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Pediatric Cervical Spine Injury

Pediatric cervical spine injury (CSI) represents a significant concern in trauma cases involving children due to the unique anatomical and biomechanical characteristics of the pediatric spine. While relatively uncommon, occurring in approximately 1–2% of pediatric trauma patients, these injuries carry a high potential for morbidity and mortality. Cervical spine injuries in children are associated with severe neurological sequelae, including paralysis, long-term disability, or death in extreme cases. Early detection and appropriate management are critical to avoid permanent damage. However, diagnosing CSI in children is challenging, with age-specific considerations that complicate the clinical decision-making process.

The epidemiology of pediatric CSI is distinctly different from that of adults due to the developmental changes in the pediatric spine. Studies show that CSI in children follows a bimodal distribution pattern, with the first peak of injuries occurring between the ages of 3 and 5 years, and a second peak between 14 and 16 years of age. Younger children are more likely to sustain injuries in the upper cervical spine (C0–C2), while adolescents tend to experience injuries in the lower cervical spine (C3–C7). These variations arise from developmental factors, including the relative size of the head compared to the body, ligamentous laxity, and incomplete ossification of the cervical vertebrae.

The most frequent cause of CSI in pediatric populations is motor vehicle collisions (MVCs), which account for approximately 50–60% of cases across all age groups. Falls from heights and sports-related injuries are also significant contributors, particularly in adolescents. Falls are the most common cause of CSI in children under 8 years, while sports-related injuries account for 20–38% of cases in older children. In some cases, blunt trauma, such as from bicycle accidents or diving injuries, can lead to axial loading, which is a particularly dangerous mechanism that increases the likelihood of a severe cervical spine injury.

Among preverbal children, diagnosing CSI is even more complex. Injuries in this age group are less common but often more severe when they occur. Preverbal children tend to have higher rates of injuries requiring surgical intervention compared to older children, with specific anatomical features such as a proportionately larger head and less muscular support in the neck region making them more vulnerable to injury.

Understanding the anatomical and biomechanical distinctions of the pediatric cervical spine is crucial for recognizing injury patterns and improving diagnostic accuracy. In children, the cervical spine is highly flexible, with incomplete vertebral ossification and increased ligamentous laxity. This flexibility, combined with a disproportionately large head, especially in infants and toddlers, places the upper cervical spine at greater risk of injury.

Before the age of 8, pediatric cervical spine injuries tend to occur more frequently in the upper cervical region (C0–C2). This is primarily due to the large head size and weaker neck muscles, which cause a higher fulcrum of motion at the craniocervical junction. As children age, the fulcrum shifts lower, and injuries to the lower cervical spine (C3–C7) become more common, reflecting a pattern more akin to adult injuries. Adolescents, therefore, show a higher prevalence of lower cervical spine injuries.

Common injury mechanisms in pediatric CSI include fractures, dislocations, and ligamentous injuries. In children, soft tissue injuries are often subtle and more challenging to detect on initial imaging. Distraction and hyperflexion injuries are also common due to the hypermobility of the pediatric spine. Such injuries often manifest as subluxations or dislocations at the C1 and C2 levels, which can result in significant morbidity if not promptly diagnosed and treated.

The early diagnosis of pediatric CSI is essential for preventing secondary injury, but it is fraught with challenges due to the nature of pediatric anatomy and the limitations of imaging techniques. While computed tomography (CT) scans and X-rays are the standard imaging modalities used to detect cervical spine fractures in trauma settings, concerns about radiation exposure in children necessitate careful consideration of when and how to use these tools.

CT scans are commonly used in trauma centers because of their high sensitivity for detecting bony injuries, but the long-term risk of radiation-induced malignancy in children, particularly those under 10 years old, has driven many pediatric trauma centers to favor alternative strategies. For example, pediatric trauma centers often rely more on plain films (X-rays) or clinical observation, reserving CT imaging for high-risk cases or when initial imaging is inconclusive. Studies have shown that pediatric trauma centers tend to perform fewer CT scans compared to adult or combined trauma centers, a reflection of their more conservative approach to radiation exposure.

Magnetic resonance imaging (MRI) is another essential diagnostic tool, especially for evaluating soft tissue and ligamentous injuries that may not be visible on CT or X-ray. MRI is particularly useful for identifying spinal cord injuries or subtle ligamentous disruptions that might otherwise go undetected. However, MRI is often impractical in the acute trauma setting because it typically requires sedation in young children and is not always readily available.

