Original Article

A prospective study of cervical spinal injuries

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Abstract:
Cervical spinal injuries are potentially the most devastating injuries. This study conducted in Central Morgue, Department of Forensic Medicine and Toxicology, S.C.B. Medical College & Hospital, Cuttack, India will help in better understanding of the mechanism of cervical spinal injury, pattern and distribution of injury along with its fatal outcome. In our study, 64% of cervical injury cases were caused by road traffic accident (RTA) cases. 77% of the population had direct impact on the cervical region at the time of incident while only 23% suffered from cervical injury due to indirect impact or transmitted force. 2% cases were exclusive of spinal cord injury while 20% of the cases had only spinal column (vertebra) involvement and the remaining 78% had both cord and column injury. The most commonly involved cervical column was C_5-C_6 (24%) with 30% involvement of C_5 vertebrae among 110 cases.
Key words: forensic science**,** forensic pathology, cervical injury, spinal cord, fatal, polytrauma

Introduction:
Cervical spinal injuries are potentially the most devastating injuries. The dual arrangement of the head & neck is that a heavy immovable object (the head) is projected over a narrow stalk (the neck) capable of supplying a broad range of movements. The upper two cervical vertebrae provide rotational movements, and the lower five, flexion and extension. This functional aspect of cervical spine explains why, as a general rule, rotational forces applied to the head are likely to injure the upper two vertebrae, and those causing extreme flexion & extension, the lower five[1].
Approximately 5-10 % of unconscious patients who present to the Emergency Department as a result of motor vehicle accident or fall have a major injury to the cervical spine.[2] Spinal injuries range from temporary & merely functional impairment due to ligament & muscle strain to vertebral fracture &dislocation, the latter often accompanied by spinal cord lesion. One-third of cervical spine fractures occur at the level of C2 and half at the level of C6 or C7. Most fatal cervical spine injuries occur in upper cervical levels, either at cranio cervical junction C1 or C2. [2] Cervical spinal injury may occur due to flexion rotation, extension rotation and axial compression resulting in fracture, subluxation and dislocation. Frequent mechanisms of cervical spine injury are transverse shear, longitudinal shear and tension created by ventroflexive and retroflexive forces. Hu et al reported on patients in the Manitoba Health Insurance Plan from 1981-1984, the most common mechanism of injury to be accidental falls with motor vehicle/ transport injuries being the 2nd most common[3].The cervical spine remains the most common level for spinal cord injury, representing 55% of all spinal cord injury. [4]

In United States alone, cervical spine injuries cause an estimated 6000 deaths and 5000 new cases of quadriplegia each year [2]. In India, no such population-based study has been conducted so far because of poor socio-economic condition, lack of documentation, deficit funds for study and so on. However, studies with limited sample and place have been conducted in different regions, medical colleges and hospitals. One of such study revealed that cervical spinal injury (36.2%) was most common among all the spinal injuries [5].
Another similar study suggested that cervical injuries were caused due to road traffic accidents (46.81%) followed by fall from height (39.72%). [6]
This study conducted in Central Morgue, Department of Forensic Medicine and Toxicology, S.C.B. Medical College & Hospital, Cuttack, India will help in better understanding of the mechanism of cervical spinal injury, pattern and distribution of injury along with its fatal outcome. It also indicates the need for intensive public education, environmental modification and strategic plans to address injury prevention along with legislative measures for safety harnesses. [5]
The main aim and objectives of this study is to determine –

- The most commonly involved site of cervical spine associated with direct and indirect trauma.
- The most common cause of cervical spinal injuries based on post-mortem findings.
- To suggest preventive measures.

Material and Methods:

This study includes 110 number of autopsy cases brought to the Central Morgue, Department of Forensic Medicine & Toxicology, S.C.B. Medical College and Hospital, Cuttack, Odisha between a time periods of November 2013-October 2015.

Inclusion Criteria

- All cases suggestive of cervical spinal injuries based on history, investigation report and treatment records.
- Additional injuries concomitant with cervical injuries particularly, facial injury, brain injury and blunt trauma are taken into account.

