International Journal of Medical Research Professionals
P-ISSN: 2454-6356; E-ISSN: 2454-6364
DOI: 10.21276/ijmrp

Original Research Article

Computed Tomographic Evaluation in Spine Trauma with Neurological Correlation in Thoracolumbar Burst Fractures

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ABSTRACT

Introduction: Radiology plays a crucial role in the evaluation of a traumatized patient by providing information that allows timely and appropriate management of the patient. Plain radiography still remains the foundation upon which the initial evaluation and diagnosis of spinal injuries are based.

Computed tomography has become an indispensable tool in the evaluation of the patients of spinal trauma, especially those with neurologic deficits. This study is taken up to evaluate the spine trauma using Multislice spiral computed tomography and an attempt is made to compare it with the conventional radiographs. The importance of computed tomography in the diagnosis of spinal fractures is proved by this study.

Methods and Materials: In all 136 patients referred to the department as cases of suspected spinal trauma with or without neurologic deficit were included in the study. Patients with spinal injury as a result of degenerative, neoplastic and infective processes like tuberculosis causing pathological fractures were excluded from the study. All the patients were examined with plain radiography and CT with sagittal, coronal and 3D reconstructions were done as routine post processing.

Results: CT better delineates the spinal injuries according to column wise location of vertebral trauma than plain radiography. 45 patients had 47 burst fractures in the thoracolumbar region. Two patients had burst fractures at 2 levels. Seven patients did not have any symptom except for mild pain and 38 patients had abnormal neurologic symptoms. There was significant correlation with neurologic involvement and spinal canal compromise more than 50%.

Conclusions: Multislice spiral computed tomography is highly significant in detection of vertebral body and posterior element fractures than conventional spine radiography. Computed tomography is extremely helpful in detection of retropulsed fracture fragment. There is significant correlation between thoracolumbar burst fractures with 50% or more spinal canal compromise of their mid sagittal diameter and neurological involvement.

Key words: Spine Trauma, CT, Burst Fractures, Spinal Canal Compromise.

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Article History:

Received: 26-10-2016, **Revised:** 23-11-2016, **Accepted:** 02-01-2017

Access this article online	
Website: www.ijmrp.com	Quick Response code
DOI: 10.21276/ijmrp.2017.3.1.022	

INTRODUCTION

Accelerated urbanization and industrialization have led to an alarming increase in the rate of accidental injuries, crime and violence. Despite improved technology for the diagnosis and treatment of spinal injuries, spinal trauma still remains the large socio-economic stress to the society.

There is a gradual trend towards increasing incidence of RTA indicating gradual urbanization of society and increase in number of vehicles on roads A vehicular accident is reported every 3 minutes and a death every 10 minutes on Indian roads.[1,2]

Adequate clinical assessment with a thorough neurological examination in cases of spinal trauma is mandatory. Prehospital care is virtually non-existent in most rural and semi-urban areas and implementation of the 'golden hour' concept is still an unachieved goal.[3] Associated injuries may distract the clinician's attention from the spine. Unless the patient is in shock or respiratory distress, the principle of immobilization needs to be observed until suitable assistance and proper equipments are available.

Radiology plays a crucial role in the evaluation of a traumatized patient by providing information that allows timely and appropriate management of the patient. Plain radiography still remains the foundation upon which the initial evaluation and diagnosis of spinal injuries are based.

Computed tomography has become an indispensable tool in the evaluation of the patients of spinal trauma, especially those with neurologic deficits. Numerous reports have documented the ability of computed tomography to detect fractures of spine, displaced bone fragments even those missed by plain films and tomograms.

Magnetic resonance imaging is the modality of choice for spinal cord imaging with its multiplanar capability and better soft tissue discrimination. However its availability at very few centers and economic constraints has made the radiologists to resort to computed tomography.

METHODS AND MATERIALS

Type of study: Prospective study

Duration of study: Nov 2009 to June 2011.

Inclusion criteria: 136 patients referred to the department as cases of suspected spinal trauma with or without neurologic deficit were included in the study.

Exclusion criteria: Patients with spinal injury as a result of degenerative, neoplastic and infective processes like tuberculosis causing pathological fractures were excluded from the study. Haemodynamically unstable patients were excluded from the study.

Written consent was taken from all patients regarding CT scanning and willingness for the study. Ethical approval for the study was obtained from institutional ethical committee

Detailed history, clinical and neurological examination findings were recorded and clinical level along with severity of injury was assessed. Each case was first subjected to plain film radiography both in AP and lateral views centering at the clinically suspected level. Open mouth views were done when C1, C2 injuries were suspected. Plain radiography findings were properly noted. The decision of CT was based on clinical findings and plain radiography findings. For example, CT was done in patients with neurological deficit, history of pain with or without normal plain radiography findings.

