Extrication Collars Can Result in Abnormal Separation Between Vertebrae in the Presence of a Dissociative Injury

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Background: Cervical collars are applied to millions of trauma victims with the intent of protecting against secondary spine injuries. Adverse clinical outcomes during the management of trauma patients led to the hypothesis that extrication collars may be harmful in some cases. The literature provides indirect support for this observation. The purpose of this study was to directly evaluate cervical biomechanics after application of a cervical collar in the presence of severe neck injury.

Methods: Cranial-caudal displacements in the upper cervical spine were measured in cadavers from images taken before and after application of collars following creation of an unstable upper cervical spine injury.

Results: In the presence of severe injury, collar application resulted in 7.3 mm ± 4.0 mm of separation between C1 and C2 in a cadaver model. In general, collars had the effect of pushing the head away from the shoulders.

Conclusions: This study was consistent with previous evidence that extrication collars can result in abnormal distraction within the upper cervical spine in the presence of a severe injury. These observations support the need to prioritize additional research to better understand the risks and benefits of cervical stabilization methods and to determine whether improved stabilization methods can help to avoid potentially harmful displacements between vertebrae.

Key Words: Cervical spine, Trauma, Collars, Secondary injury, Dissociative injury.

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Cervical extrication collars are applied to millions of blunt trauma victims with the intent of protecting the occipitocervical spine in the rare event that a severe injury has occurred to these structures. There is evidence that collars can restrict motion of the head when applied to healthy uninjured volunteers.[1] However, there is no reliable evidence that collars can effectively protect against secondary injuries to the vital structures of the neck in the presence of a severe dissociative injury.

Observed adverse clinical outcomes during management of blunt trauma victims led to the hypothesis that collars may exacerbate the clinical consequences of severe upper cervical spine injuries, possibly by generating additional distraction between vertebrae. A search of the scientific literature identified several publications that indirectly support the hypothesis that collars or inline stabilization can be associated with abnormal separation between vertebrae in the presence of a severe injury.[2–5]

The purpose of this study is to directly evaluate the biomechanical effects of brace application on the severely destabilized cervical spine. Based on previous successes, a whole cadaver model was used to answer this question.

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METHODS

Nine fresh whole human cadavers (6 women and 3 men, 64–88 years old) were obtained through the anatomic gifts program at the Department of Anatomy, Baylor College of Medicine. They were kept in a refrigerated state (2°C) before use and examined after warming at room temperature following cessation of rigor mortis. In several studies, intact neck motion in this model has been shown to be indistinguishable from asymptomatic live volunteers.[6–8] A baseline X-ray was taken, and none of the cadavers had any previous cervical conditions, interventions, or anomalies that could potentially interfere with the presence or interpretation of intervertebral motion.

In all the cadavers, the anterior and posterior restraints to intervertebral motion between the first and second cervical vertebrae were surgically destroyed through a midline posterior incision. The muscles were first carefully dissected longitudinally away from the posterior elements and their fascial and ligamentous attachments, but were otherwise left intact. A dissociative injury was simulated by severing the nuchal ligament, the left and right facet joint capsules, the tectorial membrane, the inferior aspect of the cruciate ligament, and the anterior longitudinal ligament. In addition, the odontoid was fractured at its base. The damage created to the ligaments, facet joints, and odontoid was intended to replicate injury patterns observed in previously reported dissociative injuries.[9,10] The presence of a severely unstable injury, as well as the initial reduction, was verified by fluoroscopic imaging. A commonly used conventional extrication collar (Ambu Perfit Ace) was applied after first imaging the neck without a collar.

In all parts of this investigation, collars were applied based on standard Emergency Medical Services protocol consisting of assessment of proper collar sizing, manual inline stabilization, sliding the back part under the head/neck, and then securing the front part to the back with Velcro straps.

Methods of Measurement and Data Collection

In the first four consecutive cadavers, the upper cervical spine was imaged before and after collar application using lateral fluoroscopic images that were centered at C2 (Zhiem Vision, Riverside, CA). The results were limited to what could be seen in fluoroscopic images. To obtain a more comprehensive understanding of the changes in intervertebral relations that occur with collar application, the remaining five cadavers were imaged before and after collar application using contiguous 0.67-mm thick axial computed tomography (CT) sections spaced 0.33 mm apart with a 140-mm field of view (Brilliance 64, Philips Medical Imaging, Amsterdam).

The fluoroscopic images were analyzed using previously validated[11,12] computer-assisted methods (QMA, Medical Metrics, Houston, TX). The CT data were exported in DICOM format, and measurements were made using image processing software (Microview 2.2, GE Healthcare, Ontario, CA). In all cases, distance between C1 and C2 were measured before and after application of the collar.