Exclusion Criteria

- Penetrating neck injuries with intact cervical spine.
- Cervical spinal injury in fetus.
- Skeletal remnants with cervical spinal injuries.
- Decomposed bodies.
- Decapitation injury sparing cervical region.

Study Design

In the present study, a retrospective method of survey was adopted for the following reasons –

- Less time consuming.
- A onetime retrospective survey can provide necessary information for studying the various parameters.
- Cervical spinal injury is a catastrophic event and a prospective study can affect continuation of the study. Thus, rendering the sample unfit for study.

Epidemiological tools

The interview method using a pre-designed and pre-tested questionnaire is a flexible tool and if misunderstood by the respondent, questionnaire could be rephrased with proper emphasis and explanation on the spot. Therefore, considering its advantages the technique of the interview method with structured questionnaire to obtain reliable and valid data for analysis was used for study.

Technique of study

The interview method was used for collection of relevant information about the deceased. Details were obtained from the family members, neighbors, relatives, close friends and corroborated with hospital records and police inquest report.

Thus, at the end 110 cases with kith and kin who were willing to cooperate in this study, were taken up as study sample. Informed consent was obtained from the next of kin. Data was recorded based on interview method in a pre-designed proforma.

Methods adopted for removal of spinal cord

The spinal cord can be removed either by posterior approach or anterior approach based on the dissection method adopted. Each approach has its own advantages and disadvantages.

Posterior approach:

It allows easy exposure of the uppermost cervical spine & allows direct visualization of the craniocervical junction; it is therefore recommended in neck injury cases, craniocervical instability cases and in special cases like encephalocele, myelomeningocele & Arnold-Chiari malformation. Deep contusions with blood extravasation, injuries to ligaments, and fracture of posterior parts of vertebral bodies also are demonstrated by this method. With this method the continuity between lower brain stem and upper cervical cord can be maintained.

The limitations of this approach are firstly, embalming fluids tend to leak from the incision on the back and secondly, it is less suited for pursuing the course of peripheral nerves for any length in contiguity with the spinal cord.

Considering all its advantages and disadvantages, although the upper cervical cord can be removed safely by the anterior approach, the safer posterior approach is preferred if examination of higher cervical segments is critical. Therefore, **posterior approach** was used for removal of spinal cord in our study.

- Autopsy was conducted as per the standard procedure with slight modification in dissection of cervical spinal cord with posterior approach.

Preparation of spinal cord for histopathology study

It was done by using the standard histopathological study method .Staining was done using Hematoxylin and Eosin stain.

Microscopic Observation

- Transverse cut section of cervical spinal cord at the injured site viewed under microscope.

Results:

Mechanism of trauma and mode of transport

Majority 64% (71 cases) had road traffic accidents (RTA) and fall from height 20% (23 cases) as the cause of death. Assault, fall of heavy weight and railway accidents contributed 5% (5cases) each. Only 1% (1 case) was due to industrial accident with no sports related case. Hence cervical injury is strongly associated with RTA. [Table: 1]

Out of 64% of RTA cases, 49% of the deceased were pedestrian, 34% were bike rider, 13% were riding four wheeler and only 4% were pillion rider. Whereas out of 20% fall from height, 48% comprised of fall from roof, tree or vehicle; 17% fell into well; 13% comprised of fall of heavy weight; another 13% was contributed by fall on ground or hit by an animal and lastly 9% comprised of fall from height following electrocution. 77% of the population had direct impact on the cervical region at the time of incident while only 23% suffered from cervical injury due to indirect impact or transmitted force. [Fig: 1]

Distribution of cervical injury

In this study only 2% cases was exclusive of spinal cord injury while 20% of the cases had only spinal column (vertebra) involvement and the remaining 78% had both cord and column injury. [Fig: 2]

The most commonly involved cervical column was C_5 -C_6 (24%) with the next in order being C3-C4 (20%). [Table: 2]

On distributing the cases based on the involvement of individual cervical vertebra or numbering, 30% (41 cases) of cases involved C_5 closely followed by C_4 24% (33 cases) [Table : 3].

