Effects of Cervical Spine Immobilization Technique and Laryngoscope Blade Selection on an Unstable Cervical Spine in a Cadaver Model of Intubation

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Study objective: Orotracheal intubation (OTI) is commonly used to establish a definitive airway in major trauma victims, with several different cervical spine immobilization techniques and laryngoscope blade types used. This experimental, randomized, crossover trial evaluated the effects of manual in-line stabilization and cervical collar immobilization and 3 different laryngoscope blades on cervical spine movement during OTI in a cadaver model of cervical spine injury.

Methods: A complete C5-C6 transection was performed by using an osteotome on 14 fresh-frozen cadavers. OTI was performed in a randomized crossover fashion by using both immobilization techniques and each of 3 laryngoscope blades: the Miller straight blade, the Macintosh curved blade, and the Corazelli-London-McCoy hinged blade. Intubations were recorded in real time on fluoroscopy and then transferred to video and color still images. Outcome measures included movement across C5-C6 with regard to angulation expressed in degrees of rotation and axial distraction and anteroposterior displacement with values expressed as a proportion of C5 body width. Cormack-Lehane visualization grades were also recorded as a secondary outcome measure. Data were analyzed by using multivariate analysis of variance to test for differences between immobilization techniques and between laryngoscope blades and to detect for interactions. Significance was assumed for *P* values of less than .05.

Results: Manual in-line stabilization resulted in significantly less movement than cervical collar immobilization during OTI with regard to anteroposterior displacement. Use of the Miller straight blade resulted in significantly less movement than each of the other 2 blades with regard to axial distraction. The Cormack-Lehane grade was significantly better with manual in-line stabilization versus cervical collar immobilization; no differences were observed between blades.

Conclusion: Manual in-line stabilization results in less cervical subluxation and allows better vocal cord visualization during OTI in a cadaver model of cervical spine injury. The Miller laryngoscope blade allowed less axial distraction than the Macintosh or Corzelli-London-McCoy blades. The clinical significance of this degree of movement is unclear.

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INTRODUCTION

The incidence of cervical spine injury is reported to be from 1% to 4% in all major trauma victims and may be as high as 34% in patients with severe injuries.[1-5] With orotracheal intubation (OTI) becoming the preferred technique for airway management in the trauma victim, proper cervical spine precautions are therefore imperative in preventing or worsening spinal cord injuries. Two techniques for maintaining cervical spine precautions exist. First, a rigid cervical collar, with or without towel rolls and tape, is applied in most out-of-hospital systems and often left in place during intubation. Alternately, manual in-line stabilization can be used and has been advocated to be safe during OTI. The amount of cervical spine movement produced during OTI with each of these techniques has not been fully elucidated.

Multiple different laryngoscope blades are available for use during OTI. The Miller straight blade and the Macintosh curved blade are the 2 most commonly used blades; however, their relative safety with regard to an injured cervical spine has not been defined. A new laryngoscope blade, the Corazelli-London-McCoy (CLM) hinged blade, may decrease the amount of force required to visualize the vocal cords during OTI, especially in cases of difficult anatomy (Figure 1). The optimal blade in preventing cervical spine movement during OTI has not been determined.

We created a cadaver model of cervical spine injury to compare the relative safety of 2 different immobilization techniques and each of 3 laryngoscope blades during OTI. A randomized crossover design was used, with outcome measures defined as axial distraction, anteroposterior (AP) displacement, and angular rotation.

Figure 1.
The Corazelli-London-McCoy hinged laryngoscope blade (photograph courtesy of Ken Stephen).

MATERIALS AND METHODS

The University of California at San Diego School of Medicine, Department of Anatomy, authorized and approved the use of human cadavers for this study. A total of 14 fresh-frozen cadavers were used. Cadavers were thawed for 2 to 4 hours until determined to be appropriately flexible for OTI by 2 senior emergency medicine residents. This determination required that the cadaver cervical spine be positioned in full flexion (chin to chest) and extension (body of mandible perpendicular to table) with minimal effort and that the jaw be mobile enough to allow laryngoscopic visualization of vocal cords without significant force.

