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Correlation between Neurologic Status and Spinal Injury at the Cervicothoracic Junction

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ABSTRACT

Background: With limited studies on spinal injuries occurring at the cervicothoracic junction, there is currently a knowledge gap regarding the correlation between morphology of injury and neurology and whether surgery provides a favorable neurological outcome. The primary objective was to determine whether the neurological deficit correlated with the severity of injury at this region of the spine.

Methods: All patients with injuries at the cervicothoracic junction from December 2015 to December 2020 in a government trauma hospital were included. Patient demographics, characteristics of the injury, neurological score, imaging findings, surgery details and neurological outcomes were analyzed. All patients had a minimum follow up of 2 years.

Results: Of the total 30 patients, 23 were male and 7 female with mean age 42.4 years. 90% had fall injuries with 76.7% sustaining AO type C injury and 10% with AO B2 injury. 73.4% had injury at C6-C7 level followed by 13.3% , C7-T1. Only 16.7% patients presented with intact neurology. Plain x-rays failed to detect cervicothoracic junction, injuries in 63.3% patients. Posterior stabilization was performed in 56.7%. Neurological improvement was observed in 9 patients.

Conclusions: Though cervicothoracic junction injuries are uncommon, they are highly unstable injuries and difficult to diagnose by plain x-rays. These injuries also result in profound neurological deficit. Surgical stabilization of these injuries should be considered for a favorable neurological and functional outcome.

Keywords: Cervico-thoracic junction; injuries; morphology; neurology; spine.

INTRODUCTION

With a reported incidence of 2 to 9%, cervicothoracic junction (CTJ) injuries are not common. [1,2] The majority of injuries sustained in this region of the spine are dislocations.[3] Because of the anatomic complexity, these injuries are often unstable and necessitate surgical stabilization. It is not uncommon for the initial radiological work up with plain x-rays to miss injuries in this region, resulting in worsening neurology.[4]

Further, the prevalence of neurologic impairment associated in CTJ is high (59 – 83%). A high prevalence of neurological deficit combined with failure to diagnose in the initial evaluation makes these injuries susceptible to poor outcomes.[1,2,5]

Because of the limited number of studies, there is currently a knowledge gap regarding the correlation between the morphology of injury and neurology and whether surgery provides a favorable neurological outcome.

Our primary objective was to determine whether the neurological deficit correlated with the severity of injury at the cervicothoracic junction (CTJ). The

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secondary objectives of this study were to determine: the characteristics of the injury, ability of x-rays to diagnose the injury and if surgery provided a favorable neurological outcome.

METHODS

After obtaining institutional review board approval (Reference number 61/2078/79), we performed a retrospective study from December 2015 to December 2020, in a tertiary level government trauma center. All patients with cervicothoracic injuries (C6 to T4) with more than two years follow up were included in this retrospective study. Patients with pathological fracture, previously operated cervical and cervicothoracic junction region or non-traumatic injuries were excluded. Patient demographics, characteristics of the injury, imaging findings, details of the surgical procedure and neurological outcomes were retrieved from hospital records, operative notes and discharge summaries. Morphological details of the injury and the AO classification[6] were obtained from the radio-images (x-ray and CT scans). MRI was performed in patients with incomplete neurological deficits. The preoperative neurological status, immediate postoperative neurological outcome and final follow-up neurological outcome was evaluated by the American Spine Injury Association (ASIA) score system (Table 1). All patients with translation injuries were placed in skull traction. The surgical approach was based on the reducibility of the dislocation, neurological status and morphology of the injury. The two year follow up x-rays and ASIA score charts were evaluated for implant failure and neurological improvement. Descriptive statistical analysis was performed as frequency and percentage (%).

RESULTS

Thirty patients with traumatic CTJ injuries were included in the study. There were 23 males and 7 female patients with a mean age of 42.4 years (range 18 to 73 years). 90% of the patients sustained fall injuries while 6.7% were involved in road traffic accidents (Table 1).

The majority of the injuries was at C6-C7 (73.4%) level followed by C7-T1 (13.3%) level (Table 1). Three injury patterns were observed: AO A4 (complete burst with fracture of both endplates), AO B2 (posterior tension band injury with failure through both soft tissue and bony elements) and AO C (translational injury) (Table 1). Translational injury (AO C) was the predominant pattern of injury (76.7%). There was a high incidence (53.3%) of ASIA A and B complete motor deficit patients (Table 2) and this neurological deficit pattern was predominant in AO C translational injuries (Table 3). The morphological AO A4 burst fracture pattern (13.3%), consisted of equal number of complete and incomplete neurologic deficit patients (Table 4).

