PART 1: RECOGNIZING NEONATAL SPINAL CORD INJURY

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ABSTRACT

Neonatal spinal cord injury can occur in utero, as well as after either a difficult delivery or a nontraumatic delivery. Spinal cord injury can also be related to invasive nursery procedures or underlying neonatal pathology. Early clinical signs of spinal cord injury that has occurred in utero or at delivery includes severe respiratory compromise and profound hypotonia. Knowledge of risk factors and awareness of symptoms is required for early recognition and appropriate treatment.

This article reviews the embryological development of the spinal column highlighting mechanisms of injury and identifying underlying factors that increase the risk of spinal cord injury in newborns. Signs and symptoms of injury, cervical spine immobilization, and the differential diagnosis are discussed. Nursing implications, general prognosis, and research in spinal cord injury are provided.

KEY WORDS: spinal cord, infant, newborn, injuries, trauma, birth trauma, complications, nursing, paralysis, physical assessment.

Perinatal death or loss of function is one of the 10 most frequently reported sentinel events recorded since the implementation of the Joint Commission on Accreditation of Healthcare organizations database to track sentinel events in 1995.[1] Although the database is not injury specific, it does highlight the importance of identifying serious injury and evaluating the causes in order to devise prevention strategies.

Spinal cord injury (SCI) is a rare and potentially underdiagnosed clinical condition in the newborn.[2,3] The incidence is estimated to be 1 in 80,000 live births[4]; SCIs have been documented on neonatal postmortem studies in 10% to 14.9% of cases that included evaluation of the spinal cord.[2,5-10]

Obstetrical manipulations at or around birth, such as traction or rotation, escalate the risk of SCI.[6,11] Advances in diagnostic imaging that improve the accurate estimation of fetal size and presentation and the use of cesarean birth to avoid difficult deliveries has reduced the incidence of SCI related to obstetrical maneuvers.[9,11,12] Although the diagnosis is primarily considered following a difficult or instrumented delivery, some caregivers may be unaware that SCI can occur in utero, at birth, and in the nursery setting after birth.[13,14]

Spinal cord injuries are not always related to trauma and intrapartum events.[2,4,6,15] Conditions that result in cord compression or ischemia have also been implicated. Spinal cord injury has also been cited as a rare but serious complication of 3 common neonatal procedures: lumbar puncture, umbilical arterial catheterization, and central venous catheterization (particularly with lower-extremity insertion sites).[2,14,16-18] Spinal cord injury needs to be considered in any newborn with poor tone and respiratory effort at birth—with or without a history of difficult delivery—and in infants with an abrupt change in muscle tone following invasive procedures, or those who have indwelling central arterial or venous catheters.

Coexisting hypoxic ischemic encephalopathy or the presence of neuromuscular disease complicates the diagnosis.[19] Increased awareness of the potential for both traumatic and nontraumatic SCI can expedite the diagnosis and ensure rapid treatment. Multidisciplinary consultation, coordination of care, and appropriate specialty care can then be provided.

This article is Part 1 of a series of *Focus on the Physical* articles that will explore other newborn conditions affecting the spine. Assessment of the newborn spinal dyspraphisms will be reviewed in future articles.

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1536-0903/06/0601-0008$32.00/0
doi:10.1016/j.adnc.2005.11.001

