delirium in the Intensive Care Unit**

Delirium is an acute change or fluctuation in mental status plus inattention and either disorganized thinking or an altered LOC at the time of the assessment. Several studies have confirmed that delirium occurs in 60% to 80% of mechanically ventilated patients\(^\text{9-10}\) and that it is independently associated with longer stay in the hospital, higher mortality, and poor long-term cognitive function.\(^\text{10}\)

The Richmond Agitation Sedation Scale (RASS) helps to measure the sedation and agitation of patients in an ICU and is often considered when titrating sedation medications\(^\text{11}\) (Table 6-5). Delirium is frequently evaluated with the Confusion Assessment Method for the ICU (CAM-ICU) (Figure 6-9). Because many aspects of delirium in the ICU may be preventable or treatable\(^\text{12,13}\) (e.g., hypoxemia, electrolyte disturbances, sleep deprivation, or overzealous use of sedative agents), it is recommended that respiratory therapists become familiar with these assessment tools. The Society of Critical Care Medicine guidelines for sedation and analgesia recommend that ICU teams routinely monitor all patients in the ICU for delirium.\(^\text{14}\)

**CRANIAL NERVE EXAMINATION**

There are twelve cranial nerves (CNs) connected to the undersurface of the brain, with most coming from the brainstem (Figure 6-10). Assessment of the CNs allows the clinician to “view” the brainstem all the way from its rostral to its caudal extent. The brainstem can be divided into three levels: the midbrain, the pons and the medulla. There are two CNs for the midbrain (III and IV), four CNs for the pons (V and VIII), and four CNs for the medulla (IX and XII). Because CNs never cross, except for CN IV, clinical findings are always on the same side as the CN involved (Table 6-6).

Each nerve is named according to its distribution or function. Some of the CNs are sensory only, some are motor only, and others have both functions. Therefore they are evaluated by using a combination of sensory and motor function tests. Those that have both functions allow sensory input to the brain for interpretation...
and control of muscles for function. Some functions are controlled by several CNs. For example, an acoustic problem will be assessed by testing the acoustic nerve (CN VIII) and the nearby facial nerve (CN VII). Extraocular movements (EOMs) are controlled by CNs III, IV, and VI, which are tested together. Other functions, such as the pupillary response (CN II and III), the corneal reflex (CN V and VII); and the gag reflex (CN IX and X), depend on more than one CN. Because many of the nerves cannot be tested without the patient’s cooperation, the neurologic assessment of a comatose patient may not be viewed as complete.

### SIMPLY STATED

The gag reflex (CN IX and X), the pupillary reflex (CN II and III), and the corneal reflex (CN V and VII) depend on more than one CN.
CHAPTER 6 • Neurologic Assessment

Neurologic Assessment

Oculomotor nerve (III)

Optic nerve (II)

Abducens nerve (VI)

Trochlear nerve (IV)

Facial nerve (VII)

Vest bulocochlear nerve (VIII)

Vagus nerve (X)

Accessory nerve (XI)

Hypoglossal nerve (XII)

FIGURE 6-10 The cranial nerves. Ventral surface of the brain showing attachment to the cranial nerves.

Assessment of the Cranial Nerves

<table>
<thead>
<tr>
<th>Cranial Nerve</th>
<th>Classification</th>
<th>Major Functions</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Olfactory</td>
<td>Sensory</td>
<td>Smell</td>
<td>Have patient identify a familiar scent with eyes closed (usually deferred).</td>
</tr>
<tr>
<td>II Optic</td>
<td>Sensory</td>
<td>Vision (acuity and field of vision) Pupil reactivity to light and accommodation (afferent impulse)</td>
<td>Have patient read from a card, one eye at a time. Test visual fields by having patient cover one eye, focus on your nose, and identify the number of fingers you are holding up in each of four visual quadrants.</td>
</tr>
<tr>
<td>III Oculomotor</td>
<td>Motor</td>
<td>Eyelid elevation Pupil size and reactivity (afferent impulse) Most EOM</td>
<td>Check pupillary responses by shining a bright light on one pupil; both pupils should constrict (consensual reflex). Do the same for the other eye. To check for accommodation, move your finger toward the patient’s nose; the pupils should constrict and converge. Check EOMs by having patient look up, down, laterally, and diagonally.</td>
</tr>
<tr>
<td>IV Trochlear</td>
<td>Motor</td>
<td>EOM (turns eye downward and laterally)</td>
<td>Have patient look down and in.</td>
</tr>
</tbody>
</table>

TABLE 6-6 Continued
Although a stroke is the most common cause of CN dysfunction, other abnormalities should be considered (Table 6-7).