The decision-making process regarding the need for imaging in pediatric CSI cases is guided by clinical decision rules, such as the NEXUS criteria and Canadian C-Spine Rule, which were initially developed for adults. Although these tools are frequently used in pediatric trauma cases, their accuracy and applicability to children have been questioned due to the anatomical and physiological differences between pediatric and adult patients. Several studies have found that the sensitivity and specificity of these tools vary widely when applied to children, with some cases of pediatric CSI being missed when relying solely on NEXUS criteria.

The management of pediatric cervical spine injuries involves initial stabilization, followed by a tailored treatment approach based on the severity of the injury. The first priority in managing suspected CSI is spinal immobilization, typically with a cervical collar to prevent further movement and reduce the risk of secondary neurological damage. The use of spinal motion restriction (SMR) remains standard practice in prehospital care, but concerns have arisen about its potential adverse effects, including discomfort, respiratory compromise, and the increased need for imaging to clear the cervical spine in the emergency department.

For children with low-risk injuries, such as those with no neurological symptoms, no midline tenderness, and a low-risk mechanism of injury, clinical observation and reassessment may be sufficient. However, children with high-risk injuries or concerning clinical signs require immediate imaging and referral to a pediatric spine specialist.

Most pediatric cervical spine injuries can be treated conservatively, especially in cases of stable fractures or ligamentous injuries. Conservative management typically involves continued immobilization with a cervical collar for several weeks or months, along with physical therapy to restore strength and mobility. However, approximately 15% of pediatric CSI cases require surgical intervention, particularly in cases of unstable fractures, dislocations, or injuries that result in spinal cord compression.
Surgical options vary depending on the type and location of the injury but may include spinal fusion, decompression, or instrumentation to stabilize the spine. The decision to operate is guided by factors such as the patient's age, the severity of the injury, and the presence of neurological deficits.

The long-term prognosis for children with cervical spine injuries depends on several factors, including the severity of the injury, the timing of diagnosis, and the appropriateness of the treatment provided. Children who sustain complete spinal cord injuries typically face permanent disabilities, including paralysis. However, incomplete spinal cord injuries have a better prognosis in children than in adults, owing to the greater plasticity of the pediatric nervous system.

Children with mild to moderate injuries, such as stable fractures or soft tissue injuries, generally recover well with appropriate management. However, they may be at risk for developing chronic pain, stiffness, or post-traumatic deformities such as kyphosis. Regular follow-up with a pediatric spine specialist is essential to monitor the healing process and to detect any delayed complications.

Pediatric cervical spine injuries, although rare, represent a significant concern due to their potential for serious long-term consequences. Proper understanding of the unique anatomical and biomechanical factors in children is essential for accurately diagnosing and managing these injuries. While most cases can be managed conservatively, a small proportion of children require surgical intervention to prevent permanent neurological damage. Advances in clinical decision-making tools and imaging technology have improved the detection and treatment of pediatric CSI, but challenges remain, particularly regarding the judicious use of imaging in younger children. With timely intervention and appropriate follow-up, many children with CSI can achieve favorable outcomes.

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Bruises in Children

Bruising is one of the most common physical injuries observed in children, occurring frequently due to everyday activities. However, it is also a hallmark of child abuse, especially in younger children who are unable to communicate their experiences. Differentiating between accidental and abusive bruising is critical for clinicians and child welfare professionals. Although bruises from physical abuse often go unnoticed or are misinterpreted, accurate identification is essential for preventing further harm. This essay reviews the current understanding of bruising patterns in children, focusing on how to distinguish between accidental injuries and abuse, with an emphasis on recent developments in clinical guidelines and decision-making tools.

Bruising in children is a common result of physical activity, particularly in those who are mobile. A longitudinal study by Kemp et al. (2015) revealed that bruising increases with a child's mobility, with a marked difference between non-mobile infants and those who can crawl or walk. The study found that 45.6% of early mobile children had at least one bruise, while 78.8% of walking children presented with bruises. Bruises typically appear over bony prominences such as the shins, knees, and forehead. The study also noted that bruising was rare on soft tissues like the neck, buttocks, genitalia, and hands, areas where bruising is more concerning for abuse.