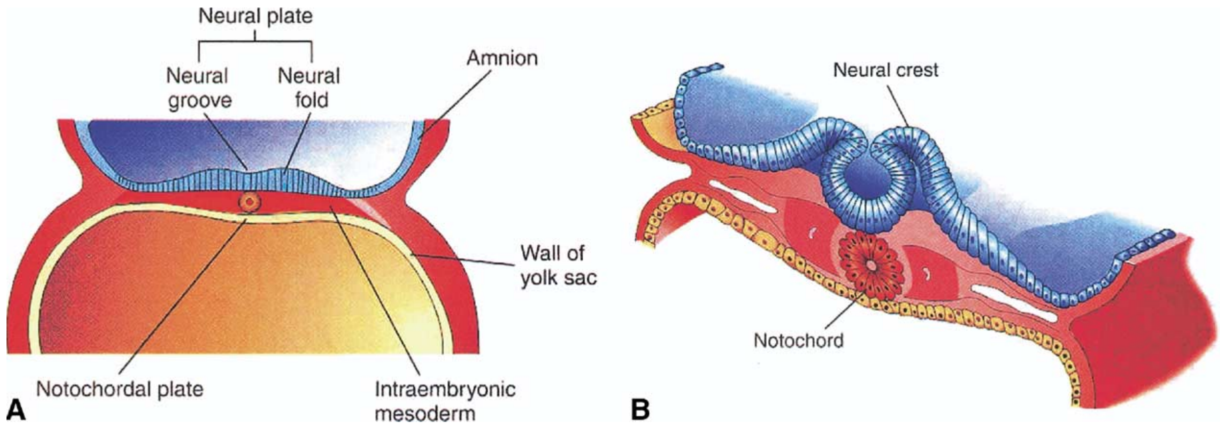

Figure 1. (A) Diagram of the early embryological development of the spine. (B) Diagram of embryological development of the spine. Notice the subsequent fusing of the neural crests to form the neural tube. Reprinted with permission. Moore K, Persaud TVN. *The Developing Human.* 7th ed. 2003:429.

Development of the Fetal Spine

Interpreting clinical findings related to SCI requires a complete understanding of the complex processes involved in the development of the neural tube, which ultimately forms the spine and spinal cord. The critical period for development of the neural tube, referred to as primary neurulation, occurs between days 16 and 28.[20] It begins with a groove that forms in the midline of the neural plate. Neural folds, known as the neural crest, develop on either side of the groove. As the groove deepens, the neural crest fuses to form the neural tube (Fig 1A and B).[20-22] Fusion begins in the middle of the embryo and extends upward (toward the head) and downward (toward the primitive tail) until formation of the neural tube is complete. Neural crest cells form the meningeal covering of the brain and spinal column. Paired segments, called somites, form on either side of the neural tube. These cells grow over the neural tube and join to form the cartilaginous precursors of the vertebral column, forming each pair of vertebrae in a cephalocaudal (head-to-toe) progression.[20]

The lateral walls of the neural tube thicken and form the spinal cord. Early in gestation, the spinal cord and the vertebral column are approximately the same length. As the fetus grows, the vertebral column grows faster than the spinal cord. The nerve roots at the end of the spinal cord, the conus medullaris, form a sheaf of nerve roots (cauda equina). As the vertebral column elongates, the end of the central canal is located higher in the vertebral column. In the last 15 weeks of gestation, the anatomic position of the spinal cord progresses upward from L4 to L2.[14,20,23] This is why lumbar punctures in newborns are performed at the anatomic level of L4 to L5, thus avoiding puncture and injury to the conus medullaris during the procedure (Fig 2 A-D).[24] In the newborn, these nerve roots are located lower in the canal than in adults.

The spinal cord is formed in 3 layers: the inner central canal, the gray matter, and the white matter. Nerve cells and capillaries are found in both the gray and white matter.[20] Consequently, the spinal cord, like the brain, is vulnerable to hypoxic ischemic injury. Hypoxic ischemic injury is often a sequelae of hypotension, hypoperfusion, and inadequate autoregulation.[2,5] Vascular occlusion can also play a role in ischemic injury to the spinal cord.[19]

The lower end (caudal) neural tube atrophies, forming a fibrous strand called the filum terminale that is present throughout life. Abnormal thickening or shortening of the filum terminale may result in a lower than expected position of the conus medullaris and plays a role in spinal cord abnormalities (discussed in future articles in this series).

At birth, the infant's vertebral column is more elastic than the spinal cord.[6,10,20,21,25,26] It is vulnerable to trauma from external forces exerted during the delivery process and may escalate the risk of SCI. When rotational forces are exerted on the vertebral column, these segments can undergo transient subluxation, injuring the cord, and then returning to normal alignment.[5,26] The primarily cartilaginous vertebral bodies in newborns do not interlock snugly to provide the same degree of protection as those of older infants.[8,26] Hypotonia exaggerates the risk of injury secondary to laxity of the supporting muscles. Any neuromuscular condition that reduces muscle tone increases the risk of SCI because these conditions allow increased stretch of the vertebral column during delivery.[5,9,11,27] Exposure to narcotics or general anesthesia at the time of the delivery may also result in decreased muscle tone and increased risk of injury.[2,26]

