# The Neonatal Neurological Examination: Improving Understanding and Performance

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## Abstract

The neonatal neurological examination is a cornerstone in the assessment of a neonate's neurological function. Although current neuroimaging and neurophysiology techniques have markedly improved our ability to assess and diagnose neurologic abnormalities, the clinical neurological examination remains highly informative, cost-effective, and time efficient. Early recognition of abnormal findings can prevent delays in diagnosis and implementation of beneficial therapies. The intent of this article is to improve the understanding and performance of the neonatal neurological examination. A standardized approach to neonatal neurological examination is described, including examination techniques and normal and abnormal findings.

**Keywords:** assessment; level of alertness; muscle tone; neurology; primitive reflexes

The neonatal neurological examination is a cornerstone in the assessment of a neonate's neurological function. Practitioners who care for neonates require not only the ability to perform an organized and thorough neonatal neurological examination but also the knowledge to understand and recognize normal and abnormal findings. Early recognition of abnormal findings can prevent delays in diagnosis and implementation of beneficial therapies. Serial examinations are important in establishing an accurate representation of the neonate's neurological status. Although current neuroimaging and neurophysiology techniques have markedly improved our ability to assess and diagnose neurologic abnormalities, the clinical neonatal neurological examination remains highly informative, cost-effective, and an efficient use of time; its value should not be underestimated. The intent of this article is to improve the understanding and performance of the neonatal neurological examination by reviewing fetal and infant brain development and the basic structure and function of the nervous system. Subsequently, a standardized approach to neonatal neurological examination is described, including specific examination techniques and normal and abnormal findings.

## Fetal and Infant Brain Development

Fetal and postnatal brain development is a dramatic, intricate, and extraordinary process; significant morphologic and functional maturation spans the first few years of life. The human brain begins to develop in the

**TABLE 1 ■ Structure and Function of the Nervous System**

| Structure | | Primary Function |
|---|---|---|
| **Central Nervous System Brain and Spinal Cord** | Cerebrum | Responsible for higher intellectual function |
| | Frontal lobe | Intellectual functioning, language, and motor skills |
| | Parietal lobe | Primary sensation area |
| | Temporal lobe | Primary auditory reception area |
| | Occipital lobe | Primary visual area |
| | Cerebellum | Coordinates movement and maintains posture |
| | Brainstem | |
| | Midbrain | Relay station for auditory and visual information |
| | Pons | Transmits information between the cerebellum and cerebrum |
| | Medulla oblongata | Autonomic functions such as heart rate, respirations, blood pressure |
| | Thalamus | Relay center for sensory impulses to cerebral cortex |
| | Hypothalamus | Autonomic control such as temperature, blood pressure, emotion<br>Behavior control such as hunger, thirst, sleep<br>Regulation of the pituitary gland |
| | Basal ganglia | Motor control and cognitive and emotion function |
| | Upper motor neurons | Transmit nerve impulses from the motor area of cerebral cortex to lower motor neurons (e.g., corticospinal tract and extrapyramidal tract) |
| **Peripheral Nervous System** | Lower motor neurons | Located mostly in the peripheral nervous system (i.e., cranial and spinal nerves); transmit nerve impulses from upper motor neurons to muscle |
| | Spinal nerves | 31 pairs (12 thoracic, five lumbar, five sacral, one coccygeal) |
| | Cranial nerves | 12 pairs |

*Sources*: Jarvis C. Neurologic system. In: Jarvis C, ed. *Physical Examination and Health Assessment*. 3rd ed. Philadelphia, PA: W.B. Saunders Company;2000:687–750; Sugerman RA. Structure and function of the neurologic system. In: McCrane KL, Huether SE, eds. *Pathophysiology. The Biologic Basis for Disease in Adults and Children*. 5th ed. St. Louis, Missouri: Elsevier Mosby;2006:411–435.

third week of gestation with the formation of the neural tube.[1] By the end of the eighth week of gestation, the basic structures of the central and peripheral nervous systems are established.[1,2] This period is followed by the rapid growth and development of the central nervous system structures. Around 15 weeks' gestation, the brain's surface begins to evolve into its characteristic pattern of folds called sulci and ridges called gyri.[1] This enfolding is theorized to be an adaptive evolutionary process that allows the large brain to fit into a space that needs to remain small enough for the birth process to occur.[1] Throughout this time frame, beginning on day 42 of gestation, neuron development, neuron migration, and myelination ensue. These are key brain maturation processes.[1] Neurons are the fundamental units of the nervous system that transmit information. Sensory neurons transmit information from the body to the brain. Motor neurons transmit information from the brain to the muscles. Millions of neurons migrate from their site of origin in the center of the brain, to the developing neocortex,[1,3] a thin layer of gray matter on the surface of the brain that is an essential information processing network involved in language, sensory perception, motor commands, and thoughts.[1] The peak period for neural migration occurs during the third to fifth months of gestation and is largely completed by midgestation.[1,3]

Myelin, a lipid-rich membrane that surrounds nerve axons, allows for faster, efficient nerve conduction. Myelination begins in the brain stem at approximately 29 weeks' gestation and progresses cephalad (upward) to the cerebral hemispheres by 42 weeks' gestation.[4] Early myelination of the motor-sensory roots and the brainstem allows for neonatal reflex behaviors such as sucking and autonomic functions such as heart rate and breathing. Myelination rapidly continues over the first two years of life and corresponds to the cephalocaudal (head-to-toe) acquisition of developmental milestones observed in childhood.[5]

Knowledge of the structure and function of the nervous system is essential to understanding the physiologic basis for the neurologic examination findings. Table 1 provides a fundamental review of the nervous system's structure and function.[6,7]

## COLLECTING DATA

### History and Clinical Stability Assessment

The neonatal neurological examination includes a comprehensive history as well as the physical components of the examination. To improve understanding of the physical examination findings, essential information should be assessed prior to the physical examination. A focused family, maternal, antepartum, and intrapartum history is important in identifying social, genetic, and obstetric risk factors that may explain the neonate's neurologic clinical presentation. Table 2 outlines the essential elements of a neurology-based family, maternal, and obstetrical history.[8]

The history should also include the neonate's gestational age, clinical stability, and recent medication exposure. Evaluation of stability includes assessment of the need for respiratory support, ability to feed, and if applicable, seizure history.

**TABLE 2 ■ Neurology-Based Family, Maternal, and Obstetrical History**

| | |
|---|---|
| **Family History** | Genetic family history<br>Birth defects<br>Seizures, developmental delay, thromboembolic or coagulation disorders<br>Stillbirths or early unexpected deaths<br>Ethnic background |
| **Maternal History** | Age<br>Preexisting medical conditions (e.g., diabetes, hypertension, renal disease)<br>Previous genetic testing<br>Stillbirths, abortions<br>Consanguinity<br>Sexually transmitted infections (e.g., syphilis, gonorrhea, HIV) |
| **Obstetric History** | Previous Pregnancies<br>  Abortions<br>  Neonatal deaths<br>  Premature births<br>Current Antepartum History<br>  Fetal growth and movements<br>  Prenatal genetic testing results (e.g., AFP, PAPP-A, hCG, nuchal translucency)<br>  Ultrasound results<br>  Sexually transmitted infections (e.g., syphilis, gonorrhea, HIV)<br>  Preeclampsia, diabetes, infection (e.g., viral illnesses)<br>  Polyhydramnios, oligohydramnios<br>  Medication or drug use (e.g., cocaine, alcohol)<br>Current Labor and Delivery History<br>  Type of delivery (e.g., cesarean section)<br>  Birth weight<br>  Apgar scores and cord blood pH<br>  Fetal distress<br>  Need for resuscitation<br>  Birth trauma |

*Abbreviations:* AFP = alpha-feto protein; hCG = human chorionic gonadotropin; HIV = human immunodeficiency virus; PAPP-A = pregnancy-associated plasma protein–A.