Materials: Computed Tomography scan system used for this study was Siemens plus 4 Volume Access with the following protocol:

Specific Anatomic Location	Spine
▪ **Scanner used**	Siemens SOMATOM Volume Access
▪ **KV / mAs / Time per Rotation (sec)/ pitch**	140 / 100 / 1 / 2
▪ **Slice Collimation (mm)**	2.5
▪ **Slice Width (mm)**	3
▪ **Feed / rotation**	5mm
▪ **Kernel**	B70s, B 30s
▪ **Increment**	2mm
▪ **Direction**	Cranio-caudal.

Scout film was obtained. The scan area included the traumatized vertebra as shown by the plain film or the scout film plus one normal vertebra above and one below. Scanning was done in supine position. All images were viewed at window settings for soft tissue 250/50 and bone 1500/400 with narrow and wide window settings as and when deemed necessary. Various reconstructions were then carried out in multiple planes including axial, coronal and sagittal plains and three dimensional volumetric reconstructions.

Statistical Analysis: Data on continuous variable was summarised in terms of mean, standard deviation whereas data on categorial variables was summarised in form of percentages. Appropriate statistical procedures like 'Z' / chi- square test for differences in proportions and t' test and ANOVA for testing within and between the group differences found in plain radiography and CT. Data was analysed on statistical software STATA version 10.1 (2009).

Table 1: Mode of Injury

S.No.	Mode of Injury	No. of patients	(%)
1	**Fall from height**	42	30.88
2	**Blunt trauma**	02	01.47
3	**Non Accidental Injuries**	38	27.94
4	**Fall of weight on back**	02	01.47
5	**Vehicular accidents**	51	**37.50**
6	**Electrocution**	01	00.74
	Total	136	100

Table 2: Distribution of Spinal Trauma

S.No	Site of injury	No of patients	(%)
1	**Cervical**	53	36.81
2	**Thoracic**	21	14.58
3	**Thoracolumbar**	56	**38.89**
4	**Lumbar**	13	09.03
5	**Sacrum**	02	01.38
	Total	145	100

Table 3: Involvement of Individual Vertebra

S.No	Level	No. of injuries
1	C1	5
2	C2	12
3	C3	6
4	C4	16
5	C5	19
6	C6	26
7	C7	15
8	T1	4
9	T2	3
10	T3	5
11	T4	8
12	T5	6
13	T6	7
14	T7	9
15	T8	12
16	T9	14
17	T10	16
18	T11	20
19	T12	33
20	L1	**47**
21	L2	24
22	L3	12
23	L4	7
24	L5	2
25	Sacrum	2
	Total	331

OBSERVATIONS AND RESULTS

The present study sample included 136 patients who suffered from spinal trauma.

The patient's age group ranged from 3 years to 85 years. The maximum numbers (33.09%) of cases were in the age group of third decade. The numbers of patients were distinctly less in the extremes of age group with average age 34 years.

Out of 136 patients included in the study, 120 were male (88.24%) and 16 were females (11.76%), male to female ratio of 7:1.

Most of the patients (37.50%) received trauma due to vehicular accidents followed by fall from height (30.88%). In another group of patients (27.94%), the trauma was due to non-accidental injuries like household injury, fall from stairs, and fall in bathroom etc. One patient of electrocution had spine injury. (Table 1)

Thoracolumbar injuries were found to be the commonest site (38.89%) followed by cervical (36.81%). The number of injuries exceeded the number of patients because some of the patients had multiple level involvements. (Table 2)

Table 3 depicts all cases with multiple contiguous and non-contiguous individual vertebral injuries according to CT. L1 were the commonest vertebra to be involved followed by T12. (Table 3)

Table 4: Column Wise Involvement in Spinal Trauma.

S. No	Column	Injuries detected on plain radiograph	Injuries detected on computed tomography	Percentage of injuries missed on radiograph (%)
1	**Anterior column**	111	124	10.48%
2	**Middle column**	087	116	25%
3	**Posterior column**	058	126	53.97%

Table 5: Associated Injuries in Cases of Spinal Trauma

Sr. No	Associated Injuries	No. of cases	Percentage (%)
1	**Occipital Condyle**	1	1.69
2	**Pulmonary Involvement**	26	44.07
3	**Rib/Sternum**	26	44.07
4	**Humerus**	1	1.69
5	**Scapula**	1	1.69
6	**Pubic Bone**	1	1.69
7	**Sphenoid**	2	3.39
8	**Zygomatic Bone**	1	1.69
	Total	59	100

Table 6: Neurologic Involvement in Spinal Trauma.

