Spinal Injuries among Paediatric Patients

ABSTRACT

Due to the distinctive anatomic and biomechanical features of the growing paediatric spine, children are susceptible to unique patterns of spinal injuries. Although clinical examination can help guide management, physicians are often required to rely on advanced imaging. Imaging interpretation can be challenging when considering that abnormal parameters among adults, are often within normal physiological limits in children. In general, spinal injuries in children younger than nine years of age are often managed non-operatively, while adolescents are typically managed by adult treatment principles. With the exception of neurologic injuries, most paediatric spinal injuries demonstrate good to excellent prognosis and outcomes.

KEYWORDS: fracture, injury, spine, paediatric, children

CME Pre-test Quiz

Epidemiology

Paediatric spine injuries account for 2% to 5% of all hospital admissions, and represent less than 2% of paediatric fractures.[1] The annual incidence of hospitalizations is approximately 100 per million and there is a decreasing trend in the annual incidence.[2] Cervical spine injuries are the most common area of involvement accounting for 47-80% of all paediatric spinal injuries, followed by lumbar and thoracic injuries.[3,4] Due to the greater head-torso ratio in younger children, weaker cervical musculature, and multiple synchondroses, the majority of cervical spine traumas occur within the C1-3 vertebral levels in children less than eight years of age.[3] Motor vehicle accidents contribute to over half of all hospitalizations with sports injuries (27%) and falls (15%) contributing to a greater proportion among adolescents.[3,5] Up to 3% of paediatric spinal injuries are due to non-accidental trauma with the vast majority occurring in toddlers and infants with an average presentation of five months of age.[3,6,7]

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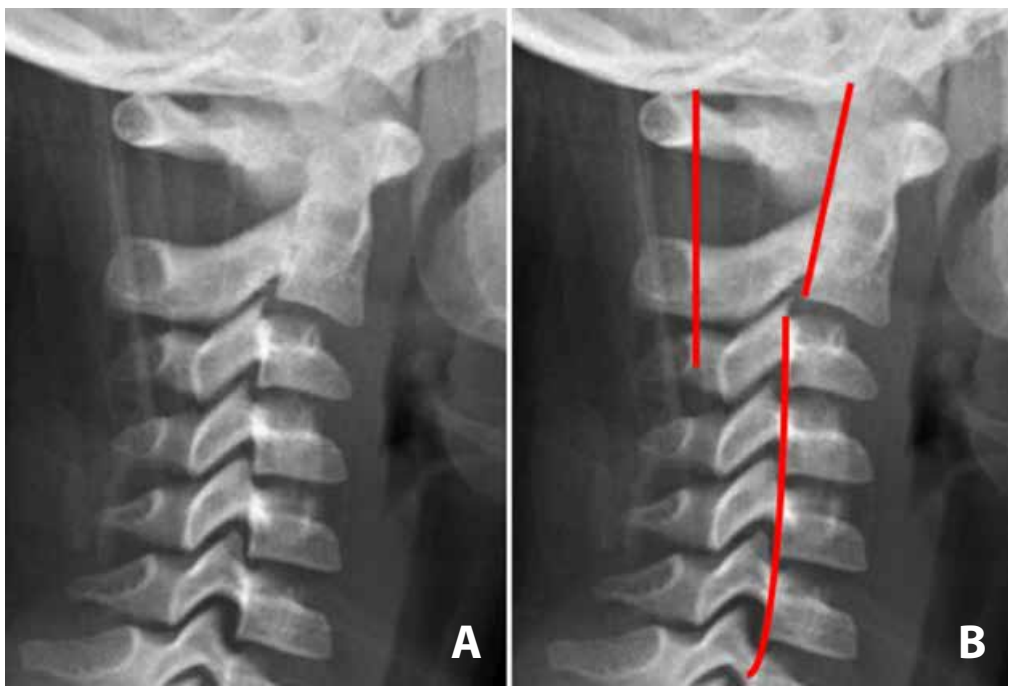
Overall, the associated mortality rate among all children admitted to hospital with a spinal injury ranges from 2-18%.[2,3] However, the variability within the reporting criteria among these studies render mortality estimates somewhat unreliable. The incidence of pathologic fractures and those secondary to metabolic insufficiency are also likely under-reported.[1,3,8,9] Among the various spinal fracture patterns, vertebral compression patterns are the most common.[3,4,10]

Pathophysiology

Several anatomic and biomechanical characteristics of the paediatric spine create unique injury patterns. As a result of ligamentous and facet-capsule laxity, more kyphosis from physiologic vertebral body wedging, greater intervertebral disc elasticity, and more horizontally oriented facets, the paediatric spine is more flexible than the adult spine and allows for a greater degree of pseudo-subluxation and movement (Figure 1).[11-13] The plasticity of the paediatric cancellous bone and the elasticity of the surrounding ligaments also results in greater biomechanical shock absorption prior to osseous compression or burst injuries.[12] Due to the normal development of the cartilaginous end plates and ring apophysis, incomplete ossification and fusion can be mistaken for fractures on plain radiographs.[13,14] Unlike adults where disc herniations tend to breach the annulus fibrosus, in children the cartilaginous apophyseal ring and growth plate are relatively weaker and herniation of the nucleus pulposus through these areas can result in unique fracture patterns.[15] Likewise, the elastic properties are believed to contribute to rare pathologies, including SCIWORA (spinal cord injury without radiographic abnormalities) where neurologic spine injuries occur without any distinct osteo-ligamentous injuries (Figure 2). This may be explained by the fact that the elasticity of the paediatric vertebral column allows up to

Figure 1: C2-3 Pseudosubluxation in Children



Lateral cervical radiographs of a 6-year-old female presenting with neck pain following a gymnastics injury. Patient is found to have a step deformity along the posterior vertebral line at C2-3 level (A). However, Swischuk's line from the C1 to C3 lamina is maintained indicating physiologic pseudosubluxation (B). Note the normal 'wedging' of the subaxial vertebral bodies due to residual cartilaginous endplates.