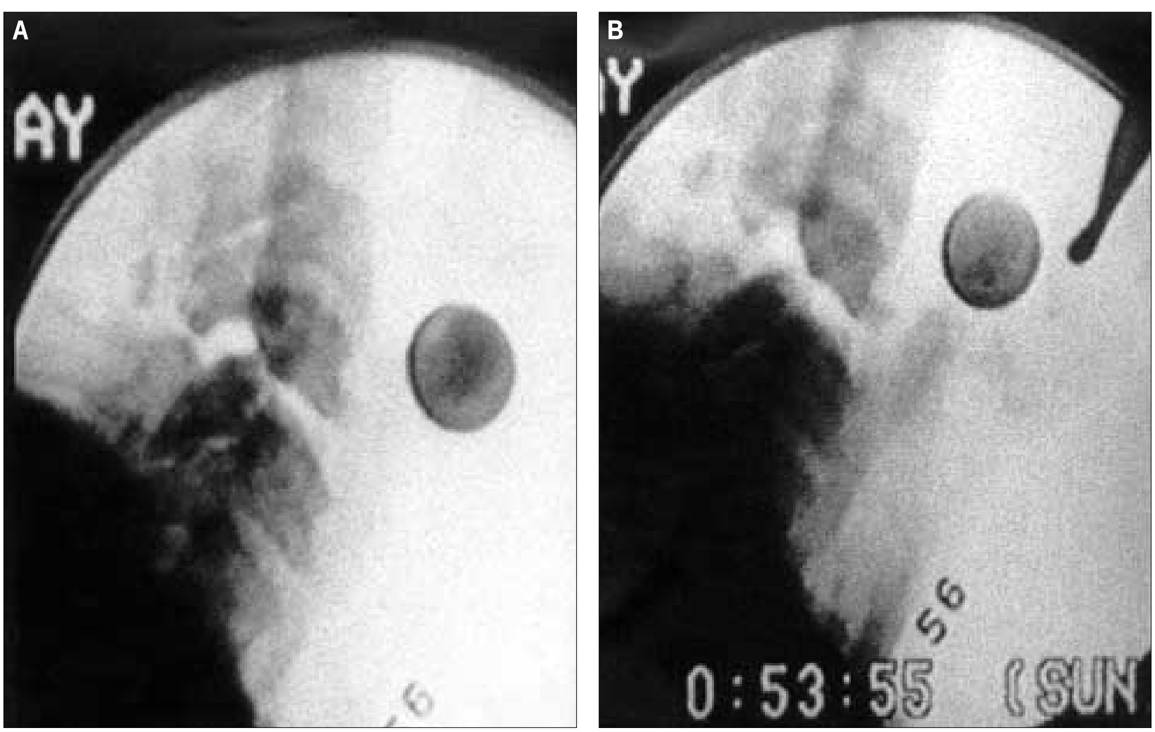
A C5-C6 surgical transection was created in all cadavers by a spine fellow to standardize the model of injury. An anterior approach was selected, with a vertical incision made along the medial aspect of the clavicular head of the sternocleidomastoid muscle. The anterior aspect of the vertebral column was entered by means of a blunt dissection between the sternocleidomastoid and the infrahyoid muscle groups. The C5-C6 interspace was located and confirmed by fluoroscopy. Surgical transection was then performed with an osteotome, with disruption of the anterior and posterior longitudinal ligaments, intervertebral disk, articular capsular ligaments, interspinous ligament, and ligamentum flavum. Complete instability of the injury was confirmed through fluoroscopy, as defined by angular displacement greater than 11 degrees and AP displacement greater than 20% of C5 vertebral body width during manipulation.[6] This also served to eliminate the possibility of stabilization by osteophytes not visible on fluoroscopy. Overlying soft tissue was replaced, and the cervical spines were returned to a neutral position before beginning the trial.

Two senior emergency medicine residents then performed OTI with each of 3 laryngoscope blades: the Miller straight blade, the Macintosh curved blade, and the CLM hinged blade. Each of 2 different immobilization techniques, manual in-line stabilization and cervical collar immobilization, were also used. Manual in-line stabilization was performed by using one hand on either side of the cadaver head and either the index or middle finger held at the opening to the auditory canal. The individual providing stabilization crouched below and to the left of the intubator and was instructed to maintain the cervical spine in a neutral position without application of axial traction. Immobilization with a cervical collar was performed by using a standard rigid cervical collar in either standard or small adult sizes. Towel rolls were positioned on either side of the head, and athletic tape was used to stabilize the forehead superiorly and the cervical collar inferiorly to the table. A crossover design was used in which all 3 blades and both immobilization techniques were used in random order for each cadaver. Intubators were not blinded to either the blade type or immobilization technique used, although they were not allowed to look at the fluoroscope screen during OTI.