Sr.No	Symptom/Sign	No. of Cases	Percentage (%)
1	**Paraparesis**	**41**	**29.08**
2	**Paraplegia**	28	19.86
3	**Quadriparesis**	32	22.70
4	**Quadriplegia**	9	06.38
5	**Monoparesis**	1	00.71
6	**Loss of Autonomic Control**	5	03.55
7	**Pain**	23	16.31
8	**No Neurological Deficit**	2	01.42
	Total	141	100

The above table shows column wise distribution of injuries seen in spinal trauma cases and their detection on plain radiograph and computed tomography. Plain radiograph failed to detect injury of anterior column in 13 patients, middle column in 29 and posterior column in 66 patients. (Table 4)

Associated injuries were seen in 36 cases. The above table shows incidence of associated injuries in cases of spinal trauma. Rib fractures (44.07%) and pulmonary involvement (44.07%) were the commonest associated injury. The number of associated injuries exceeded the number of patients because many of the patients had more than one injury. (Table 5) One hundred and eleven patients had neurological involvement. The number of symptoms exceeded the number of patients because some of the patients had associated loss of autonomic control. Paraparesis was the commonest presenting neurological feature. (Table 6)

Two patients had no neurological deficit. Hence, the number of neurological involvement is less than the number of patients. Autonomic control loss was associated with other neurological symptom. Neurological involvement was maximum in patients with thoracolumbar injuries 54 cases (40.30%). Paraparesis was the commonest neurological involvement in thoracolumbar injuries 29 cases (21.64%) followed by quadriparesis in cervical injuries 27 cases (20.15 %). (Table 7) The commonest vertebral fracture was burst fracture (58.22%).(Table 8)

There were total 85 burst fractures, of which 47(55.29%) burst fractures occured at thoracolumbar region with L1 (25.88%) vertebra was the commonest vertebra to be involved followed by T12 (23.53 %).(Table 9)

In 88 patients multilevel involvement was present out of which 14 (15.91%) patients had non-contiguous involvement. (Table 10)

Table 7: Distribution of neurological involvement according to site of injury.

Sr. No	Type of neurological involvement	Cervical	Thoracic	Thoraco lumbar	Lumbar	Total
1	Quadriparesis	27	5	0	0	32
2	Quadriplegia	6	1	2	0	9
3	Paraparesis	2	5	**29**	5	41
4	Papaplegia	3	9	14	2	28
5	Monoparesis	1	0	0	0	1
6	Pain	9	1	9	4	23
	Total	48	21	**54**	11	134

Table 8: Type of Vertebral Body Fracture.

Sr. No	Type of fracture	No of involved vertebrae	(%)
1	Burst fracture	85	58.22
2	Compression fracture	18	12.33
3	Sagittal fracture	06	04.11
4	Horizontal fracture	02	01.37
5	Triangular fracture (corner)	24	16.44
6	Hangman's fracture	01	0.68
7	Dens fracture	06	04.11
8	Atlas fracture	02	01.37
9	Tear drop fracture	02	01.37
	Total	146	100

Table 9: Distribution of burst fractures

Cervical		Thoracic		Thoracolumbar		Lumbar	
Level	No of cases	Level	No of cases	Level	No of cases	Level	No of cases
C1	0	T1	0	T11	06	L2	3
C2	0	T2	0	T12	19	L3	3
C3	0	T3	1	L1	**22**	L4	2
C4	0	T4	5			L5	0
C5	6	T5	3				
C6	2	T6	2				
C7	1	T7	5				
		T8	2				
		T9	1				
		T10	2				
Total	9(10.59%)	Total	21(24.71%)	Total	**47(55.29%)**	Total	8(9.41%)

Table 10: Multilevel involvement in spinal trauma.

Sr.No	Multilevel involvement	No of cases	Percentage (%)
1	Contiguous	74	84.09
2	Non – contiguous	14	15.91
	Total	88	100

Table 11: Comparison of results of Plain radiography VS Computed tomography at different site of fractures.