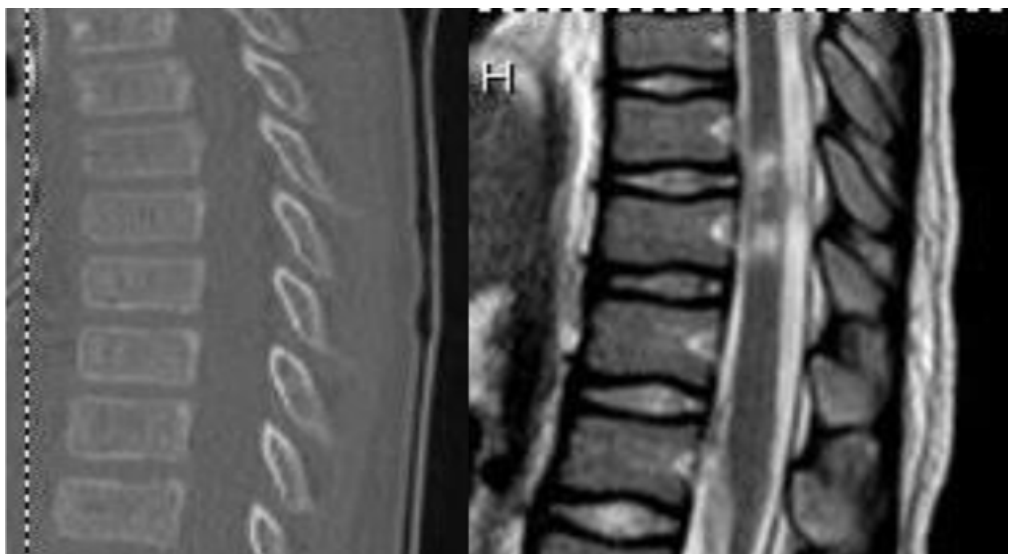
two inches of lengthening prior to fracture or ligament disruption while the spinal cord can only lengthen 0.25 inches before irreparable neurologic injury occurs.[10,16] In children under 13, the extensive vascularity and active growth plate allow for exceptional healing and compensatory correction to restore vertebral shape and height.[17] Thereafter, the paediatric vertebral column begins to demonstrate adult-like characteristics.

History and Physical Examination

Over two-thirds of patients with spinal injuries present with significant associated skeletal and visceral injuries.[3,5,18] The American College of Surgeons recommends that all children presenting with significant trauma should be evaluated with an Advanced Trauma Life Support (ATLS®) protocol and be kept immobilized until spinal injuries have been ruled out.[5] Standard musculoskeletal and neurologic examinations should be safely performed with log-rolling techniques. Due to a higher head-to-body ratio, children younger than eight years of age should not be immobilized on a standard flat board; if a specialized paediatric spine board with an occipital recess is not available, the torso can be elevated on a flat board with 2-3cm of padding to prevent inadvertent cervical flexion (Figure 3).[12,19] If the patient is wearing a helmet, removing the helmet requires at least two people to minimize cervical spine movement. Otherwise, the helmet should remain on until the patient is in a controlled safe environment.[20]

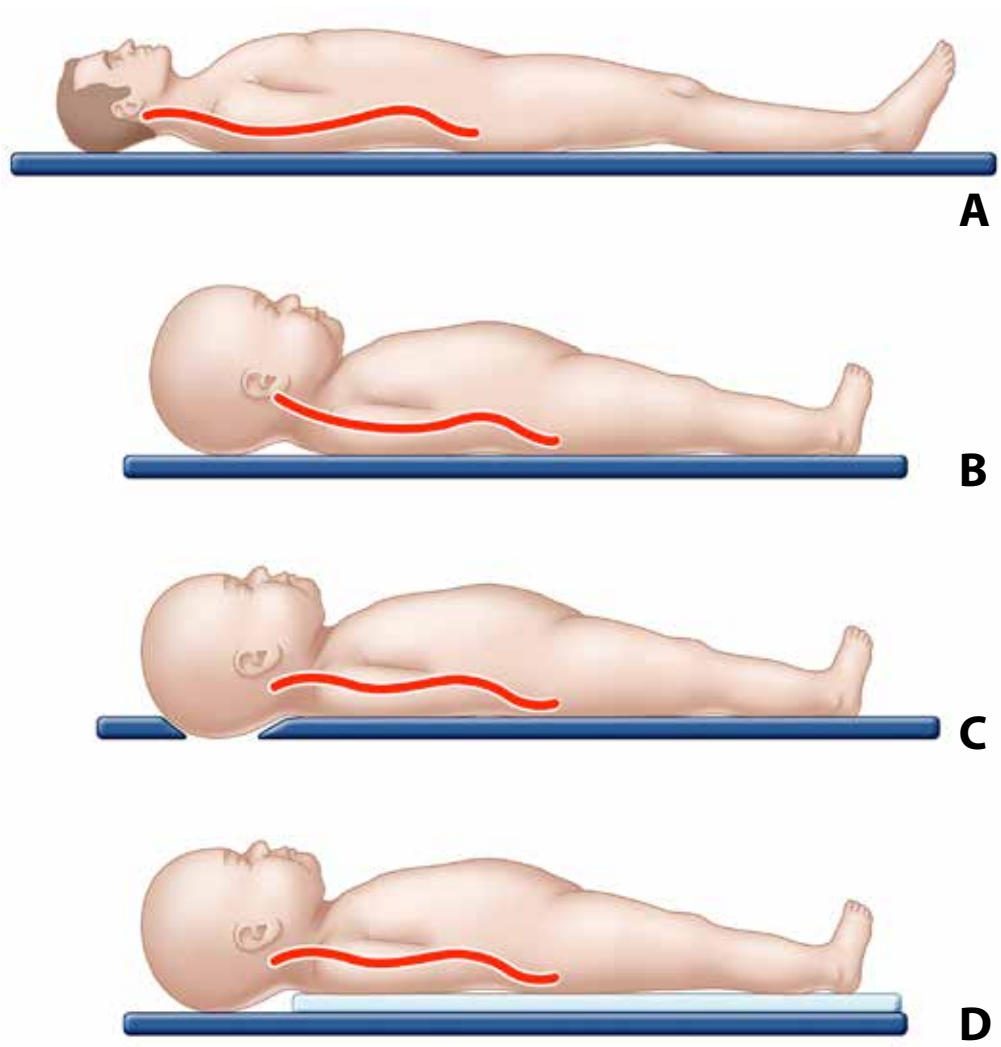
Clinical examination has a fairly low sensitivity (29-87%) and specificity (36-75%) for detecting spinal column injuries.[3,6,21] The 'seat-belt' sign, the presence of bruising/abrasions in the horizontal/diagonal distribution of a seatbelt, and spinal crepitus can identify potentially serious spinal injuries.[3,22] Delayed neurologic deterioration, as far along as two weeks from the time of initial injury, has been reported in up to 27% of paediatric patients with spinal cord injuries. For cases admitted to hospital,

