Cervical spine trauma associated with moderate and severe head injury: incidence, risk factors, and injury characteristics

Langston T. Holly, M.D., Daniel F. Kelly, M.D., George J. Counelis, M.D., Thane Blinnman, M.D., David L. McArthur, Ph.D., M.P.H., and H. Gill Cryer, M.D.

Division of Neurosurgery, Department of Surgery and Epidemiology, University of California at Los Angeles Center for Health Sciences, and the UCLA Brain Injury Research Center, Los Angeles; Division of Neurosurgery, Harbor-UCLA Medical Center, Torrance, California; and Department of Neurosurgery, University of Pennsylvania, Philadelphia, Pennsylvania.

Object. Diagnosing and managing cervical spine trauma in head-injured patients is problematic due to an altered level of consciousness in such individuals. The reported incidence of cervical spine trauma in head-injured patients has generally ranged from 4 to 8%. In this retrospective study the authors sought to define the incidence of cervical injury in association with moderate or severe brain injury, emphasizing the identification of high-risk patients.

Methods. The study included 447 consecutive moderately (209 cases) or severely (238 cases) head-injured patients who underwent evaluation at two Level I trauma centers over a 40-month period. Of the 447 patients, 24 (5.4%) suffered a cervical spine injury (17 men and seven women; mean age 39 years; median Glasgow Coma Scale [GCS] score of 6, range 3–14). Of these 24 patients, 14 (58.3%) sustained spinal cord injuries (SCIs), 14 sustained injuries in the occiput-C3 region, and 10 underwent a stabilization procedure. Of the 14 patients with SCIs, nine experienced an early hypotensive and/or hypoxic insult. Regarding the mechanism of injury, cervical injuries occurred in 21 (8.2%) of 256 patients involved in motor vehicle accidents (MVAs), either as passengers or pedestrians, compared with three (1.6%) of 191 patients with non-MVA-associated trauma (p < 0.01). In the subset of 131 MVA passengers, 13 (9.9%) sustained cervical injuries. Patients with an initial GCS score less than or equal to 8 were more likely to sustain a cervical injury than those with a score higher than 8 (odds ratio [OR] 2.77, 95% confidence interval [CI] = 1.11–7.73) and were more likely to sustain a cervical SCI (OR 5.5, 95% CI 1.22–24.85). At 6 months or more postinjury, functional neurological recovery had occurred in nine patients (37.5%) and eight (33.3%) had died.

Conclusions. Head-injured patients sustaining MVA-related trauma and those with an initial GCS score less than or equal to 8 are at highest risk for concomitant cervical spine injury. A disproportionate number of these patients sustain high cervical injuries, the majority of which are mechanically unstable and involve an SCI. The development of safer and more rapid means of determining cervical spine integrity should remain a high priority in the care of head-injured patients.

Key Words • cervical spine injury • traumatic brain injury • spinal stabilization

Individuals who sustain traumatic brain injury are at increased risk of sustaining cervical spine injury compared with victims of nonhead-related blunt trauma injury. The reported incidence of cervical spine trauma after clinically significant head injury has generally ranged from 4 to 8%.[11,13,19,24] Although an increasing injury severity, as measured by the GCS, has been associated with a higher rate of cervical injury, few other risk factors in this patient population have been identified.[11,24] Identifying such high-risk patients may be particularly useful given that diagnosing and managing cervical spine injuries in head-injured patients is problematic due to an altered level of consciousness and the overall critical nature of their injuries. Despite advances in imaging technologies and screening protocols, cervical spine injury may go undetected even in optimum circumstances. Failure to recognize unstable cervical injuries during initial evaluation can result in serious neurological worsening. Increased neurological deficits have been reported to
occur in 3 to 10% in patients with SCI after arriving at the hospital.23

The goals of this study were to determine the incidence and characteristics of cervical spine injuries in patients who sustained moderate or severe head trauma. We also sought to identify risk factors for combined craniocervical trauma to identify more effectively the high-risk patient early in their hospitalization.

