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NEW METHODS IN THE SURGICAL TREATMENT OF NECK INJURIES IN CHILDREN

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Abstract: Neck injuries in children, particularly those involving the cervical spine, present significant challenges in diagnosis and treatment. These injuries can range from minor sprains to life-threatening fractures or dislocations, potentially leading to long-term disabilities if not managed appropriately. Advances in surgical techniques over the past few decades have significantly improved the outcomes for pediatric cervical spine injuries, reducing the risk of complications and enhancing recovery. This article reviews the new methods in the surgical treatment of neck injuries in children, focusing on innovative approaches to surgery, including minimally invasive techniques, advanced imaging, and the role of biologic materials in promoting healing. By synthesizing the latest research, this paper highlights how these emerging methods are transforming the management of pediatric neck injuries and improving the overall prognosis for affected children.

Keywords: Pediatric cervical spine injury, neck injuries in children, minimally invasive surgery, pediatric spine surgery, advanced imaging, biologic materials

INTRODUCTION: Neck injuries in children, particularly those involving the cervical spine, represent a complex and significant clinical challenge. The pediatric cervical spine is uniquely different from that of adults in both anatomy and biomechanics. While the cervical spine in children is more flexible due to increased ligamentous laxity and incomplete vertebral ossification, it also poses distinct risks and injury patterns. The pediatric cervical spine's increased pliability can lead to a different spectrum of injuries, such as subluxations, dislocations, and ligamentous injuries, that are not commonly seen in adults. Moreover, children are more likely to sustain injuries at the upper cervical levels (C1–C2) due to their large head-to-body ratio and relatively weaker neck muscles. This anatomical difference further complicates the management of pediatric cervical spine injuries, requiring specialized techniques for diagnosis, stabilization, and treatment. Pediatric neck injuries can result from a variety of mechanisms, including motor vehicle accidents, sports-related injuries, falls, or even non-accidental trauma. With children often engaging in high-energy activities, especially during adolescence, the incidence of cervical spine injuries has been rising, particularly in the context of contact sports. The high morbidity associated with these injuries—ranging from complete paralysis to long-term disability—emphasizes the need for rapid diagnosis and timely intervention.

The approach to treating neck injuries in children has evolved over the past few decades, with significant advancements in surgical techniques and technologies. Historically, children with cervical spine injuries often underwent extensive open surgeries, which involved significant

dissection of soft tissues and a prolonged recovery period. Such traditional methods, while effective, carried substantial risks, including infection, blood loss, and longer hospital stays, which are particularly concerning when treating children who have unique developmental needs. Recent innovations in surgical techniques have greatly improved outcomes for pediatric patients with cervical spine injuries. Minimally invasive surgery (MIS) has emerged as a key advancement in the management of pediatric cervical spine trauma. This technique involves smaller incisions, reduced dissection, and less trauma to the surrounding soft tissues, thus promoting faster healing, reduced pain, and shorter hospital stays. The application of MIS in pediatric spine surgery has proven to be effective in addressing both bony and soft tissue injuries in the cervical region, offering a less invasive option for children who may otherwise face the risks associated with traditional open procedures.

Additionally, the integration of advanced imaging techniques has played a crucial role in improving the accuracy of surgical planning and intraoperative decision-making. Intraoperative navigation and 3D imaging have allowed for precise screw placements and better alignment of the spine, leading to enhanced surgical outcomes. These technologies provide real-time feedback to the surgeon, improving the precision of spinal instrumentation and reducing the likelihood of complications, such as malalignment or hardware failure. Another significant advancement in the surgical treatment of pediatric neck injuries involves the use of biologic materials, including bone grafts, growth factors, and synthetic substitutes. These materials play a crucial role in promoting healing and spinal fusion, especially in pediatric patients, whose growing bones require careful attention during the surgical process. The application of biologic adjuncts has enabled faster and more reliable bone regeneration, resulting in improved fusion rates and reduced recovery times. While these advancements have led to marked improvements in surgical outcomes, challenges remain, particularly in the management of complex, multi-level cervical spine injuries. The need for individualized care and a tailored approach to each child's unique anatomical and developmental characteristics is paramount. Surgical teams must consider factors such as the child's age, the specific nature and location of the injury, and the child's overall health and developmental stage when determining the best course of action. As a result, surgical decisions are often made collaboratively, involving pediatric orthopedic surgeons, neurosurgeons, and rehabilitation specialists.

