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TECHNICAL NOTE

PATHOLOGY/BIOLOGY

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A Novel Method for Removing a Spinal Cord with Attached Cervical Ganglia from a Pediatric Decedent*

ABSTRACT: A diagnosis of child abuse is dependent on a comprehensive and accurate assessment of injury in the context of a thorough investigation. However, signatures of trauma are often subtle and interpretation can be very difficult. Recently, researchers have refocused their attention from the head to the neck in search of traumatic signatures of abusive head trauma. HCIFS has developed a technique to remove the cervical spinal cord with the ganglia attached that is less destructive and more time and cost efficient than alternative methods previously published. Once removed, the dorsal nerve roots and ganglia are evaluated for the presence of hemorrhage. The authors performed a small pilot study using the novel method to evaluate 20 decedents with a history of blunt force trauma and eight without a traumatic history. Fifteen of the traumatic deaths and two of the nontraumatic deaths were found to have dorsal nerve root and/or ganglia hemorrhage.

KEYWORDS: forensic science, forensic pathology, blunt force trauma, child abuse, spinal cord, cervical ganglion

A diagnosis of child abuse is dependent on a comprehensive and accurate assessment of injury in the context of a thorough investigation. However, signatures of trauma are often subtle, especially in young children, and when recognized, interpretation of trauma can be very difficult. In no case is this sentiment more applicable than with blunt head trauma. The triad of anoxic encephalopathy, retinal hemorrhage, and subdural hemorrhage has, in some literature, been associated with the so-called shaken baby syndrome (SBS). Yet, these findings are not exclusive to violent shaking and the very existence of the diagnosis has become controversial. Moreover, even the traumatic etiology of subdural hemorrhage, retinal hemorrhage, and brain swelling has been questioned. As a result, researchers in child abuse must identify anatomic markers associated with abusive head injury and delineate the relationship between the markers and injury mechanism.

Recently, the investigation of injuries associated with abusive head injury has been redirected from intracranial injury to cervical injury. For example, Geddes et al. (1) evaluated the neuropathology of 53 cases of abusive head trauma. The majority of the cases they examined did not demonstrate traumatic brain damage, yet one-third of the cases demonstrated evidence of stretch injury within the craniocervical region. The authors hypothesized that the majority of the clinical picture of SBS, that is, apnea, global hypoxia, and secondary brain swelling, could be caused by the hyperflexion/hyperextension of the neck during violent shaking. In 2005, Downs developed a method to access the cervical and thoracic nerve roots during autopsy (2). The technique required the internal detachment and extraction of the cervical and thoracic vertebrae with the surrounding soft tissue and posterior region of the ribs. The technique allowed examination of the spinal cord structures including nerve roots, paravertebral soft tissue, and posterior regions of the ribs. He used the technique in five cases of abusive head injury and found intraparenchymal hemorrhage within the dorsal root ganglia in all cases.

Matshes et al. (3), restricting Downs' *en bloc* method to the cervical region, examined the 3rd, 4th, and 5th cervical nerve roots extracted from 35 decedents with an average age 6 months. The researchers removed the entire cervical spinal column including the spinal cord, vertebrae, intervertebral disks, neurovascular structures, and adjacent soft tissue. The specimens were formalin-fixed, decalcified, dissected, and microscopically examined. Twelve (34%) of the decedents were suspected victims of hyperextension/hyperflexion of the neck, 21 (60%) died from nontraumatic causes, and two (6%) died from abdominal trauma. All of the cases suspicious for hyperflexion/hyperextension were positive for nerve root hemorrhage. Nerve damage was identified in two cases that were not suspicious for hyperflexion/hyperextension; however, one case had a possible traumatic event prior to death and was classified as undetermined cause and manner of death. Matshes et al. (3) theorized that the injury to the nerve roots disrupts the diaphragm, greatly compromising respiration, and ultimately causing death.

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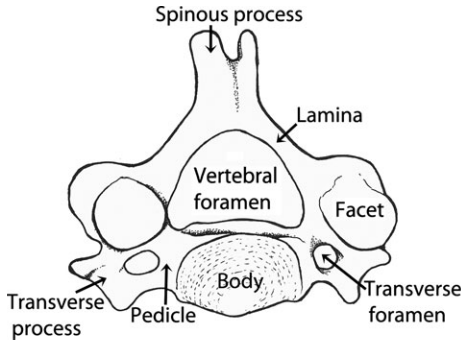

FIG. 1—*Anatomical diagram of a cervical vertebra with landmarks labeled.*

The Mashes et al. (3) technique to remove the spinal cord is invasive as well as labor and time intensive. The Harris County Institute of Forensic Sciences (HCIFS) has developed an extraction method that provides access to the complete spinal cord with the attached ganglia and is less invasive and time intensive. The goal of this technical report is to present the novel technique for spinal cord removal and to illustrate its value through a small pilot study of cervical nerve root and dorsal root ganglia hemorrhage.