Etiology of and Predisposing Factors for Spinal Cord Injury

The mechanisms of SCI in newborns include:[11]

- Tearing or laceration of the spinal cord, dura, or nerve roots;

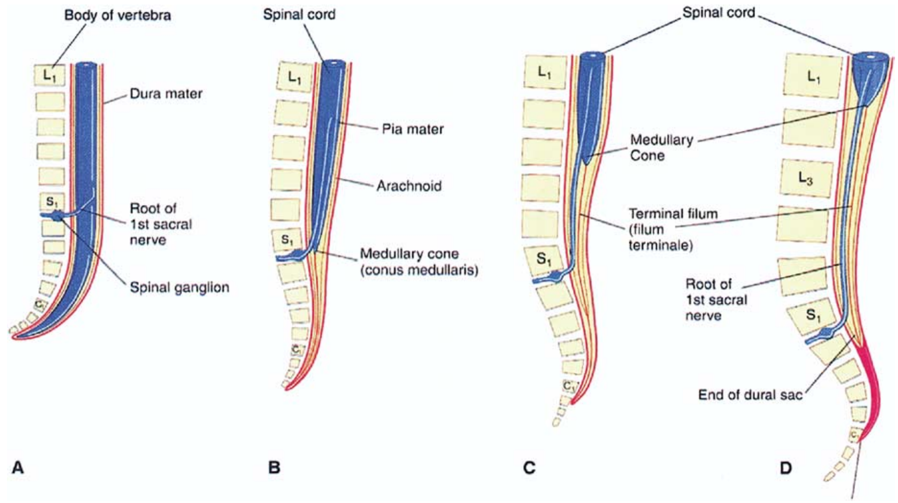

Figure 2. Diagram of spinal cord. Note differences in the termination and ascension of the conus medullaris of the spinal cord at different gestational ages. (A) 8 weeks, (B) 24 weeks, (C) newborn, and (D) adult. These anatomic differences are important to consider during lumbar puncture. Reprinted with permission. Moore K, Persaud, V. *The Developing Human,* 7th ed. 2003;436.

- Compression of the spinal cord;
- Ischemia and/or infarction of the spinal cord.

Any fetal malpresentation, especially breech, face, frontal, transverse, or the need for external cephalic version, may increase the risk of injury. Macrosomia, shoulder dystocia, and a prolonged second stage of labor may also increase the risk of difficult delivery, thereby increasing the risk of SCI.[8,25] In utero hyperextension of the fetal head has been associated with SCI. The suspected mechanism of injury is a vascular insult.[15,19,26,28]

The cervical spinal cord is particularly prone to injury related to intrapartum mechanical trauma.[29] Longitudinal traction during vaginal breech deliveries and rotational forces >90° with torsion of the neck can result in a dislocation injury and spine fracture.[3-6,15,26] The use of forceps may further increase stretch and pressure on the infant's neck.[8,10] Table 1 provides a list of factors that increase the risk of SCI.

Spinal cord injury following a difficult vaginal delivery is well documented.[2,29] However, it is also reported in nontraumatic cephalic vaginal births and in cesarean births.[29] Although less recognized, spinal cord injury also occurs well after birth, in the neonatal period. Because SCI in newborns is rare, information accumulated from case reports is an important source for documenting potential etiology and symptoms.

Transection

The most severe form of SCI is transection of the spine.[8,10,11] Transection results in complete paralysis below the level of injury and is irreversible (Figs 3A and 3B).[27] Injuries caused by compression or ischemia are less severe and have the potential for partial or complete recovery.[27]

Compression

Both epidural and subdural hematomas of the spinal cord can cause cord compression and symptoms of SCI.[9,12] Hematoma formation has been described in utero; the injury is compounded when a bleeding diathesis is present. One case report describes an infant with thrombocytopenia secondary to maternal antihuman platelet antigen (HPA-1a) antibody who presented at birth with petechiae, hypotonicity, paralysis

Table 1. Predisposing Factors for Spinal Injury

Antenatal Factors
- Breech presentation[8,9]
- External cephalic version[2,30]
- Hyperextension of the fetal head[2,5,30]
- Perinatal viral insult[2]
- Vascular insult[2]
- Prenatal ischemic insult[19]