On redistributing the cases based on the involvement of anatomical landmarks of cervical vertebra, it was observed that the body of cervical vertebra was most commonly involved in 41% (76 cases) followed by articular facet with 28% (53 cases) [Fig: 3]. The other parts of cervical vertebrae involvement in our study also depict a significant P value. The values being lamina 13% (25 cases), pedicle 12% (23 cases) and transverse process 6% (11 cases) [Table: 4].

Biomechanics of cervical spine injury

Biomechanically, 61cases (55%) had hyperextension pattern of injury [Fig: 4].

Spinal cord injury

In this study we observed that 83.50% (92 cases) of spinal cord was injured while 16.50% (18cases) were intact. Out of those 83.50%, 67% (72cases) revealed hemorrhagic spinal cord and 16.50% (18cases) showed non-hemorrhagic (edematous) spinal cord [Table: 5].

Discussion:

India has witnessed rapid urbanization, motorization, industrialization and migration of people resulting from socio-economic growth and development in the last two decades. Injuries are a major public health problem in India. Santayana Gururaj in 2011 stated, that road crashes and deaths have increased from 68,351 in 1995 to 1,26,896 by 2009 with a national average of 110/million population, though the real incidence of Spinal Cord Injury is not yet known because of lack of national registry [7]. Sekhon and Fehlings reported that the incidence of Spinal Cord Injury varies between 15 and 40 per million each year in developed countries [4].

Data from developed countries clearly establishes RTA as the main cause of spinal cord injury. In United States, cervical injury was caused by 50% motor vehicle collision, 20% falls and 15% were sports related (i.e. 10%- 15% of all football players). J Allan Goodrich suggested that 20% of lower cervical spine injury was caused by motor vehicle accident [8]. Langston T. Holly et al found 8.2% cervical injury patients involved in MVAs and 1.6% cervical injury patients in Non-MVA-Associated Trauma [9]. Hu R, Mustard CA et al found that the most common cause of cervical injury was accidental falls followed by motor vehicle or transport injuries [3]. The study conducted by Hitosugi, Masahito et al suggested that most of the cervical injury was caused by traffic accident (41.3%) and slips (24.8%) closely followed by assaults (17.4%) and fall from height (9.2%) [10]. According to the study by Bucholz, Robert W. et al incidences of 24% of cervical spinal injury were revealed in RTA [11]. Towards the end of 20th century, J. P. Wyatt and his colleagues did a research on fatal falls downstairs in Scotland,

during their study they found that 53% fatal falls resulted in death at the scene of accident [12]. Narayan Reddy and O P Murty noted the common causes of spinal fracture to be falling from a height, diving and being thrown from automobile [13]. Injury prevention strategies should focus towards the need for better transport facilities, provision of safer roads, stringent traffic rules, as wearing seat belts, helmets, advocating speed limit, proper traffic signals, mandatory traffic classes before awarding the license and alcohol awareness in India. Interpretation and implementation of better laws with severe penalties can reduce the risk factors.

The findings in our study are in agreement with Hitosugi, Masahito et al in the sense that the most common cervical hyperextension injuries was of the C_5-C_6 region [10].

The part of cervical vertebra involved in our study was close to the findings of Hitosugi et al who found fracture dislocation of the body of the vertebra to be involved in 30% cases of the cervical involvement followed by fracture dislocation of articular facet [10]. Reddy and Murty found the common sites of fracture to be both upper and lower cervical regions and junction of thoracic and lumbar segments. Fracture-dislocations and fracture of the laminae can damage the spinal cord [13].

The biomechanics found in our study was in accordance with T Ohshima et al study [14]. Reddy and Murty also stated that hyperextension is the most common mechanism of fracture of spine [13].