Figure 2: Spinal Cord Injury Without Radiographic Abnormalities (SCIWORA)



Lateral CT scan (A) of the spine in a 9-year-old boy involved in a motor vehicle accident with no bony injuries. Clinical examination demonstrated complete paraplegia and anesthesia below T11. MRI (B) demonstrated focal signal changes in the spinal cord in the T10-T11 region.

Figure 3: Spinal Boards for Paediatric Patients Avoid Cervical Flexion



Due to the larger head-to-body ratio among children, supine positioning on a regular spinal board will result in cervical flexion in children under 8 years of age (B) compared to adults (A). As a result, paediatric spinal boards may either have a recess for the occiput (C) or the patient can be elevated by 2-3cm of blankets or padding (D).

reliable documentation using the International Standards for Classification of Spinal Cord Injury worksheet of the American Spinal Injury Association is highly recommended every 2-4 hours during the first two days then followed by daily assessments for up to two weeks.[3,6,23,24] The implementation of tertiary surveys in paediatric patients can improve the recognition of both spinal and extra-spinal injuries.[25] Follow-up outpatient evaluations can include coronal and sagittal balance evaluations, including Adam's forward bending test to monitor for subtle deformity progression, asymmetry of the shoulders, any obliquity of the pelvis, and to confirm if the head remains centered over the pelvis on both coronal and sagittal planes.

Imaging

Plain radiographs of the entire spine are indicated as secondary adjuncts to the ATLS® protocol among polytrauma patients, patients with positive clinical findings suggestive of a spine injury, Glasgow coma scale scores of less than 15, or any child with suspected non-accidental trauma due to child abuse.[26] Otherwise, to determine if cervical imaging is indicated and whether the images can be used to exclude cervical spine injuries, both the NEXUS and Canadian Cervical Spine Rule criteria can be applied to children older than two years of age.[27] Approximately 11-61% of spinal injuries involve more than one vertebral level and 7% are non-contiguous.[1,4] Therefore, when an injury is identified at any specific segmental level, complete radiographs of the entire spine are also indicated. Because of their ability to significantly improve injury identification, advanced imaging modalities like Computed Tomography (CT) or Magnetic Resonance Imaging

(MRI) should be considered.[3,28] However, the radiation profile must also be considered due to a calculated 25% relative risk reduction of thyroid cancer when MRI is chosen over CT.[29] MRI has the further advantage of better sensitivity for identifying neurologic and ligamentous soft tissue injuries. For these reasons, MRI is the preferred assessment modality for evaluating spinal injuries. This is particularly true when vertebral body compression fractures demonstrate a greater than 50% anterior height loss on plain radiographs or to evaluate for spinal hematomas and soft tissue injuries.[3,6,30-33]

The presence of ossification centers and synchondroses render the evaluation of paediatric spine imaging challenging. In children under five years, open mouth views of the cervical spine are neither useful nor easily obtained.[3] Often, parameters considered abnormal in adults can be within normal physiologic ranges among children (Table 1). These factors underline the importance of consulting paediatric musculoskeletal radiologists when encountering questionable radiographic findings.