Table 1. Patient Demographics and Injury Profile.

Total number of patients	**30**	**Percentage (%)**
Mean age (years)	42.4	
Minimum age (years)	18	
Maximum age (years)	73	
Male	23	76.7%
Female	7	23.3%
Fall Injury	27	90%
Road Traffic Accidents	2	6.7%
Blunt Trauma	1	3.3%
Level of Injury		
C6-C7	22	73.4%
C7-T1	4	13.3%
C6	3	10%
C7	1	3.3%
AO Classification		
AO A4	4	13.3%
AO B2	3	10%
AO C	23	76.7%

Table 2. Neurological status prior to surgery and post-surgery.

	Pre-operative	Immediate Post operative	2 years post operative
ASIA A	9 (30%)	9 (30%)	9 (30%)
ASIA B	7 (23.3%)	4 (13.3%)	4 (13.3%)
ASIA C	2 (6.7%)	3 (10%)	2 (6.7%)
ASIA D	7 (23.3%)	9 (30%)	1 (3.3%)
ASIA E	5 (16.7%)	5 (16.7%)	14 (46.7%)

Table 3. Correlation between Morphology, Neurology and Level of Injury.

Level of Injury	AO Classification	Number of patients	ASIA Score	Number of patients
C6-C7	B2	2 (9.1%)	A	7 (3.6%)
	C	20 (90.9%)	B	5 (22.7%)
			C	1 (4.5%)
			D	5 (22.7%)
			E	4 (46.5%)
C7-T1	B2	1 (25%)	A	0 (0%)
	C	3 (75%)	B	1 (25%)
			C	1 (25%)
			D	1 (25%)
			E	1 (25%)
C6	A4	3 (100%)	A	2 (66.7%)
			B	1 (33.3%)
C7	A4	1 (100%)	D	1 (100%)

Table 4. Correlation between Neurology and Morphology of Injury.

AO classification	ASIA Score	Number of patients
AO A4	A	2
	B	1
	C	0
	D	1
	E	0
AO B2	A	1
	B	0
	C	0
	D	0
	E	2
AO C	A	6
	B	6
	C	2
	D	6
	E	3

Table 5. Surgical Approach.

Surgical Approach	Number (%)
Anterior	11 (36.7%)
Posterior	17 (56.7%)
Combined	2 (6.6%)
Anterior Approach	
Anterior cervical discectomy & fusion	6
Anterior cervical corpectomy & fusion	5
Posterior Approach	
C7 pedicle screws inserted	15
C7 pedicle screws not inserted	2
AO Classification	**Approach (number of patients)**
AO C	Anterior (6)
	Posterior (15)
	Anterior-Posterior-Anterior (2)
AO A4	Anterior (3)
	Posterior (1)
AO B2	Anterior (2)
	Posterior (1)

Posterior approach was the preferred surgical approach (56.7%). Exclusive anterior approach was utilized in eleven patients while a combined approach was performed in two patients (Table 5). Anterior approach with discectomy was performed for AO B2 injuries and corpectomy was utilized in patients with AO A4 injuries. For the AO C translational injuries, after reduction in skull traction anterior instrumentation was performed in six patients. In fifteen patients operated upon posteriorly, either a unilateral or bilateral C7 pedicle screws were inserted. Because of the fractured pedicles at C7, pedicle screw insertion in C7 vertebrae could not be performed in two patients.

In the immediate postoperative period, three of the ASIA B patients improved to ASIA C; the two ASIA C patients improved by one neurological grade. There was no immediate improvement in the ASIA D and ASIA A neurological patients. At two years follow up, all ASIA D patients (23.3%) improved to ASIA E. However no neurological improvement was seen in the ASIA A patients even at two years (Table 2).

The two-year x-rays did not show any evidence of implant related complications like screw loosening, rod or screw breakage or plate back out even in the two patients without screws in the C7 pedicle.

CSF leak was observed in one patient with a C6-C7 AO C translational injury with ASIA A neurology during anterior cervical corpectomy and fusion. It was managed by packing with a muscle-fat on-lay patch graft. Spontaneous pneumothorax developed in one patient three days after a posterior approach and was managed with a chest tube insertion. One patient with ASIA A injury with posterior instrumentation died three years after surgery due to pulmonary embolism.

