Do Concomitant Cranium and Axis Injuries Predict Worse Outcome? A Trauma Database Quantitative Analysis

Prashant Chittiboina, M.D., M.P.H.,¹ Anirban Deep Banerjee, M.D., M.Ch.,¹ and Anil Nanda, M.D., F.A.C.S.¹

ABSTRACT

We performed a trauma database analysis to identify the effect of concomitant cranial injuries on outcome in patients with fractures of the axis. We identified patients with axis fractures over a 14-year period. A binary outcome measure was used. Univariate and multiple logistic regression analysis were performed. There were 259 cases with axis fractures. Closed head injury was noted in 57% and skull base trauma in 14%. Death occurred in 17 cases (6%). Seventy-two percent had good outcome. Presence of abnormal computed tomography head findings, skull base fractures, and visceral injury was significantly associated with poor outcome. Skull base injury in association with fractures of the axis is a significant independent predictor of worse outcomes, irrespective of the severity of the head injury. We propose that presence of concomitant cranial and upper vertebral injuries require careful evaluation in view of the associated poor prognosis.

KEYWORDS: Cervical spine, axis fractures, craniovertebral junction, skull base, trauma database

Fractures of the axis vertebra constitute 20% of acute cervical spine fractures.¹ These are unique vertebral injuries due to the anatomy and biomechanics of occipito-atlanto-axial complex/the craniovertebral junction.² Large number of patients with axis fractures have associated injuries: adjacent spine, head injury, spinal cord injury.¹⁻⁴ Association of injuries of cranium and upper cervical spine is well known.^{1,3-8} Upper cervical spine fractures associated with head injuries and/or skull base fractures (i.e., concomitant cranial and vertebral injuries) may intuitively indicate the magnitude of initial trauma. Although, such a conclusion may seem obvious, to our knowledge, no study has been performed to quantita-

tively assess the effect of concomitant cranial and vertebral injuries on outcomes. The purpose of our study was to identify quantitative predictors of worse outcome in patients with fractures of the axis associated with cranial injuries.

MATERIAL AND METHODS

The study population consisted of trauma referrals or direct admissions to a single Level 1 trauma center. At the time of admission, and throughout the hospitalization, data regarding admission status, diagnoses, and management were entered in a prospectively collected

¹Department of Neurosurgery, Louisiana State University Health Sciences Center, Shreveport, Louisiana.

Address for correspondence and reprint requests: Anil Nanda, M.D., F.A.C.S., Chair and Professor, Department of Neurosurgery, P.O. Box 33932, LSUHSC, Shreveport, LA 71130-3932 (e-mail: ananda@lsuhsc.edu).

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trauma database. Trauma One (Lancet Technology, Boston, MA) software was used for collecting data. A query string for all patients with axis fractures was generated in a 14-year period (1994 through March 2008). Two hundred and fifty-nine patients with axis fractures were identified. Patients with odontoid fractures, traumatic spondylolisthesis of the axis, and non-odontoid, non-Hangman's axis fractures were included in the study. Initial radiology reports of radiographs and spiral computed tomography (CT) scans were documented. Secondary confirmation of the diagnosis of axis fracture was made by examination of the radiographs and CT scans.

Skull base fracture was defined as fracture of the antrum, ethmoid bone, internal ear, maxillary sinus, nasal sinus, occiput, orbital roof, sphenoid sinus, and temporal bone. All patients with loss of consciousness were included in the concussive head injury group.⁹ Abnormal CT head was defined as fractures of the cranial vault, skull base fractures, traumatic subarachnoid hemorrhage, traumatic intracerebral hemorrhage, cerebral contusion, subdural hematoma, and extradural hematoma. Outcome was defined at time of discharge. A binary outcome measure was used. Good outcome was defined as a discharge Glasgow Outcome Score (GOS) 4 and 5. Injury Severity Score (ISS) was used for evaluating the severity of extracranial injury.

Statistical Methods

Statistical analysis software (SAS Institute Inc., Cary, NC) was used for data analysis. Initial analysis was performed with univariate analysis of factors affecting outcome. Contingency tables were created, and chi square and odds ratios were calculated. Significance level was set at $p < 0.05$. In further data analysis, logistic regression analysis was performed with stepwise introduction of craniovertebral injuries.