Labor and Delivery Factors
- Asphyxia[6]
- Difficult delivery[2,5]
- Forceps application[5,30]
- Fracture/dislocation of spine[8]
- Precipitous delivery[2,30]
- Shoulder dystocia[30]

Infant Factors
- Bleeding diathesis[3]
- Congenital vertebral anomalies[2,5,10,30]
- Hypotension[48]
- Hypotonia[2,30]
- Prematurity[2,30]
- Coarctation of the aorta repair[34]
- Invasive procedures in the newborn period[2,14,16-18,33]

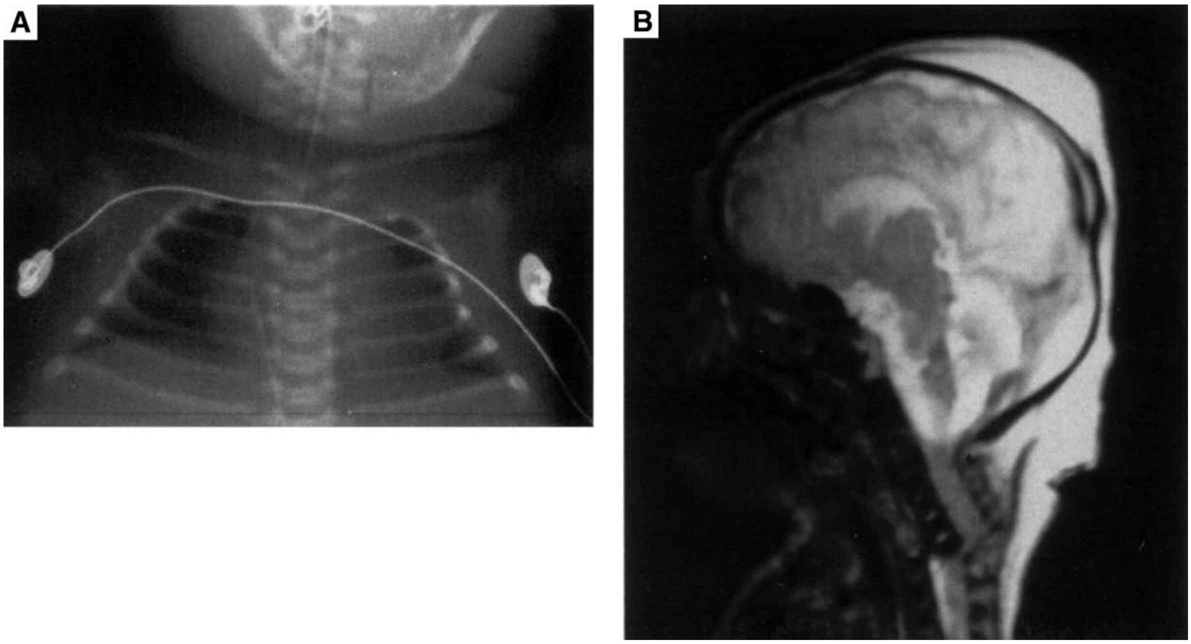

Figure 3. (A). Radiograph showing disruption of cervical spine. Note the shadow of the endotracheal tube crossing the chasm in the cervical spine. (B) Magnetic resonance image showing displacement of cervical spine. Courtesy of Dr. Michael Speer, with permission.

of the left and weakness of the right upper extremities, severe head lag, and early respiratory distress. Magnetic resonance imaging (MRI) revealed hemorrhage into the fourth ventricle and medulla that extended to C5.[30]

Hematoma and spinal cord compression is a rare, albeit serious potential complication of lumbar puncture (LP), particularly in very premature infants in whom the conus medullaris may still be ascending.[14] A case report of decreased lower extremity movement following an LP in a 22-week gestation infant was recently published. Magnetic resonance imaging showed a somewhat atypical termination of the conus medullaris at L3 in this infant. Surgical exploration of the spinal cord confirmed an intramedullary hematoma resulting from puncture of the conus medullaris, presumably during the LP.[14] Laceration of the leptomeninges can also result in a spinal fluid leak and compression of the cauda equina.[31]

Compression fractures from extreme flexion during an LP can also occur in premature infants and likely result from retropulsion and anterior wedging of vertebral bodies.[13] Osteopenia, often seen in very-low-birth-weight infants, increases the likelihood of vertebral injury during procedures such as LP. See Sidebar 1 for clinical tips for gentle and effective immobilization for LP in fragile premature infants.