Cervical Injuries

Whiplash Associated Disorder

Cervical injuries are the commonest spinal injury in children, and soft tissue cervical injuries are much more frequent than fractures. Symptoms of whiplash associated disorder (WAD) are routinely found in

Table 1: Examples of Normal Radiographic Imaging Variants found in Children[1,4,34]

• Atlanto-dental Interval up to 5mm until nine years of age (3mm limit in older children)
• Persistent odontoid synchondrosis until 11 years of age
• Incomplete atlas arch ossification until seven years
• "Pseudo-Jefferson fracture" with 6mm of combined Atlanto-axial facet widening (ie. Rule of Spence) until seven years of age
• C2-3 anterolisthesis (with maintained Swischuk's line)
• Prevertebral soft tissue swelling (up to 6mm at C3 level)
• Loss of Cervical lordosis with straightening until 16 years of age (kyphosis still considered pathologic)
• Subaxial spine incomplete vertebral body-neural arch fusion until seven years of age
• <3mm of anterosuperior vertebral body wedging
• Corticated Limbus vertebra
• Congenital spondylolysis and spondylolisthesis

children with hyperflexion cervical injuries from car accidents.[35] Bracing has not been shown to be beneficial among WAD injuries and although children may appear initially asymptomatic, almost half of them do not develop symptoms until 24 hours after the accident. However, outcomes are much more favorable among children than adults, with symptoms resolving at an average 28 days after injury.[35]

Stingers and Spear-Tacklers Spine

Cervical soft-tissue injuries are also commonly encountered during sporting activities. A transient brachial plexopathy, known as a 'stinger' or 'burner' due to the distinctive burning pain within the arm, occurs when the neck is forced into an extended and laterally flexed position as occurs in rugby, wrestling, or football. Patients can return to play when their symptoms disappear but should be restricted from play and reevaluated if they sustain three or more stingers within a year, if the symptoms involve more than one extremity, or if symptoms do not completely resolve.[20] Cervical spine radiographs are indicated with an acute injury and persistent neck pain. However, if there are persistent neurologic deficits or unremitting pain symptoms, patients should undergo an MRI evaluation prior to returning to sports.[20] However, many presentations remain controversial and even a history of transient quadriparesis with severe spinal canal stenosis, is still only considered a relative contraindication for return to sports.[20] The presence of "Spear Tackler's Spine", however, where the normal cervical lordotic curve becomes straightened or reversed, is an absolute contraindication to contact sports participation due to the high risk of catastrophic neurologic injuries (Figure 4). These patients often present with transient bilateral radiculopathy or even quadriparesis, and unlike 'stinger' patients who maintain a normal cervical morphology, the repetitive axial loads from tackling with their heads (hence the name), results in structural changes with loss of normal cervical lordosis, disc prolapses, and cervical stenosis.[36] As a result, these patients are susceptible to significant neurologic injuries and should be restrained from participating in contact sports.

Upper Cervical Injuries

In children, fractures are more common in the neck than they are in the rest of the spine, but soft tissue trauma is more common than bony injuries. Atlanto-occipital dissociation injuries, due rapid deceleration mechanisms, are rare but are more likely to occur in children under six years of age. The literature suggests they are missed

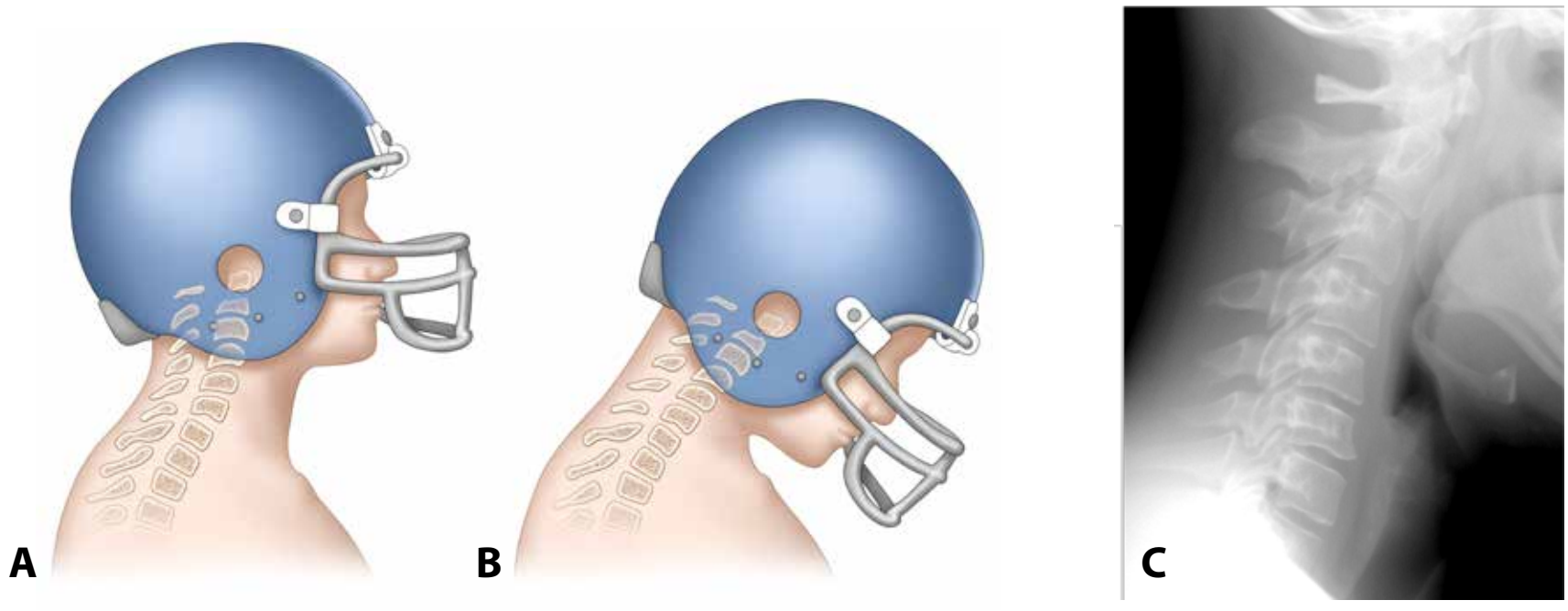
on initial evaluation in up to 60% of patients due to difficulty interpreting and visualizing occipito-cervical landmarks and shifts.[4] Traction is obviously contraindicated and the high incidence of residual instability makes fusion the preferred treatment.[37] Atlas fractures, presenting with significant loss of rotational movement and/or torticollis, are exceedingly rare in children. A hard collar or Halo vest, with the neck in extension to maintain reduction, can be used for 4-6 weeks as long as radiographic evidence of reduction is confirmed; cervical traction or surgical arthrodesis may otherwise be necessary.[4,38] Odontoid and Hangman fractures are similarly treated with external immobilization for 12 weeks and rarely require operative intervention.[16,39,40] Overall, the majority of upper cervical injuries in children can be managed non-operatively.