Materials and Methods

Successful removal of the spinal cord with the nerve roots and dorsal root ganglia attached begins with a full understanding of the vertebral structure (Fig. 1). The vertebrae can be visualized in three columns: anterior column, lateral column, and posterior column. The anterior column consists of the vertebral body. The lateral column consists of the right and left pedicles, the transverse foramina in the cervical vertebrae, and transverse process in the thoracic and lumbar vertebrae and the superior and inferior articular facets. The posterior column consists of the right and left laminae and spinous process. In the cervical and upper thoracic regions, the dorsal root ganglia lie in between the pedicles and immediately anterior to the overlapping facets. In the mid and lower thoracic and lumbar regions, the ganglia are within the vertebral foramen. To access the cervical and upper thoracic ganglia, they must be "unroofed" by removing the posterior column at the level of the pedicle.

To remove the spinal cord with the nerve roots and dorsal root ganglia attached while maintaining the integrity of the decedent's neck, the following steps are taken. First, reflect the musculature from the vertebral spinous processes and laminae to visualize the bony landmarks (Fig. 2). Second, perform a laminectomy of the complete vertebral column (Fig. 3). The laminectomy is performed with a standard autopsy oscillating saw such as a Stryker saw (Mopec, Oak Park, MI). Next, cut the overlaying articular facets of each vertebra, bilaterally (Fig. 4). Third, cut each pedicle and retract the freed segment of bone (Fig. 5). The articular facets and pedicles can be cut with a manual clipper such as a coral cutter (Ocean Wonders 6 inch Stony Coral Bone Cutter, Decorah, IA). Fourth, cut the nerve lateral to the ganglion and free the ganglion from the surrounding soft tissue (Fig. 6). Finally, remove the complete spinal cord, from the level of the brain stem to the cauda equina (Fig. 7). Freeing the ganglia and removing the spinal cord is performed using a standard scalpel blade. Once removed, fix the spinal cord in 10% formalin; then, section and stain following standard histological protocol.

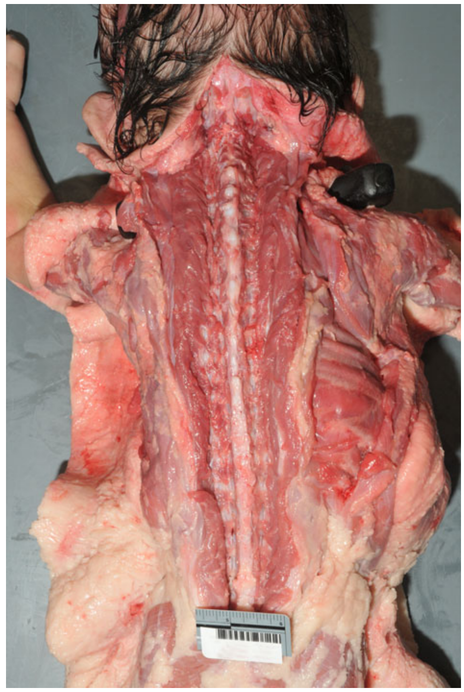

FIG. 2—*Exposed spinous processes of a pediatric decedent.*

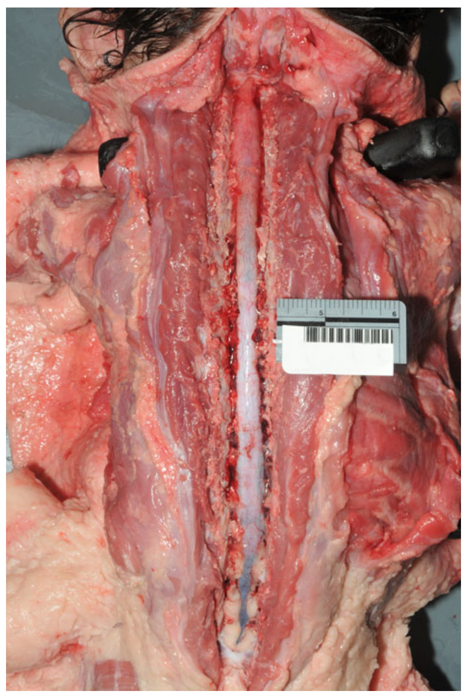

FIG. 3—*Exposed spinal cord following a laminectomy of the complete vertebral column.*