Ischemia

Vascular insults early in embryonic life can cause a vertebral column malformation resulting in narrowing of a segment of the spinal cord.[19] In utero interruption of blood supply and vascular occlusion accounts for some cervical cord injuries.[15,19] It is theorized that this is the mechanism of injury for infants in the breech position with neck hyperflexion in utero who suffer from subsequent SCI.

Prenatal or perinatal spinal stroke, characterized by prominent infarctions in the grey matter, along with select white matter involvement, has been described after a nontraumatic deliveries.[19] The rich capillary networks in the cervical and lumbosacral sections of the spinal cord have high oxygen demands and can be negatively impacted by decreases in blood flow.[19] The spinal cord is also vulnerable to in utero hypoxic ischemia events. Acute infarction of the spinal cord results in neuronal necrosis and extensive cavitations in the spinal cord.[2] In these cases, a notable absence of fetal movements is reported before the delivery.[15]

Spinal stroke has also been implicated as the etiology of paralysis following placement of umbilical arterial catheters and can result in paraplegia.[2,17-19,26,32] Disruption of normal blood flow as a result of a malpositioned or infiltrated central catheter may result in local ischemic injury.

Extravasation of parenteral fluids from a central vessel catheter into the spinal canal has been described in a 30-week gestation infant with a saphenous percutaneous central catheter.[16] After the infant developed fever and seizure-like movements, elevated triglycerides (presumably from the intralipids) were found in

Sidebar 1. Clinical Tips for Appropriate Positioning for a Lumbar Puncture

One technique for holding an infant for a lumbar puncture is to position the infant on the side and bring feet to hands and hold them together to create a curve in the lumbar spine. This position prevents flexion of the neck and helps maintain an open airway. It is important to note that the infant's head does not need to be held down to the chest to optimize access to the intravertebral spaces in this position.

Analgesia reduces the distress of infants and makes the procedure easier to perform.[47] Provide adequate pain control by using sucrose with pacifier, EMLA cream at the site, and/or subcutaneous lidocaine at the site to prevent the need for forceful positioning.[47]

the spinal fluid. A cross-table lateral abdominal radiograph showed the line deviating posteriorly at L5 to S1 to enter the venous plexus. Although the line was removed immediately, the infant developed paraplegia.

Another case report highlights the potential for femoral venous line migration into the paraspinous musculature with infusion of parenteral fluids into the spinal canal resulting in paralysis.[33] Because the injuries were localized, rather than global (as seen with hypoxic ischemic encephalopathy), ischemia of the spinal cord was considered to be the cause of SCI in these infants.[12,19]

Spinal cord ischemia with subsequent paraparesis or paraplegia is a rare complication of operations on the descending aorta (risk is 0.5% to 1.5% during primary repair of coarctation). Hypothermic cardiocirculatory arrest or the use of heparinized shunts to maintain adequate distal perfusion pressure after aortic clamping are used to protect the spinal cord from ischemic injury.[34]

Examination of the Spine in Infants With Suspected Injury

In neonates SCI may present as profound global hypotonia or asymmetry of movement. The presence of respiratory distress, birth depression, hypoxic ischemic encephalopathy, or brachial plexus injury may interfere with early recognition of SCI.[2,11,25-27]

Clinical signs and symptoms of SCI are summarized in Table 2. The clinical manifestations depend on the level and severity of the injury. Although injury can occur anywhere along the spinal cord, the most common sites are the lower cervical and upper thoracic spine in breech deliveries and the upper to midcervical area in cephalic presentations. If the lesion is above C4, total respiratory compromise may occur.

When presented with a hypotonic infant with respiratory compromise, especially if the infant has risk factors associated with SCI, simultaneously secure the airway and immobilize. Immobilize both the head and neck until radiographs of the cervical spine can be obtained and carefully reviewed to assess for separation of the vertebrae. Further evaluation with ultrasound or MRI may be needed to clear the spine.[8,26] Examination of the infant with suspected injury is important; however, consideration must be given to preventing hypoxia or causing additional mechanical injury.