*Source*: Horns, LaBronte K. Recording and evaluating the neonatal history. In: Tappero EP, Honeyfield ME, eds. *Physical Assessment of the Newborn: A Comprehensive Approach to the Art of Physical Examination*. 6th ed. New York, NY: Springer Publishing Company; 2019:9–21.

### Gestational Age Assessment

Neurological findings differ between neonates born preterm and those born at term. Estimating a neonate's gestational age is critically important in ensuring an appropriate interpretation of neurological maturity and expected neurological findings. Additionally, areas of the central nervous system affected by injury differ based on a neonate's stage of brain development. Hypoxic–ischemic brain injury in a term infant results in a predilection for gray matter injury while white matter injury predominates in premature infants with hypoxic–ischemic brain injury.[9] This phenomenon is referred to as selective vulnerability.[10]

Antenatally, an ultrasound performed in early pregnancy is the most reliable method for determining gestational age.[11] Postnatally, validated scoring systems to evaluate neuromuscular and physical maturity, such as the Dubowitz neurological examination and Ballard Score, can be used to estimate a neonate's gestational age.[12–15] Limitations associated with gestational age scoring tools include an overestimation and underestimation of the gestational age and since the examination occurs only at one point in time, it may not accurately reflect the neonate's neurological status.[12,16] Importantly, if abnormalities are identified using these scoring tools, further evaluation is required because these scoring tools are not diagnostic for a specific neurologic condition.[17] The external characteristics reported to be helpful in estimating gestational age include an assessment of the neonate's ear cartilage, breast tissue, plantar surface creases, and external genitalia.[13,18] Further information regarding gestational age assessment is beyond the scope of this article, but can be found in resources such as www.ballardscore.com.

## THE NEONATAL NEUROLOGICAL EXAMINATION

### Head and Face Examination

The face of the neonate should be carefully examined and the skull, fontanels, and sutures inspected and gently palpated for findings of an underlying nervous system condition.

**Fontanels**. Fontanels are the membranous space between the bones of the neonates skull ("soft spot"). In a quiet neonate, the fontanels should be soft and flat. The diamond-shaped anterior fontanel, located at the junction of the coronal and sagittal sutures, measures 1–4 cm in a full-term neonate.[19] The triangular-shaped posterior fontanel, located at the junction of the lambdoidal and sagittal sutures, is small, admitting only the tip of a finger.[19] Increased intracranial pressure should be suspected if, with the infant at rest, the fontanels are full or bulging. Increased intracranial pressure in the neonate may be secondary to conditions such as hydrocephalus, intracranial hemorrhage, or infection.

**Sutures**. Sutures, the palpable ridges between skull bones, can split or separate up to approximately 1 cm in neonates.[20] Sutures are separated to allow for changes in head shape required for the birth process. During birth, head molding may occur, causing the sutures to override or overlap.[20] Head molding is usually temporary and often normalizes over the first week of life. Increased intracranial pressure should be suspected with widely split or open sutures, particularly if associated with a full fontanel. An abnormal head shape in combination with sutures that feel ridged rather than overriding, may be a sign of craniosynostosis, the premature closure of sutures.

**Skull Inspection and Palpation**. The shape of the skull at birth may reflect the mode of delivery. For example, neonates born by cesarean section will often have a well-rounded head and neonates born via the vaginal route may have head molding as a result of passage through the birth canal. The skull of a neonate should be palpated for abnormalities including extracranial fluid collections that can be associated with birth trauma, including caput succedaneum, cephalohematoma, and subgaleal hemorrhage.[21,22] Table 3 describes these extracranial fluid collections in a newborn. A heightened index of suspicion for extracranial hemorrhages should exist for neonates with a history of difficult delivery, particularly if an instrumented delivery with vacuum or forceps was required. Figure 1 illustrates the extracranial fluid collections in a newborn.

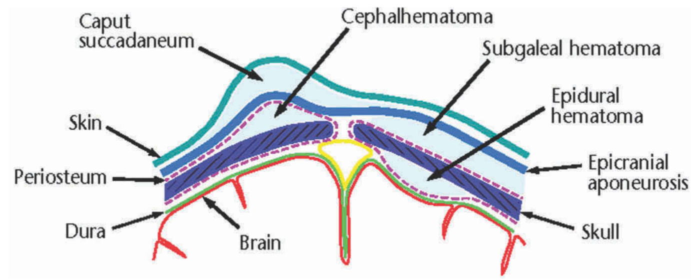
**Head Circumference Measurements**. The occipital-frontal circumference (OFC) of the head is an indirect indicator of a neonate's intracranial volume (brain and cerebrospinal fluid volume) and brain growth. Trending and accuracy of head circumference measurements is achieved with serial measurements plotted on a standardized growth chart. As shown in Figure 2, measuring the OFC is best achieved by using a nonstretchable measuring tape positioned above the ears and eyebrows and around the most prominent aspect of the occiput. To improve accuracy, three measurements should be obtained and the largest measurement recorded on a standardized head growth chart.[20] The mean head circumference in a neonate at 40 weeks' gestation is approximately 34.5 cm for girls and 35 cm for boys, ranging between 33 cm and 37 cm for the 10th and 90th percentile, respectively.[23] Microcephaly is a head circumference measurement two standard deviations below the mean for age. Conversely, macrocephaly is a head circumference measurement two standard deviations above the mean for age. Microcephaly or macrocephaly may indicate the presence of a central nervous system abnormality.

**TABLE 3 ■ Extracranial Fluid Collections in a Newborn**

| Type | Characteristics |
|---|---|
| Caput succedaneum | Serosanguineous fluid leak from the subcutaneous tissue into the area above the periosteum<br>Due to pressure on the fetal head during delivery<br>Present immediately after birth<br>Usually crosses suture lines<br>Often resolves within the first few days after birth |
| Cephalohematoma | Collection of blood between the periosteum and the skull<br>Due to damage to blood vessels, usually from a traumatic delivery<br>Does not cross suture lines<br>Usually takes several weeks to resolve |
| Subgaleal hemorrhage | Accumulation of blood between the epicranial aponeurosis and the periosteum<br>Due to rupture of emissary veins in the subgaleal space, usually from a traumatic delivery<br>Subgaleal space is capable of holding a neonate's entire blood volume<br>Risk of life-threatening, hypovolemic shock |

*Sources*: Nicholson L. Caput succedaneum and cephalohematoma: The Cs that leave bumps on the head. *Neonatal Netw*. 2007;26(5):277–281; Reid J. Neonatal subgaleal hemorrhage. *Neonatal Netw*. 2007;26(4):219–227.

**FIGURE 1 ■ Extracranial and extradural hemorrhages in the newborn.**




*Source:* From Sheikh, A. M. H. Public domain with credit.

**FIGURE 2 ■ Measuring the occipital-frontal circumference.**

*Source:* Courtesy of The Hospital for Sick Children, Toronto, Ontario.

**Face Examination**. Examination of a neonate's face requires close inspection of facial features including eyes, nose, ears, mouth, and mandible for developmental abnormalities. Observation of the face from the frontal and lateral view allows for visualization of the depth, height, position, and shape of facial structures. Facial abnormalities may represent a normal isolated finding or may be a sign of a genetically based abnormality with associated brain anomalies.[24] If concerning facial dysmorphisms are evident, observation of the physical features of family members may raise suspicion of an inherited chromosomal or genetic abnormality.[24] A facial nerve palsy should be suspected if there is facial asymmetry, which is often observed as a unilateral lack of expression and loss of facial muscle movement. A facial palsy caused by injury to the seventh cranial nerve may occur because of trauma from intrauterine nerve compression or a difficult delivery, particularly if instrumentation with forceps was required.[25] A developmental or congenitally acquired facial palsy may be syndrome-associated. Absence or hypoplasia of the depressor anguli oris muscle should be suspected if facial asymmetry is evident only during crying. Commonly referred to as asymmetric crying facies, there is facial symmetry at rest but facial asymmetry during crying. Asymmetric crying facies is characterized by the downward movement of the corner of the mouth on the normal side while the affected opposite side does not move when the neonate is crying.[25] A tented appearance of the upper lip is suggestive of low tone and may represent an underlying neuromuscular disorder such as congenital myotonic dystrophy.[26] Congenital myotonic dystrophy is a maternally inherited neonatal disorder that often presents with hypotonia, respiratory insufficiency, and oropharyngeal and gastrointestinal dysfunction.[27]