DISCUSSION

The cervicothoracic junction (CTJ) is a region of complex anatomy where a flexible, lordotic cervical spine transitions to a rigid, kyphotic thoracic spine.[7] The transitional anatomy can result in high stresses that predisposes the region to instability from trauma.[8] The proximal segment of the CTJ varies from C6 or C7 and extends down to T3 or T4.[8,9] Although there have been reports on various pathologies affecting the CTJ, there is limited literature exclusively on injuries at the CTJ.[1-3,5] Most of these papers report on a few cases. In one of the largest series, Evans reported on 14 patients with CTJ injuries over a period of 27 years.[2] The largest series in the literature belongs to Lenoir et al., who reported on 30 patients with CTJ injuries that were treated over a period of six years.[10] We work in a

high volume trauma hospital with an average of 13,350 trauma patients treated per year. Because there are few large series in the literature regarding this topic, we sought to document our experience with treating theses injuries over a period of five years. We identified 30 patients with CTJ injuries that were treated at our trauma center and analyzed their injury patterns, neurologic deficits and treatment outcomes. This equals the number in Lenoir's paper, as the largest series in the literature.[10] In contrast to previous studies, we have described in detail the morphology, classification and level of injury versus the neurology deficit.

In our patients, the majority of the injury was at C6-C7 followed by C7-T1. Only three types of injuries were observed, the commonest being AO type C 76.7%, followed by AO B2 and AO A4. This is in contrast to Lenoir's study where dislocations comprised only 12 patients.[10-14] In another study where multiple etiologies at the CTJ were included, only 6 patients had dislocation out of 21 traumatic causes.[15] One possible explanation for the majority of our patients sustaining AO type C injury could be due to the mechanism of injury. In the study conducted by Lenoir, 23 sustained motor vehicle accidents. [10] This is in contrast to our study wherein 90% of the injuries were fall injuries. This mode of injury is common in the developing and third world where falls are sustained from a hill, tree or height.[16-18]

Only 16.7% patients presented with intact neurology. 53.5% patients with C6C-7 and 75% patients C7-T1 level injuries, had some form of neurological deficit. It was observed that patients with AO type C injury had greater neurological deficits. In our study 86.9% with AO C injury had neurological deficits with more than half (52.7%) sustaining complete motor paraplegia (ASIA A and B). In the three patients with AO type B2 injury, only one had complete paraplegia (ASIA A) and the remaining two had normal neurology. Three of the four patients with AO A4 injury had complete motor paraplegia (ASIA A and B) and the remaining one had ASIA D neurology.

In our study none of the complete paraplegic (ASIA A) patients recovered. Of the 16 patients with incomplete deficit (ASIA B to D), 5 patients improved by at least one grade postoperatively which increased to nine patients at two years **(Table 2)**. Complete neurological recovery was observed in nine patients. This is similar to previous studies where there has been complete or partial neurological improvement. [10,15]

The CTJ is difficult to visualize on plain radiographs. In polytrauma, obese patients or patients with short necks, additional views such as swimmer's and oblique views can be difficult to obtain. In our series, plain x-rays were not able to demonstrate the injury in nineteen patients (63.3%). This is similar to the finding in Evan's series, in which two thirds of dislocations at C7-T1 level were misdiagnosed on initial evaluation. [2] Additional x-ray views were not performed and all patients underwent CT scans. With the routine use of CT scans when cervical trauma is suspected, the prevalence of missed injuries of the CTJ should continue to diminish.