Table 2. Clinical Signs of Spinal Cord Injury

Neurological
- Hypotonia/weakness[2-4,26,30]
- Absent spontaneous limb movements[2-4,29]
- Weak or absent grasp reflex[5]
- Absent deep tendon reflexes[3]
- Weak cry[3]
- Sensory loss below the lesion[9]
- Urinary retention/incontinence[3,11,26]
- Poor rectal tone[2,3,5,26]

Respiratory
- Respiratory compromise/apnea[2,3,29]
- Paradoxical respirations[3,26]
- Bell-shaped chest on radiograph[25,28]
- Recurrent pneumonia[25,28]

Table 3. Determining the Level of Spinal Cord Injury

Upper Cervical C2 to C4
More common in cephalic deliveries[5,26,28,39]
- Severe respiratory compromise or failure[10,26]
- Flaccid quadraplegia[8] or tetraplegia[4]

Cervical-Thoracic C4 to T4
More common in breech deliveries[5,28,39]
- Diaphragmatic breathing/paradoxical respirations[3,26]
- High thoracic paraplegia[8]
- Lower extremity weakness[26]
- Abdominal distension[26]
- Atonic anus[26]
- Urinary retention[26]

Figure 4. Placing the infant prone allows clear visualization of the entire spine. Observe for symmetry as well as any obvious boney or skin defects.

Once the airway is secured, provide bag and mask ventilation. Intubation may be necessary to prevent secondary injury from hypoxia. Avoid neck hyperextension during intubation. Keep the spine straight and maintain proper neck alignment. One option is to use a double mattress to elevate the shoulders. Later, a cast or custom orthosis or mattress with a recess cut out for the back of the head can be designed to accommodate an infant's relatively large occiput and maintain a neutral neck position.[5]

Once the airway is established, the steps of the Neonatal Resuscitation Program are completed, and the spine has been cleared, perform a more complete examination. Modify the approach based on the infant's medical status.

Continue to monitor the respiratory status carefully. Apnea occurs with high cervical lesions. Injury occurring between C4 and T2 may involve the lower extremities only, or may affect the diaphragm and result in decreased function of the external respiratory muscles. If diaphragmatic breathing occurs, early radiographs will reveal a bell-shaped chest. Observe for paradoxical or "see-saw" respirations. These may be seen in infants with SCI who are spontaneously breathing.[10,25,27,28] In this type of breathing, part of the chest moves in on inspiration and out during exhalation. Muscle weakness may predispose the infant to recurrent pneumonia, atelectasis, and hypoventilation.[25,28] Injuries below T4 have relatively better outcomes.[28] Table 3 summarizes the presenting symptoms according to the level of injury.

Monitor temperature carefully during and after initial stabilization.[26] Decreased spontaneous muscle activity and limited flexion may contribute to hypothermia.

Examine the infant's posterior surface with the infant in the prone position if stable (Fig 4). Alternatively, if ventilation is required, 2 care providers can carefully logroll the infant to a side-lying position for the examination. Visualize the full length of the spine evaluating for open defects such as myelomeningocele or cutaneous markers that suggest underlying pathology. Gently and systematically palpate the entire spine for integrity of vertebral bodies and small masses (Fig 5).[35] Myelomeningocele and cutaneous markers will be explored in future articles in this spinal column assessment series.

Next, perform a thorough neurological evaluation. Observe the infant's resting posture, spontaneous movements, and overall tone. Evaluate the palmer grasp, Moro, truncal incurvation, and Babinski reflexes, noting any weakness or asymmetry of movement.[35] Test for level of sensation by touch or pinprick while monitoring the infant's facial features for a grimace. Absence of sensation in an area will identify the level of injury.[11] Test for decreased deep tendon reflexes; although diminished deep tendon reflexes are present in the acute stage of SCI, spasticity may develop later in life and is often mistaken for cerebral palsy.[2,11,26]

Beyond the initial presentation, observe for abdominal distension that may indicate urinary retention.[27] If urinary retention is present, continue to monitor for temperature instability, jaundice, and other nonspecific signs of infection which may be symptoms of a urinary tract infection related to urinary stasis.[36] Evaluate the tone of the anal sphincter; a relaxed tone and frequent or constant stooling may occur with SCI and will require meticulous skin care and the use of barrier creams to prevent skin breakdown. Provide careful positioning and gentle range of motion to prevent contractures.[26] See Figs 6A, B and Fig 7 for gentle handling strategies.