## Skin and Spine Examination

Because both the skin and the nervous system are derived from ectoderm during embryonic development, a careful inspection of the skin and spine is essential because abnormalities may indicate an underlying neurological condition. The neonate should be turned prone or side-lying for optimal visualization of the spine. Hair tufts, dimples, or tracts along the spine can indicate the presence of a spinal dysraphism (spine or spinal cord abnormality) such as spina bifida occulta (vertebrae malformation). Dimples or tracts should be visualized for the presence of a skin covering. Instrumentation of dimples or tracts should not be completed because of the risk of infection or injury. A pale-pink macular lesion (port-wine stain) over the face may be a sign of Sturge–Weber syndrome, a disorder associated with eye and cerebral vessel abnormalities and an increased risk of glaucoma and seizures.[18] Certain skin pigmentation lesions may indicate a neurocutaneous-associated neurologic disorder. Light brown to dark brown café au lait ("coffee with milk") macules larger than 0.5 cm in diameter or more than six in number, particularly in the presence of axillary freckling, requires evaluation for neurofibromatosis. Neurofibromatosis is a genetic disorder causing the development of nervous system tumors.[28] Hypopigmented white skin lesions also called "ash leaf spots" are suggestive of tuberous sclerosis, a genetic disorder associated with benign multiorgan tumor growths that can impair organ function (e.g., brain, heart, eyes, kidney).[28] In light-skinned neonates, these skin lesions may be difficult to visualize and the use of an ultraviolet light (Wood's lamp) can aid in illuminating these lesions.[29]

## Neurologic Functional Assessment

The neonatal neurological examination framework includes an evaluation of a neonate's level of alertness, cranial nerve function, motor and sensory system function, and the presence of primitive reflexes. Understanding the physiologic basis of these assessments can aid examiners in identifying where in the nervous system pathology exists if an abnormality is identified.[17,30] Table 4 summarizes the areas of the central nervous system evaluated during the neonatal neurological examination.[17] The tools required for completion of a neonatal neurological examination are a nonstretchable measuring tape; an ophthalmoscope; a bright object, such as a red ball; a bell; a cotton-tipped applicator; and a reflex hammer.

**Observation**. Observation is considered by some experts to be the most important neonatal neurological examination technique.[18] Although the neonatal neurological examination involves several manual maneuvers and techniques to elicit reactions, considerable information about the neonate's level of alertness, cranial nerve function, and motor function can be garnered by simply watching. Observation is best performed when the neonate is in a quiet alert state, which most frequently occurs between feedings. Ideally, the neonate should be lying supine, unclothed in a warm room with the head in midline with no confining rolls or boundaries. This position allows for the accurate assessment of a neonate's resting posture, spontaneous movements, and limb position. Lighting should be adequate to facilitate observation; excessive light should be avoided as this may cause agitation. Table 5 provides a series of questions an examiner should consider while observing a neonate. Table 6 provides an example of information that can be garnered by observation alone.

**TABLE 4 ■ Components of the Neonatal Neurologic Functional Examination**

| Exam Component | Area of Nervous System Being Evaluated |
|---|---|
| Level of alertness | Higher brain function |
| Cranial nerves | Brainstem and cranial nerve function |
| Motor system (includes tendon reflexes) | Brain's motor system and peripheral motor function (e.g., spinal cord, nerves, or muscles) |
| Primitive reflexes | Brainstem-mediated motor movements and some cortex function |
| Sensory system | Brain and peripheral sensory system function through response to touch and pain |

*Source*: Wusthoff CJ. How to use: The neonatal neurological examination. *Arch Dis Child Educ Pract Ed*. 2013;98:148–153.

**TABLE 5 ■ Questions to Consider During Observation**

| |
|---|
| What is the neonate's state of consciousness (awake/sleep state)? |
| What is the neonate's level of alertness (e.g., normal, stupor, coma)? |
| Are there dysmorphic features? |
| What is the neonate's eye position? |
| Are eye movements symmetrical? |
| Is there facial symmetry? |
| What position are the limbs in at rest? |
| Are there spontaneous limb movements? |
| Do the limb movements appear similar on each side? |
| Are skin lesions present? |

**TABLE 6 ■ Neurologic Examination: Observation Example**

Observe neonate in a supine position with the head midline and with no confining boundaries
Level of alertness: crying.
No obvious dysmorphic features.
No facial or limb asymmetry in midline positioning.
Spontaneous limb movements present.
Hips abducted and legs partially flexed.
Arms flexed.
Hands loosely open with thumbs extended.

*Source*: Courtesy of The Hospital for Sick Children, Toronto, Ontario.

**Level of Alertness Assessment**. A level of alertness assessment provides information about the integrity of the neonate's higher brain function. A level of alertness assessment evaluates a neonate's ability to respond to the environment through observation of spontaneous eye opening, spontaneous movements, and response to stimulation (e.g., shining a light in the neonate's eyes).[31] It is important to first determine the neonate's baseline state of consciousness or behavioral state. Reactions to stimulation can vary depending on the neonate's state of consciousness (Table 7).[32,33] Several terms are used to describe a neonate's level of alertness including normal, stupor, coma, irritable, or lethargic (Table 8).[18,31] Gestational age is also vital to consider when performing a level of alertness assessment. For example, an infant <28 weeks' gestation will sleep most of the time but with ongoing maturation periods of wakefulness will gradually increase.[31] A state of consciousness and level of alertness assessment is performed using the following steps.

1. Observe the neonate for approximately two minutes, evaluating the breathing pattern, spontaneous movements, eye movements, and responsiveness to the environment (e.g., natural noises).
2. Identify the neonate's state of consciousness (behavioral state) (e.g., quiet alert, deep sleep; see Table 7).

**TABLE 7 ■ Neonatal Behavioral Sates (State of Consciousness)**

| State | Description |
|---|---|
| Light sleep | Sleep with rapid eye movements and low levels of activity. |
| Drowsiness | A transition state.<br>Drowsy state between awake/sleep or sleep/awake. |
| Quiet alert | Calm and quiet with a bright look. Minimal activity. |
| Active alert | Awake and active. Periods of fussiness. |
| Crying | Loud and strong crying with increased motor activity. |

*Sources*: Brazelton TB. *Neonatal Behavioral Assessment Scale. Spastics International Publications: Clinics in Developmental Medicine.* Monograph #50. London, England: William Heinemann, Philadelphia: J.B. Lippincott, 1973; VandenBerg KA. State systems development in high-risk newborns in the neonatal intensive care unit. Identification and management of sleep, alertness and crying. *J Perinat Neonat Nurs*. 2007; 21(2): 130–139.

**TABLE 8 ■ Levels of Alertness in the Neonate**

| Level of Alertness | Description |
|---|---|
| Normal | Neonate responds normally to arousal and this arousal response is associated with normal motor movements of the limbs and face. |
| Slight to moderate stupor | Neonate is sleepy (slight) or asleep (moderate) with diminished or absent arousal and motor responses (slight or moderate). |
| Deep stupor or coma | Neonate cannot be aroused; motor responses are diminished or absent (coma). |
| Irritable | Neonate cannot be soothed, is agitated, and cries with minimal stimulation. |
| Lethargic | Neonate is unable to maintain an alert state. |

*Sources*: Volpe JL. Neurological examination: Normal and abnormal features. In: Volpe JL, Inder TE, Barra BT, et al., eds. *Volpe's Neurology of the Newborn*. 6th ed. Philadelphia, PA: Elsevier; 2018;191–205; Yang M. Newborn neurologic examination. *Neurology*. 2004;62;E15–E17.

3. Evaluate the neonate's response to stimulation by moving the neonate or shining a light in the neonate's eyes.
4. Identify the neonate's level of alertness (see Table 8).