Sr. No	Site of trauma	No. of patients having fractures on plain radiograph & % (n=136)	No. of patients having fractures on CT & % (n=136)	p value
1	Vertebral body	110 (80.9)	111 (81.6)	0.8765 NS
2	Lamina	20 (14.7)	81 (59.6)	0.0001 HS
3	Pedicle	13 (9.6)	43 (31.6)	0.0001 HS
4	Transverse process	49 (36.0)	81 (59.6)	0.0001 HS
5	Spinous process	28 (20.6)	59 (44.4)	0.0001 HS
6	Facetal joint	10 (7.4)	48 (35.3)	0.0001 HS

Note: 'n' = Number of patients; NS- Not Significant; HS- Highly Significant; S- Significant

Table 12: Comparison of results on percentage of spinal canal narrowing in patients with thoracolumbar burst fractures according to Frankel's grading system

Sr. No	Grade	No of patients with thoracolumbar burst fracture	Mean % narrowing	SD	P value
1	A+B (no motor function)	12	62.5	8.9	0.001 HS
2	C (useless motor function)	13	58.4	8.0	0.001 HS
3	D (useful motor function)	13	48.9	10.4	0.033 S
4	E (normal)	7	33.6	19.0	Reference category
	Total	45	52.9	14.6	

Note: 'n' = Number of patients; SD- Standard Deviation; HS- Highly Significant; S- Significant

Table 13: Comparison of results on percentage of spinal canal narrowing in patients with thoracolumbar burst fractures according to Frankel's grading system.

Sr. No	Grade	% Spinal canal narrowing		Total No of patients (%)
		No of Patients(%) with </= 50%	No of Patients(%) with >/= 50%	
1	A+B	0(0.0)	12(100)	12(100)
2	C	0(0.0)	13(100)	13(100)
3	D	4(30.8)	9(69.2)	13(100)
4	E	5(71.4)	2(28.6)	7(100)

The above table shows number of patients having fractures and there percentages at different sites on plain radiograph and computed tomography and p value showing their significance. (Table 11) The above tables show significant correlation between patients with spinal canal narrowing > 50% and severity of neurological involvement. (Table 12 & 13)

DISCUSSION

The development of Computed tomography has opened a new dimension in the evaluation of the spine trauma. Moreover, recent improvements including sagittal and coronal reconstruction, improved resolution and short scan time has greatly increased the value and applicability of this technique. CT provides optimal management of patients by early and accurate diagnosis in patients with spine trauma.

Denis[4] expanded on this model, developing the most common model used for assessing spinal stability. In this model, the vertebra is divided into 3 separate columns: anterior, middle, and posterior. The AC is comprised of the anterior one half of the vertebral body along with the ALL and the anterior portion of the annulus fibrosis. The MC is made up of the posterior annulus fibrosus along with the posterior one half of the vertebral body and the PLL. The PC consists of the posterior ligamentous complex and the posterior bony elements. When 2 of the 3 columns are disrupted, the fracture is considered unstable.

As reported in various studies on spinal trauma our study also states vehicular accidents as the most important cause possibly due to urbanisation.

Comparison between plain radiography and CT in detection of fractures of different parts of vertebra:

1. Vertebral Bodies: In present study, total 136 patients were studied out of which number of patients with vertebral body fractures detected on plain radiograph and CT were 110(80.9%) and 111(81.6%) respectively, the p value being 0.8765 which is not significant.

2. Posterior Elements

Pedicles: In present study total 13 (9.6%) patients had fracture of pedicle on plain radiography while on CT 43 (31.6%) patients had pedicle fracture with highly significant p value 0.0001.

Laminae: On plain radiography 20 (14.7%) patients had fracture of lamina while CT detected the fractures in 81 (59.6%) patients.

Transverse process: In present study transverse process fractures were found in 49 (36%) and 81 (59.6%) patients on plain radiography and CT respectively with highly significant p value of 0.0001.

Spinous process: In present study total 28 (20.6%) patients of transverse process fractures were detected on plain radiography and 59 (44.4%) patients on CT with highly significant p value of 0.0001.

Facetal joint: 10 patients had facetal joint abnormalities on plain radiography while CT detected the abnormality in 48 patients which is highly significant with p value 0.0001. The facet joint abnormality included fractures as well as subluxation and locking including both unilateral (Figure 1) and bilateral facetal (Figure 2) joint locking.

Patients having 2 abnormalities on same level or different levels were counted as one. On CT subluxation was noted in 24 patients, unilateral facetal joint locking in 10 and bilateral facetal joint locking in 10 patients and fractures in 4 patients. On plain radiograph, unilateral facetal joint locking in 3 and bilateral facetal joint locking in 7 cases. It is difficult to detect subluxation on plain radiograph. Most of the facetal joint locking cases were observed at cervical level.

Thus on comparing the results of plain radiography and computed tomography at different sites of fracture, CT was found to be highly significant (p value = 0.0001) in detection of fractures posterior element (lamina, pedicle, spinous process, transverse process and facetal joint). CT is therefore far better and superior to plain radiographs in detection of posterior element fractures.