RESULTS

The mean age of the 259 patients included in the study was 39.4 (median 34.5, range 1 to 89) with a male predominance (64%). The racial distribution echoed the general population surrounding the institution (White 68.34%, Black 29.34%, and Hispanic 1.93%). A majority of the patients sustained axis fractures after motor vehicle crash (83%), with falls reported as the second most common cause (10%). Other etiologies included gunshot wounds (3%), assault (2%), and falling objects (2%). Arrival Glasgow Coma Score (GCS) grade was assigned to the patients based on standard technique. Patients in good GCS grade (GCS 13 to 15; 77%) outnumbered the patients in moderate (GCS 9 to 12; 5%) and poor grade (GCS 3 to 8; 18%). Upon admission and initial workup, 17 patients (6.7%) were taken immediately to the

operating room; these patients were operated upon for nonspinal conditions. Extrication collars were applied to all patients in the field or the emergency department (ED). All collars were then converted to Miami-J collars upon stabilization and transfer to intensive care unit (ICU) or floor. HALO devices were applied to 51 (19%) and cervical traction devices to 39 (15%). These patients also received hard cervical collars (Miami-J) upon removal of immobilization or traction. Among the rest, 57 (22.4%) were stable enough to be transferred to the floor, albeit with a hard cervical collar. About 70% of the patients needed a higher level of inpatient care including ICU or step-down units.

Associated Injuries

A third of the patients (85, 33%) presented with fractures in other cervical spinal levels. At the contiguous levels, atlas and C3 vertebra fractures were seen in 33 (13%) and 27 (10%), respectively. Concomitant vertebral fractures were seen in thoracic (12%), lumbar (15%), and sacral levels (5%). Although, over half of the patients (57%) suffered head injury, only 28% (72 patients) had abnormal CT head findings. Skull base fractures were seen in 15%. Associated long bone injuries were seen in 85 (33%) and visceral injury in 103 (40%) (Table 1). Upon admission, external immobilization device was placed on 51 patients. Twenty-nine patients underwent surgery for reduction and internal fixation of axis fractures. Posterior surgical approach was more commonly used (58%). While 56 patients needed ventilatory support, a tracheostomy was needed in at least 25 patients. A percutaneous endoscopic gastrostomy (PEG) for enteral feeds was performed in 16 patients.

Outcomes

A large majority of patients (71%) were discharged to home. Twenty-six (10%) patients required inpatient

Table 1 Associated Injuries That Were Observed in Patients with Axis Fractures

Associated Injuries	Percentage	Frequency
Atlas fracture	12.79	33
C3 vertebra fracture	10.47	27
Cervical spine fractures		
at other levels	32.82	85
Thoracic spine fractures	11.97	31
Lumbar spine fractures	14.67	38
Sacral fractures	5.02	13
Head injury	56.98	147
Abnormal CT head finding	27.91	72
Skull base fracture	13.95	36
Visceral injury	39.77	103
Long bone fractures	32.82	85

Table 2 Contingency Tables

Injury	DF	Chi Square Value	Prob.	Odds Ratio
Fracture of atlas	1	2.3427	0.1259	1.91
Fracture of C3 vertebra	1	0.0119	0.9133	1.06
Cervical spine fractures at other levels	1	0.0979	0.7544	1.11
Head injury	1	2.3989	0.1214	1.69
Abnormal CT head finding*	1	16.557	0.0001	3.75
Skull base fracture*	1	4.6864	0.0304	2.36
Visceral injury*	1	15.1237	0.0001	3.59
Long bone fractures	1	0.4344	0.5098	1.25

Results of two by two contingency tables to evaluate the effect of various injuries on binary outcome. The likelihood of poor outcome was calculated with each injury. DF, degrees of freedom; Prob., probability.

*Statistically significant.

rehabilitation. Inpatient facilities including long-term acute care and nursing homes received 30 (11%) patients with axis fractures. Seventeen patients succumbed to their injuries after arrival. Further analysis of these patients was done to identify patterns leading to death. In these, abnormal CT head findings were reported in 10 patients, with associated skull base fractures in 6 patients.

Good outcome at the time of discharge was noted in 82%, with poor outcome in 18%. Contingency tables were created to investigate the likelihood of poor outcome with various injuries. Presence of abnormal CT head finding, skull base fractures, and visceral injury was significantly associated with poor outcome. Presence of concomitant spinal fractures or long bone fractures was not associated with poor outcome (Table 2). Procedures such as PEG, tracheostomy, and tracheal intubation at arrival were associated with poor outcome. Neither application of external immobilization device, nor sur-

gical fixation of axis fracture had any significant correlation with poor outcome. Surgical stabilization or external immobilization of axis is performed for severe fractures; therefore a lack of correlation leads us to believe that severity of the axis fracture itself has no predictive value for outcomes (Table 3).