Assessment of the neonate's cry quality should also be completed as an abnormal cry may indicate an underlying neurological abnormality. A loud, lusty cry is normal for a term neonate, while a depressed or ill neonate may exhibit a weak cry. A high-pitched cry can indicate an underlying neurologic condition, such as meningitis.

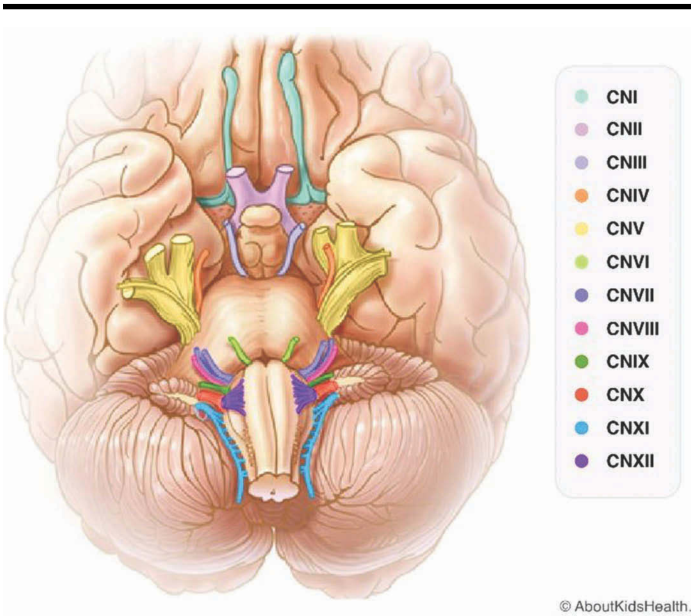
**Cranial Nerve Examination**. Cranial nerve testing evaluates brainstem function. There are 12 pairs of cranial nerves that supply the head and neck; the vagus nerve, the longest cranial nerve, also supplies the thorax and abdomen (Figure 3). Cranial nerve assessment involves a combination of observation and specific maneuvers. Several cranial nerves can simultaneously be tested with one maneuver. For example, observing the neonate's suck and swallow evaluates cranial nerves V, VII, IX, X, and XII. Table 9 outlines the 12 cranial nerves, their functions, and how to test and interpret their functions in a neonate.[18,34,35]

**TABLE 9 ■ Neonatal Cranial Nerve Testing and Interpretation**

| Cranial Nerve | | Function | Testing in the Neonate | Normal Neonatal Response |
|---|---|---|---|---|
| I | Olfactory | Smell | Rarely tested.<br>If tested, use a strong scent (e.g., clove, mint). | Change in behavior such as grimacing, startle, sucking.<br>Response present >32 weeks' gestation. |
| II | Optic | Vision | Shine light in peripheral visual field.<br>Fundoscopic exam.<br>Move a bright object side to side (e.g., red ball) 10–12 inches from neonate's eyes. | ≥28 weeks' gestation: blinks in response to light.<br>Optic disk is pale whitish-gray<br>≥34 weeks' gestation: able to fix and follow. |
| III<br>IV | Oculomotor<br>Trochlear | Pupil response and eye movements | Check pupillary light response.<br>Assess spontaneous eye movements and symmetry. | Pupils begin to react to light at 30 weeks' gestation.<br>Symmetrical eye movements. |
| VI | Abducens | Eye movements | Vestibular-ocular reflex (doll's eye maneuver): gently rotate head to the side and assess direction of eye deviation. | Normal doll's eye reflex: eyes deviate away from direction of rotation (i.e., if head turned to right, eyes deviate to the left).<br>Doll's eye maneuver can be used as early as 25 weeks' gestation. |
| V | Trigeminal | Facial sensation, sucking | Rooting reflex.<br>Sucking reflex. | Rooting reflex and suck present. |
| VII | Facial | Facial motility, sucking | Observe facial symmetry at rest and with crying (forehead wrinkling, nasolabial folds). | Symmetry present. |
| VIII | Acoustic | Hearing | Assess response to loud noises (e.g., clapping, bell). | ≥28 weeks' gestation: blink or startle. |
| IX<br>X | Glosso-pharyngeal<br>Vagus | Swallowing<br>Gag | Observe for swallowing.<br>Test gag with a small tongue blade or during suctioning. | Gag reflex, swallowing present.<br>≥34 weeks' gestation: breathing, sucking, and swallowing synchrony begins. |
| XI | Spinal | Sternocleidomastoid muscle function | Gently turn head side to side.<br>Compare shoulder height. | Head turns side to side without difficulty.<br>Symmetrical shoulder height. |
| XII | Hypoglossal | Tongue function | Assess for tongue symmetry and fasciculations. | Tongue symmetry present without fasciculation. |

*Sources*: Heaberlin PD. Neurologic assessment. In: Tappero EP, Honeyfield ME, eds. *Physical Assessment of the Newborn: A Comprehensive Approach to the Art of Physical Examination*. 6th ed. New York, NY: Springer Publishing Company; 2019:167–192; Khan OA, Garcia-Sosa R, Hageman JR, Msall M. Core concepts: Neonatal neurological examination. *NeoReviews*. 2014;15;e316–e324; Volpe JL. Neurological examination: Normal and abnormal features. In: Volpe JL, Inder TE, Barra BT, et al., eds. *Volpe's Neurology of the Newborn*. 6th ed. Philadelphia, PA: Elsevier; 2018;191–205.

**FIGURE 3 ■ Cranial nerves.**




*Source:* With permission from The Hospital for Sick Children About Kids Health www.aboutkidshealth.ca.

**Motor Examination**. The neonatal motor examination evaluates the motility and power of major muscle groups through assessment of passive and active tone, resting posture, and tendon reflexes.[18] A key principle of infant motor growth and development is that it progresses in a cephalocaudal (head to toe) and proximal to distal direction (motor skills develop from the center of the body outward to the extremities).[36] Tone is first assessed by observing the resting posture. Axial tone is assessed using vertical and horizontal suspension maneuvers.

Muscle tone is defined as the constant, low-level muscle tension or contraction that helps stabilize joints and maintains posture against gravity. In the last three months of fetal life, maturation of tone progresses in an upward caudal-cephalic (tail to head) direction.[18,37,38] This pattern of maturation corresponds to myelination of the motor pathways.[31] Specifically, limb tone increases from minimal resistance and limb extension at 28 weeks' gestation to the presence of, first, flexor tone in the lower extremities, followed by flexor tone in the upper extremities. By term gestation, the limbs should assume a flexion posture.[18,31] Most newborn infants, including preterm infants, preferentially position their heads to the right. This asymmetry appears to result from a normal asymmetry in cerebral function with the left hemisphere facilitating head movement to the right.[18,39]

Muscle tension normally increases when a muscle is pulled or stretched, so muscle tone can be evaluated by assessing two types of tone: passive tone and active tone. Passive tone assesses the passive resistance of the appendicular muscles. The appendicular muscles include the muscles of the upper and lower extremities and the muscles of the shoulder and pelvic girdle. During passive tone testing, the neonate remains at rest while certain movements are applied. Various joint angles such as the popliteal angle can be used to quantify passive tone.

*Passive Appendicular Tone Assessment.* Appendicular (limb) tone is assessed by evaluating the resistance of the limbs to these passive movements: arm traction, leg traction, and popliteal angle. The appendicular tone assessment is ideally completed when the neonate is in a quiet alert state. Each limb should be tested separately with the neonate in the supine position. Arm traction is assessed by holding the neonate's wrist and gently pulling the arm to a vertical position while assessing resistance and elbow flexion as the shoulder lifts off the surface. Leg traction is assessed by holding the neonate's ankle and gently raising the leg into a vertical position while assessing resistance and knee flexion as the buttocks elevate off the surface (Figure 4). Normal arm and leg traction responses in term neonates occur when the elbow and knee flex and the flexion is maintained as the shoulder and buttocks lift off the surface. Passive manipulation of the limbs should elicit symmetrical responses. As gestational age decreases, there is less flexion and resistance of the limbs.