Pekka Saukko and Bernard Knight found that cervical parts of the spinal segment are closely associated with head injuries and vehicular accidents. The upper two cervical vertebrae provide most of the rotational movement of the head, whilst the lower neck allows flexion and extension. Violent force applied to the head tends to damage those parts of the neck corresponding with this functional distinction. Spinal damage may be caused by compression, hyper flexion and hyperextension stress [15]. Shkrum and Ramsay elaborated that forces acting on the vertebral column are rotational (accounting for flexion, extension, lateral flexion and torsion) and linear (causing a pushing together [compression], a pulling apart [distraction] of various part of the vertebral column). In simple terms vertebrospinal injuries can be categorized, irrespective of their site and causation as follows:

- Fracture of the vertebral body or posterior elements without subluxation.
- Fracture without subluxation.
- Subluxation without fracture.
- Spinal Cord Injury without radiographic evidence of fracture or subluxation.

Although rostral cervical injuries are frequently associated with skull and brain injuries, a head impact is not necessary for a fatal cervical spinal injury to occur although abrupt and extensive movement (whiplash) of the neck is invariable. High cervical injuries are also sometimes accompanied by blunt force injuries to the mandible. Deployment of airbags causes high cervical fractures if the subject is sitting too close to the air bag. The principal cause of Spinal Cord Injury is mechanical compression of the spinal cord because of fracture-dislocation during which loss of stability leads to the movement of one vertebra relative to an adjacent vertebra. As a consequence, the spinal cord is pinched between the dorsal surface of the body of one vertebra and the ventral surface of the lamina of the adjacent vertebra [16].

There are 2 types of injury to spinal cord: Hemorrhagic and Non-hemorrhagic. Clinically there is a strong correlation between the length of the spinal cord edema and the clinical outcome. The most important factor however is whether there is hemorrhage, since hemorrhagic spinal cord injury has an extremely poor outcome.

In a study conducted by H. T. Chang it was observed that sub-acute spinal cord contusion revealed few lymphocytes and plenty of macrophages/ activated microglia at the injury sites in consistent with previous report [17]. Recent studies have shown that injection of blood-derived macrophages activated exogenously may be beneficial in rodent models of spinal cord injury. Similar revelation has also been observed in our study. However, much remains to be learned about the mechanisms involved in this apparent beneficial effect. Although this experimental therapy of injecting blood-derived macrophages for human spinal cord injury is now currently undergoing Phase II clinical trial, reproducible results using this protocol in larger animal models of spinal cord injury, including primates, are disturbingly lacking. Moreover no information is available regarding the possible interactions between the exogenously activated macrophages and the macrophage/ microglia intrinsically activated by spinal cord injury. There is no doubt that caution must be exercised in the planning, initiation and conduct of human clinical trials in spinal cord injury.

Conclusion:

- 64% of cervical injury cases were caused by road traffic accident (RTA) cases. Out of 64%, only 49% of the deceased were pedestrian and 34% were bike rider.
- 77% of the population had direct impact on the cervical region at the time of incident while only 23% suffered from cervical injury due to indirect impact or transmitted force.
- 2% cases were exclusive of spinal cord injury while 20% of the cases had only spinal column (vertebra) involvement and the remaining 78% had both cord and column injury.
- The most commonly involved cervical column was C_5-C_6 (24%) with 30% involvement of C_5 vertebrae among 110 cases.

  Fracture dislocation of the body of the vertebra comprised of 41% of the cervical involvement closely followed by fracture dislocation of articular facet 28%.
- Biomechanically, most of the cases had hyperextension (55%) pattern of injury.
- Out of 83.50% of injured spinal cord, 67% revealed hemorrhagic spinal cord and 16.50% showed non-hemorrhagic (edematous) spinal cord.
- Spinal cord contusion revealed few lymphocytes and plenty of macrophages/ activated microglia at the injury sites. Based on these finding several clinical trials are being done with the hope to cure spinal cord injury in near future.