Occipital condyle fractures: In the present study one patient of right occipital condyle fracture was detected which was missed on plain radiograph. The patient had come with history of road traffic accident and had pain in cervical region. Thus occipital condylar fracture should be suspected in all patients sustaining high energy blunt trauma to the head and upper cervical spine resulting from axial loading, lateral bending, rotation and/or direct blow[5].

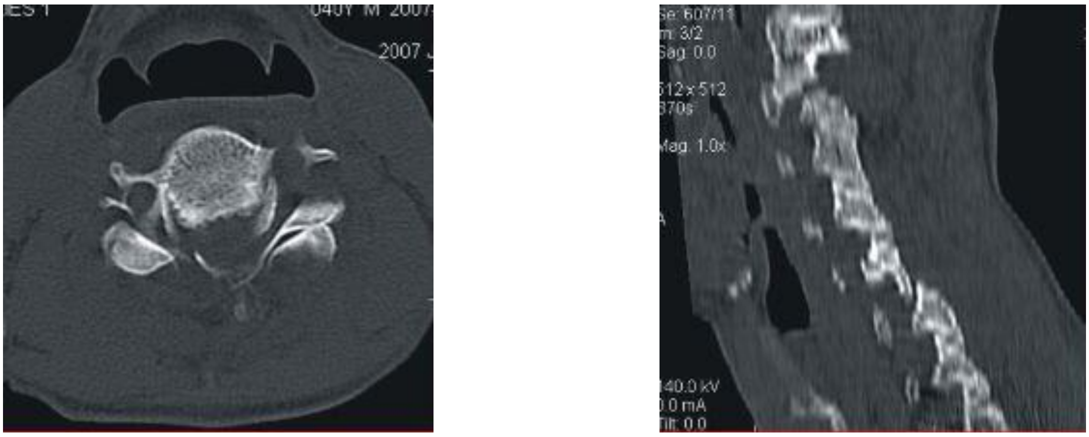

Fig 1: CT cervical spine axial (1a) and sagittal (1b) views showing unilateral left C5-C6 facetal joint locking

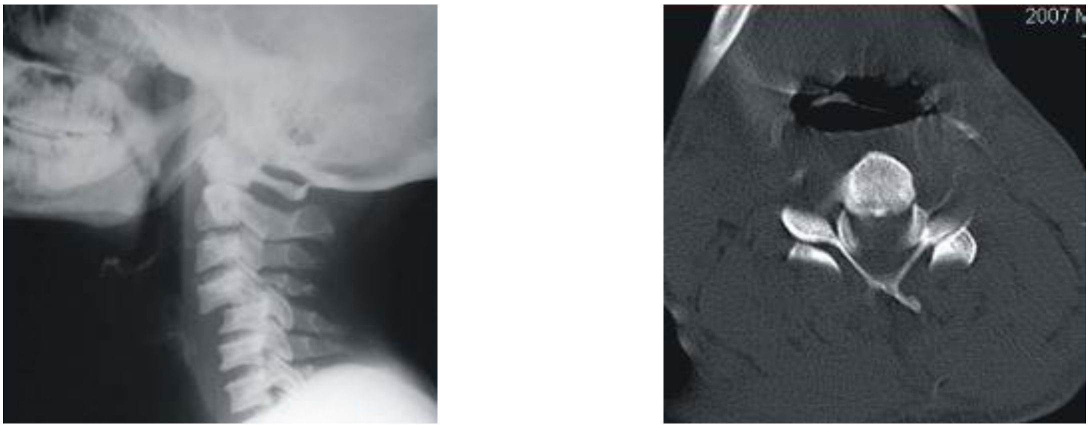

Fig 2: Lateral radiograph cervical spine (2a) and CT axial view (2b) showing reverse bun sign on CT s/o bilateral C4-C5 facetal joint locking.