The popliteal angle is assessed by gently flexing the thigh over the abdomen and then with one finger behind the heel,

**FIGURE 4 ■ Leg traction in a term neonate—knee flexion maintained as buttocks lifts off surface.**

*Source:* Courtesy of The Hospital for Sick Children, Toronto, Ontario.

**FIGURE 5 ■ Popliteal angle in a term neonate (~90-degree angle).**

*Source:* Courtesy of The Hospital for Sick Children, Toronto, Ontario.

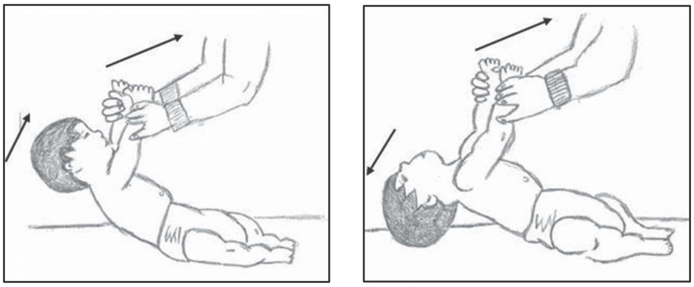
gently extending the leg until resistance is met (Figure 5). When resistance is met, the angle formed at the knee between the upper and lower leg is measured. In a term neonate the angle is approximately 90 degrees. With decreasing gestational age, the angle increases because tone is reduced (i.e., popliteal angle is approximately 150 degrees in a 28-week gestational age neonate). Too much resistance (flexion) or too little resistance (extension) with arm traction, leg traction, and popliteal angle measurements indicates appendicular hypertonia or hypotonia, respectively.[40] Asymmetrical responses may indicate a unilateral brain injury.

Active tone testing assesses the resistance of the axial muscles when the neonate is in an active situation. Axial muscles consist of the muscles of the central axis of the body including the head, back, and thorax muscles. The "pull-to-sit" maneuver is one measure commonly used to assess active tone.[41]

*Active Axial Tone Assessment.* To evaluate the axial tone (head and trunk tone), the neonate must actively participate. The maneuvers used in this assessment are horizontal suspension, vertical suspension, and pull-to-sit (head lag). The pull-to-sit maneuver is assessed by gently pulling the neonate toward a sitting position by holding the neonate's wrists while slightly supporting the head. A term neonate should be able to lift their head slightly or is able to lift the head in line with the body (Figure 6a).[12,40] In term neonates, axial hypotonia may be suspected if the head drops back and stays back (Figure 6b). Axial hypertonia may be suspected if the head pulls in front of the body line.

Horizontal suspension is assessed by suspending the neonate in a prone position and observing the limb and head positions in relation to the trunk. A normal response in a term neonate occurs when the neonate's back is straight, the head is in line with the back, and the limbs are flexed (Figure 7a).

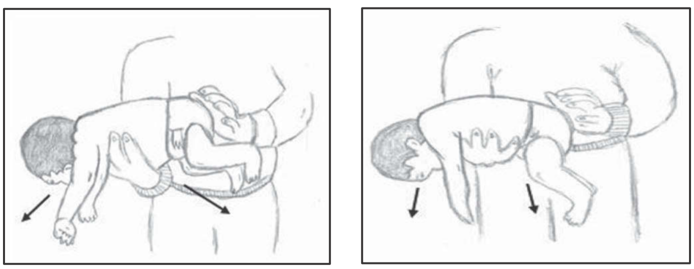
**FIGURE 6 ■ (a) Normal versus (b) abnormal head lag in a term infant.**



(a) (b)

*Source:* Courtesy of The Hospital for Sick Children, Toronto, Ontario.

**FIGURE 7 ■ (a) Normal versus (b) abnormal horizontal suspension in a term infant.**



(a) (b)

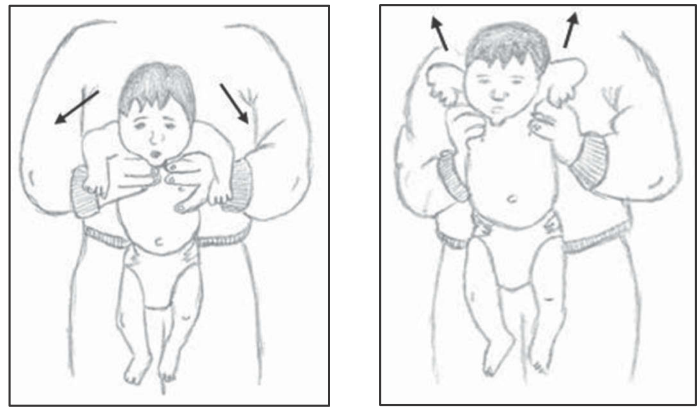
*Source:* Courtesy of The Hospital for Sick Children, Toronto, Ontario.

In term neonates, axial hypotonia may be suspected if the back is curved and the head and limbs hang straight (Figure 7b). Axial hypertonia may be suspected if the back is straight and the neonate's head is above the line of the body. Vertical suspension is assessed by holding the neonate upright with the examiner's hands positioned under the neonate's arms and around the chest. Term neonates should be able to maintain their head in midline briefly and should not feel as if they will slip through the examiner's hands (Figure 8a). In term neonates, axial hypotonia and shoulder girdle weakness may be suspected if the neonate feels like he will slip through the examiner's hands (Figure 8b).

*Resting Posture Assessment.* Posture is tone at rest. Passive tone, which influences the posture a neonate assumes, increases with gestational age and follows a caudocephalic direction (e.g., flexion in the lower extremities is followed by flexion in the upper extremities). A posture assessment is performed by:

1. Placing the neonate in a supine position on a flat surface with no confining rolls or boundaries.
2. Placing the head in midline position to avoid stimulating asymmetries associated with the tonic neck reflex.

**FIGURE 8 ■ (a) Normal versus (b) abnormal vertical suspension in a term infant.**



(a) (b)

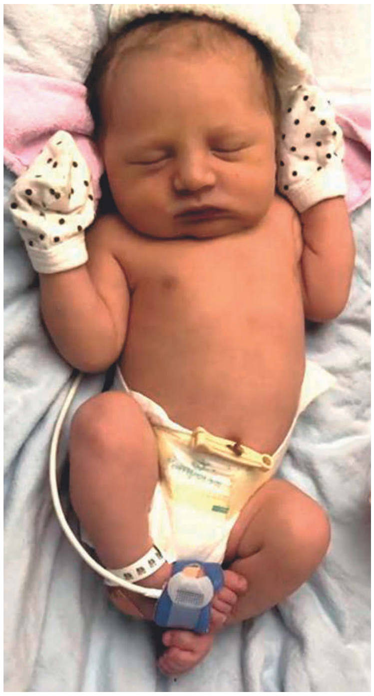
*Source:* Courtesy of The Hospital for Sick Children, Toronto, Ontario.

3. Uncovering the neonate to allow for full visualization.
4. Carefully observing limb position, the number and quality of spontaneous movements, and symmetry of movements.
5. Assessing the neonate's thumb positioning. A thumb-in-fist posture is the predominant hand position in term neonates.[18,42,43] The hands should intermittently loosely open spontaneously. Over the first few months of life, the fists gradually become loosely closed to allow for voluntary grasping.[43]

A normal term neonate at rest lies with hips abducted and partially flexed and the knees and arms flexed (Figure 9). There are frequent generalized and alternating fluent movements of the arms and legs.[12] A 28-week gestational age neonate's limbs are extended and lie flat against the bed.[12] Hypotonia, a decrease in muscle contractility, is more commonly observed in a neonate with a neurologic disorder than is hypertonia.[18] Hypotonia is clinically identified as a diminished resistance to muscle movement or stretch and/or diminished tendon reflexes. Hypertonia is an increase in muscle contractility and is clinically manifested as an increased resistance to passive muscle movement or stretch and/or increased tendon reflexes.