Fluoroscopy was used with a direct input line to VHS video recording. The entire intubation was videotaped, and real-time images were later frozen at the point of maximal C5-C6 separation and transferred to Kodachrome (Kodak, Rochester, NY) slide film by using a 35-mm camera mounted on a tripod at a fixed distance from the monitor. These still frames were then projected onto a screen to allow measurements to be made (Figure 2). Proper endotracheal tube position was confirmed on fluoroscopy.

To determine the amount of movement across the unstable cervical spine lesion, we defined movement in 3 planes as our primary outcome measures. All values rep-

Figure 2.
Kodachrome images used in data acquisition. The injured cervical spine model before laryngoscope blade engagement (A) and with full engagement during orotracheal intubation (B).



resent the change from baseline before laryngoscopy to the point of maximal displacement. Axial distraction was defined as the change in C5 and C6 intervertebral distance. This value was calculated as an average of the change in intervertebral distance between the anterior and posterior aspects of C5 and C6, with a positive value indicating axial separation. The measurement of AP displacement was defined as the change in horizontal distance between the anteroinferior aspect of the body of C5 and the anterosuperior aspect of the body of C6. The absolute values for AP displacement were used because impingement into the spinal canal by either C5 or C6 was believed to be significant. Angular rotation was defined as the change in the angle between the inferior surface of the body of C5 and the superior surface of the body of C6. A positive value indicates an opening of the anterior aspect of the intervertebral space. These are represented in Figure 3. Both AP displacement and axial distraction were expressed as a proportion of C5 body width to account for x-ray beam diffraction and variable amounts of enlargement with projection, as well as to account for variability in vertebral body and canal sizes across the cadavers. Data regarding the best Cormack-Lehane grade obtained during laryngoscopy were recorded for each attempt as a secondary outcome measure.

Data were analyzed by using PC!Info (Retriever Data Systems, Seattle, WA). Multivariate analysis of variance was used to detect differences between immobilization techniques and between laryngoscope blade types and to investigate a possible interaction between the 2 variables. When significant differences were observed with regard to blade type, univariate analysis was performed by using paired *t* testing with a Bonferroni correction to determine directionality. Multivariate analysis of variance was used to detect Cormack-Lehane grade differences between immobilization techniques and blade types. Significance was assumed for a *P* value of less than .05.

RESULTS

Significantly less movement during OTI was observed with the use of manual in-line stabilization than cervical collar immobilization with regard to AP displacement into the spinal canal (7.5% versus 13.7% of C5 body width, *P*=.03). There were no significant differences with regard to axial distraction or angular rotation. Significantly less movement was observed during OTI with the use of the Miller straight blade versus the Macintosh or CLM blades with regard to axial distraction (6.1% versus 11.0% and

Figure 3.
Schematic representation of C5-C6 injury and movement definitions as primary outcome measures. A, Axial distraction; D, AP displacement; ϕ, angular rotation.