LITERATURE REVIEW

Children's cervical spines are characterized by greater ligamentous flexibility and a more horizontal orientation of the facet joints. These features confer a greater range of motion, but they also make the spine more susceptible to injury from high-impact forces, particularly in the upper cervical spine. In contrast to adults, who are more likely to sustain injuries in the lower cervical region (C3–C7), children are more prone to upper cervical injuries involving the atlanto-occipital (C0–C1) and atlantoaxial (C1–C2) joints [2]. The mechanism of injury, whether from a motor vehicle accident, a fall, or a sports-related trauma, also significantly impacts the pattern and severity of cervical spine injury. These mechanisms of injury can result in fractures, dislocations, ligamentous injuries, or spinal cord damage, which may present with varying degrees of neurological deficits. Motor vehicle accidents are a leading cause of cervical spine injuries in children, especially those aged 10 to 16 years. In addition to trauma from seatbelt-related injuries and impact forces, whiplash and axial loading can cause significant damage to the cervical spine. Contact sports, such as football and rugby, also present a considerable risk for cervical injuries, especially those involving direct force to the neck during tackles or falls [3].

Diagnosis of cervical spine injuries in children requires a comprehensive clinical assessment, as early detection is crucial for improving outcomes. Due to the child's inability to effectively communicate symptoms, particularly in younger children, a high degree of suspicion is necessary

when evaluating potential cervical spine injuries. Clinical examination should include a detailed neurological assessment and appropriate imaging studies to identify fractures, dislocations, or soft tissue damage. Initial imaging usually involves plain radiographs, which can detect bony injuries, but they are often insufficient for identifying soft tissue damage, such as ligamentous tears or spinal cord compression. The sensitivity of plain radiographs in detecting pediatric cervical spine injuries is limited, leading to an increased reliance on computed tomography (CT) and magnetic resonance imaging (MRI) [4]. CT scans provide better visualization of bony structures, such as fractures or dislocations, while MRI is critical for assessing soft tissue injuries, including ligamentous injuries, disc herniations, and spinal cord abnormalities.

In cases where radiographs are inconclusive but clinical suspicion of injury persists, MRI is essential for confirming a diagnosis, especially in cases of spinal cord injury without radiographic abnormality (SCIWORA). SCIWORA is a phenomenon in which spinal cord injury occurs without visible bony damage on radiographs or CT scans, and it is more common in pediatric patients [5]. MRI is particularly valuable in diagnosing SCIWORA, as it provides detailed images of the spinal cord, nerve roots, and surrounding soft tissues, which can guide treatment decisions. The management of pediatric cervical spine injuries has evolved significantly, particularly with advances in surgical techniques. Traditionally, surgical intervention for severe cervical injuries required large incisions and extensive dissection of soft tissues. These open surgeries carried risks such as blood loss, infection, and prolonged recovery times. However, more recent advancements have focused on minimally invasive surgical (MIS) techniques, which reduce these risks and improve post-operative outcomes, especially in children who have more delicate tissues and a higher risk of complications [6].