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Table 1: Mechanism of trauma

Mechanism of trauma	Number of cases (N = 110)	Z score for 15.71±5.9995	P value	Result
RTA	71 (64%)	9.22268	<0.00001	ES
Fall from height	23 (20%)	1.2160	0.111992	NS
Assault	5 (5%)	-1.7865	0.03705	S
Fall of heavy weight	5 (5%)	-1.7865	0.03705	S
Railway accident	5 (5%)	-1.7865	0.03705	S
Industrial accident	1 (1%)	-2.454	0.007064	S
Sports related	0 (0%)	-2.621	0.004304	S

Table 1: P value is significant for all except for fall from height. *p value >0.5 is not significant (NS), p<0.5 is significant (S), p<0.001 is highly significant (HS) and p<0.00001 is extremely significant (ES).

Table 2: Site of vertebral column involved

Site of vertebral column	Number of cases (N = 110)	Z score for 8.4615±2.9697	P value	Result
C1C2	2 (2%)	-9.202	0.013833	S
C2C3	9 (8%)	0.1552	0.438332	NS
C3C4	23 (20%)	4.8697	< 0.00001	ES
C4C5	20 (18%)	3.8594	5.7E-05	ES
C5C6	27 (24%)	6.2167	< 0.00001	ES
C6C7	5 (4.5%)	-1.192	0.116631	NS
C1	1 (1%)	-2.539	0.005558	S
C2	0 (0%)	-2.875	0.00202	S
C3	3 (3%)	-1.865	0.031091	S
C4	4 (4%)	-1.528	0.06325	NS
C5	9 (8%)	0.1552	0.438332	NS
C6	5 (4.5%)	-1.192	0.116631	NS
C7	3 (3%)	-1.865	0.031091	S

Statistically, Z-score was 6.2167 with p value <0.00001 for C_5-C_6 vertebra. Table 2: P value is not significant for C3C4, C6C7, C4, C5 and C6. *p value >0.5 is not significant (NS), p<0.5 is significant (S), p<0.001 is highly significant (HS) and p<0.00001 is extremely significant (ES).

Table 3: Cervical vertebra involved

Cervical vertebra	Number of cases (N = 110)	Z score for 19.2857±3.5831	P value	Result
C1	2 (2%)	-4.824	< 0.00001	ES
C2	12 (9%)	6.6176	< 0.00001	ES
C3	30 (22%)	2.9902	0.001394	HS
C4	33 (24%)	3.8275	6.5E-05	ES
C5	41 (30%)	6.0602	< 0.00001	ES
C6	13 (10%)	-1.754	0.039715	S
C7	4 (3%)	-4.266	<0.00001	ES

Statistically the Z score for C_5 and C_6 was 6.0602 and -1.754 respectively with significant p values. Table 3: P value is significant for all seven individual vertebras. *p value >0.5 is not significant (NS), p<0.5 is significant (S), p<0.001 is highly significant (HS) and p<0.00001 is extremely significant (ES).

Table 4: Part of cervical vertebra involved

Cervical vertebra	Number of cases (N = 110)	Z score for 37.6±5.06	P value	Result
Body	76 (41%)	7.5889	< 0.00001	ES
Articular Facet	53 (28%)	3.0435	< 0.001169	HS
Lamina	25 (13%)	-2.490	0.006387	S
Pedicle	23 (12%)	-2.885	0.001957	HS
Transverse Process	11 (6%)	-5.257	< 0.00001	ES

Statistically, Z score for body of cervical vertebra was 7.5889 and p value < 0.00001 which is extremely significant. Table 4: P value is significant for all the parts of cervical vertebra.

Table 5: Spinal cord involvement

Cervical vertebra	Number of cases (N = 110)	Z score for 36.67±4.38	P value	Result
Hemorrhagic	74 (67%)	8.523	< 0.00001	ES
Non-hemorrhagic	18 (16.5%)	-4.263	1E-05	ES
Intact	18 (16.5%)	-4.263	1E-05	ES

Statistically, the Z score for hemorrhagic spinal cord is extremely significant with P value < 0.00001. Table 5: P value is significant for hemorrhagic, non-hemorrhagic and intact spinal cord. *p value >0.5 is not significant (NS), p<0.5 is significant (S), p<0.001 is highly significant (HS) and p<0.00001 is extremely significant (ES).