For X-ray analysis, the distraction between C1 and C2 was measured at the anterior and posterior boundaries of the spinal canal from lateral fluoroscopic images. The anterior boundary of the spinal canal was measured as the distance from the posterior wall of the C2 vertebral body at the level of the superior facet surface to the point where the inferior surface of the C1 ring intersected the posterior border of the dens. A second posterior measurement was made between the superior border of the spinolaminar line of C2 and inferior border of the posterior tubercle of C1. These points were chosen for several reasons. Currently, there is no consensus on the radiographic points that can be measured from a lateral X-ray to accurately represent axial distraction between C1 and C2. Other commonly used measurements such as Power's Ratio and Harris lines do not accurately reflect vertical displacement at the C1–C2 level.[13,14] The two measurements were performed between points that could be reproducibly identified on lateral X-rays and have intimate proximity to the spinal canal and cord. Relative displacements were calculated by subtracting distances measured before and after application of a collar.

For the five cadavers spines evaluated with CT, the average distraction between the C1 and C2 facets was calculated as a measurement that summarizes axially directed distraction at this level. The relative displacements were calculated by subtracting distance measures before and after application of a collar. In addition, for the CT-based assessments, visualization software (AVS 5.6, Advanced Visual Systems, Waltham, MA) was used for each cadaver to spatially register the second cervical (C2) vertebra between the scans taken with and without the collar. The cervical spines were then visualized from different view points while alternately displaying the scans with and without the collar. This allowed enhanced visualization of the details and complexities of relative motion between the upper cervical vertebrae and the occiput.

RESULTS

Application of cervical collars caused grossly abnormal increased separation at the site of a severely injured C1–C2 level in every cadaver. In the four cadavers in which lateral

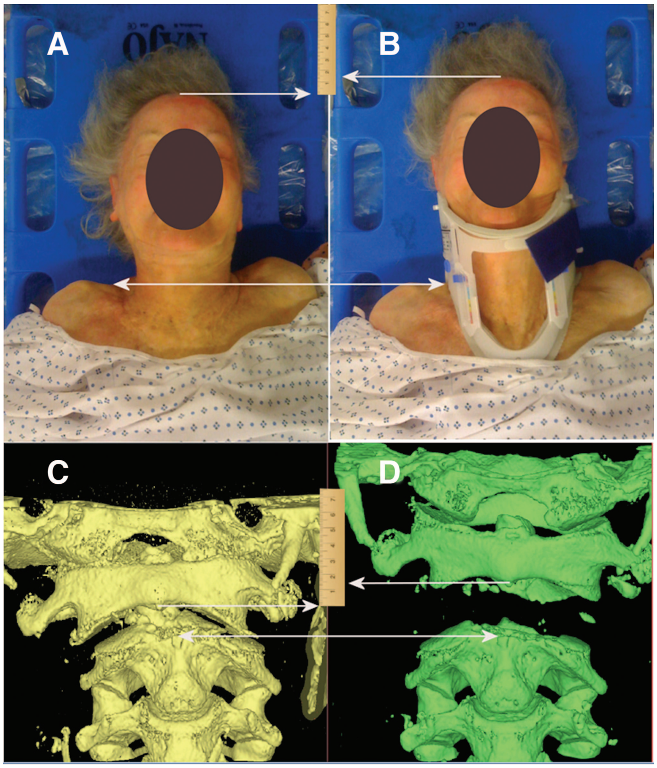

Figure 1. (*A–D*) Gross displacement (*B* compared with *A*) of the head relative to the body (16 mm) when an extrication collar was applied in the presence of a severe instability was consistent with the internal displacements between the occiput and the subaxial cervical spine (14 mm) measured from fine-cut CT examinations in this fresh whole human cadaver (*D* compared with *C*).

C-arm images of the cervical spine were assessed, the average distraction was 3.23 mm (SD 1.65; range, −0.39 to 4.96) and 6.43 mm (SD 4.67; range, 1.59–11.39) for anterior and posterior measurements, respectively. In the five cadavers in which CT was used for analysis, the average distraction for right and left facets was 9.23 mm (SD 6.21; range, 0.36–17.5) and 5.24 mm (SD 2.66; range, 1.85–9.2), respectively. Gross displacement of the cadaver's head relative to the body was visually apparent and was consistent with the internal displacements observed in the CT images (Fig. 1, A–D).

Baseline vertebral alignment on CT before the cervical collars were applied showed minor malreductions that occurred after creation of the injury. These consisted of small rotational and lateral or posterior translational misalignment of C1 on C2 in the axial plane. Application of the collar significantly worsened axial malalignment by causing distractive separation of the head and C1 vertebra away from C2.

There was variation between cadavers in how C1 separated from C2. For example, the gap between the left facet was larger than that on the right in some cadavers, with the opposite occurring in other cadavers. To provide a single measure of separation between C1 and C2 in each cadaver, the average of the measurements made in each cadaver was also calculated. The mean of these average separation measures for the nine cadavers was 7.3 mm (SD, 4.0 mm).

To provide a reference for the interpretation of these measurements, radiographic images from a previously completed study of cervical collars were reanalyzed to measure the distraction between C1 and C2 that occurred when a collar was applied to healthy uninjured volunteers.[15] The average distraction measured in healthy volunteers when a collar was applied was −0.001 (SD, 0.52 mm; range, 1.43–1.29 mm; upper limit of the 95% confidence interval was 1.03 mm) for anterior measurements and −0.04 mm (SD 1.47 mm; range, 3.2–4.81 mm; upper limit of the 95% confidence interval was 2.84 mm) for posterior measurements.