This research highlighted that bruising in pre-mobile infants is rare, and when present, warrants further investigation. Infants who are not yet rolling over rarely have bruises, and any bruising in these children should be considered suspicious. The study also emphasized that bruises tend to occur on the front of the body due to the natural tendencies of children to fall forward when they lose balance.

Bruising is the most common injury resulting from child abuse and is often the first visible sign of maltreatment. However, differentiating between accidental bruising and bruising caused by abuse can be challenging due to the general prevalence of bruising in children. Several studies have shown that abusive bruising tends to occur in non-bony areas, such as the torso, neck, and ears. These are fewer common sites for accidental bruises, especially in young, non-mobile children. Additionally, patterned bruises—those with distinct shapes or outlines that suggest the use of an object—are highly indicative of abuse and should raise immediate concern.

The presence of petechiae (small red or purple spots caused by bleeding into the skin) can also suggest a high-force impact, which is more consistent with abusive trauma. Another red flag for abuse is the presence of multiple bruises in various stages of healing, indicating repeated trauma. However, it is important to note that dating bruises based on their color is unreliable. A systematic review concluded that the color of a bruise cannot accurately determine its age. Clinicians should therefore refrain from using bruise color as a method for determining when an injury occurred, particularly in child protection cases.

Recent advances in clinical guidelines have aimed to assist healthcare providers in identifying bruises that may indicate child abuse. One of the most significant developments in this area is the TEN-4 FACESp clinical decision rule, developed by Pierce et al. (2021). This tool is designed to help clinicians assess whether bruising is more likely to be accidental or abusive, particularly in children under four years old.

The TEN-4 FACESp rule focuses on specific areas of the body: bruises on the torso, ears, neck, frenulum, angle of the jaw, cheeks, eyelids, and subconjunctiva are considered highly suspicious for abuse. Additionally, any bruising in an infant younger than five months, or any patterned bruising, raises concern. The rule has been validated with a sensitivity of 95.6% and a specificity of 87.1%, making it a reliable tool for clinicians.

Wood et al. (2015) also developed guidelines for performing skeletal surveys (SS) in young children with bruising. Skeletal surveys involve a series of radiographs used to detect occult fractures that may accompany bruises, particularly in cases of suspected abuse. These guidelines recommend performing an SS for children under six months of age with bruising, regardless of the location of the bruise. For older children, SS is recommended if bruising occurs on the cheek, ears, neck, upper arms, torso, or other less commonly bruised areas. The necessity of performing an SS decreases with age unless the bruises are in non-bony areas, which are more consistent with abuse.

Differentiating between accidental and abusive bruising involves a comprehensive evaluation of the child's developmental stage, bruise location, and the history provided by caregivers. Accidental bruises typically occur on bony areas of the body, such as the shins and knees, and are most commonly associated with everyday activities like falling or bumping into objects. In contrast, abusive bruising is more likely to occur on soft tissues or areas that are not prone to accidental contact, such as the back, buttocks, and neck.
Studies have shown that bruises from accidental injuries are typically singular or few in number. A study by Pierce (2017) indicated that most accidental bruises result from a single incident, with more than one bruise being relatively rare in typical accidents. Conversely, multiple bruises from a single event, especially if they are in various stages of healing, are more consistent with repeated trauma or abuse. Linear or patterned bruises, such as those caused by belts or hands, should also raise immediate suspicion.

Bruising is a common occurrence in children, particularly those who are mobile. However, it is also a sentinel injury in cases of child abuse. Differentiating between accidental and abusive bruising is a challenge that requires careful evaluation of bruise location, child development, and the history of the injury. Tools like the TEN-4 FACESp clinical decision rule provide valuable guidance to clinicians, helping to identify when bruising is more likely due to abuse rather than an accident. As research in this area continues, it is hoped that these tools and guidelines will become even more refined, allowing for earlier intervention and the prevention of further abuse in vulnerable children.

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Thoracoscopic Division Vascular Rings

Vascular rings are congenital anomalies of the aortic arch system, resulting in the formation of a complete or incomplete ring that compresses the trachea, esophagus, or both, causing symptoms such as dysphagia, respiratory distress, and chronic cough. Traditionally, these anomalies were treated through open thoracotomy, but advancements in thoracoscopic techniques have enabled less invasive interventions with promising outcomes.