**SENSORY EXAMINATION**

Clinically, there are two major somatosensory pathways that are examined. The first is the spinothalamic (ST) part of the anterolateral system, and the second is the dorsal column-medial lemniscus (DCML) system. The principle sensory modalities for the ST system are pain and temperature. The principle sensory modalities for DCML system are vibratory, position sense, and discriminatory or integrative sensation. Spinal cord and lower brainstem lesions can result in sensory dissociation, which means one sensory system is affected but the other is not.

Sensory evaluation is performed by having the patient respond to stimuli at a specific location. It evaluates the ability to perceive and identify specific sensations with the patient’s eyes closed. The patient must be able to cooperate with the examination by communicating whether or not the sensation is felt and whether both sides of the body feel it equally. The assessment of light touch, pinprick, and temperature sensation can be achieved by applying a cotton swab, clean pin, and a cold or warm object, respectively, to various parts of the body. The clinician should begin with the patient’s feet and move upward. Comparing one side with the other is valuable in localizing the specific site of abnormality. To test vibratory sensation, use a low-frequency tuning fork.

**TABLE 6-7**

<table>
<thead>
<tr>
<th>Cranial Nerve</th>
<th>Cause of Impairment</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Trauma to the cribiform plate, frontal lobe mass or stroke, and nasal problems (e.g., allergic or viral)</td>
</tr>
<tr>
<td>II</td>
<td>Eye disease or injury, diabetic retinopathy and glaucoma are major causes, occipital lobe mass or stroke.</td>
</tr>
<tr>
<td>III, IV, and VI</td>
<td>Brainstem injury or compression (e.g., tumor, stroke, intracranial bleeding, diabetic neuropathy [can cause temporary palsies]).</td>
</tr>
<tr>
<td>V</td>
<td>Stroke in the contralateral sensory cortex.</td>
</tr>
<tr>
<td>VII</td>
<td>Stroke-induced (central palsy).</td>
</tr>
<tr>
<td>VIII</td>
<td>Sensorineural hearing loss as a result of age or noise exposure, tumors at cerebellopontine angle, acoustic neuroma, earwax or middle ear disease can cause temporary hearing loss.</td>
</tr>
<tr>
<td>IX and X</td>
<td>Stroke.</td>
</tr>
<tr>
<td>XI</td>
<td>Neck injury.</td>
</tr>
<tr>
<td>XII</td>
<td>Stroke.</td>
</tr>
</tbody>
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**Motor Examination**

A bedside neurologic assessment almost always includes an evaluation of motor function. Because the clinician assesses the patient’s ability to move on command, they must be awake, willing to cooperate, and able to understand what the examiner is asking.

Motor strength is assessed bilaterally by having the patient flex and extend his/her arm against your hand, squeezing your fingers, lifting his/her leg while you press down on the thigh, holding his/her leg straight and lifting it against gravity, and flexing and extending his/her foot against your hand. Each extremity is graded by using a motor scale from 0 (no movement) to +5 (full range of motion with full strength). In an unconscious patient, the assessment of motor response is performed by applying a noxious stimulus and observing the patient’s response to it. Central stimulation, such as sternal pressure, produces an overall body response and is more reliable than peripheral stimulation. In an unconscious patient, peripheral stimulation, such as nail bed pressure, can elicit a reflex response, which is not a true indicator of motor activity.

If central stimulation is necessary, it should be performed judiciously because deep sternal pressure can easily bruise the soft tissue above the sternum. A less traumatic alternative to sternal pressure is to squeeze the trapezius muscle. Supraorbital pressure should not be used for central stimulation on patients with facial fractures or vagal nerve sensitivity. The response to pain varies depending on the level of neurologic function. Normally, pain causes the patient to attempt to remove the source of the pain or to withdraw from the painful stimulation. If the cerebral cortex is functioning, there is a withdrawal from painful stimuli in a predictable and reflexive manner. The symmetry and pattern of the motor response to noxious stimuli, as well as associated neurologic symptoms, should be documented for all patients suspected of having a neurologic disease.