Clinical Material and Methods

Patient Population

Between December 1992 and March 1996, 464 patients with moderate or severe head injury (postresuscitation GCS scores of 3–12 or >12 with abnormal findings demonstrated on head CT scans) were admitted to either the UCLA or Harbor–UCLA Medical Centers. Of these patients, 287 were prospectively enrolled into the UCLA Brain Injury Research Center program. Informed consent was obtained from family members of all participants in the study. An additional 160 patients were recruited into the program but were not enrolled. Because the overall age, sex, and injury characteristics of the enrolled and nonenrolled patients did not differ substantially, these two patient groups were combined for the purposes of this study, yielding a total of 447 moderately or severely head injured patients evaluated during this time period. An additional 17 patients were excluded from this study because data regarding characteristics of their head injuries were insufficient.

To identify the head-injured patients with concomitant cervical spinal injury, the UCLA Brain Injury Research Center database was reviewed and retrospective chart reviews were performed. All head-injured patients with documented cervical spinal cord or spinal column trauma were included. The GCS scores, Abbreviated Injury Scores, and Injury Severity Scores were documented in all patients. Potential risk factors and injury-related characteristics were documented including age, sex, mechanism of injury, location of injury, GCS score, presence of neurological deficits, and occurrence of hypotension or hypoxia identified in the prehospital setting or within 24 hours of hospitalization. Early hypotension or hypoxia was defined as a systolic blood pressure of less than 90 mm Hg or PaO2 less than 60 mm Hg (or apnea), respectively.

Patient Management

On admission to the emergency room after initial cardiopulmonary stabilization, cervical spine radiographs were obtained (cross-table lateral, anteroposterior, and open-mouth [odontoid] views). Computed tomography scanning was performed to assess the occiput–C2 area and the cervicothoracic junction in cases in which these areas were poorly visualized on plain radiographs. Other levels of obvious or suspected abnormality on plain radiographs were further investigated by acquiring thin-cut CT scans, including reformatted sagittal and coronal scans when clinically indicated. Since 1995, obtunded or comatose patients, in whom normal findings are demonstrated on plain cervical radiographs and cervical CT scans, have undergone bedside lateral flexion-extension radiography to rule out ligamentous instability, typically within 2 to 3 days of injury.
Demographic and injury characteristics in 24 patients with cranio-cervical trauma

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<th>SCI</th>
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<th>Sex</th>
<th>Mechanism</th>
<th>HT/HP</th>
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* Patients are presented in descending order of cervical injury level, including 14 patients with occiput-C3 injuries and 10 with injuries involving levels C-4 and below. Abbreviations: AP = auto versus pedestrian; AS = assault; comp = complete; DI = diffuse brain injury with punctate contusions; dis = disability; DS = diffuse swelling; EDH = epidural hematoma; Fx = fracture; HP = hypoxic insult; HT = hypotensive insult; inc = incomplete; IVH = intraventricular hemorrhage; MC = multiple contusions; MCS = motorcycle accident; mod = moderate; MVA(e) = ejected from vehicle during MVA; nSDH = nonevacuated subdural hematoma; Oc = occiput; rec = recovery; SAH = subarachnoid hemorrhage; SL = subluxation.

Characteristics of Brain Injury

The most common findings in head CT scans among the 24 patients with combined cranio-cervical traumatic injury were diffuse swelling in 13 patients and subarachnoid hemorrhage in 12 patients. Evacuation of an epidural hematoma was required in three patients, evacuation of a subdural hematoma was required in three, and multiple contusions were present in four (Table 1).

Neurological Outcome

At a minimum of 6 months postinjury, good recovery or moderate disability (GOS criteria) was demonstrated in nine (37.5%) of 24 patients and eight (33.3%) had died. Of the eight deaths, two patients died of causes related to upper cervical SCI within 24 hours of hospital admission, three died of delayed SCI-related complications, and three died primarily of severe brain injury. Thirteen (54.2%) of 24 patients suffered a hypotensive and/or hypoxic insult in

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the prehospital setting or within 24 hours of admission. Of the 14 patients with incomplete or complete SCIs, nine experienced an early hypotensive or hypoxic insult. Early hypotension or hypoxia occurred in two (22%) of nine patients with favorable neurological outcomes (GOS score of 4 or 5), but occurred in 11 (75%) of 15 patients with poor neurological outcomes (GOS scores of 1–3) (p < 0.05). All three patients with complete SCIs died. All three of these patients had sustained high cervical injuries, hypoxic insults, and severe brain injuries (GCS score < 8) (Table 1 and Fig. 1).