*Clonus*, the repetitive muscle contraction that occurs in response to rapid tendon stretching, frequently accompanies hyperreflexia. An upper motor neuron lesion should be suspected if an abnormal amount of clonus is present. Clonus is most commonly evaluated in the ankle or Achilles reflex by briskly dorsiflexing the foot.[44] Five to ten beats of clonus in a neonate is considered normal if the clonus is symmetrical and there are no other concerning neurologic signs.[18] Clonus rapidly diminishes with age and by three months of age more than a few beats of clonus is considered abnormal.[18]

**FIGURE 9 ■ Normal posture in term neonate.**



*Source:* Courtesy of The Hospital for Sick Children, Toronto, Ontario.

If there is increased resistance (hypertonia) or decreased resistance (hypotonia), pathology of the nervous system may be present. Also, a persistently, tightly-fisted hand that does not spontaneously open, also referred to as a "cortical thumb" sign, may indicate the presence of an upper motor neuron abnormality.[42,43] Diminished or lack of limb movement may indicate a peripheral neve injury of the brachial plexus. Erb's palsy, the most common brachial plexus injury in the newborn, results from injury to cervical nerve roots C5 to C7, causing an adducted, internally rotated arm with elbow extension and wrist flexion. Clinically, the findings are sometimes referred to as a bad shoulder with a good hand.[45]

*Tendon Reflexes.* Tendon reflexes represent the contraction of a muscle in response to stretching of the muscle spindles. Tendon reflexes of the biceps (cervical nerve root C5, C6), patellar or knee jerk (lumbar nerve root L4), crossed adductors (lumbar nerve roots L3, L4), and Achilles (lumbar nerve roots L2 to L4) are the most commonly tested tendon reflexes in the neonate.[18,46] A crossed adductor reflex occurs when there is adduction of the contralateral thigh when the reflex is tested. A crossed adductor response is normal in the first few months of life but is only present in <10 percent of normal infants after eight months of age.[18] Normally, tendon reflexes will diminish with repeated stimulation, a phenomenon referred to as habituation.[47]

Eliciting tendon reflexes in neonates can be challenging. Using a reflex hammer, the examiner's finger is tapped after being placed over the tendon of the designated muscle. When tapping, the motion of the hammer should be allowed to be influenced by gravity. Gentle tapping of the tendon should elicit a response that can either be felt and/or visualized. Placing a finger over the tendon during tapping permits the detection of the muscle response if the reflex is not visible.[46] Table 10 describes how to perform tendon reflex testing. Figures 10a and 10b illustrate patellar and Achilles tendon reflex testing. Tendon reflexes are graded 0 to 4+ with 0 indicating no response and 4+ indicating a hyperactive response. A 2+ grading is normal.[46] A descriptive rather than numerical grading scale may be preferred as it describes what is observed (Table 11).[48] Diminished or absent tendon reflexes are associated with lower motor neuron lesions (i.e., indicative of a reflex arc lesion). Conversely, hyperactive tendon reflexes or repeating reflexes (clonus) are associated with upper motor neuron lesions.

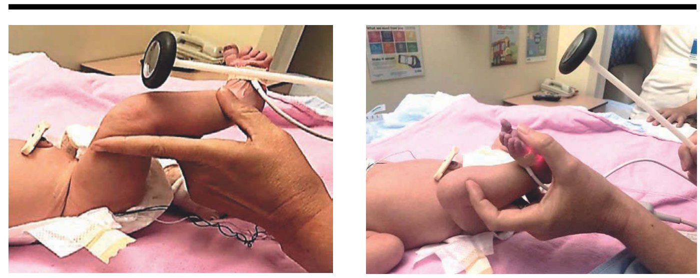
*Assessment of Primitive Neonatal Reflexes.* Primitive reflexes are brainstem-mediated, protective, and survival motor reflexes that are elicited in response to a specific sensory

**TABLE 10 ■ How to Perform Tendon Reflex Testing with a Reflex Hammer**

| Reflex | Nerve Root | Procedure |
|---|---|---|
| Biceps | C5, C6 | While holding neonate's arm in flexion, examiner places their thumb on the neonate's tendon in the antecubital fossa and strikes the thumb. |
| Patellar (knee jerk) | L4 | Examiner strikes patellar tendon while supporting the neonate's knee in a flexed position. |
| Crossed adductor | L3, L4 | Examiner strikes their finger that is positioned over the medial aspect of the neonate's knee. |
| Ankle (Achilles) | L2–L4 | Examiner strikes their finger that is positioned over the plantar aspect of the neonate's partially dorsiflexed foot. |

*Abbreviations:* C = cervical; L = lumbar.
*Source*: Kuban KC, Skouteli HN, Urion DK, Lawhon GA. Deep tendon reflexes in premature infants. *Pediatr Neurol.* 1986;2(5):266–271.

**FIGURE 10 ■ Tapping stretches the tendon causing the reflex to be elicited.**



(a) (b)

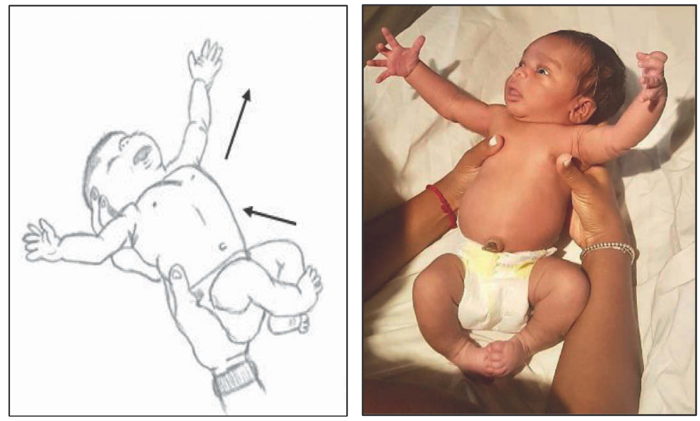
*Source:* Courtesy of The Hospital for Sick Children, Toronto, Ontario.

**TABLE 11 ■ Grading Tendon Reflexes**

| Numerical Grading | | Descriptive Grading |
|---|---|---|
| **0** | No response; abnormal | Absent |
| **1+** | Slight but definitely present response; may or may not be normal | Diminished |
| **2+** | Brisk response; normal | Normal |
| **3+** | Very brisk response; may or may not be normal | Exaggerated |
| **4+** | A tap elicits a repeating reflex (clonus); abnormal | Clonus |

*Sources*: Kuban KC, Skouteli HN, Urion DK, Lawhon GA. Deep tendon reflexes in premature infants. *Pediatr Neurol*. 1986;2(5):266–271; Mercuri E, Ricci D, Pane M, Baranello G. The neurological examination of the newborn baby. *Early Human Development*. 2005: 81(12):947–956; Walker HK. Deep tendon reflexes. In: Walker HK, Hall WD, Hurst JW, eds. *Clinical Methods: The History, Physical, and Laboratory Examinations*. 3rd ed. Boston, MA: Butterworths; 1990. Chapter 72.

**FIGURE 11 ■ Moro reflex.**



*Source:* Courtesy of The Hospital for Sick Children, Toronto, Ontario.