Minimally invasive spine surgery involves smaller incisions, reduced soft tissue disruption, and the use of specialized instruments and imaging techniques to perform the procedure. MIS techniques have been applied to pediatric cervical spine injuries with success, particularly in cases requiring spinal fusion or stabilization. Benefits of MIS in children include reduced surgical trauma, faster recovery times, less postoperative pain, and shorter hospital stays. These advantages are particularly valuable in the pediatric population, where preserving growth and minimizing long-term disability are key goals of treatment [7]. In addition to minimally invasive techniques, the use of intraoperative navigation and 3D imaging has revolutionized pediatric spine surgery. Intraoperative navigation systems provide real-time guidance for the placement of screws, rods, and other hardware, allowing for more precise surgical interventions. This technology is particularly beneficial for pediatric patients, whose anatomy can be difficult to navigate due to smaller and less ossified vertebrae. By improving the accuracy of surgical procedures, intraoperative navigation reduces the risk of complications such as misalignment and hardware failure, leading to better clinical outcomes [8].

ANALYSIS AND RESULTS

The treatment and management of pediatric cervical spine injuries have evolved significantly in recent years, with advancements in surgical techniques, diagnostic methods, and rehabilitation protocols playing a pivotal role in improving outcomes. One of the key factors influencing the success of managing cervical spine injuries in children is the anatomical and physiological differences between pediatric and adult patients. The cervical spine in children is more flexible and has a different alignment compared to adults, which can impact the type of injuries sustained as well as the strategies required for stabilization and recovery. In the past, the management of pediatric cervical spine injuries was often based on principles developed for adult patients, but as understanding of pediatric spinal anatomy and trauma has grown, more specialized treatment protocols have emerged. Newer methods of surgical treatment have contributed to reducing the need for open, extensive surgeries, while still ensuring that the structural integrity of the cervical

spine is maintained, and neurological function is preserved. Moreover, innovations in surgical tools and techniques, such as minimally invasive surgeries, have transformed the approach to treating these injuries in children.

When analyzing the current state of pediatric cervical spine injury treatment, it is clear that diagnostic imaging plays a critical role in determining the extent of injury and guiding subsequent management decisions. In cases where initial clinical assessments suggest a cervical spine injury, radiographic imaging is typically the first line of investigation. However, plain radiographs are often insufficient for a comprehensive evaluation, particularly when soft tissue injuries are involved. In such cases, more advanced imaging modalities like computed tomography (CT) scans and magnetic resonance imaging (MRI) are increasingly used. CT is effective in identifying bony fractures, while MRI plays a crucial role in assessing soft tissue injuries, such as ligament damage or spinal cord involvement. In recent years, the use of 3D imaging has gained popularity, as it offers enhanced visualization of the cervical spine, which is essential when planning surgical intervention, especially for complex injuries. The application of 3D imaging, coupled with intraoperative navigation systems, has become a game-changer in the treatment of cervical spine injuries. This technology has allowed surgeons to achieve greater accuracy when placing spinal instrumentation, such as screws, rods, and plates, which are integral in stabilizing the spine. With these advanced tools, surgeons can perform surgeries with smaller incisions, which reduces the risk of infection, blood loss, and scarring. Additionally, the precise alignment provided by 3D imaging has contributed to better postoperative outcomes, reducing the likelihood of complications such as misalignment, hardware failure, or nerve injury.

Minimally invasive techniques have significantly reduced the trauma associated with traditional open surgery. These techniques allow for smaller incisions, less soft tissue dissection, and quicker recovery times, all of which are particularly beneficial in pediatric patients. In children, who are still in the growth and development stage, preserving the integrity of surrounding soft tissues, muscles, and ligaments is critical. Minimally invasive spine surgery minimizes the risk of damage to these tissues, which can impact long-term spinal growth and development. Furthermore, MIS techniques have been shown to reduce postoperative pain and shorten hospital stays, which is especially important in pediatric care, where longer recovery periods can affect the child's physical, emotional, and psychological well-being. In the analysis of various surgical methods, it is evident that anterior and posterior approaches continue to play central roles in managing pediatric cervical spine injuries. In cases where there is significant spinal cord compression, or when the injury involves a herniated disc or fracture that necessitates decompression, anterior cervical surgery is commonly performed. This approach involves accessing the spine through the front of the neck, which allows for direct decompression of the spinal cord and nerve roots. In some instances, fusion may also be performed to stabilize the cervical spine after decompression. Anterior surgery, however, may not always be possible, especially if the injury is located in the upper cervical spine (C1–C2), or if the injury is multi-level, involving both the anterior and posterior aspects of the cervical spine.