A correlation matrix was then created to evaluate the relationship between outcome, as defined by GOS, and factors at admission. GOS at discharge was correlated with ISS score (because it encompasses greater number of organs, and as a conglomerated expression) and severity of head injury. Of note, a negative correlation was seen with GCS at admission. Age and the extent of vertebral column injuries (measured by spine abbreviated injury score—Spine AIS) were not found to be correlating with GOS. Predictably, the severity of head injury (measured by closed head injury abbreviated injury score—CHI AIS) was negatively correlated with the admission GCS. Severity of head injury was also correlated with the extent of spine injury (Table 4). We performed a stepwise regression analysis to evaluate the effects of injuries adjacent to axis on outcomes. Presence of skull base fracture was a significant predictor of poor outcome ($p = 0.03$) while the presence of other spine fractures was not (Table 5). This indicated that, in our patient population, concomitant cranial-vertebral injuries were associated with worse outcomes, irrespective of the severity of admission GCS.

Table 3 Interventions

Intervention	Chi Square Value	Prob.
Intubation*	18.07	0.0001
PEG*	11.48	0.0007
Tracheostomy*	6.71	0.0096
External immobilization	2.35	0.125
Cervical spine fixation	0.54	0.4608

Patients that needed general surgical interventions such as intubation, PEG, and tracheostomy had significantly worse outcomes. Worse outcomes were not noted in patients that needed interventions to address instability arising from severe fractures of axis alone. PEG, percutaneous endoscopic gastrostomy; Prob., probability.

*Statistically significant

Table 4 Correlation Matrix

	GCS	Age	ISS	Spine AIS	CHI AIS
GOS	-0.43	0.22	0.59	0.11	0.34
<i>p</i> value	<0.0001	0.0006	<0.0001	0.1008	<0.0001

Both Injury Severity Score (ISS) and severity of brain injury (CHI AIS) were positively correlated with Glasgow Outcome Score (GOS) at discharge. Glasgow Coma Score (GCS) at arrival was negatively correlated with mRS.

Table 5 Stepwise Regression Analysis

Factor	DF	Prob.	Odds Ratio
Fracture of atlas	1	0.1259	1.91
Fracture of C3 vertebra	1	0.9133	1.06
Cervical spine fractures at other levels	1	0.7544	1.11
Skull base fracture	1	0.0304	2.36

A stepwise regression analysis revealed a significant predictive value of concomitant craniovertebral injury. Patients with axis fractures and skull base fractures had significantly worse outcomes when compared to those with spine injuries alone.

DISCUSSION

Radiographic evaluation of injuries to the cervicocranium is fraught with difficulties. Complex anatomy, physiologic motions, and normal variants may confound the presence and significance of injuries to this region.^{4,10} CT has an established role in initial diagnosis and stratification of trauma patients. Routine use of CT to evaluate craniovertebral injuries is widely supported.^{4-7,11-13} The use of CT has resulted in a greater incidence of diagnosis of concomitant injuries to the baso-cranial and upper vertebral region. Bloom et al performed a prospective study to determine the incidence of occipital condyle fractures. The authors reported a 16.4% rate of occipital condyle fractures, concluding that thin slice CT of the cervicocranium is indicated in victims of high energy trauma. They also noted that the majority of patients recover fully from this injury with the use of a hard cervical collar.¹¹ Johnson et al argued for an increased awareness of basal temporal bone fractures. In a review of existing literature, they suggested that an early involvement of otolaryngologist/neuro-otologist in evaluation and management of basal temporal bone fractures can improve long-term functional outcomes.¹³ Saboori et al reported that the presence of risk factors, including loss of consciousness, seizure, and focal neurological deficits, can be used to predict abnormal CT scans of the head in trauma. The authors attempted an algorithmic approach to develop guidelines for better management of patients with minor head trauma.¹⁴ Such an algorithmic approach has been supported by Hunink while advocating the PROACTIVE approach in determining cost-effectiveness of imaging strategies.¹² Results from the IMPACT study confirm the prognostic value of CT in traumatic brain injury. Abnormal findings in CT head were found to be significant predictors of outcomes in traumatic brain injury.¹⁵

As the use of CT for diagnosing injuries to the craniovertebral region becomes established, several authors have attempted to identify associations among injuries to the various components of this region. Kirshenbaum et al suggested a high incidence of upper cervical spine fractures in patients with significant head trauma.⁶ Link et al agreed with routine inclusion of craniovertebral CT for workup of patients with substantial cranial trauma. They found that up to 13% of patients with head trauma had upper cervical spine fractures. Among the patients with upper cervical fractures, 29% had intracranial hemorrhage and skull fracture, including calvarium and skull base, was seen in 29%.⁷ In our patient population we saw a similar rate of abnormal CT head findings (28%), although the rate of skull base fractures was lower (15%). Feiz-Irfan et al have drawn attention to the risk of neurovascular injuries in association with skull base injuries.¹⁶ In a review of 54 patients with intracranial hemorrhage, Frye et al reported the incidence of upper cervical spine fracture

in two patients (3.7% of cases), concluding that intracranial hemorrhage is not a significant predictor of upper cervical spine injury.¹⁷ The rate of concurrent craniovertebral injuries in this series is unknown.