**TABLE 12 ■ Neonatal Primitive Reflexes**

| Reflex | Onset in Utero (Weeks) | How to Elicit Reflex | Integrates (i.e., Suppressed/Inhibited) |
|---|---|---|---|
| Palmer grasp | 28 | Place finger in palm | Five to six months<br>Allows for voluntary grasping |
| Tonic neck | 35 | See text | Six months<br>Allows for rolling over and reaching or grasping |
| Moro | 28 | See text | Six to eight months<br>Allows for sitting |
| Plantar grasp | 28 | Touch ball of foot with thumb causing toes to curl down | Seven to nine months<br>Allows for standing and walking |
| Rooting | 28 | Stroke cheek near mouth causing head to turn toward stimulus | Three months |
| Sucking | 26–28 | Touch lips with gloved finger or soother | Ten to twelve months |
| Swallowing | 12 | Observe for swallowing | 32–34 weeks<br>Stronger synchronization with sucking |

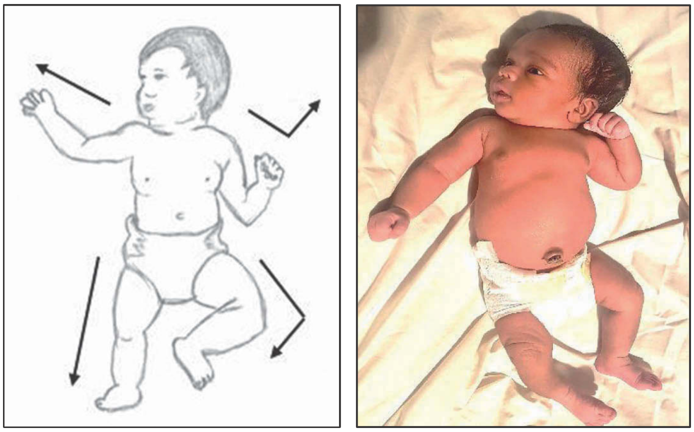
*Sources*: Gardner SL, Goldson E, Hernandez JA. The neonate and the environment: Impact on development. In: Merenstein GB, Gardner SL, Enzman Hines M, Hernandez JA, eds. *Merenstein & Gardner's Handbook of Neonatal Intensive Care.* 8th ed. St. Louis, MO: Mosby Elsevier; 2016:262–314; Volpe JL. Neurological examination: Normal and abnormal features. In: Volpe JL, Inder TE, Barra BT, et al., eds. *Volpe's Neurology of the Newborn.* 6th ed. Philadelphia, PA: Elsevier; 2018;191–205.

stimulus. Primitive reflexes provide information about the neonate's brainstem and cortical function. They develop in utero and are well-developed by term. As the central nervous system matures and cortical inhibition develops, starting at around four to six months of age, the primitive reflexes begin to diminish and are replaced by voluntary motor activities. Table 12 describes the major neonatal primitive reflexes.[18,49] Survival primitive reflexes include the rooting and sucking reflexes. Protective reflexes include the palmer grasp, plantar grasp, Moro, tonic neck, and gag. Absence of an expected reflex in a neonate may indicate general depression of the central or peripheral nervous system motor functions (i.e., lower motor neuron, nerve, and muscle function). Asymmetry may indicate motor cortex lesions or trauma-related peripheral bone or nerve injury.

The Moro reflex (Figure 11) is elicited by suddenly allowing the neonate's head and shoulders to drop a few inches in relation to their trunk into the examiner's hands. The reflex is produced by the suddenness of this stimulus, not the distance of the fall. The term neonate responds by opening his hands and extending and abducting the arms. This motion is followed by arm flexion back toward the body (similar to a hugging motion). A neonate will often cry when the Moro is stimulated.[18,31] An absent or asymmetric response may indicate an upper motor neuron abnormality. In addition, a unilaterally absent response may occur with an upper extremity injury, such as one of the brachial plexus (e.g., Erb's palsy), or fracture of the humerus or clavicle. Persistence of the Moro reflex may delay sitting and head control.

The tonic neck reflex (Figure 12) is elicited when with the neonate in the supine position, the head is turned to one side, resulting in extension of the upper extremity on the side to which the face is rotated and flexion of the upper extremity on their occiput side. The lower extremities exhibit a similar

**FIGURE 12 ■ Tonic neck reflex.**



*Source:* Courtesy of The Hospital for Sick Children, Toronto, Ontario.

but diminished response.[18] This positioning is commonly referred to as the fencing position. The reflex appears at 35 weeks' gestation and disappears by six months of age. The tonic neck reflex is inhibited as head control develops and the cerebral cortex matures. Persistence of the reflex is indicative of a central nervous system abnormality.

**Sensory Examination**. The sensory examination in the neonate is limited to evaluating response to touch and, if required, response to pain. Evaluation of the neonate's sensory system involves touching the face, trunk, and limbs with a cotton-tip applicator while observing for a facial response or change in behavior after each maneuver. If required, crying or extremity withdrawal should occur with painful stimulation.

## CONCLUSION

A thorough, thoughtful, and systematically performed neonatal neurological examination can identify both normal and important abnormal findings. The value of observation should not be underestimated as observation alone can provide extensive information about the neonate's status. Serial examinations are important in establishing an accurate representation of the neonate's neurological status. Practitioners involved in the care of neonates must have the ability to perform a neonatal neurological examination. Early recognition of abnormalities allows for prompt investigation and can prevent delays in therapeutic interventions. The neonatal neurological examination remains a highly informative, cost-effective, and time-efficient technique in the care of neonates.

## REFERENCES


1. Stiles J, Jernigan T. The basics of brain development. *Neuropsychol Rev.* 2010;20:327–348. https://doi.org/10.1007/s11065-010-9148-4
2. Lenroot RK, Giedd JN. Brain development in children and adolescents: Insights from anatomical magnetic resonance imaging. *Neurosci Biobehav Rev.* 2006;30(6):718–729. https://doi.org/10.1016/j.neubiorev.2006.06.001
3. Volpe JJ. Overview: Normal and abnormal human brain development. *Ment Retard Dev Disabil Res Rev.* 2000;6(1):1–5. https://doi.org/10.1002/(SICI)1098-2779(2000)6:1<1::AID-MRDD1>3.0.CO;2-J
4. Inder TE, Huppi PS. In vivo studies of brain development by magnetic resonance techniques. *Ment Retard Dev Disabil Res Rev.* 2000;6(1):59–67. https://doi.org/10.1002/(SICI)1098-2779(2000)6:1<59::AID-MRDD8>3.0.CO;2-E
5. Kinney HC, Brody BA, Kloman AS, et al. Sequence of central nervous system myelination in human infancy. II. Patterns of myelination in autopsied infants. *J Neuropathol Exp Neurol.* 1988;47(3):217–234. https://doi.org/10.1097/00005072-198805000-00003
6. Jarvis C. Neurologic system. In: Jarvis C, ed. *Physical Examination and Health Assessment.* 3rd ed. Philadelphia, PA: W.B. Saunders Company; 2000:687–750.
7. Sugerman RA. Structure and function of the neurologic system. In: McCrane KL, Huether SE, eds. *Pathophysiology. The Biologic Basis for Disease in Adults and Children.* 5th ed. St. Louis, Missouri: Elsevier Mosby; 2006:411–435.
8. Horns LaBronte K. Recording and evaluating the neonatal history. In: Tappero EP, Honeyfield ME, eds. *Physical Assessment of the Newborn: A Comprehensive Approach to the Art of Physical Examination.* 6th ed. New York, NY: Springer Publishing Company; 2019:9–21.
9. Miller S, Ferriero DM. From selective vulnerability to connectivity: Insights from newborn brain imaging. *Trends Neurosci.* 2009;32(9):496–505. https://doi.org/10.1016/j.tins.2009.05.010
10. Ho M, Patton AC, Delone DR, et al. Brain injury in the preterm and term neonate. *Curr Radiol Rep.* 2016;4:39. https://doi.org/10.1007/s40134-016-0161-0
11. Butt K, Lim K. Determination of gestational age by ultrasound. SOGC clinical practice guidelines. *J Obstet Gynaecol Can.* 2014;36(2):171–181. https://doi.org/10.1016/S1701-2163(15)30664-2
12. Dubowitz L, Ricci D, Mercuri E. The Dubowtiz neurological examination of the full-term newborn. *Ment Retard Dev Disabil Res Rev.* 2005;11:52–60. https://doi.org/10.1002/mrdd.20048
13. Ballard JL, Khoury JC, Wedig K, Wang L, Ellers-Walsman BL, Lipp R. New Ballard score, expanded to include extremely premature infants. *J Pediatr.* 1991;119(3):417–423. https://doi.org/10.1016/S0022-3476(05)82056-6
14. Dubowitz LM, Dubowitz V, Goldberg C. Clinical assessment of gestational age in the newborn infant. *J Pediatr.* 1970;77(1):1–10. https://doi.org/10.1016/S0022-3476(70)80038-5
15. Ballard JL, Novak KK, Driver M. A simplified score for assessment of fetal maturation of newly born infants. *J Pediatr.* 1979;95(5, pt 1):769–774. https://doi.org/10.1016/S0022-3476(79)80734-9
16. Lee AC, Panchal P, Folger L, et al. Diagnostic accuracy of neonatal assessment for gestational age determination: A systematic review. *Pediatrics.* 2017;140(4):e20171423. https://doi.org/10.1542/peds.2017-1423
17. Wusthoff CJ. How to use: The neonatal neurological examination. *Arch Dis Child Educ Pract Ed.* 2013;98:148–153. https://doi.org/10.1136/archdischild-2013-303640
18. Volpe JL. Neurological examination: Normal and abnormal features. In: Volpe JL, Inder TE, Barra BT, et al., eds. *Volpe's Neurology of the Newborn.* 6th ed. Philadelphia, PA: Elsevier; 2018;191–205.
19. Gardner SL, Hernandez JA. Initial nursery care. In: Merenstein GB, Gardner SL, Enzman Hines M, Hernandez JA, eds. *Merenstein & Gardner's Handbook of Neonatal Intensive Care.* 8th ed. St. Louis, MO: Mosby Elsevier; 2016:71–104.
20. Johnson PJ. Head, eyes, ears, nose, mouth, and neck assessment In: Tappero EP, Honeyfield ME, eds. *Physical Assessment of the Newborn: A Comprehensive Approach to the Art of Physical Examination.* 6th ed. New York, NY: Springer Publishing Company; 2019:61–77.