For the pilot study, spinal cords were removed following the presented technique during pediatric autopsies as part of the standard autopsy protocol over a 2-year period. All retained cervical nerve root ganglia obtained for each case were sectioned and stained following standard H&E protocol. Each section of the spinal cord was examined using a light microscope

FIG. 4—*The image shows the positioning of the cutting instrument to cut the overlaying facets of two vertebrae.*

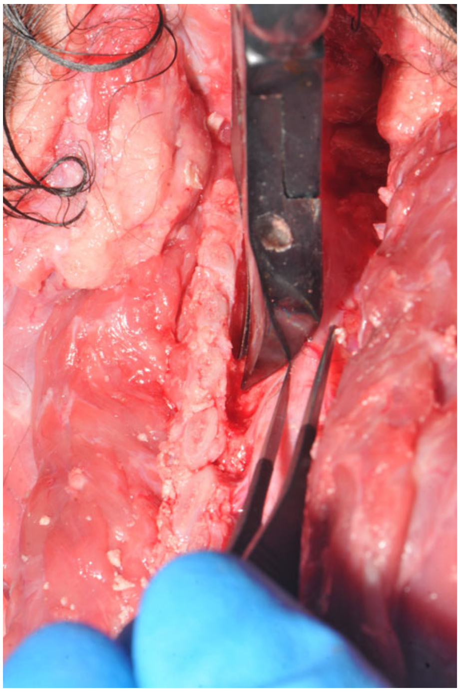

FIG. 5—*The image shows the positioning of the cutting instrument to cut the pedicle.*

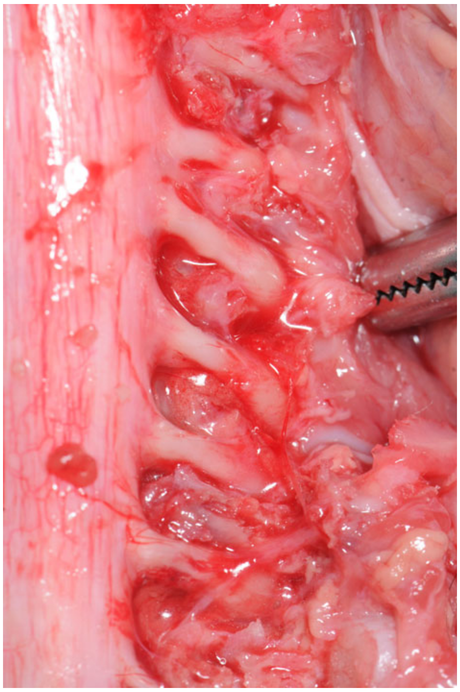

FIG. 6—*Exposed nerve roots and ganglia.*

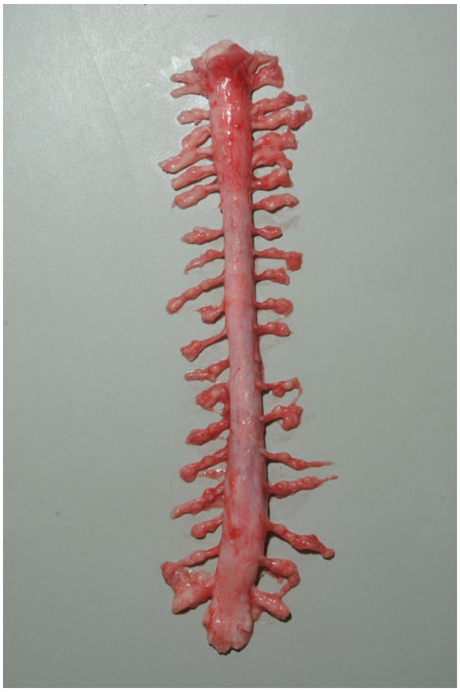

FIG. 7—*Removed spinal cord with attached ganglia.*

(Olympus BX41, Melville, NY, USA). Each dorsal root ganglion and nerve root was scored for absence or presence of intraparenchymal hemorrhage. The total number of ganglia and nerve roots for each case as well as the number positive for hemorrhage were counted. All cases with an undetermined cause and manner of death were excluded from the study. In addition, cases without at least four cervical ganglia available for examination were excluded.