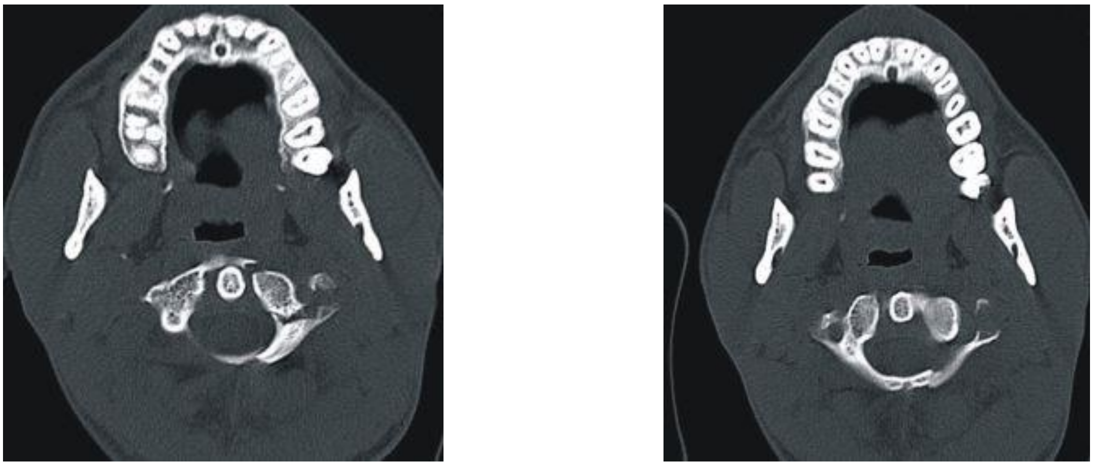

Figure 3: CT cervical spine axial views (3a&3b) showing Type I Jefferson's fracture.

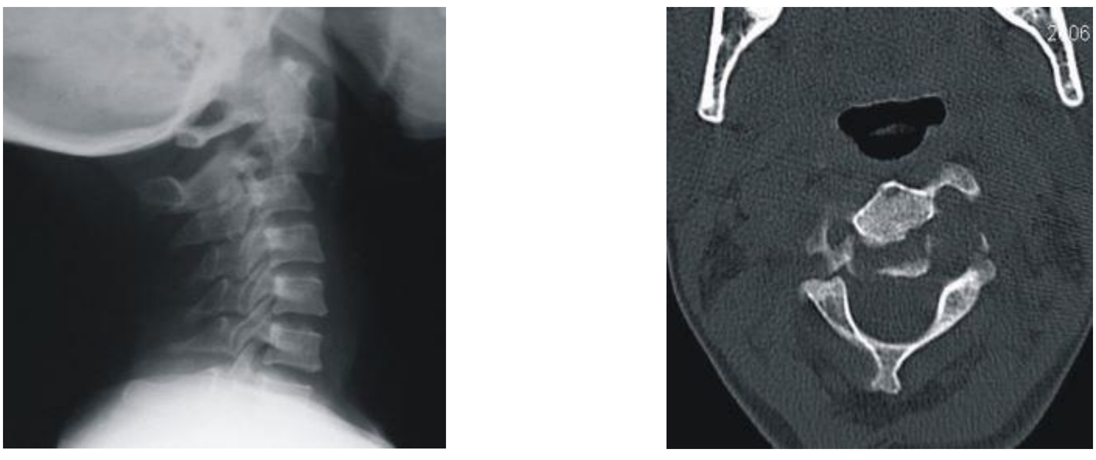

Fig 4: Radiograph lateral view (4a) and CT axial view (4b) cervical spine showing Hangman's fracture.

Atlas fractures: Fractures of atlas are classified into 5 types as:

1. Jefferson's burst fracture
2. Posterior arch fracture
3. Horizontal fracture of anterior arch
4. Lateral mass fracture
5. Transverse process fracture

In present study CT scan detected one Jefferson's fracture (Figure 3), one anterior arch fracture and one anteroinferior triangular fracture of anterior arch and two rotatory subluxation of atlantoaxial joint. Plain radiograph could detect only 3 of these injuries.

Axis fractures: In present study there were 6 odontoid; 3 triangular vertebral body fracture 2 involving the posteroinferior corner and 1 involving the anteroinferior corner; 1 involving both the lamina and 1 involving right foramina transverseria; 1 Hangman's fracture (Figure 4).

In 1974, Anderson and D'Alonzo[6] proposed a classification for odontoid fracture with three distinct fracture types determined by location of fracture line.

Type I - fracture through the tip of odontoid process
Type II - fracture through the base of odontoid process
Type III - fracture extending into body of C2 vertebra

According to the classification, in present study there were 3 type III (Figure 5), 2 type II and 1 type I fractures of odontoid fracture on CT scan.

These were identified on open mouth view but the type of fracture was interpreted wrongly. Out of 11 C2 fractures plain radiograph was unable to detect two fractures.