Subaxial Cervical Injuries

Subaxial spine injuries are similarly uncommon in children under nine years of age. These include flexion, rotation, and distraction patterns that tend to occur between C5 and C7 vertebral bodies.[4] Tear drop fractures of the vertebral body can represent severe anterior or posterior tension band disruptions of the longitudinal ligaments, and present as small oblique fractures along the vertebral body corners (Figure 5).

Vertebral compression and burst fractures, as well as unilateral

Figure 4: Spear-Tackler's Spine With Loss of Normal Cervical Lordotic Curve



Due to the repetitive axial loading during sporting injuries, the normal cervical lordosis (A) becomes increasingly kyphotic (B). This eventually results in structural changes to the spine (C) rendering it more susceptible to neurologic injuries as seen in this lateral c-spine x-ray of an 18-year-old patient with acute C4-5 kyphotic deformity.

facet dislocations with confirmed reduction, can be managed with external bracing (e.g. Halo vest or cervical-thoracolumbar support orthosis [CTLSO]). Even among bilateral facet dislocations that demonstrate complete disruption of the posterior tendon band structures, treatment remains controversial among children since halo-vest management and fusionless posterior instrumentation have both demonstrated good outcomes.[1,20,42,43] Subaxial injuries are typically managed with external immobilization and rarely require operative intervention, although adult instrumentation techniques have been employed in children as young as three years of age.[44] A brief summary of surgical indications for cervical injuries is included in Table 2.

Return to Play

A major concern in children is the safety of resuming sports. Restoration of full painless cervical range of motion and normal strength are usually considered an adequate indicator.

Figure 5: Anterior Tear Drop Fracture With Loss of Cervical Lordosis and Resulting Anterior Longitudinal Ligament Disruption

Lateral cervical radiograph (A) demonstrating an antero-inferior teardrop fracture of the vertebral body. Drawing (B) of the associated soft tissue injury demonstrating disruption of the anterior longitudinal ligament. [Case courtesy of Dr Chris O'Donnell, Radiopaedia.org][41]

Table 2: Various Surgical Indications among Paediatric Cervical Spine Injuries
• Atlanto-dental interval >5mm
• Odontoid fracture with >5mm of displacement or 11° of angulation
• >7mm of combined Atlanto-axial facet overhang or widening (Rule of Spence)
• >5mm displacement of Type I & II Hangman fractures, all type III fractures (Levine & Edwards Classification)
• Failed non-operative management of Type I-IV traumatic atlanto-axial rotatory displacement
• Bilateral facet fracture with >1cm facet widening or >40% articular involvement
• Flexion-distraction injuries with significant posterior ligamentous disruption
• Teardrop fractures of the vertebral body
• Progressive neurologic deficits or deformity
• Residual cervical dynamic instability on lateral flexion and extension radiographs

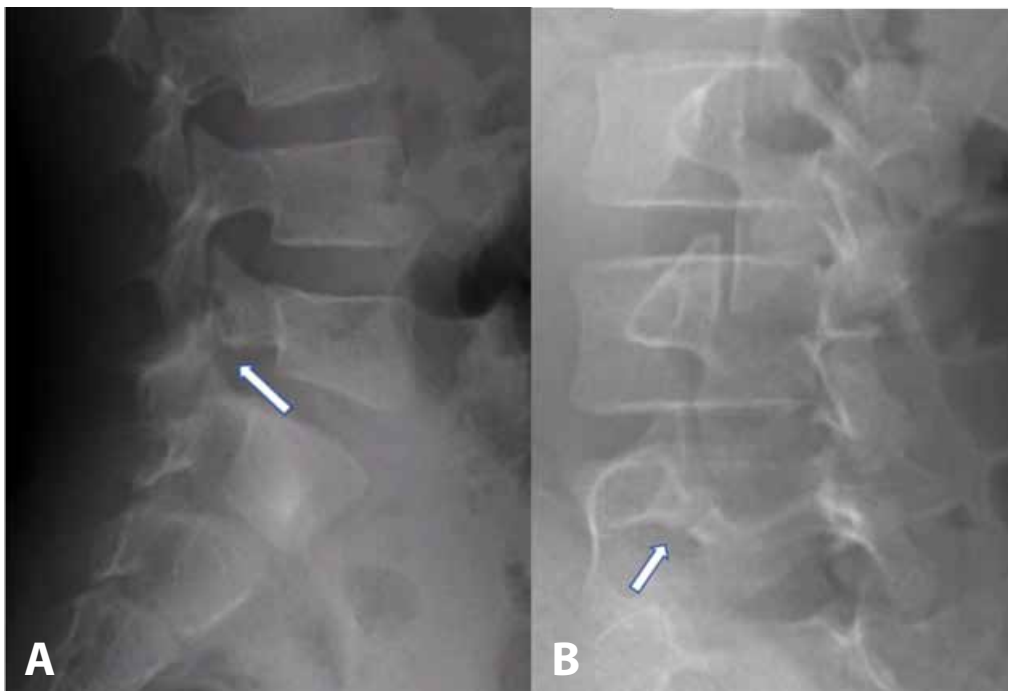
However, Kepler *et al.* have proposed several absolute contraindications; occipito-cervical fusions, atlantoaxial instability, significant spinal malalignment (Spear Tackler's Spine), subaxial spinal instability (demonstrated by dynamic spondylolisthesis on flexion and extension views), relative canal stenosis from retropulsed fragments, prior spinal fracture in a patient with congenital stenosis, any residual neurologic deficits, and cervical arthrodesis of three or more levels.[20] The management of an os odontoideum (the separation of a portion of the odontoid process from the body of the axis) remains controversial.[4] Overall, the outcome of paediatric cervical spine injuries is generally favorable and the majority of children are able to return to full activities with no restrictions.

