Operative management of traumatic cervical spine distraction and complete cord transection in a 3-year-old patient

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This report describes the presentation and operative treatment of a 3-year-old boy who survived a motor vehicle accident that resulted in a C6–7 distraction injury, complete avulsion of the spinal cord, and gross spinal instability. Only 5%–10% of all spinal cord and vertebral column injuries occur in children. Survival after such an injury is exceptionally rare in very young patients and is associated with severe neurological deficits. The authors discuss the substantial ethical challenges involved in the care of a patient with this injury. To their knowledge, only two other cases of survival have been reported in pediatric patients following motor vehicle trauma resulting in complete injury to the lower cervical spinal cord.

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KEY WORDS complete cord injury; cervical distraction; complete cord transection; traumatic spine injury; surgical management; cervical fusion; trauma

Case Report

History and Examination

The patient, a previously healthy 3-year-old boy, had partially freed himself from the upper harnesses of the 5-point restraint of his forward-facing car seat in the rear driver side position. The vehicle was traveling at approximately 40 miles per hour. While attempting to re-secure the child, the driver veered the vehicle into a stopped bus. Still partially restrained, the boy remained in his car seat and was not ejected during the collision.

He was pulseless at the scene and received approximately 2 minutes of cardiopulmonary resuscitation. Upon arrival to the emergency department, his Glasgow Coma Scale score was 3. On physical examination, he had a large forehead laceration, responsive pupils, abrasions and bruising of the abdomen, and priapism. Chest radiography revealed a 2.7-cm distraction injury at C6–7 (Fig. 1). Com-

ABBREVIATIONS BSAER = brainstem auditory evoked response; SSEP = somatosensory evoked potential; tcMEP = transcranial motor evoked potential.


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Computed tomography angiography demonstrated that the vertebral artery injuries were limited to a blunt cerebrovascular injury Grade 2 injury of the left V₁ segment and Grade 1–2 injury of the right V₁ segment (Fig. 2).³⁴ There was also a Grade 1 injury of the bilateral proximal internal carotid arteries. The patient was placed in halo-vest fixation without attempting to reduce the distraction, while we determined the full extent of his injuries and established the goals of care with his family. Magnetic resonance imaging confirmed complete transection of the cervical cord and edema in the spinal cord extending into the medulla (Fig. 3). There was no evidence of upper cervical bony or ligamentous injury requiring stabilization. Magnetic resonance imaging of the brain demonstrated only a small left cerebellar infarct as well as small amounts of intraventricular blood and scattered, thin subarachnoid hemorrhage. Electroencephalography demonstrated diffuse slowing, no epileptiform discharges, and mild hemispheric asymmetry.

During the initial 48 hours of the patient’s hospitalization, we described the severity and irreversibility of his neurological compromise to his parents. The discussion included our belief that, should he survive his acute injury, he would remain quadriplegic and ventilator dependent for the duration of his life. He would also require a multitude of surgical procedures, endure considerable psychological and physical insults, and potentially harbor substantial resentment regarding his quality of life. His parents very much wished to proceed with aggressive therapy, and with the input of the critical care service, we agreed to assess his clinical progress over a period of 48–72 hours. During this period, his cognitive function improved substantially. He began responding appropriately to verbal commands, and by hospital Day 6, he was communicating through facial expressions and blinking. Prior to initiating medical interventions that were more than supportive, we undertook two multidisciplinary care conferences, which included each of the clinical services involved in the patient’s care. Despite the exceptionally grim prognosis and our concerns regarding the probable clinical course, the boy’s parents felt very strongly that given his cognitive sta-
In this context, we agreed to pursue surgical intervention to support activities of daily living and minimize deformity. We did not request an ethics consultation.

**Closed Reduction With Neurophysiological Monitoring**

In an effort to reduce the distraction and assess the potential for associated vascular compromise, the patient underwent closed reduction under neurophysiological monitoring on hospital Day 8. Under fluoroscopic guidance, the halo ring was loosened from the rods and gentle reduction was undertaken, followed by re-securing of the halo ring. With approximately 50% reduction of the C6–7 distraction, there were transient and slight decreases in the amplitudes of the brainstem auditory evoked responses (BSAERs). Fluoroscopy, however, demonstrated almost immediate regression of the C6–7 distraction to approximately 3 cm.