Fig 1: Impact at the time of incident

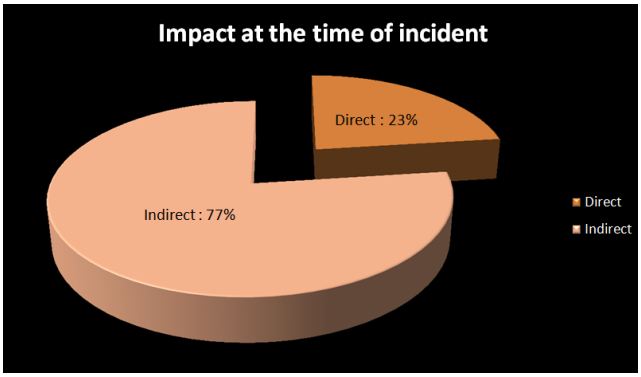


Fig 2: Distribution of cases according to the injury

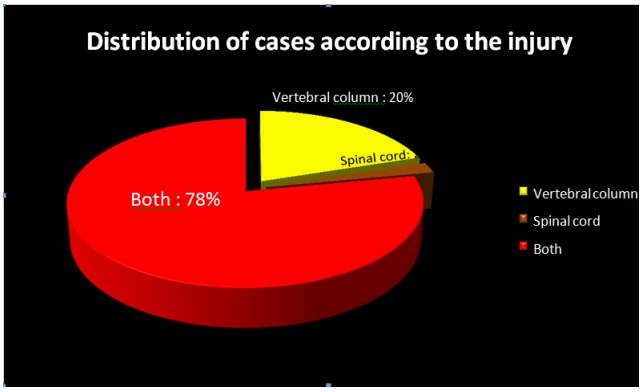


Fig 3: Distribution of injury according to the most commonly involved location

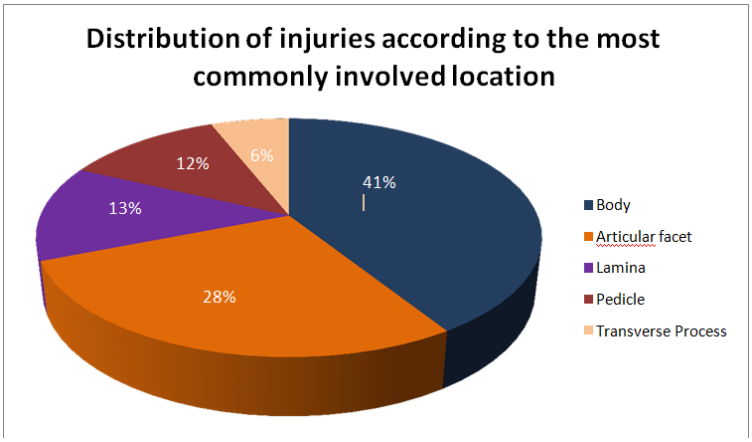
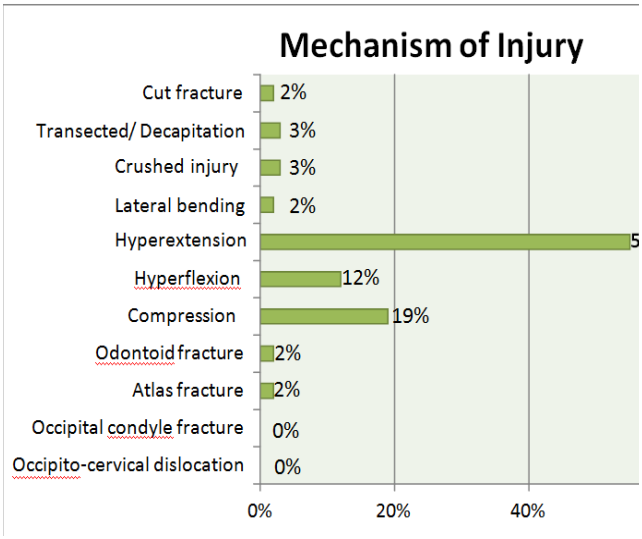


Fig 4: Mechanism of injury



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