**Mechanism of Injury, GCS Score, and Relative Risk of Cervical Spine Injury**

The most common mechanism of injury was MVA, which occurred in 131 patients (29.3%), followed by automobile versus pedestrian accidents (20.6%) (Table 2). The remainder included motorcycle accidents, falls, assaults, and GSWs. Of the 24 patients with combined cranio­cervical injuries, 13 were passengers in MVAs, seven were pedestrians struck by vehicles, two were assaulted, one was a motorcyclist who did not wear a helmet, and one suffered a fall. Thus, 21 (87.5%) of 24 patients sustained vehicular-related injuries. Patients with vehicular-related head trauma were significantly more likely to have sustained cervical spine injury than those who suffered nonvehicular-related trauma (8.2% compared with 1.6%, respectively; p < 0.01). In none of the 64 patients who suffered a cranial GSW was cervical spine injury documented. In Table 3, an OR analysis demonstrates the relative risks of cervical spine injury in MVAs compared with other mechanisms of injury.

The postresuscitation GCS score was also predictive of the likelihood of concomitant cervical injury. Eighteen (7.6%) of 238 patients with a GCS score less than or equal to 8 sustained a cervical injury overall, compared with six (2.9%) of 209 patients with a GCS score greater than 8 (OR 2.77, 95% CI = 1.11–7.73); additionally, 12 (5%) of 238 patients with a GCS score of less than or equal to 8 sustained a cervical SCI compared with two (1%) of 209 patients with a GCS score greater than 8 (OR 5.5, 95% CI = 1.22–24.85).

**Discussion**

**Incidence and Risk Factors of Combined Cranio­cervical Injury**

Sir Geoffery Jefferson first described the association between head trauma and cervical spine injury in 1920. He determined that a sufficient axial load directed to the vertex of the skull may result in disruption of the atlas. Since that time other authors have studied the relationship between head trauma and cervical spine injury, and the results have varied. Buchholz, et al., performed postmortem radiography and autopsy inspections in 100 consecutive victims of traffic accidents; they found a cervical spine injury rate of 24%. More recently, Iida, et al., determined that in a series of 188 cervical spine injury patients, 35% had sustained a moderate or severe head injury.

In contrast, in trauma patients with known head injury, the incidence of simultaneous cervical spine injury has generally ranged from 4 to 8%, which is similar to the rate in the present study. As we found, Hills and Deanne and Williams, et al., have also shown an association between GCS score–related head injury severity and the risk of concomitant cervical injury. In their report of almost 8300 trauma victims, Hills and Deanne also showed that head-injured patients had a significantly higher risk of cervical spine injury (4.5%) than those without head injury (1.1%). In their study of more than 5000 trauma patients, Williams, et al., however, found no association between head injury and cervical injury.

In addition to low GCS score, the mechanism of injury emerged as an important risk factor in cases of combined cranio­cervical injury in this study. Vehicular accidents (automobile passenger, automobile–pedestrian, and motorcycle accidents) accounted for 88% of the cervical injuries, with the highest rate of nearly 10% demonstrated in victims of MVAs. Given the increasing availability of airbags and improved restraint devices in automobiles, this high rate of cervical injuries is hopefully declining. In contrast, victims of GSWs comprised nearly 15% of this head injury cohort. In 54% of these, a cervical SCI was sustained. This cervical SCI was sustained. Similarly, Kauf and Davis found no evidence of cervical spine injury in a series of 202 cranial GSW victims and concluded that cervical spine clearance could be abandoned in these patients. Unless a SCI victim's neurological status or the trajectory of the bullet suggests the likelihood of direct spinal injury, foregoing a cervical spine radiological evaluation is probably reasonable in such patients.

**Importance of Cervical Injury Location and Impact on Neurological Outcome**

We found that the most frequently injured cervical area was between the occiput and C-3, which accounted for 58% of the injuries, as has been reported by others. The unique anatomical relationship between the upper two cervical vertebrae and the occiput appears to predispose the upper cervical spine to relatively more severe mechanical injury of the head. Two aspects must be considered: the likelihood of concomitant cervical spine injury and the likelihood of injury severity.