The significance of concomitant baso-cranium and vertebral fractures in clinical management remains unknown.⁵ In practical terms, presence of associated skull base fractures may not influence the algorithms of clinical management. An example of such an injury would be a fracture of the clivus. Koonsman et al addressed the issues of management of patients with skull base injuries. In a retrospective review of 259 patients with skull base injuries, the authors were able to generate groups to stratify the morbidity and mortality. They reported that the group with intracranial pathology in association with skull base fractures had the highest morbidity and mortality (11% and 7%, respectively). Although, this report is useful in developing strategies for clinical management of patients with skull base injuries, concomitant upper vertebral injuries were not addressed. A low spinal fracture rate of 1.15% was reported by the authors. It is unclear whether CT scan of the cervical spine was routinely performed on these patients.¹⁸ Our study indicates that skull base fractures and abnormal CT head associated with upper cervical spine injury may predict worse outcome, in spite of a negative correlation with the admission GCS. Notwithstanding the severity of the head injury, CT findings of concomitant craniovertebral injuries may help focus attention on patients with a higher risk for poor outcome. Stratifying care for these patients might help improve outcomes.

The need for adequate triage and allocation of limited resources is important for clinicians. In a consensus statement, the Society of Critical Care Ethics Committee has called for development and use of predictive instruments to promote a more efficient and equitable use of intensive care resources.¹⁹ Accurate prediction of patient outcomes based on initial workup and appearance remains a challenge. Currently, the sensitivity of the existing models and physician predictions regarding outcome for emergency room patients remains poor.²⁰ The GCS is simple to use, and can be applied at the bedside. However, the inter-rater reliability remains low, and the individual components of the scale have similar receiver operating characteristic curve to that of total GCS score for predicting certain outcomes. The therapeutic intervention scoring system (TISS) helps in evaluating the need for resource allocation. Although, TISS has been shown to be effective in stratification and prediction of ICU costs, its use for triage has been questioned. Several physiologic scoring systems are being developed and tested that are specific to the ED setting. A successful application of these systems will depend on ease of use and availability,

and accuracy of prediction.²¹ An excellent source for forming predictive guidelines for traumatic brain injury patients is the IMPACT study. In a multivariate analysis of 8509 patients, abnormal CT head findings emerged as powerful prognostic indicators in traumatic brain injury.²² Even though there is a push for development of more accurate predictive instruments, it is recognized that outcome prediction is not synonymous with clinical judgment. When it comes to an individual patient, the existing scoring systems are fraught with uncertainty,^{21,23} especially with regard to "associated" injuries. Our study is an attempt to identify markers that may predict worse outcomes in multifactorial trauma patients in the ED. We hope that such an addition to the existing knowledge base will help improve the predictive models and instruments for stratification of trauma patients.

Limitations

The study is based on data collected from one institution only. The results from this study may not be applicable to the general population or patient groups from other hospitals. A population-based study to examine the effects of baso-cranial and upper vertebral injuries on outcome would be highly desirable to generalize the results. The limited scope of the study prevented us from examining the effect of pathomorphological changes in brain or associated metabolic alterations on outcomes. In spite of a negative correlation with admission GCS, it remains to be seen whether the association with poor outcomes is specifically due to concomitant anatomic injuries or if it is an indicator of a higher severity of injury overall resulting in a worse outcome. In addition, the effect of spinal neurologic injury was not examined in our study. A larger, prospective study would help eliminate these limitations of our study.

CONCLUSION

In our patient population, severity of axis injury itself or with other spine injuries was not associated with worse outcomes. But, skull base injuries in association with fractures of the axis were a significant predictor of worse outcomes; more importantly, the association emerged to be irrespective of the severity of the head injury. We propose that presence of concomitant cranial and upper vertebral injuries require careful evaluation in view of the associated poor prognosis. In our opinion, routine CT of craniocervical junction is useful in stratifying patients in this regard.

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NOTES

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