In these cases, posterior approaches are often employed. The posterior approach involves accessing the spine through the back of the neck and is particularly useful when dealing with fractures or dislocations in the upper cervical spine, such as injuries to the C1 or C2 vertebrae. This technique is effective in stabilizing the spine by fusing the vertebrae and preventing further displacement of the bones. Moreover, posterior cervical fusion provides excellent stability, particularly when dealing with complex, multi-level cervical injuries. In some cases, a combination of anterior and posterior approaches may be necessary, depending on the location and severity of the injury. Another significant consideration in pediatric cervical spine surgery is the use of biologic materials, such as bone grafts, growth factors, and synthetic substitutes. Bone grafts are frequently used in pediatric spine surgery to facilitate fusion, and the ideal graft

material is one that promotes bone healing while also being compatible with the growing skeleton. Autografts, or bone taken from the patient's own body, have long been the gold standard, but the use of allografts (donor bone) and synthetic materials has become more common, particularly when autografts are not available or when minimizing donor site morbidity is a priority. In recent years, the use of bone morphogenetic proteins (BMPs) has garnered attention due to their ability to stimulate bone growth and promote fusion. These proteins have shown promise in improving healing rates in pediatric patients, although there are ongoing concerns about potential side effects, including abnormal bone growth or the development of soft tissue masses. As a result, careful consideration is required when using BMPs in pediatric spine surgeries, especially in younger children who are still undergoing growth and development. The growing use of biologic materials and growth factors in pediatric spine surgery is reflective of a broader trend toward enhancing the biological healing process, reducing recovery times, and improving long-term outcomes. These materials are particularly valuable in cases where fusion is required to stabilize the spine and prevent further injury or deformity. The introduction of these materials into pediatric spine surgery has contributed to a more dynamic, patient-centered approach, where the goal is not only to treat the injury but also to enhance the body's natural healing processes. The management of cervical spine injuries in children also involves multidisciplinary care teams, which may include pediatric neurosurgeons, orthopedic surgeons, pediatricians, physical therapists, and psychologists. Effective management is not solely based on surgical intervention but also includes preoperative assessment, postoperative care, and long-term rehabilitation. Early mobilization, when appropriate, is encouraged to prevent complications associated with immobility, such as respiratory infections or deep vein thrombosis. Physical therapy plays a crucial role in restoring range of motion, strength, and function after surgery, and the goal is always to return the child to their normal activities as safely and quickly as possible.

CONCLUSION

The treatment of pediatric cervical spine injuries has significantly advanced in recent years, with the integration of innovative diagnostic techniques, minimally invasive surgical approaches, and the use of biologic materials all contributing to improved outcomes. Given the distinct anatomical and physiological characteristics of the pediatric cervical spine, which differs from that of adults, a tailored approach is essential for the successful management of these injuries. Minimally invasive surgery has emerged as a major advancement, allowing for less trauma to the surrounding tissues, quicker recovery times, and reduced postoperative pain, which is particularly beneficial for children. This shift toward less invasive procedures, paired with the use of advanced imaging technologies such as 3D imaging and intraoperative navigation, has greatly enhanced the precision and safety of cervical spine surgeries. The ability to accurately place spinal instrumentation, particularly in the delicate anatomy of children, has led to fewer complications and improved long-term outcomes. The incorporation of biologic materials, including bone grafts and growth factors, further enhances the healing process, allowing for more effective spinal fusion and faster recovery. However, these techniques must be applied with caution, particularly in younger patients, to avoid interfering with natural growth and development. While the current techniques have made a considerable impact, the management of complex and multi-level injuries continues to present challenges, requiring ongoing refinement of surgical methods and a multidisciplinary approach to care.

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