Thoracolumbar Injuries

Classification of Thoracolumbar Injuries

A wide variety of thoracic and lumbar spinal fracture patterns have been described. Minor injuries include those to the articular process, transverse process, spinous process, or pars interarticularis, while more significant injuries involve compression and burst fractures, flexion-distraction and fracture-dislocation patterns. The Denis three-column classification is the most commonly referenced classification, but newer scoring systems like the Thoracolumbar Injury Classification and Severity (TLICS) scoring system, are

Figure 6: Pars Interarticularis Fracture in a 13 year-old gymnast



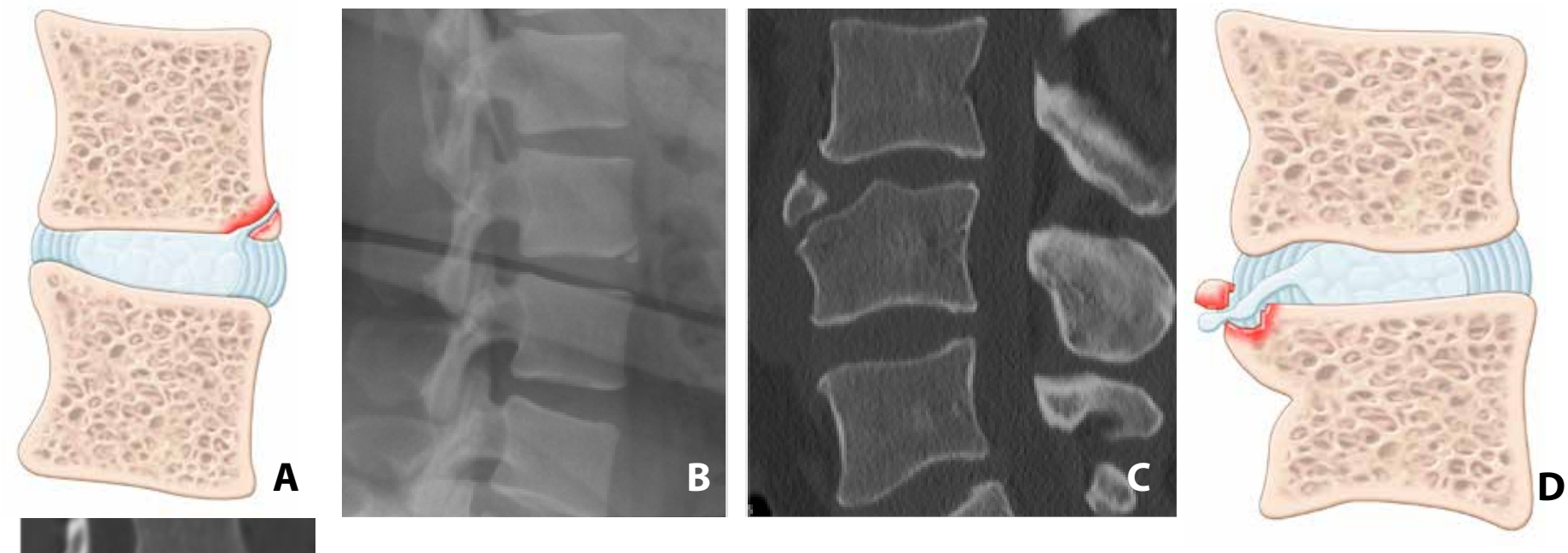
Lateral (A) and oblique (B) plain radiographs of the lumbar spine. White arrows identify a linear fracture lucency within the pars interarticularis region confirming an L5 spondylolysis.

increasingly more popular and simpler to apply.[1,5,13,45] In fact, only the TLICS scoring system has been validated in children and scores of 3 or less indicate a stable fracture pattern.[45,46]

Pars Interarticularis and limbus Injuries

Although fractures of the pars interarticularis are often encountered in teenagers with lower back pain, acute fractures are exceedingly rare in children and are more likely related to chronic or acute-on-chronic findings of isthmic spondylolysis from repetitive hyperextension movements (Figure 6). Pars injuries are generally managed with observation for slip progression, activity modification, and possible bracing.[47] An injury unique to the paediatric lumbar spine is the limbus fracture which can be difficult to distinguish from a tear-drop fracture or limbus vertebra. Limbus fractures often have smaller fracture fragments than tear drop fractures (Figure 7). Limbus vertebrae are due to failed fusions of the secondary ossification centers and result in well-corticated vertebral corner fragments, which appear to poorly fit into position, and are not associated with an acute injury. Limbus and tear-drop fractures are due to acute injuries and can be difficult to distinguish without advanced imaging. Tear-drop fractures result from extension-avulsion fractures or flexion compression fracture mechanisms. Limbus fracture are due to herniations of the nucleus pulposus that rupture through the weaker cartilaginous apophyseal ring and growth plate rather than the annulus fibrosus as seen in adults. This results in a small fracture along the corner of the vertebra which is inadequately visualized on plain radiographs in over one-third of cases and often requires MRI imaging for diagnosis.[11,15,48,49] As opposed to tear drop fractures, which are unstable, limbus fracture are stable, but can cause spinal canal compromise and radiculopathy symptoms when they herniate posteriorly into the spinal canal or foraminal region. The