Vascular rings are rare congenital anomalies resulting from aberrant development of the branchial arch arteries. The most common types of vascular rings include double aortic arches (DAA) and right aortic arch (RAA) with an aberrant left subclavian artery (LSCA) and ligamentum arteriosum. Symptoms typically arise in early childhood, although they can also present later, and may include airway compression leading to stridor and recurrent respiratory infections, or esophageal compression causing feeding difficulties and dysphagia.

Thoracoscopic surgery has been introduced as a minimally invasive alternative to the traditional open thoracotomy approach. The thoracoscopic method involves dividing the vascular structure responsible for the ring, typically the ligamentum arteriosum or the non-dominant aortic arch, through several small incisions under video guidance.

The initial reports on thoracoscopic division of vascular rings demonstrate favorable outcomes. One study reported one of the earliest experiences with thoracoscopic surgery in nine pediatric patients, all of whom were symptomatic prior to surgery. The study highlighted the safety and feasibility of the approach, noting no intraoperative complications and an average operative time of 107 minutes. Postoperatively, five patients experienced complete symptom resolution, while the rest showed significant improvement. The mean hospital stay was four days.

Another study reviewed three cases involving a complete vascular ring, where patients showed immediate recovery post-surgery. The median operative time was longer (180.5 minutes), and complications such as chylothorax and vocal cord palsy were noted but resolved without long-term effects. This study suggested that thoracoscopic division of vascular rings may provide faster recovery times compared to traditional thoracotomy.

Multiple studies have compared the thoracoscopic and open thoracotomy approaches for vascular ring division, highlighting key differences in operative time, recovery, and complication rates. One study compared outcomes in 200 pediatric patients who underwent either thoracoscopic or open surgery. Thoracoscopic surgery was associated with shorter hospital stays (1.2 days vs. 3.4 days) and fewer postoperative complications compared to thoracotomy. Both methods demonstrated excellent outcomes, with a freedom from reintervention rate of over 90% at 10 years.

Another study also observed a reduced incidence of chylothorax, and shorter intensive care unit (ICU) stays in the thoracoscopic group. The study found complete symptom resolution in 71% of patients who underwent thoracoscopic surgery, compared to 63% in the open group. Furthermore, the thoracoscopic approach showed an advantage in terms of postoperative pain management and cosmesis.

The standard thoracoscopic procedure involves placing the patient in a lateral decubitus position with single-lung ventilation to optimize visualization. Typically, three to four ports are inserted for instruments and the thoracoscope. Division of the vascular structure is usually achieved using vessel-sealing devices such as Ligasure or surgical staplers. Studies have emphasized the importance of careful preoperative imaging, often with computed tomography angiography (CTA), to precisely map the vascular anatomy and plan the surgery.

Another report described long-term outcomes following thoracoscopic division of vascular rings in pediatric patients, with a median follow-up of 95 months. The study found that 88% of patients experienced symptom improvement, while the need for reintervention was minimal. This study highlighted the safety and durability of thoracoscopic surgery, even when Kommerell’s diverticulum was left untreated.

Postoperative complications, though relatively rare, can include vocal cord paresis, chylothorax, pneumothorax, and recurrent nerve injury. In most cases, these complications are transient and resolve with conservative management. Studies emphasize the importance of meticulous dissection around the recurrent laryngeal nerve to avoid nerve damage. Another study noted that although complications like vocal cord paresis occurred in both thoracoscopic and open surgery groups, the overall complication rates were similar.

The need for chest tube placement after thoracoscopic surgery has diminished in recent years. One report noted that while earlier cases required chest tubes, later cases often did not, contributing to shorter hospital stays and faster recovery times.

Long-term follow-up data indicate that thoracoscopic division of vascular rings is highly effective in providing lasting symptom relief. One study reported that the vast majority of patients showed improvement in dysphagia and respiratory symptoms at a median follow-up of nearly eight years. The durability of symptom relief, even without resection of Kommerell’s diverticulum, was particularly notable.

Thoracoscopic division of vascular rings has proven to be a safe and effective alternative to traditional open thoracotomy. It offers several advantages, including shorter hospital stays, faster recovery, and fewer postoperative complications. While both techniques demonstrate high rates of long-term symptom relief, thoracoscopy provides additional benefits in terms of cosmesis and postoperative pain management. As surgical techniques and instruments continue to evolve, thoracoscopic vascular ring division is likely to become the preferred approach for treating this congenital anomaly.

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