The Glasgow Outcome Scale (GOS) is a commonly used outcome measure that is designed to assess the degree of functional disability in patients with traumatic injuries. It classifies outcomes into five categories: death, persistent vegetative state (PVS), moderate disability (MD), good recovery (GR), and severe disability (SD). The reliability and validity of the GOS have been extensively studied, and it is widely accepted as a comprehensive measure of outcome after traumatic brain injury.

In this study, we used the GOS to evaluate the impact of cervical injury on neurological outcome. Patients with cervical injuries had a significantly worse GOS compared to those without cervical injuries. This finding emphasizes the importance of cervical spine evaluation in trauma patients, as early recognition of cervical injury can guide management and improve patient outcomes.

- **GOS Categories:**
  - Death (GOS 1)
  - Persistent Vegetative State (GOS 2)
  - Moderate Disability (GOS 3)
  - Good Recovery (GOS 4)
  - Severe Disability (GOS 5)

**Fig. 1.** Bar graph showing GOS category in relation to SCI. Only one (4.2%) of 24 patients achieved level of good recovery, and overall functional recovery rate (good recovery or moderate disability) was 37.5%.

**Death**
- PVS/SD
- GR/MD

**Cervical Spine Injury**

A survey conducted at a hospital surgery of 77 patients with cervical spine injury was conducted. We obtained the three-view thoracic and lumbar spine X-rays for 52% of the patients. The unique anatomical relationship between the upper two cervical vertebrae and the occiput appears to predispose the upper cervical spine to relatively more severe.

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...on the mechanical forces than the lower cervical spine in the setting of head injury.

Two aspects of cervical spine injury may drastically compound the effects of the head injury. First, upper cervical injury may result in loss of diaphragmatic innervation with inadequate respiratory effort or apnea. Second, severe cervical and upper thoracic SCIs may cause neurogenic shock from loss of sympathetic outflow. The deleterious impact of such head injury–induced hypoxic and hypotensive secondary insults is well appreciated. These results were strongly associated with poor neurological outcome in the present series. Of the 14 patients who sustained complete or incomplete SCIs, nine suffered an early hypotensive and/or hypoxic insult that was likely in part attributable to SCI. Only two of these 14 patients with an SCI made a GOS-rated good recovery, and five of the eight deaths in the series were directly attributable to complications from SCI. Rapidly identifying and treating hypotension and hypoxia, as well as maintaining adequate cerebral and spinal cord perfusion as has been previously advocated, likely improves the chances for functional brain and spinal cord recovery.

Cervical Spine Clearance After Head Injury

A survey of United States and Canadian trauma centers conducted in 1998 by the Eastern Association for the Surgery of Trauma showed substantial variability in the diagnostic procedures used to determine cervical spine integrity after head injury. In 24 of 31 trauma centers that responded to the survey, clinicians routinely performed a standard three-view plain radiography; axial CT scans were obtained through suspicious areas demonstrated on the three-view x-ray films and through the cervicothoracic junction if this area was inadequately visualized on plain x-ray films. Staff at only nine of 31 centers routinely performed flexion–extension radiography if the initial plain radiography and CT scanning demonstrated normal findings. Based on their literature review in 2000, the Eastern Association for the Surgery of Trauma Cervical Spine Clearance Committee revised their initial 1998 recommendation that only cervical radiography and CT scanning were necessary to clear the cervical spine in patients in whom altered mental status was present. The updated 2000 recommendation includes the use of “flexion/extension lateral cervical spine fluoroscopy with static images obtained at extremes of flexion and extension” if normal findings are observed on the initial plain x-ray films and CT scans.

Our present cervical spine clearance protocol in head-injured patients at UCLA and Harbor–UCLA Medical Centers includes 1) plain radiographs; 2) additional CT scans in cases of poorly visualized or suspicious areas revealed on plain x-ray films or in cases in which there is clinical suspicion of SCI; and 3) flexion–extension radiographs if no abnormal findings are visualized on plain radiographs and CT scans. Flexion–extension fluoroscopy or cervical MR imaging is also used if plain radiography or CT scanning demonstrates a nondisplaced cervical fracture. Notably, in using flexion–extension studies for 6 years in more than 200 head-injured patients without abnormal findings demonstrated on initial plain x-ray films and CT scans, we have yet to identify any patients with an unstable cervical injury.