21. Nicholson L. Caput succedaneum and cephalohematoma: The Cs that leave bumps on the head. *Neonatal Netw*. 2007;26(5):277–281. https://doi.org/10.1891/0730-0832.26.5.277
22. Reid J. Neonatal subgaleal hemorrhage. *Neonatal Netw*. 2007;26(4):219–227. https://doi.org/10.1891/0730-0832.26.4.219
23. Barbier A, Boivin A, Yoon W, et al. Canadian neonatal network. New reference curves for head circumference at birth, by gestational age. *Pediatrics*. 2013;131(4):e1158–e1167. https://doi.org/10.1542/peds.2011-3846
24. Haslam RHA. Clinical neurological examination of infants and children. In: Dulac O, Lassonde M, Sarnat HB, eds. *Handbook of Clinical Neurology, Pediatric Neurology, Part 1*. Amsterdam, The Netherlands; 2013:17–25.
25. Shapira M, Borochowitz ZU. Asymmetric crying facies. *Neoreviews*. 2009;10(10):e502–e509. https://doi.org/10.1542/neo.10-10-e502
26. Darras BT, Volpe JL. Muscle involvement and restricted disorders. In: Volpe JL, Inder TE, Barra BT, et al., eds. *Volpe's Neurology of the Newborn*. 6th ed. Philadelphia, PA: Elsevier; 2018;922–923.
27. Zapata-Aldana E, Ceballos-Saenz D, Hicks R, Campbell C. Prenatal, neonatal and early childhood features in congenital myotonic dystrophy. *J Neuromuscul Dis*. 2018;5(3):331–340. https://doi.org/10.3233/JND-170277
28. Tekin M, Bodurtha JM, Riccardi VM. Café au lait spots: The pediatrician's perspective. *Pediatrics in Review*. 2001;22:82–90. https://doi.org/10.1542/pir.22-3-82
29. Witt C. Skin assessment. In: Tappero EP, Honeyfield ME, eds. *Physical Assessment of the Newborn: A Comprehensive Approach to the Art of Physical Examination*. 6th ed. New York, NY: Springer Publishing Company; 2019:45–59.
30. Zafeiriou DI. Primitive reflexes and postural reactions in the neurodevelopmental examination. *Pediatr Neurol*. 2004;31(1):1–8. https://doi.org/10.1016/j.pediatrneurol.2004.01.012
31. Yang M. Newborn neurologic examination. *Neurology*. 2004;62;E15–E17. https://doi.org/10.1212/WNL.62.7.E15
32. Brazelton TB. *Neonatal Behavioral Assessment Scale. Spastics International Publications: Clinics in Developmental Medicine. Monogrpah #50*. London, England: William Heinemann, Philadelphia, PA: J.B. Lippincott; 1973.
33. VandenBerg KA. State systems development in high-risk newborns in the neonatal intensive care unit. Identification and management of sleep, alertness and crying. *J Perinat Neonat Nurs*. 2007;21(2):130–139. https://doi.org/10.1097/01.JPN.0000270630.96864.9a
34. Khan OA, Garcia-Sosa R, Hageman JR, Msall M. Core concepts: Neonatal neurological examination. *NeoReviews*. 2014;15;e316–e324. https://doi.org/10.1542/neo.15-8-e316
35. Heaberlin PD. Neurologic assessment. In: Tappero EP, Honeyfield ME, eds. *Physical Assessment of the Newborn: A Comprehensive Approach to the Art of Physical Examination*. 6th ed. New York, NY: Springer Publishing Company; 2019:167–192.
36. Plauche Johnson C, Blasco PA. Infant growth and development. *Pediatrics in Review*. 1997;18;224–242. https://doi.org/10.1542/pir.18-7-224
37. Philip AG. Historical perspectives: Neurologic maturation of the neonate. *NeoReviews*. 2003;4;e199–e206. https://doi.org/10.1542/neo.4-8-e199
38. Amiel-Tison C. Neurological evaluation of the maturity of newborn infants. *Arch Dis Child*. 1968;43:89–93. https://doi.org/10.1136/adc.43.227.89
39. Rönnqvist L, Hopkins B. Motor asymmetries in the human newborn are state dependent, but independent of position in space. *Exp Brain Res*. October 2000;134(3):378–384. https://doi.org/10.1007/s002210000467
40. Romeo DM, Ricci D, van Haastert IC, et al. Neurologic assessment tool for screening preterm infants at term age. *J Pediatr*. 2012;161(6):1166–1168. https://doi.org/10.1016/j.jpeds.2012.07.037
41. Bodensteiner JB. The evaluation of the hypotonic infant. *Semin Pediatr Neurol*. 2008;15(1):10–20. https://doi.org/10.1016/j.spen.2008.01.003
42. Poropat F, Naviglio S, Taddio A, Gortani G. Cortical thumb sign. *J Pediatr*. 2013;163(2):605. https://doi.org/10.1016/j.jpeds.2013.03.020
43. Jaffe M, Tal Y, Dabbah H, et al. Infants with a thumb-in-fist posture. *Pediatrics*. 2000;105:E41. https://doi.org/10.1542/peds.105.3.e41
44. Zimmerman B, Hubbard JB. Clonus. StatPearls. https://www.ncbi.nlm.nih.gov/books/NBK534862/
45. Tappero EP. Musculoskeletal system assessment. In: Tappero EP, Honeyfield ME, eds. *Physical Assessment of the Newborn: A Comprehensive Approach to the Art of Physical Examination*. 6th ed. New York, NY: Springer Publishing Company; 2019:139–166.
46. Kuban KC, Skouteli HN, Urion DK, Lawhon GA. Deep tendon reflexes in premature infants. *Pediatr Neurol*. 1986;2(5):266–271. https://doi.org/10.1016/0887-8994(86)90017-2
47. Rothwell JC, Day BL, Berardelli A, Marsden CD. Habituation and conditioning of the human long latency stretch reflex. *Exp Brain Res*. 1986;(63):197–204. https://doi.org/10.1007/BF00235664
48. Mercuri E, Ricci D, Pane M, Baranello G. The neurological examination of the newborn baby. *Early Hum Dev*. 2005;81(12):947–956. https://doi.org/10.1016/j.earlhumdev.2005.10.007
49. Gardner SL, Goldson E, Hernandez JA. The neonate and the environment: Impact on development. In: Merenstein GB, Gardner SL, Enzman Hines M, Hernandez JA, eds. *Merenstein & Gardner's Handbook of Neonatal Intensive Care*. 8th ed. St. Louis, MO: Mosby Elsevier; 2016:262–314.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