Subtle central weakness (such as with early CNS malignancy) can be tested via **pronator drift**. Ask your patient to hold his/her arms forward with palms up. In mild cortical weakness, the patient’s hand on the weak side pronates and drifts down.

Lesions of the LMN result in loss of strength, tone, and reflexes and muscle showing wasting and fasciculations. Table 6-8 summarizes some of the clinical findings of UMN and LMN lesions.
Deep Tendon Reflexes

Deep tendon reflexes evaluate spinal nerves and include the triceps, biceps, brachioradialis, patellar, and the Achilles tendon. Although deep tendon reflexes are not routinely assessed, they should be tested in any patient with a spinal cord injury or symptoms consistent with a neurologic problem. The patellar reflex or “knee-jerk” is tested by tapping on the patellar tendon with a reflex hammer while the patient’s leg hangs loosely at a right angle with the thigh. Normally, the lower leg jerks forward when this reflex is intact (Figure 6-12). The absence of this reflex is known as Westphal’s sign.

The reflexes are graded on a scale from 0 to 5+, with 0 being no reflex, 2+ being normal, and 5+ being hyperreflexia with clonus (repeated rhythmic contractions). Abnormal or absent deep tendon reflexes indicate abnormalities in anatomic components required for the reflex arc to occur. These structures include the muscle, the nerve fibers going from the tendon to the spinal cord, and the nerve fibers returning from the spinal cord to the muscle. Myasthenia gravis and botulism are diseases characterized by abnormal deep tendon reflexes caused by abnormalities of the neuromuscular junction that impair the normal impulse transmission. Table 6-9 illustrates the spinal nerve level assessed with each reflex. Absent deep tendon reflexes may be a sign that the patient is at risk for respiratory failure.

**DEEP TENDON, SUPERFICIAL, AND BRAINSTEM REFLEXES**

Reflex assessment encompasses deep tendon, superficial, and brainstem reflexes.

**Deep Tendon Reflexes**

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**SIMPLY STATED**

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Superficial Reflexes

The **plantar reflex** is the only superficial reflex that is commonly assessed and should be tested in comatose patients and in those with suspected injury to the L4 to L5 or S1 to S2 areas of the spinal cord. To assess the plantar reflex the examiner strokes the lateral plantar aspect of the foot with the handle of a reflex hammer or thumbnail. The stroke should begin at the heel and move up the foot, in a continuous motion, along the outer aspect of the sole and then across the ball to the base of the big toe. The normal response is plantar flexion (curling under) of the toes. Dorsiflexion of the great toe with fanning of remaining toes, **Babinski’s sign**, is abnormal, except in children up to 12 to 18 months of age (Figure 6-13). The presence of Babinski’s sign could indicate a lesion of the UMN or brain disease caused by damage to the corticospinal tract.  

Brainstem Reflexes

Brainstem reflexes are evaluated in stuporous or comatose patients to determine if the brainstem is intact. Protective reflexes, such as coughing, gagging, and the corneal response, are usually evaluated as part of the assessment of the CNS.

**Gag Reflex**

CNs IX and X are especially important to the RT because they control a variety of functions. CN IX controls the muscles of swallowing that are needed to prevent aspiration. This function of CN IX is evaluated by testing the patient’s **gag reflex**. This test is performed by gently inserting a tongue depressor into the back of the throat. Although some healthy individuals have a minimal or absent gag reflex, its absence may increase the risk for aspiration and endotracheal intubation may be necessary to protect the lungs. The ability to cough with suctioning can be tested in an intubated patient and implies an intact CN X. This test should not be attempted on nonintubated patients in the ICU because of the risk of aspiration. Stimulation of CN X while suctioning the airway may result in the presence of bradycardia caused by vagal stimulation. This could become clinically significant in hemodynamically unstable patients.

**SIMPLY STATED**

Although some healthy individuals have a minimal or absent gag reflex (CNs IX and X), its absence may increase the risk for aspiration, and endotracheal intubation may be necessary to protect the lungs. The ability to cough with suctioning can be tested in an intubated patient and implies an intact CN X.