**Anterior Procedure**

On hospital Day 16, the patient underwent anterior instrumented fusion at C6–7, followed by posterior instrumented fusion from C-5 to T-2. The supine patient was secured on the operating table using the halo ring. Neurophysiological monitoring was used to evaluate brainstem function. Monitoring included BSAERs, transcranial motor evoked potentials (tcMEPs), and somatosensory evoked potentials (SSEPs), and its primary purpose was the evaluation of BSAERs during the reduction. We were concerned that rapid reduction of the injury could lead to the occlusion of major cervical arteries, which could manifest as a precipitous decrease in the amplitude or increase in the latency of these signals. In such a scenario, we would consider fusion without reduction, recognizing that the risk of fusion failure would be elevated. As expected, no tcMEPs or SSEPs were obtained. Rib autograft was obtained using standard techniques. A longitudinal anterior cervical incision and standard approach revealed the severely distracted C6–7 interspace with dural avulsion evidenced by CSF leakage. The C-6 segment was substantially retrolisthesed relative to C-7. The intervertebral disc was removed from the C-7 vertebral body. Reduction required the assistance of nursing staff translating the torso superiorly, toward the fixed skull. The C6–7 interspace could be reduced to approximately 7 mm, but this was lost with the release of upward force on the patient’s torso. An appropriately sized fibular strut allograft was fashioned. A 16-mm Vectra-One anterior cervical plate (Synthes Inc.) was secured to the C-7 vertebral body. The fibular strut graft was held in position while the reduction was again achieved. At this point, the C-6 screw was placed. On two occasions, C-6 screw pull-out resulted when the patient’s torso was released. With the third attempt, the C-6 screw was positioned at the junction of the C-6 superior endplate and C5–6 disc space, and reduction was maintained (Fig. 4).

**Posterior Procedure**

The patient was turned prone, and we verified with fluoroscopy that the anterior construct remained stable. Through a significantly widened C6–7 interlaminar space, we identified dural avulsion and spinal cord transection.

Using a freehand technique, we placed 4.5-mm pedicle screws bilaterally at T-1 and T-2. During this process, the transected spinal cord herniated posteriorly, consistent with interbody graft displacement. This was fluoroscopically verified (Fig. 5). The graft was removed, providing visualization of the C6–7 interbody space and anterior

![FIG. 4. Intraoperative lateral fluoroscopic image demonstrating reduction of the injury with good position of an interbody graft and anterior cervical plate. The superior screw is positioned at the junction of the C-6 superior endplate and C5–6 disc space.](image)

![FIG. 5. Intraoperative lateral fluoroscopic image demonstrating posterior displacement of the interbody graft into the spinal canal during placement of the posterior instrumentation. As a result of the traumatic spinal cord transection, the graft was removed posteriorly without additional neurological injury.](image)
cervical plate. The avulsed portion of the spinal cord herniating posteriorly was cut sharply and discarded. A portion of the rib autograft was morselized, mixed with de-mineralized bone matrix putty, and packed into the C6–7 interspace and spinal canal at that level. We positioned 4.0-mm screws in the C-6 lateral masses and the left C-5 lateral mass. We could not position a screw in the right C-5 lateral mass; therefore, a sublaminar wire was used. Following standard decortication, the rib autograft was secured between the 4.0-mm titanium rods using sutures.

Postoperative Course
The patient was maintained in halo-vest immobilization for 6 months postoperatively. Computed tomography studies at that point demonstrated fusion (Fig. 6). At 22 months after surgery, the patient remained neurologically unchanged.

Discussion
Survival after complete lower cervical spinal cord injury is uncommon among pediatric patients. Ramrattan and colleagues reviewed the case of a 15-month-old patient who had been treated with anteroposterior fusion following a complete discoligamentous disruption at C6–7. The patient had not presented with significant distraction, and initial imaging was read as normal. The injury was identified following a detailed neurological examination and MRI. Matsumoto and colleagues reported their experience with an 18-month-old girl who had survived following a complete discoligamentous disruption with cervical spinal cord transection at C5–6. She had also suffered bilateral vertebral artery injury and had probably survived as a result of collateral circulation through the circle of Willis.