Diagnostics to Identify Spinal Cord Injury

Occasionally, radiographs identify fractures and dislocations or reveal a bell-shaped chest, suggesting an absence of function of the external muscles of respiration.[6,37] Because the vertebrae of a newborn contain a large proportion of cartilage, simple radiographs are usually not helpful in diagnosing SCI.[8,9]

Ultrasound may be a useful noninvasive bedside study to evaluate the spine.[5,6,9,31] The appearance of the normal spinal cord and the craniovertebral junc-

Figure 5. Gently palpate each vertebrae along the entire spine.

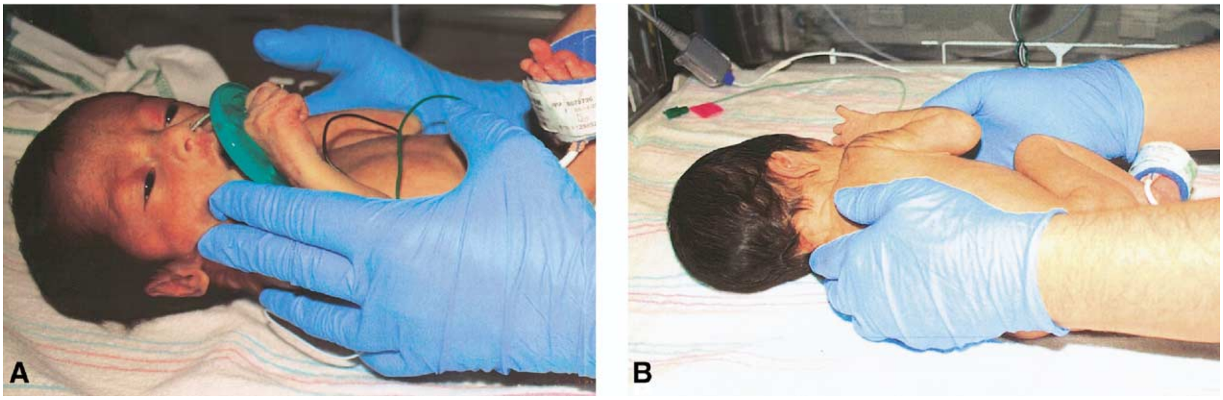

Figure 6. Handle infants gently, especially infants who are premature or hypotonic. (A) Carefully support infants in a tucked position when turning. (B) Maintain proper anatomic alignment of the head, neck, and spine throughout the turn.

tion is well described.[28,37] Three-dimensional ultrasound shows the alignment of posterior spinal segments and the integrity of vertebral bodies.[38]

Computed tomography identifies bony structures better than ultrasound; however, artifact from bone may produce false-negative results.[9] Magnetic resonance imaging gives the best resolution of subacute and chronic lesions and provides good visualization of the cartilage as well as the bone and spinal cord.[3,4,6,8,9,26] Spinal cord injury may occur in the absence of radiographic evidence. This type of injury is often termed SCI without radiographic abnormality (SCIWORA).[5]

Somatosensory evoked potentials are helpful in demonstrating the level of complete motor and sensory paralysis.[9,26] The usefulness in cervical spinal cord lesions is limited in newborns due to the relatively small bioelectric potentials produced in that area.[9] Myelograms also give small responses so the level and pathology of the lesion are difficult to isolate.[3]

Differential Diagnosis of Spinal Cord Injury

An accurate diagnosis is important to guide appropriate care, to support and counsel families, and to minimize medical-legal risk.[6] Diagnosis of birth-related SCI is often delayed due to coexisting conditions, such as hypoxic ischemic encephalopathy, occurs in >60% of infants with SCI.[3,5,9]