**Pupillary Reflex**

Pupillary light reflexes provide information regarding the status of the brain and the sympathetic and parasympathetic nervous systems. Pupillary function is controlled by the midbrain and evaluates CNs II and III. **Pupillary reflex** is determined by briefly passing a bright light in front of both open eyes while carefully watching the iris in both eyes for movement. Pupil size, congruency, and response to light and accommodation should be described.

The acronym **PERRLA** is commonly used to refer to normal pupils that are equal, round, and reactive to light and accommodation (movement). Any visible change in the pupils’ size is noted. **Anisocoria** is a neurologic term indicating that one pupil is larger than the other. **Mydriasis**, or pupillary dilation, may be caused by serious brain injury or inadvertent exposure of the eyes to inhaled anticholinergics. **Miosis** or small “pinpoint” pupils usually result from pontine hemorrhage or from ingestion of narcotics or organophosphates. Pupillary responses almost always remain intact in metabolic causes of coma. Midposition and fixed pupils often indicate severe cerebral damage (Figure 6-14).

**SIMPLY STATED**

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Corneal Reflex

The corneal reflex is used to test the afferent CN V and the efferent CN VII. The test is performed by lightly touching the cornea with a cotton swab. The normal response is that the patient should blink both eyes. The presence of this response implies an intact ipsilateral fifth cranial nerve, intact central pons, and intact bilateral seventh cranial nerves. Testing must be performed bilaterally to evaluate both afferent components of the fifth cranial nerve. Most clinicians omit the corneal reflex test unless there is sensory loss on the face as per history or examination, or if cranial nerve palsies are present at the pontine level (Figure 6-15).

Oculocephalic and Oculovestibular Reflexes

Abnormalities of extraocular movement (CN II, III, IV, and VI) have prognostic importance in the ICU. Normal movement of the eyes requires an intact midbrain connection. The resting position of the gaze, the presence of nystagmus, and the response to head movements and cold tympanic membrane stimulation should be identified. To test the oculocephalic reflex, or doll's eyes reflex, turn the patient's head briskly from side to side; the eyes should turn to the left while the head is turned to the right, and vice versa. If this reflex is absent, there will be no eye movement when the patient's head is moved side to side. Cervical spine stability must be ensured before oculocephalic maneuvers are performed. To test the oculovestibular reflex, also known as the ice caloric or cold caloric reflex, a physician instills at least 20 ml of ice water into the ear of a comatose patient. In patients with an intact brainstem, the eyes will move laterally toward the affected ear. In patients with severe brainstem injury, the gaze will remain at midline.

COORDINATION, BALANCE, AND GAIT EXAM

The principal area of the brain that is examined by the coordination, balance, and gait examination is the cerebellum. Cerebellar dysfunction results in decomposition of movements and undershooting and overshooting of goal-directed movements (dysmetria). Decomposition of movement and dysmetria are the main elements of ataxia.
Lesions at various levels from the cerebrum to the upper cervical cord can cause abnormal changes of the breathing pattern (Figure 6-17).

The most common abnormal respiratory pattern seen in patients with neurologic disorders is Cheyne-Stokes respiration, which consists of phases of hyperpnea that regularly alternate with episodes of apnea. Figure 6-18 was obtained from a patient with a stroke that shows tidal volume waxing in a smooth crescendo and once a peak is reached, waning in an equally smooth decrescendo. Cheyne-Stokes respiration usually has an intracranial cause, although it can be caused by hypoxemia and cardiac failure.

Ataxic breathing is a marker of severe brainstem dysfunction seen as an irregular and unpredictable breathing pattern that indicates that all brain function above the medulla is absent. Despite the nonspecificity of most breathing patterns, the respiratory pattern can provide valuable clues to the cause of coma.

Because the brainstem and vagus nerve (CN X) play an important role in vasomotor tone, conditions affecting these areas can cause vital signs to change. However, a change in vital signs does not necessarily indicate neurologic deterioration, as they tend to change too late to prevent irreversible brain damage. Increased intracranial pressure (ICP), such as in herniation syndromes, produces a specific set of changes known as Cushing’s triad. Cushing’s triad consists of increasing systolic blood pressure with a widening pulse pressure, bradycardia, and bradypnea. Cushing’s triad is, however, a late sign of increased ICP. Once this pattern of vital signs occurs, brainstem herniation is already in progress and it may be too late to reverse it.