DISCUSSION

In nine whole, fresh human cadavers with simulated severe dissociative injuries to the upper cervical spine, application of a cervical extrication collar resulted in grossly abnormal distraction at the injured level. Although the collars did not cause the injuries, they appeared to promote further separation between vertebrae.

Multiple previous studies document that, in the presence of a severe injury, grossly abnormal intervertebral motion can occur at the time of the injury as well as during subsequent medical procedures.[10,16,17] Although these injuries are potentially catastrophic, in certain circumstances, they are clearly survivable. It is not known how much and for how long malalignment can be tolerated, but most would agree that minimizing or better yet avoiding any positional abnormality as much as possible would optimize neurologic injury and ultimate clinical recovery.

Evidence that application of a cervical extrication collar can lead to catastrophic neurologic complications in patients with unstable cervical injuries has been previously described.[4,5,10,18–20] A critical analysis of these reports supports the concern that the application of a collar could potentiate neurologic and/or vascular injury. Although this can occur at any level, the upper cervical spine seems to be particularly vulnerable.[21]

In this study, frank separation of the head and upper neck from the rest of the spine was seen in every cadaver after a cervical collar was applied. This suggests that collar application acts in part by pushing the head away from the body, resulting in internal stretching and translation of soft tissues, including the spinal cord and vertebral arteries. The magnitude and duration of sustained distraction that can result in neurologic deficit is not yet known. It is likely that distraction of the spinal cord is generally undesirable and that this could contribute to "secondary injury" when present in a trauma victim.

The amount of intervertebral motion that was measured in the cadavers seems similar to that of clinical reports of upper cervical dissociative injuries.[3,14,22–25] Although some of those reported patients survived, the majority of the injuries resulted in death or disability.[14,22–25] Harris et al.[14] noted that all but one of the 23 patients who died of neck injuries had grossly abnormal occipital-vertebral relationships. The magnitude of distraction measured at the basion-dens interval in these studies was similar to the axial distraction of the occiput from the spine measured in this study.[14,22–24,26]

Several other investigators reported that patients with massive damage to the upper cervical spine can survive the initial injury if appropriately managed.[10,27,28] Unfortunately, the optimum management protocol has yet to be established and validated. In a recent Cochrane Review, there were no studies found to be considered high-level scientific evidence.[1] This is not surprising because it is inherently difficult to generate randomized controlled clinical studies for scientific evidence regarding the optimum approach to protecting the cervical spine in trauma victims, particularly in the prehospital period.

This study had several limitations. Although the whole cadaver model has been used in many published studies, the muscle tone present in conscious patients cannot be reproduced in this model.[17,29,30] The whole cadaver model may represent a worst case clinical scenario of an unconscious patient in which active muscle stabilization of the spine is eliminated.

An additional limitation is that the injuries that were surgically created may represent only one type of a wide spectrum of injuries that occurs in actual trauma. Nevertheless, the experimentally created misalignment of the spine caused by collar application in this study seems similar to that described in many publications.[9,22,28,31,32] In addition, the displacements between the occiput and cervical spine in cadavers were almost identical to those observed during manual traction in patients with unstable cervical injuries,[3,17] suggesting that current conventional braces produce a distraction type moment on the cervical spine.

The overall implications and clinical significance of these observations is not known. However, it is known that neurologic damage to the spine is a major concern with >12,000 new spinal cord injuries occurring each year in the United States.[33] In particular, severe injuries to the cervical spine have been found in up to 3.7% of trauma victims,[34] and secondary neurologic deterioration can occur in these patients.[35–38] Cervical spine injuries are common in blunt trauma fatalities and are reported to be a cause of death in 8% to 35% of motor vehicle fatalities.[9,39–44] Clearly, uncontrolled distractive forces on the neck offer no advantages. This study supports the need to better understand the risks and benefits of cervical extrication collars on blunt trauma victims and to determine whether improved methods to stabilize the cervical spine could potentially improve outcomes. Additional scientific evidence is needed to validate management protocols that could reduce the number of preventable neurologic injuries. It is not yet known whether a proportion of the >40,000 motor vehicle-related fatalities each year[45] could be prevented if separation between vertebrae at the site of a severe injury were avoided during management of trauma victims.

CONCLUSIONS

In the presence of a severe upper cervical injury, application of a cervical extrication collar to a whole cadaver can create grossly abnormal distraction between vertebrae at the injury level. Although the extrication collar did not cause the injuries, their application seemed to effectively push the head away from the shoulders, and this was associated with abnormal intervertebral displacements. Thus, contemporary extrication collars may not be offering optimal stability in all cases. Pending further evidence, a careful assessment of the cervical spine for the presence of a dissociative injury in severe trauma victims who arrive in a collar is prudent, particularly if the patient is obtunded or about to be sedated.

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