Results

A total of 28 cases were included in the study, 17 males and 11 females. The ages ranged from 1 month to 2 years, with a median age of 5 months. The cause of death was classified as blunt force trauma for 20 of the cases (experimental group); the cause of death was nontraumatic for eight of the cases (control group) (Table 1). Cervical nerve root and/or ganglion

TABLE 1—*Causes of death of the study population.*

Cause of Death	Number of Decedents
Blunt force trauma	20
Co-sleeping	5
Acute pneumonia	1
SIDS	1
Complications of Walker–Warburg syndrome (congenital cerebro-ocular dysplasia with muscular dystrophy)	1

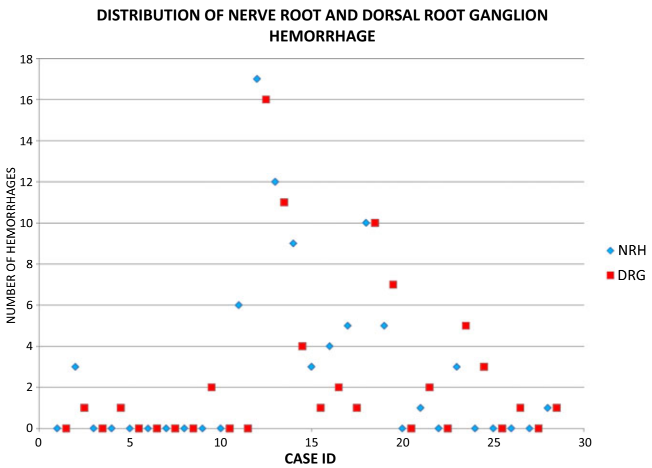

FIG. 8—*A scatter plot of the number of cervical dorsal root ganglia (DRG) and nerve root (NRH) positive for hemorrhage.*

TABLE 2—*Average number of nerve roots and dorsal root ganglia with hemorrhage.*

	Average (Range)
Control group NRH*	0.375 (0–3)
Experimental group NRH	3.8 (0–17)
Control group DRG†	0.25 (0–1)
Experimental group DRG	3.3 (0–16)

*Nerve root hemorrhage.
†Dorsal root ganglion hemorrhage.

hemorrhage was identified in 15 cases of the experimental group and two cases of the control group (Fig. 8). The number of cervical nerve roots and ganglia with hemorrhage is remarkably different between the experimental and control cases (Table 2).

Discussion

The novel method to remove a spinal cord with the ganglia attached as presented here is less destructive, and more time and cost efficient than alternative methods previously presented in the literature (2,3). Removing the spinal cord without the cervical vertebrae maintains the integrity of the decedent's neck. In addition, eliminating the need to thin section vertebral bone greatly reduces the time and cost of preparing histological slides.

Several procedural tricks were identified during the pilot study. The best approach to exposing the cervical ganglia is to start in the mid-cervical region and then progress inferiorly and next superiorly. Remove the lateral column of each vertebra before moving onto the next vertebra, (i.e., cut the overlaying facets and pedicle, and then remove the segment of bone). Expose each ganglion, and then free them all from the surrounding soft tissue at one time. Use a sharply pointed manual cutting instrument such as a coral cutter.

During the pilot study, nerve root and dorsal root ganglion hemorrhages were scored as either present or absence. A few of the cases, especially the control groups, presented with very sparse hemorrhage. The authors felt that the hemorrhage in these cases was insignificant and most likely artifactual in nature, but scored the structure as positive for hemorrhage as per the study protocol. In hindsight, a more granular scoring system that allows for scoring the presence of the hemorrhage on a scale may be better suited for the analysis. For example, a scoring system that includes the categories of absence, sparse, and prominent would allow more flexibility when evaluating the amount of hemorrhage present in each structure. With use of the scaled scoring system and a large study population, the value of nerve root and ganglion hemorrhage and the occurrence of artifactual hemorrhage could be measured.

Conclusion

Cervical nerve root and dorsal root ganglion hemorrhage is a potential signature of abusive head trauma in pediatric decedents. Presented is a method to remove the spinal cord with the ganglia attached while maintaining the integrity of the decedent's neck. Also presented are the results of a small pilot study illustrating that the ganglia were successfully removed when the presented method was followed.

Acknowledgments

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