There are three primary reasons to measure intracranial pressure (ICP): (1) to monitor patients at risk of life-threatening intracranial hypertension, (2) to monitor for evidence of infection, and (3) to assess the effects of therapy aimed at reducing ICP. Mean ICP of a supine patient is normally 10 to 15 mm Hg. Although small fluctuations are normal during the cardiac cycle, variability greater than 10 mm Hg is suggestive of serious neurologic compromise. Elevations in ICP to 15 to 20 mm Hg compress the capillary bed and compromise microcirculation. At ICP levels of 30 to 35 mm Hg, venous drainage

**SIMPLY STATED**

Cerebellar dysfunction results in decomposition of movements and undershooting and overshooting of goal-directed movements (dysmetria).

Dysfunction of different systems of the cerebellum may result in a myriad of signs and symptoms that include nystagmus, truncal instability (titubation), truncal ataxia, ataxia of speech (scanning dysarthria), and ataxia of the extremities (appendicular ataxia). Ataxia caused by disease of the cerebellar hemispheres will be ipsilateral to the dysfunctional hemisphere.

Cerebellar assessment may not be necessary in a problem-focused examination, and it cannot be done if the patient cannot or does not follow commands. Coordination may be simply assessed by having the patient hold up his/her finger and having the patient move his/her finger back and forth from your finger to his/her nose. Ask the patient to alternately touch his/her nose with his/her right and left index fingers. Finally, have the patient repeat these tasks with his/her eyes closed. The movements should be rapid, smooth, and accurate.

Balance can be assessed using the Romberg test if the patient is able to stand and is not restricted to bed. Have the patient stand with his/her feet together, arms at the sides, and eyes open; the patient should be able to stand upright with no swaying. If the patient can do that, have him/her close his/her eyes and stand the same way. If the patient falls or breaks the stance after closing the eyes, the Romberg test is positive, indicating proprioceptive or vestibular dysfunction.

All levels of the neural axis contribute to gait, although most gait abnormalities are motor in nature. In assessing gait, it is important to watch not only the lower extremities but also the upper extremities for normal associated movements. To assess gait, ask the patient to walk without shoes around the examining room or down the hallway, first with his/her eyes open, then closed. A smooth, regular gait rhythm and symmetric stride length is expected.

**VITAL SIGNS AND THE NEUROLOGIC SYSTEM**

The nervous system is intricately connected to the mechanics of respiration. From the cerebral cortex to the LMNs, the nervous system regulates respiratory effort. Automatic breathing is regulated primarily by lower brainstem nuclei via the pneumotaxic and apneustic autonomic respiratory centers. The most vital neurons are located in the ventral respiratory group (VRG) of the medulla. The VRG, the dorsal respiratory group (DRG), and the pontine respiratory group (PRG) form the pontomedullary regulatory generator (Figure 6-16). This generator works at a subconscious level and results in rhythmic contraction and relaxation of the respiratory muscles but may be modified by pulmonary and cardiovascular reflexes.

**MONITORING INTRACRANIAL PRESSURE**

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is impeded and edema develops in uninjured tissue. Even when autoregulatory mechanisms are intact, cerebral perfusion cannot be maintained if ICP increases to within 40 to 50 mm Hg of the mean arterial pressure (MAP). When ICP approximates MAP, perfusion stops and the brain dies.

Currently available ICP monitoring techniques fall into two categories: fluid-filled systems with external transducers, such as intraventricular catheter and subarachnoid bolts, and solid-state systems with miniature pressure transducers that can be inserted in the lateral ventricle, brain parenchyma, or subarachnoid or epidural space. It is extremely important for the RT to remember that although hyperventilation is associated with lower ICP values because of the vasoconstriction of brain blood vessels associated with hypocapnia, the cerebral perfusion pressure (CPP) is the most critical element to monitor. CPP is a result of the MAP minus the ICP.

**FIGURE 6-16** Schematic representation of the neural control of breathing. CC, Central chemoreceptors; DRG, dorsal respiratory group; NA, nucleus ambiguous; PRG, pontine respiratory group; V, sensory nucleus of V; VRG, ventral respiratory group.