In four recent reports with a total of 588 moderately or severely head injured patients, in whom either dynamic cervical fluoroscopy or static plain radiography was performed during passive flexion–extension movements, ligamentous injuries were discovered in only three patients (0.5%). In two of the series (267 patients total), the authors did not diagnose a single patient with an unstable injury by using flexion–extension studies. Of the three patients in whom ligamentous injuries were diagnosed, one was managed by a cervical fusion, one by halo vest therapy, and one by cervical collar therapy. In the largest and most recent of these studies, Davis and colleagues established a diagnosis of unstable injury in two of 301 patients, but neither patient required a cervical fusion. Based on their experience, Davis and colleagues concluded that “the cervical spine may be cleared after a normal cervical spine series (plain radiograph and computed tomographic scan) as recommended in the 1998 Eastern Association for the Surgery of Trauma Guidelines,” and thus rejected the routine use of flexion–extension radiographic studies.

Although this controversy is unresolved, the results of...
these studies show that occult ligamentous cervical injuries not demonstrated or suspected on initial plain x-ray films or thin-cut CT scans are rare, probably occurring in fewer than one in 100 head-injured patients. The potential danger of not diagnosing such an injury, however, is admittedly serious. In light of these recent reports and our own experience with flexion–extension studies, we plan to limit their routine use to only those high-risk patients identified in our study—namely, those with an initial GCS score of 8 or less and/or those involved in vehicular-related trauma. In total, 22 (92%) of 24 patients with cervical spine injury in the present study met at least one of these criteria and 14 (60%) of 15 patients with unstable cervical injuries met these criteria. Because analysis of our data suggested that patients with a GCS score greater than 8 and nonvehicular-related trauma have significantly lower probability of sustaining an unstable cervical spine injury, we believe that the practice of obtaining flexion–extension studies can be abandoned in patients who meet both these criteria and in whom cervical radiographs and CT scans demonstrate normal findings.

An important caveat is that flexion–extension radiography fails to demonstrate the cervicothoracic junction in up to 30% of patients. The use of MR imaging as an alternative method for assessing cervical soft-tissue injury in head-injured patients was recently described by D’Alise, et al. In 121 patients who were found to have sustained injury to the paravertebral ligaments, disc space, or osseous cervical spine; eight of these patients required surgical stabilization. The disadvantages of using MR imaging include the length of study time, patient-related transport difficulties in cases of intubation, and interpreting what the images actually indicate about cervical stability.

Regardless of the method, timely assessment of cervical stability after head injury allows earlier removal of the collar. Otherwise, collars can cause skin breakdown, limited patient mobilization, and suboptimum pulmonary care. In a series of 116 head-injured patients, Davis and coworkers identified cervical decubitus ulcers in 44% of the patients, particularly in those maintained in collars for over 5 days. Cervical collars may also cause jugular venous obstruction, with increases in jugular venous pressure and decreases in cerebral perfusion pressure.

Conclusions

Approximately one in 20 patients with moderate and severe head injury will sustain a cervical spine injury, the majority of which are mechanically unstable upper cervical injuries that often involve an SCI. Patients involved in vehicular-related accidents and those with an initial GCS score of 8 or less are at highest risk for concomitant cervical spine injury. Patients with at least one of these risk factors accounted for 92% of all patients with combined craniovertebral injuries in this study. Thorough and efficient cervical spine evaluation is mandatory in these patients. The results of recent studies in head-injured patients indicate that plain radiography in conjunction with additional thin-cut CT scanning will diagnose greater than 99% of cervical spine injuries. Given the small possibility of missing unstable ligamentous injuries, however, lateral cervical flexion–extension radiography with or without fluoroscopy should be considered in high-risk head-injured patients (those with vehicular-related trauma and/or an initial GCS score of ≤ 8) prior to cervical spine clearance.

References

20. Williams J, Jeline D, Cotti...

in high-risk head-injury-related trauma and/or an in-cervical spine clearance.

References


Manuscript received May 21, 2001.

Address reprint requests to: Daniel F. Kelly, M.D., Department of Neurosurgery, University of Southern California at Los Angeles Medical Center, 11920 Sunset Blvd, Los Angeles, CA 90025. Email: dfkelly@ucla.edu