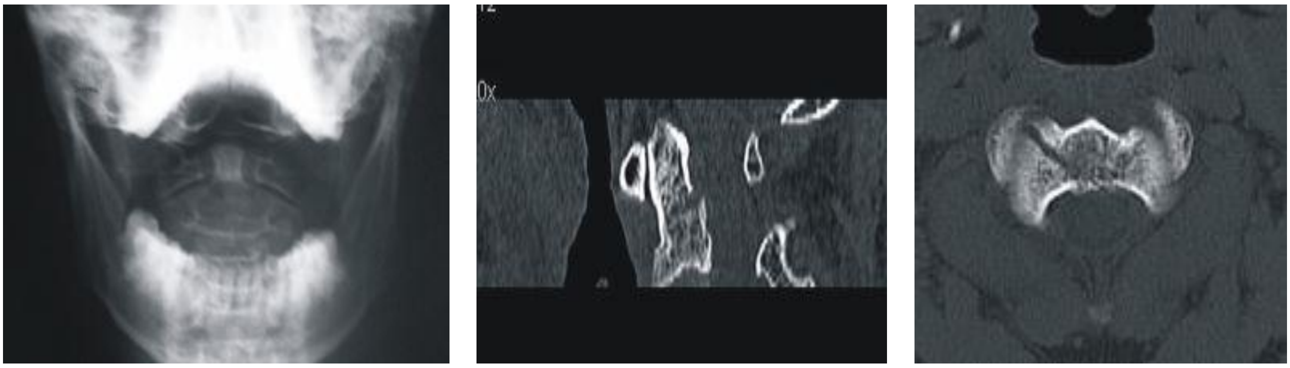

Fig 5: Radiograph open mouth view (5a) showing type II dens fracture. In same patient, CT cervical spine sagittal (5b) and axial view (5c) revealing type III dens fracture.

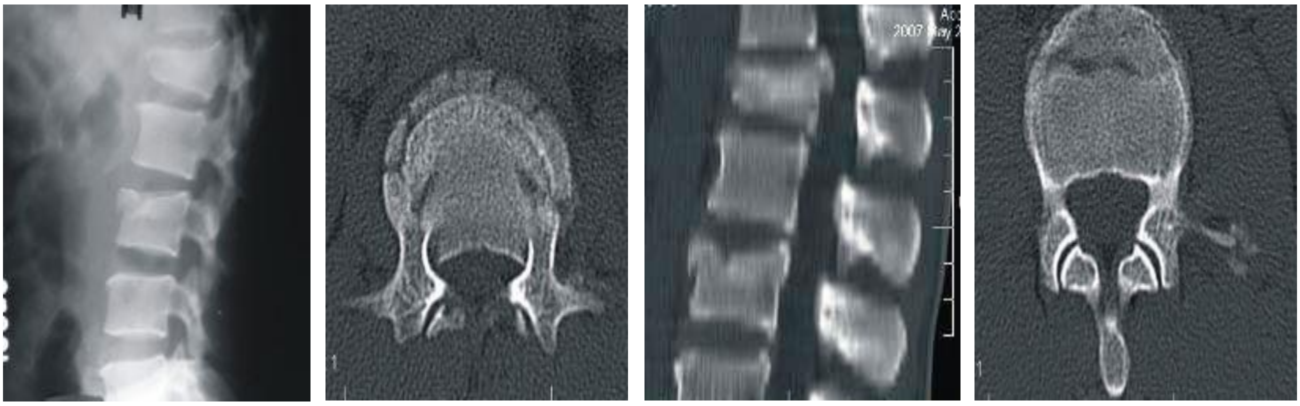

Fig 6: Radiograph lateral view (6a) shows compression fracture of L1 vertebral body and anterosuperior triangular fracture of L3 vertebral body and CT axial and sagittal (6c) images in same patient revealed L1 burst fracture with retropulsion of fracture fragment (6b) into the spinal canal and also transverse process fracture (6d).