Figure 7: Limbus Vertebra and Fractures



Herniations of the nucleus pulposus (A) can travel across the apophyseal ring resulting in failed fusion of the secondary ossification center and a residual well-corticated limbus vertebra fragment (B). The resulting fragment can often appear to poorly fit into position (C). Alternatively, Limbus fractures tend to present as smaller avulsion fractures or bone flecks due to herniations of the nucleus pulposus (D) and are only appreciated on CT or MRI scans in up to one-third of cases (E).
[Courtesy of A. Abdelrahman, A. Al Kabbani, F. Gaillard, and M. Nazar. Radiopaedia.org][41,50,51]

management of limbus fractures is similar to that of disc herniations, and good outcomes are reported in up to 97% of patients.[48]

Treatment of Thoracolumbar Injuries

Stable thoracolumbar fractures (e.g. TLICs score <4) in children are treated non-operatively, especially spondylolysis and fractures with maintained ligamentous integrity. Although bracing may sometimes be indicated, stable thoracolumbar injuries must be managed with observation and activity modification until serial upright radiographic images demonstrate fracture stability and maintained spinal alignment to confirm satisfactory healing.[1,10,52] Sagittal kyphotic angles may progress by up to 15° even among stable fractures.[53] Unstable fractures in older children can be managed according to adult treatment principles.[1,52] In children under nine years of age, the literature suggests that even unstable fractures can be managed non-operatively with bracing or casting as a first-line of treatment.[1,10,13] Bracing vertebral fractures below L3 may require a thigh extension and those above T6, a cervical extension.[13,39]

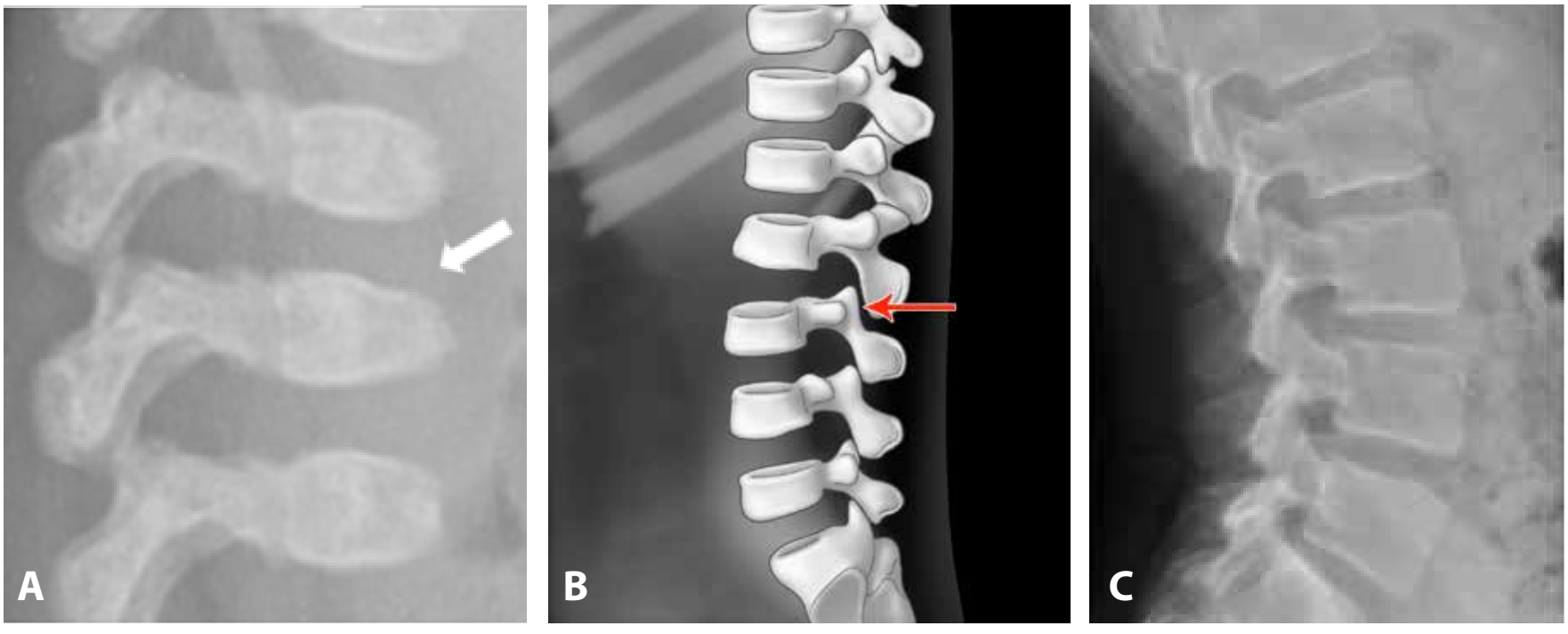
Several small case series have reported on the safe non-surgical management of burst and flexion-distraction fractures in children.[53-55] Surgery is indicated among patients with progressive neurologic deficits, progressive deformity, or failed non-operative management.[1,8,55] Table 3 contains a summary of common relative indications for operative management of thoracolumbar fractures. Pedicle screw instrumentation constructs have been used successfully in patients as young as eight months of age. Unlike adults, posterior fusion constructs are often unnecessary due to better ligamentous healing potential. Due to the