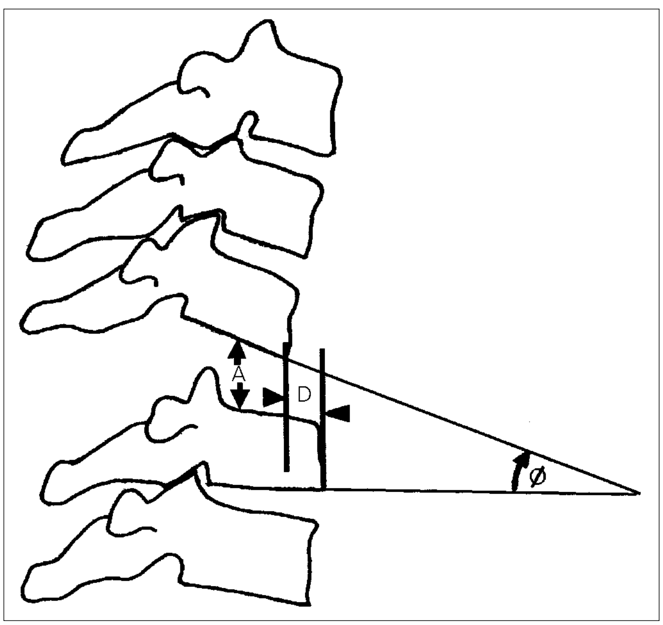


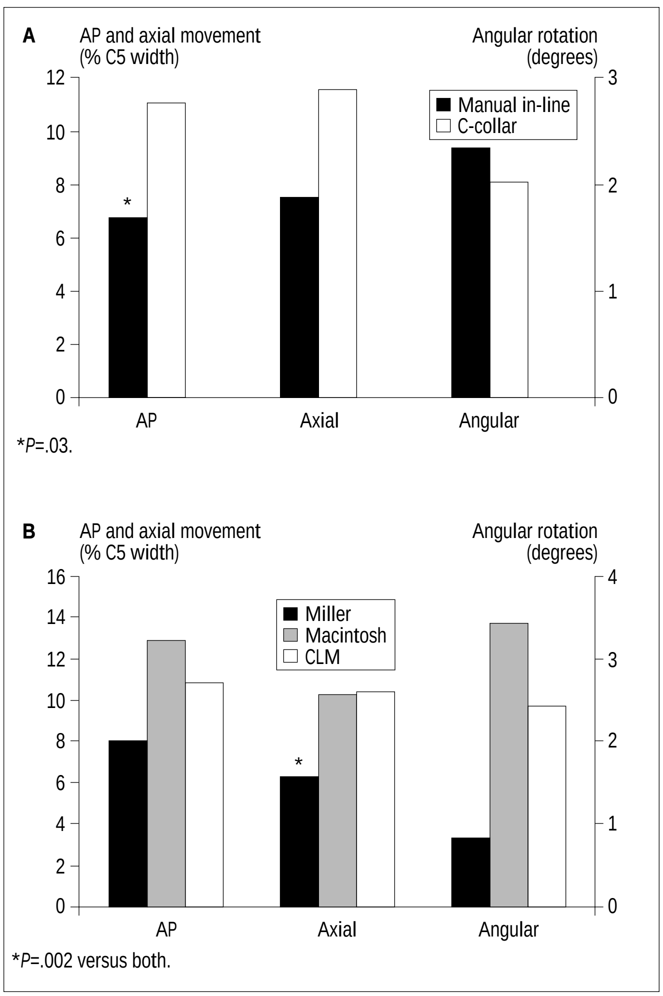
Table.
Values for both immobilization techniques and each of 3 blade types with regard to movement during endotracheal intubation in 3 planes.

	Blade Type			
Stabilization Type	**Miller**	**Macintosh**	**CLM**	**Combined**
AP				
Manual in-line	4.7 (9.8)	11.1 (2.2)	6.7 (2.1)	7.5*
Cervical collar-tape	11.4 (2.9)	14.6 (3.7)	15.5 (2.7)	13.7
Combined	8.0	12.8	10.8	10.5
Axial distraction				
Manual in-line	3.6 (2.2)	9.6 (3.3)	7.1 (5.0)	6.8
Cervical collar-tape	8.8 (3.9)	10.8 (4.5)	13.9 (3.9)	11.1
Combined	6.2†	10.2	10.3	8.8
Angular rotation				
Manual in-line	0.3 (2.0)	3.1 (1.2)	3.7 (1.4)	2.3
Cervical collar-tape	1.3 (1.2)	3.7 (1.7)	1.1 (1.3)	2.0
Combined	0.8	3.4	2.4	2.2

Values expressed as means (±SD). Plane values expressed as follows: AP, percentage of C5 body width; axial distraction, percentage of C5 body width; and angular rotation, degrees.
*$P<.05$ versus cervical collar-tape.
†$P<.05$ versus each of the other 2 blades.

11.6%, *P*=.009). There were no significant differences between the blades with regard to AP displacement or angular rotation. These results are displayed in the Table and Figure 4. No interactions between immobilization technique and laryngoscope blade type were observed. All intubations were achieved on the first attempt, and there were no esophageal intubations. The Cormack-Lehane grade obtained during laryngoscopy was significantly better with manual in-line stabilization versus cervical collar immobilization (1.4 versus 2.3, *P*<.05), but no difference in grade was observed between the Miller, Macintosh, and CLM laryngoscope blades.