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FIGURE 6-18 Cheyne-Stokes respiration showing the typical tidal volume waxing in a smooth crescento and decrescendo pattern.

**KEY POINTS**
- Injuries that involve the nervous system often affect the patient’s respiratory system and the ability of the patient to cooperate with respiratory care procedures.
- Many neurologic functions of particular importance to the RT such as regulation of heart rate, blood pressure, and breathing are located in the brainstem.
- Damage to cervical spine roots of C3 to C5 may result in complete paralysis of the diaphragm.
- The GCS is the most widely used instrument for quantifying neurologic impairment.

**KEY POINTS—cont’d**
- Delirium in ventilated patients is associated with longer stays in the hospital, higher mortality, and poor long-term cognitive function.
- An absent gag reflex (CN IX and X) may increase the risk for aspiration.
- The ability to cough with suctioning implies an intact CN X.
- The most common abnormal respiratory pattern seen in patients with neurologic disorders is Cheyne-Stokes respiration.
- CPP is the most critical element to monitor in patients with head injury when monitoring ICP.
ASSESSMENT QUESTIONS

See Evolve Resources for answers.

1. Which of the following is not an important factor when determining the frequency of the neurologic assessment?
   a. Patient’s diagnosis
   b. Acuity of the condition
   c. How rapidly changes are occurring or expected to occur
   d. Shift change

2. Which of the following is not part of the brain?
   a. Cerebrum
   b. Cranial nerves
   c. Brainstem
   d. Cerebellum

3. Where in the nervous system is regulation of breathing located?
   a. Brain cortex
   b. Medulla
   c. Cerebellum
   d. Brainstem

4. Which of the following is the most common cause of nerve root pathology caused by compression?
   a. Herniated vertebral disc
   b. Spinal tumor
   c. Spinal cord injury
   d. Infection

5. Which of the following diseases may be suggested by the involvement of multiple nerve roots?
   a. Myasthenia gravis
   b. Guillain-Barré syndrome
   c. Brain tumor
   d. Intracranial hypertension

6. Injury to the cervical spine roots C2 to C4 is associated with which of the following abnormalities?
   a. Absence of deep tendon reflexes
   b. Babinski’s sign
   c. Paralysis of the diaphragm
   d. Doll’s eyes

7. Which of the following is the most important examination in the neurologic examination?
   a. Sensory examination
   b. Motor examination
   c. Level of consciousness
   d. Gait examination

8. What is the most widely used instrument to quantify neurologic impairment?
   a. The Merck Gait Evaluation
   b. Glasgow Coma Scale
   c. APACHE
   d. Mini-Mental State Examination

9. Which Glasgow coma scale score is typically an indication for endotracheal intubation?
   a. <9
   b. <10
   c. <12
   d. <14

10. Which of the following cranial nerves are evaluated with the gag reflex?
    a. II and III
    b. V and VII
    c. I and II
    d. IX and X

11. Which of the following diseases are characterized by abnormal deep tendon reflexes caused by abnormalities of the neuromuscular junction?
    a. Syphilis
    b. Myasthenia gravis
    c. Cerebritis
    d. Multiple sclerosis

12. The presence of dorsiflexion of the great toe with fanning of remaining toes while testing the plantar reflex is known as which of the following?
    a. Babinski’s sign
    b. “Jerk” reflex
    c. Patellar reflex
    d. Quadriceps reflex

13. Which of the following cranial nerves is intact if cough is present while suctioning the airway?
    a. I
    b. IX
    c. X
    d. XII

14. Which of the following does not describe the acronym PERRLA?
    a. Positioned
    b. Accommodation
    c. Round
    d. Reactive

15. Which of the following anatomic areas is compromised if the patient has dysmetria?
    a. Cerebrum
    b. Pons
    c. Cerebellum
    d. Brainstem

16. Which of the following respiratory patterns consists of phases of hyperpnea that regularly alternate with episodes of apnea?
    a. Biot’s
    b. Ataxic
    c. Apneustic
    d. Cheyne-Stokes

17. Which of the following is the most critical parameter to keep in mind when managing a patient with intracranial hypertension?
    a. Mean arterial pressure
    b. Cerebral perfusion pressure
    c. Intracranial pressure
    d. Pulse pressure
References


Bibliography