Table 3: Relative Indications for Surgical Management of Paediatric Thoracolumbar Fractures[a]

Radiographic	Clinical
• Unstable fracture patterns[b]	• Spinal cord or cauda equina injury
• >50% loss of vertebral height	• Progressive neurologic deficits
• >33% to 50% spinal canal compromise by fracture fragments	• Progressive spinal deformity
	• Injuries associated with multisystem trauma
• >15-30° Cobb kyphotic angle	• Failed nonoperative management
• >17° progressive kyphotic deformity	• TLICS score <4[c]
• >2.5-mm vertebral translation	
• >10° to 20° progressive scoliosis in patients with SCI	
• Compression or burst fractures with significant posterior ligamentous injuries	
• Purely ligamentous fracture-distraction injuries	
• Fracture-dislocation injuries	
• Widening of pedicles	
• Bilateral facet dislocations	

aGeneral summary of combined radiographic values from individual publications11,13,33,55,56.
bAs defined by various classification systems (e.g, Denis Classification, TLICS, other).
cTLICS = Thoracolumbar Injury Classification and Severity Score. A score of 4 is indeterminate and a score exceeding 4 suggests the need for surgical intervention.

Figure 8: L2 Vertebral Compression Fracture Remodelling



Lateral radiographs of a toddler sustaining an L2 compression fracture with 22° kyphotic angle. Although unavailable, initial radiographs also demonstrated widening of the posterior facet joint complex indicating an unstable fracture pattern (illustrated image B). Contrary to adult management principles, this injury was treated with a brace. At seven years of age, the patient has complete restoration of vertebral height and remains asymptomatic (C).

subcutaneous prominence of spinal hardware in younger patients, hardware irritation accounts for 80% of post-operative surgical complications and revision procedures.[1,6,9,10,52,53]

Prognosis of Thoracolumbar Fractures

Outcomes of thoracolumbar injuries are generally good to excellent and less than 30% of paediatric patients report long-term back pain symptoms at a 30 year follow up.[10,13,39,57] Non-surgical management is a reliable option among younger patients. Unlike adults, due to residual apophyseal vertebral growth, children under 13 years of age will demonstrate some degree of vertebral body height restoration (Figure 8).[17] Long term complications include premature growth arrest, spinal deformities and scoliosis, syringomyelia, autonomic dysreflexia, chronic pain, instability, pseudarthrosis, adjacent segment disease, and delayed neuropathy from tethering (the latter presenting with toe walking, leg spasms, and upper motor neuron signs).

Spinal Cord Injuries

All patients under the age of seven with neurologic deficits that cannot be explained peripherally, should undergo a full spine MRI with sedation.[58] In order to prevent any further deficits among patients with spinal cord injuries (SCI), expert opinion

SUMMARY OF KEY POINTS

- Due to the unique properties of the growing spine, including greater elasticity, osseous plasticity, presence of growth centers, relatively strong ligaments, and greater joint mobility, paediatric patients are susceptible to unique fracture patterns and injuries.
- There are absolute contraindications regarding return to play decisions.
- Children under 13 years of age with vertebral body compression fractures can progressively restore their vertebral height until skeletal maturity.
- The vast majority of spine injuries among children under nine years of age, even when relatively unstable, can be managed non-operatively.
- Pre-adolescent patients with complete spinal cord injuries are at high risk for developing progressive scoliosis and have not been shown to demonstrate any better neurological outcomes when compared to adults.

recommends avoiding hypotension and maintaining mean arterial pressures greater than 85mmHg for up to 5 days.[59] The use of steroids within 8 hours of the injury has never been validated in children and the serious adverse effects of steroids have limited their use.[60] Medical society guidelines do not recommend their use for paediatric SCI patients.[61] Children with complete or high-grade incomplete SCI do not demonstrate any better neurological recovery than adult patients.[62] Likewise, unlike adult patients with complete SCI, skeletally immature children have up to a 90% incidence of progressive scoliosis. Since bracing has not been shown to be effective for curves greater than 20°, operative intervention is required for the vast majority of SCI patients under ten years of age.[33] Annual radiographs and early surgical intervention are advocated to prevent progression until skeletal maturity is reached.[13,63]

Conclusion

Spinal injuries are relatively uncommon in paediatric patients. The majority arise from high-energy motor vehicle injuries. The unique anatomic and biomechanical features of the growing spine result in distinctive injury patterns and favorable outcomes. Clinical examination may be unreliable, and a high index of suspicion with the use of advanced imaging techniques may be necessary for reliable diagnosis. Adult principles can be used to guide management among adolescent patients, while children under nine years of age even with unstable fracture patterns are frequently managed non-operatively. Follow up until

CME

Post-test Quiz

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skeletal maturity, especially among spinal cord injury patients, is necessary to limit fracture sequelae, deformities, and complications. The majority of paediatric spinal injuries show good to excellent long-term outcomes.

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CLINICAL PEARLS

The cervical spine is the commonest area of spine injuries with the C1-3 vertebral levels being more commonly seen in children under eight years of age.

A standard immobilization board should not be used for children under eight years of age without an occipital recess or 2-3cm of padding to elevate their body relatively to their head

Adult radiographic spinal parameters are often unreliable in children and severe neurologic injuries can be sustained in spite of normal imaging results.

Clinical examination is fairly unreliable for identifying spinal column injuries among pre-school patients and it is often necessary to rely on advanced imaging.

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