Diagnosis is based on the level, extent, and nature of the lesion as established by clinical examination, diagnostic imaging, and electrophysiological data.[9] The differential diagnosis includes:

- Brain stem injury[5]
- Spinal epidural hematoma[4]
- Neuromuscular disorders[2,3,11,15,26]
- Spinal dysraphism[9]
- Syringomyelia[9]
- Congenital intraspinal tumor[9,11]
- Brachial plexus injury[5,9,30,39]
- Hypoxic ischemic encephalopathy[3,5,9]
- Congenital torticollis[9]
- Respiratory distress syndrome[9]
- Sepsis

Prognosis and Ongoing Research

Increased awareness of the unique developing anatomy and vulnerability of the newborn spine may enhance prevention, allow for early recognition, and ensure prompt treatment of SCI. Diagnosis is often delayed due to coexisting injuries and SCI is often not considered until clinical signs become clear.

Although milder degrees of injury may potentially

Figure 7. Always support the head, neck, and shoulders of an infant when lifting, holding, or turning.

improve, severe injury is typically irreversible.[11,27] Lesions above C4 paralyze the diaphragm and require life-long ventilator support.[3,26] Infants with severe SCI often develop spinal deformities.[39] Focal cord narrowing seen on MRI is associated with poor mobility.[2] The best prognostic indicator is the resumption of breathing, especially on the first day of life,[26-28] and the recovery of limb motor function in the first 3 months.[3,4,28]

Important research efforts focused on neuroprotection and regeneration of nerve cells in the early stages of injury are underway. Neuroprotection interrupts secondary processes of injury such as edema, ischemia, inflammation, excitotoxicity, cytokine release, and apoptosis. A number of pharmacological agents are being evaluated including methylprednisolone, GM-1 ganglioside, erythropoietin, minocycline, and edaravone.

The use of Schwann cell implants to create cellular bridges to fill damaged areas of the spine, is also being investigated, along with neural stem cell transplant therapy. Researchers anticipate the need for a multilevel approach to SCI. Once therapies are proven effective the dose, duration, and timing have to be determined, along with their safety and efficacy in the newborn population.[26,40-45]

Nursing Implications

Caring for the infant with an SCI includes the following challenges for nurses:

- Recognition of symptoms;
- Coordination of consultants and diagnostic testing;
- Prevention of complications;
- Provision of support and education for parents.

Immobilize the infant's head and neck until the spine can be assessed by diagnostic imaging.[8,26] Assemble an individualized interdisciplinary team headed by the neonatologist.[46] A neurology consult will help establish the diagnosis and identify potential treatment options. Consult neurosurgery and orthopedic surgery if SCI is suspected; they can assist with proper immobilization, confirming the diagnosis, and management of long-term orthopedic problems.[5] A pediatric urology consultation is useful for infants with associated urinary retention. Include parents in all team discussions and decisionmaking.

Change the infant's position frequently to prevent pressure sores and joint contractures. After the infant is stable, physical medicine and rehabilitation will direct ongoing occupational and physical therapy to prevent progressive deformities. Encourage parents to learn and participate in the infant's physical therapy.

Parents need to understand the full extent of the injury and any available treatment options. Documentation and communication should be accurate and nonjudgmental.

The occurrence of an SCI is devastating to parents who may need the opportunity to grieve before they can accept the challenge of caring for an infant with special needs. Provide emotional support and involve clergy or spiritual leaders according to parents' wishes. The unit social worker can assist parents with financial planning, an application for social security benefits, and mobilize other community resources.

Summary

Spinal cord injury is a rare but serious condition. The unique anatomy and incomplete development of the spinal cord and protective structures make the newborn uniquely vulnerable to SCI. Diagnosing SCI in newborns is challenging due to the wide range of differential diagnoses and associated problems. The nurse who receives the infant in the labor and delivery suite, or cares for the infant in the neonatal intensive care unit, is uniquely positioned to identify risk factors, perform serial systematic physical assessments, identify signs and symptoms, and ensure rapid identification of SCI in newborns.

Acknowledgments

The author thanks Carol Tournage Carrier, RNC, MSN, CNS, for support and photography; Rebecca Schultz, RN, MSN, PNP, for critiquing the manuscript; and Dr. Michael Speer for use of radiographs and MRIs.

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