There has been much controversy as to the approach. Biomechanical studies favor posterior approach to the anterior approach while clinical studies of late suggests similar effectiveness.[12,13,19-25] In a systematic review of anterior alone stabilization for cervical dislocations, the authors support the efficacy and success of anterior alone instrumentation.[24] In a prospective study, the fusion status and patient's satisfaction via the anterior approach have been reported to be satisfactory.[25] In our study, anterior approach was performed in patients with incomplete deficits, AO A4 and B2 injuries and reducible dislocations. None of the stand-alone anterior instrumentations had any implant failure or instability at two years. Since all of the lower instrumented vertebrae (LIV) fell above the manubrium – LIV line as outlined by Cho[7], none of the patients undergoing the anterior approach required a medial clavicular excision or sternotomy. There are some challenges when the treatment is performed posteriorly. The thick lateral masses of the proximal cervical vertebrae transitions into thin lateral masses at C7 and further into wide pedicles of the proximal thoracic vertebrae.[11] This varied anatomy poses some challenges during posterior instrumentation, especially if C7 lateral mass screws are combined with T1 pedicle screws. Because C7 lateral mass screws have a medial starting point and are directed laterally, while the thoracic pedicle screws are started more laterally and directed medially, if the instrumentation extends below T1, either a lateralizing connector or a coronally bent rod needs to be utilized. Additionally, the starting points of the two screws are in close proximity, so the screw heads can abut each other. This can usually be avoided by careful planning. Additionally dual diameter rods can be utilized to fix the cervical screws to the thoracic screws. Finally, there is a mismatch between a relatively short and thin C7 lateral mass screw and a long, thick, T1 pedicle screw. This can be avoided, when the anatomy permits, by using C7 pedicle screws, which provide for a stronger construct. [14] Alternatively, if C7 pedicle screws are not possible, one can augment the construct with a 3rd rod joining laminar screws into C7 and T1 or spinous process cables around the two segments.

The weaknesses of our study are as follows. In spite of the study being conducted in a high volume trauma

center, the number of patients presenting with CTJ injuries is limited. Due to the limited number of patients, analytical statistical tests could not be performed. Nevertheless, with 30 patients in our series, this equals the largest series in the literature. Another limitation is the retrospective nature of the study. A third limitation is that the study was carried out in a lower income country where fall injuries are more prevalent than motor vehicle injuries as seen in developed economies. Although the mechanism of injury might be different, resulting in a different distribution of the types of spinal injuries, the knowledge acquired from these injuries are universal and applicable to all such injuries. Despite these limitations, several observations relevant to injuries at the CTJ can be made from our study: CTJ injuries are not very common. The majority of the injuries in our series were due to fall injuries. Bi-segmental involvement with dislocations was the predominant morphological pattern of injury. More than half of the injuries presented with motor paraplegia. CT scans should be the preferred imaging of choice. Since all injuries at this level were unstable injuries, surgery is almost always indicated, unless there are extenuating medical circumstances.

CONCLUSIONS

CTJ injuries are not very common but when they do occur, they are most commonly, highly unstable injuries with profound neurological deficits. These injuries are often difficult to diagnose with plain x-rays and CT scans should be utilized. Surgical stabilization of these injuries should be considered for a favorable neurological and functional outcome.

CONFLICT OF INTERESTS

One of the authors declare the following conflict of interests. Stocks: Axiomed, Expanding, Orthopedics, Spineology, Spinal Kinetics, Amedica, Vertiflex, Benvenue, Paradigm Spine. Board Member: North American Spine Society. Consultant: Nuvasive, Happe Spine. The remaining authors declare that there is no conflict of interest.

REFERENCES

1. Nichols CG, Young DH, Schiller WR. Evaluation of cervicothoracic junction injury. Ann Emerg Med. 1987;16(6):640-642.[Article]

2. Evans DK. Dislocations at the cervicothoracic junction. J Bone Joint Surg Br. 1983;65(2):124-127.[Article]

3. Vanden Hoek T, Propp D. Cervicothoracic junction injury. Am J Emerg Med. 1990;8(1):30-33. [Article]

4. Jelly LM, Evans DR, Easty MJ, Coats TJ, Chan O. Radiography versus spiral CT in the evaluation of cervicothoracic junction injuries in polytrauma patients who have undergone intubation. Radiographics. 2000 Oct;20(suppl_1):S251-9.[Article]

5. An HS, Vaccaro A, Cotler JM, Lin S. Spinal disorders at the cervicothoracic junction. Spine. 1994 Nov 1;19(22):2557-64.[Article]

6. Vaccaro AR, Koerner JD, Radcliff KE, Oner FC, Reinhold M, Schnake KJ, et al. AOSpine subaxial cervical spine injury classification system. European spine journal. 2016 Jul;25(7):2173-84. [Article]

7. Cho W, Buchowski JM, Park Y, Maeda T, Nabb CE, Riew KD. Surgical approach to the cervicothoracic junction: can a standard Smith-Robinson approach be utilized?. Clinical Spine Surgery. 2012 Jul 1;25(5):264-7.[Article]

8. Vialle LRG. AOSpine Masters Series, Volume 5: Cervical Spine Trauma. 1st edition. (Öner FC, Vaccaro AR, eds.). Thieme; 2015.