Figure 4.
Graphic representations of comparisons between immobilization techniques (A) and laryngoscope blade types (B) for movement during orotracheal intubation in 3 planes. AP displacement and axial distraction (expressed as a percentage of C5 body width) and angular rotation (expressed in degrees).



DISCUSSION

Manual in-line stabilization resulted in less subluxation into the spinal canal during OTI than cervical collar immobilization with both towel rolls and tape in a cadaver model of cervical spine injury. This suggests that manual in-line stabilization may be safer in protecting the injured cervical spine during OTI with low cervical injuries. The cervical collar may act as a fulcrum during laryngoscope blade engagement with injuries at this level. Alternatively, the cervical collar may obstruct vocal cord visualization and require the application of additional force; the decreased Cormack-Lehane grade obtained suggests that the presence of a cervical collar makes laryngoscopy significantly more difficult, supporting this theory.[7] The differences we observed here may have been even greater if towel rolls and tape were not used, as is often the case in many out-of-hospital systems or emergency departments. We also observed that the Miller straight blade resulted in less axial distraction during OTI than either the Macintosh curved blade or the CLM hinged blade in the same cadaver model of intubation. Although axial distraction may be less important than AP displacement with regard to spinal cord compromise, the force required for cord visualization with a Miller blade may be decreased or applied in such a manner that less movement occurs during OTI with a low cervical spine injury.

Because of the relatively low incidence of cervical spine injuries and the difficulties in performing controlled trials with these patients, previous research has been retrospective or has used healthy volunteers to compare cervical spine stabilization techniques.[8-13] Although OTI appears to be safe when proper immobilization techniques are applied, neither manual in-line stabilization nor cervical collar immobilization had previously emerged as superior. One group used a single cadaver with a cervical spine injury and plain radiographs to document movement. The authors observed that a rigid cervical collar resulted in more movement during OTI than no stabilization at all, but no comparison with manual in-line stabilization was made.[14]

Axial traction is no longer recommended as a stabilization technique in trauma patients with suspected cervical spine injury because of concerns for exacerbating a preexisting spinal injury by hyperdistraction at the fracture site.[10,15-18] One study documented an increased amount of distraction during application of axial traction in patients with cervical spine fractures versus those with an intact cervical spine.[10] In addition, new neurologic deficits and the exacerbation of preexisting deficits have been documented with axial traction.[15-18]

Little has been written about the use of manual in-line stabilization without axial traction during OTI of patients with potential cervical spine injuries. Evidence does exist, however, that release of the anterior compartment of the cervical collar may facilitate vocal cord visualization during OTI.[7,19,20] These results and our findings here suggest that maintaining a patient in a cervical collar during OTI may both increase cervical spine movement and hinder vocal cord visualization.

Although multiple studies have addressed the issue of blade selection for patients with potential cervical spine injuries, the results have been equivocal, with no blade emerging as superior. Many have addressed this question indirectly by using outcome measures such as the amount of force required and visual grade achieved.[7,21,22] In one study, the Miller straight blade required 30% less head extension and exerted force than the Macintosh during OTI of healthy subjects.[23] Another study with a single cadaver with a cervical spine injury resulted in no difference between the Miller straight blade and Macintosh curved blade with regard to cervical spine movement during OTI.[14] The recently introduced CLM hinged blade appears to have some advantages over the Miller straight blade and Macintosh curved blade with regard to head extension and force required but has not been evaluated in a cervical spine injury model.[21,22] Anecdotal evidence suggests that the CLM blade may also be useful in cases of complicated anatomy and may reduce the catecholamine response to OTI, factors that we did not evaluate in this study.[24,25]