In our case, the patient presented with a dramatic distraction injury. He probably survived the initial trauma because the injury occurred at C6–7, where the vertebral arteries were not tethered within the bony vertebral canals and could therefore stretch without avulsing. Thus, despite his catastrophic spinal cord injury, the boy did not suffer a fatal brainstem infarct or cervical hemorrhage. The debilitating, yet nonlethal, nature of his injury presented complex ethical challenges for his family and caregivers. These played a large part in delaying definitive surgical stabilization. The decision to proceed with aggressive management was influenced greatly by the consistent cognitive improvements the patient exhibited during the days following his injury. As described above, the clinical services agreed to undertake an aggressive management course only after a series of in-depth discussions and multidisciplinary care conferences with the patient’s parents. While we believed that an ethics consultation was reasonable, we also believed that honoring their consistent and unified preference for aggressive management was most in keeping with current principles of ethical patient care.

While there is little formal literature regarding the role of ethical parameters in decision making for children with severe spinal cord injuries, the American Medical Association Code of Medical Ethics states that the decision of a family member regarding the care of a patient who is not competent to make his or her own medical decisions should generally be accepted by physicians, with the exception of 4 circumstances: “1) there is no available family member willing to be the patient’s surrogate decision maker; 2) there is a dispute among family members and there is no decision maker designated in an advance directive; 3) a health care provider believes that the family’s decision is clearly not what the patient would have decided if competent; and 4) a health care provider believes that the decision is not a decision that could reasonably be judged to be in the patient’s best interests.” In such cases, an ethics committee review is often requested prior to turning to the legal system for resolution, if necessary. In our case, there was no dispute among the patient’s family members. While the treating services harbored substantial misgivings, the decision to treat could be reasonably judged to be in the child’s best interests. Given these circumstances and despite the treating teams’ concerns regarding the long-term prognosis, we elected to proceed without a formal ethics consultation.

Once the decision to perform operative reduction and stabilization was made, we elected to conduct the anterior portion of the procedure before the posterior. This decision was made given concerns that disectomy and graft placement may be made more complex following reduction and posterior instrumentation. However, the stronger bone purchase of the posterior instrumentation could have facilitated reduction without substantially compromising the goals of the anterior approach. The posterior dislodge-
ment of the interbody graft may have been less likely, and
the position of the anterior screws may have been more
favorable had alignment been established prior to the an-
terior portion of the procedure. Alternatively, identification
and retrieval of a displaced interbody graft could have been
more complicated with a posterior followed by an anterior
approach.

During the 15 days between the boy’s injury and definitive
surgery, he was managed in a halo vest. An attempt to
maintain some element of reduction using the halo vest
was unsuccessful. Multiple groups describe the successful
use of halo-vest fixation following pediatric subaxial cervi-
cal spine injury.32 However, recent guidelines aptly sum-
marize the challenges associated with pediatric cervical
spine immobilization, and this case emphasizes the limits
of halo fixation in the context of highly unstable distraction
injuries.18,31,33

Our patient faces significant medical challenges as he
ages. Comorbidities, such as neurogenic bowel and bladder,
pressure ulcers, thrombotic events, and ventilator-assoc-
iated pneumonia, are frequent sequela of spinal cord
injury.29,24,28,29 Pediatric patients bear particular risk for
global spine instability.14,20,22 Neuromuscular scoliosis is
expected to develop in nearly all children with cervical
spinal cord injuries, making spine alignment a unique con-
sideration.14,20,22,23 Treatment implications are especially
difficult for very young children who are at significant risk
for pulmonary complications and high mortality if early
thoracic posterior spine fusion is performed.15,19,30 Allow-
ing the deformity to grow unchecked, however, places the
child at risk for the development of thoracic insufficiency
syndrome.6–8

For these reasons, continued monitoring for spinal de-
formity will be a mandatory component of follow-up for
our patient. Bracing and growth-sparing spinal surgery
may become necessary if severe scoliosis develops be-
fore adequate pulmonary function for adulthood has been
achieved. His care is currently coordinated in a multidis-
ciplinary clinic for children with myelomingingocele and
other spinal defects.

Conclusions

To our knowledge, this patient represents the third re-
ported case of the survival of a pediatric patient following
lower cervical spinal cord avulsion from a motor vehicle
accident.23,30 Surgical management of his case was under-
taken as a consequence of the specific anatomical charac-
teristics of the injury, specifically, the lack of damage to the
large cervical arteries and brain. This case offers valu-
able learning points regarding the management of severe
pediatric cervical spine injury.

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