9. Vialle LRG. AOSpine Masters Series, Volume 6: Thoracolumbar Spine Trauma. 1st edition. (Bellabarba C, Kandziora F, eds.). Thieme; 2015.

10. Lenoir T, Hoffmann E, Thevenin-Lemoine C, Lavelle G, Rillardon L, Guigui P. Neurological and functional outcome after unstable cervicothoracic junction injury treated by posterior reduction and synthesis. The Spine Journal. 2006 Sep 1;6(5):507-13.[Article]

11. Stanescu S, Ebraheim NA, Yeasting R, Bailey AS, Jackson WT. Morphometric evaluation of the cervico-thoracic junction. Practical considerations for posterior fixation of the spine. Spine. 1994 Sep 1;19(18):2082-8.[Article]

12. Kotani Y, Cunningham BW, Abumi K, McAfee PC. Biomechanical analysis of cervical stabilization systems. Spine. 1994;19(22):2529-39.[Article]

13. Vaccaro AR, Falatyn SP, Scuderi GJ, Eismont FJ, McGuire RA, Singh K, Garfin SR. Early failure of long segment anterior cervical plate fixation. Journal of spinal disorders. 1998 Oct 1;11(5):410-5.[Article]

14. Zhao LJ, Xu RM, Ma WH, Jiang WY. Evaluation of the value of pedicle screws for cervicothoracic fracture-dislocation. Orthopaedic Surgery. 2010 Feb;2(1):27-31. [Article]

15. Ramieri A, Domenicucci M, Ciappetta P, Cellocco P, Raco A, Costanzo G. Spine surgery in neurological lesions of the cervicothoracic junction: multicentric experience on 33 consecutive cases. European Spine Journal. 2011 May;20(1):13-9.[Article]

16. Dhakal GR, Bhandari R, Dhungana S, Poudel S, Gurung G, Kawaguchi Y, et al. Review of subaxial cervical spine injuries presenting to a tertiary-level hospital in Nepal: challenges in surgical management in a third world scenario. Global spine journal. 2019 Oct;9(7):713-6. [Article]

17. Shah G, Dhakal GR, Gupta A, Hamal PK, Dhungana S, Poudel S. Outcome of cervical spine trauma patients admitted to the intensive care unit at a tertiary government referral trauma center in Nepal. Global spine journal. 2021 Jan 18:2192568220980703.[Article]

18. Dhakal GR, Paudel S, Dhungana S, Gurung G, Kawaguchi Y. Epidemiological Characteristics of Dorsal and Lumbar Spine Trauma Presenting to a Trauma Hospital in Kathmandu, Nepal: Formulation of a National Spine Policy. Spine Surgery and Related Research. 2018:2017-0087.[Article]

19. Chapman JR, Anderson PA, Pepin C, Toomey S, Newell DW, Grady MS. Posterior instrumentation of the unstable cervicothoracic spine. Journal of neurosurgery. 1996 Apr 1;84(4):552-8.[Article]

20. Kreshak JL, Kim DH, Lindsey DP, Kam AC, Panjabi MM, Yerby SA. Posterior stabilization at the cervicothoracic junction: a biomechanical study. Spine. 2002 Dec 15;27(24):2763-70.[Article]

21. Kulkarni AG, Dhruv AN, Bassi AJ. Posterior Cervicothoracic Instrumentation: Testing the Clinical Efficacy of Tapered Rods (Dual-Diameter Rods). *Journal of Spinal Disorders & Techniques*. 2015;28(10):382-388. [Article]

22. Mazel C, Hoffmann E, Antonietti P, Grunenwald D, Henry M, Williams J. Posterior cervicothoracic instrumentation in spine tumors. Spine. 2004 Jun 1;29(11):1246-53. [Article]

23. Grubb MR, Currier BL, Stone J, Warden KE, An KN. Biomechanical evaluation of posterior cervical stabilization after a wide laminectomy. Spine. 1997 Sep 1;22(17):1948-54.[Article]

24. Lee W, Wong CC. Anterior-alone surgical treatment for subaxial cervical spine facet dislocation: a systematic review. Global spine journal. 2021 Mar;11(2):256-65. [Article]

25. Abdelgawaad AS, Metry AB, Elnady B, El Sheriff E. Anterior cervical reduction decompression fusion with plating for management of traumatic subaxial cervical spine dislocations. Global Spine Journal. 2021 Apr;11(3):312-20.[Article]