The amount of movement across an injured cervical spine required to exacerbate an existing cervical spine injury is difficult to quantify and has not been fully elucidated. Although previous studies document discrepancies between the degree of cervical spine injury and the incidence of neurologic damage, AP displacement into the spinal canal appears to carry a significantly worse prognosis with regard to neurologic outcome.[26-29] One study demonstrated that athletes with abnormally narrow spinal canals have a higher frequency of neurologic dysfunction after cervical spine injury.[30] This led to the development of the Torge ratio, defined as the canal width divided by vertebral body width at the same cervical level. Individuals with a Torge ratio less than 0.8 (normal=1.0) appear to be at higher risk for spinal neuropraxia after sustaining a cervical spine injury. Although this cannot be extrapolated to define a threshold amount of displacement into the canal considered to be dangerous, it provides further support for recommendations to minimize this movement whenever possible. This also implies that the ratio of displacement relative to vertebral body width may have more clinical significance than the absolute amount of displacement when reporting outcome measures, justifying our use of C5 body width percentage for measurements of AP displacement and axial distraction. In addition, our use of proportions eliminated the difficulties in standardizing units of length given the variability in x-ray diffraction with fluoroscopy and subsequent video projection in obtaining measurements.

The amount of angular displacement necessary for cord damage is similarly unclear. Clinical standards on the basis of retrospective data have been developed that regard angulation exceeding 11 degrees to be unstable; however, a significant amount of individual variability exists.[6] There is even less experimental evidence regarding the amount of axial distraction considered clinically significant. Much of our current practice is based on studies regarding axial traction for OTI, as mentioned above.[15-18] Thus, the clinical significance of the amount of movement in this study is unclear; however, minimizing the amount of cervical spine movement should be considered important in preventing adverse neurologic outcomes until further evidence suggests otherwise.

Other airway techniques may provide additional safety when managing potential cervical spine injuries but were not included here. Nasotracheal intubation requires that the patient have spontaneous respirations and may be associated with a significant incidence of complications, including bacteremia, bleeding, local tissue damage, and intracranial hypertension.[31,32] Furthermore, if concerns exist for a possible cribiform plate fracture, nasotracheal intubation should not be performed because of the risk of intracranial penetration. The amount of cervical spine movement during cricothyrotomy is unknown, and the procedure is invasive with frequent complications, including hemorrhage, tracheal injury, and infection.[33]

There are obvious limitations in applying the results of a cadaver model to human patients. No clinical outcome measures are available in nonliving subjects, and tissue characteristics change significantly after death. We attempted to standardize injuries by using a spine fellow to create all transections, which were then confirmed fluoroscopically before data acquisition. In the clinical setting, however, no 2 fractures are the same, and our C5-C6 injury may be very different from a high cervical spine injury. We chose the lower cervical spine because of increased mobility and high injury rate at this level.[5]

As discussed previously, the clinical significance and generalizability of the degree of movement observed here has not been established. In addition, our model does not take into account the degree of trauma inflicted on the cord by the initial injuring force, which may be more significant than any subsequent movement. Unfortunately, the ideal model to address these issues does not exist, and controlled human trials are methodologically difficult and ethically questionable.

The investigators in our study were not blinded to the laryngoscopic blade or immobilization technique used, leading to potential biases. The improvement in Cormack-Lehane grade obtained with manual in-line stabilization versus cervical collar immobilization may be related to the amount of force required for vocal cord visualization, and it is possible that operators applied greater force with certain laryngoscope blades or immobilization techniques on the basis of these biases. It would be difficult to blind investigators to these variables, and we believed that the best way to avoid these biases was to hide the fluoroscope screen from the intubator during OTI so that the actual movement was not available in real time.

Finally, the transfer of fluoroscopic images to slide film and subsequent measurement of projected images was performed for convenience and may have resulted in measurement inaccuracies. We attempted to overcome this issue through the use of proportions, as discussed. Fluoroscopy appears to have some distinct advantages over radiographic evaluation of spinal movement in capturing extremes of displacement because this is a dynamic rather than a static modality. Ultimately, digitization of fluoroscopic images with computerized calculation of measurements may be the most accurate and efficient way to acquire data.

In conclusion, we observed that manual in-line stabilization allowed less AP displacement into the spinal canal during OTI than cervical collar immobilization in a cadaver model of cervical spine injury. Because the cervical collar also inhibits vocal cord visualization during OTI, we recommend that the cervical collar be removed and manual in-line stabilization be performed during OTI in a patient with potential cervical spine injury. We also observed less axial distraction during OTI with use of the Miller straight blade compared with both the Macintosh or CLM blades. Operator familiarity with a given blade may be more important in establishing a definitive airway, however, than the risk of worsening a cervical spine injury.

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