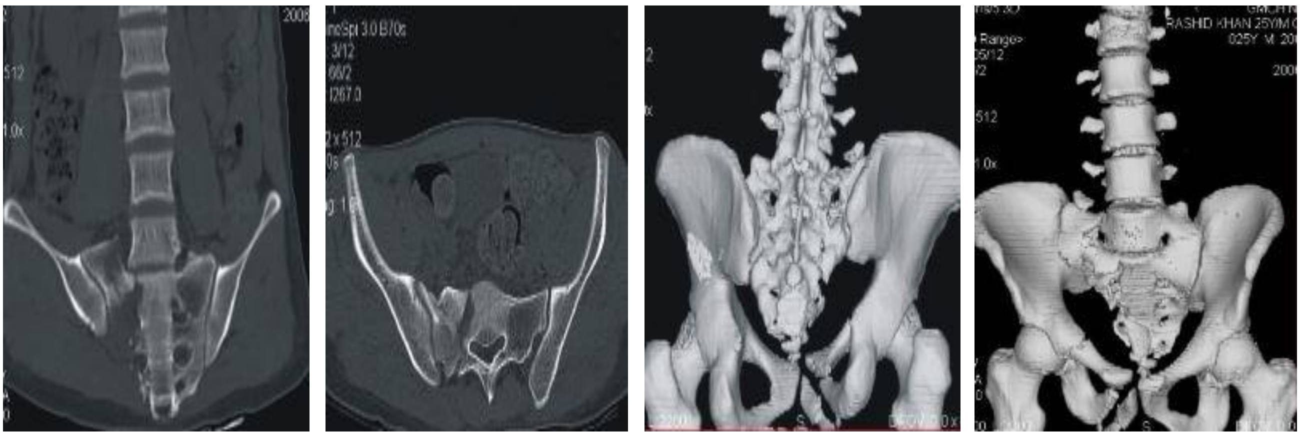

Fig 7: CT lumbosacral spine axial (7b), coronal MIP reconstruction(7a), coronal and sagittal 3D reconstructions (7c,7d) showing burst fracture of L1 vertebra and other posterior element fractures with type II sacral fracture.

Clay Shoveller's fracture: J. James Cancelmo[7] in 1972 demonstrated a "double" spinous process shadow in the anteroposterior view and found it to be a helpful diagnostic sign. In the present study isolated spinous process fracture was not seen. These were seen in combination with other vertebral body or posterior element fractures.

Burst fractures: Burst fractures are the most disruptive type of injury to the vertebral column. These relatively common fractures usually produce one or more large fragments from the posterior aspect of the vertebral body. Most of these are displaced into the spinal canal causing spinal compromise and neurologic involvement. These are unstable injuries. On plain radiograph we find disruption of the posterior vertebral body line; however this is not specific finding in burst injuries[8].

In present studies Burst fracture (Figure 6) was the commonest vertebral body fracture seen in 85 (58.22%) vertebrae. 85 burst fractures occurred in 76 patients. 47(55.29%) of 85 burst fractures occurred in thoracolumbar region which was the commonest region of involvement. 21 of 85 burst fractures involved L1 (24.71 %) vertebra, the commonest to be involved followed by T12 (23.53 %). Seven (9.21%) of 76 patients had burst fractures at two level and three level in 1 patient. Retropulsion was seen in 69 of the burst fractures with moderate to severe canal compromise.

Neurological deficit with spinal canal compromise in burst fractures in thoracolumbar region:

In burst fractures spinal canal narrowing is produced by retropulsion of vertebral body fracture fragments into the spinal canal. In this study using sagittal reconstructions mid sagittal diameters were measured at the level of maximum displacement of fracture fragment and at immediate adjacent uninvolved level of same magnification. The percentage of narrowing was then calculated. There were 45 patients with 47 burst fractures in the thoracolumbar region. Two patients had burst fractures at 2 levels. Seven patients did not have any symptom except for mild pain. Of the 38 patients with abnormal neurological examinations 13 were Frankel[9] grade D (useful motor function), 13 were Frankel grade C (useless motor function), 12 had no motor function (Frankel grade B or A).

Seven burst fractures were associated with normal neurological examination. There mean canal narrowing was 33.6% (except for two patients with >50% narrowing). The mean canal narrowing for the patients with abnormal neurologic group A+B, C and D was 62.5%, 58.4% and 48.9% respectively (except for two patient with <50% narrowing). The difference in spinal canal narrowing was highly significant with the p value 0.001. These results were comparable to study conducted by P G Trafton[10] with mean canal narrowing in patients with normal and abnormal neurologic group 34% and 56% respectively. There was significant correlation between the increase in spinal canal narrowing with mean % narrowing >50% and neurologic involvement.

Sacral fractures:

Denis in 1988 classified sacral fractures as

- Zone-I injuries are entirely lateral to the neural foramina
- Zone-II injuries involve the neural foramina but not the spinal canal
- Zone-III injuries extend into the spinal canal with primary or associated fracture lines

In present study sacral fracture (Figure 7) was seen in two patients. Reformatted images were helpful in diagnosing sacral fracture. All though CT is better in evaluation of vertebral body and posterior element fractures it has limited role in diagnosis of spinal cord injuries. MRI is the best modality for diagnosing spinal cord and intervertebral disc injuries like cord contusion, hematoma, transection of cord and traumatic intervertebral disc herniation because of its multiplanar capability and soft tissue resolution.

CONCLUSION

CT examinations take less time with superior contrast resolution and capacity for manipulating images via sagittal and coronal reconstructions makes CT the examination of choice in spinal trauma patients. Different types of fractures, their distribution and pattern are better studied on computed tomography. Multislice spiral computed tomography is highly significant in detection of vertebral body and posterior element fractures than conventional spine radiography. Computed tomography is extremely helpful in detection of retropulsed fracture fragment. There is significant correlation between thoracolumbar burst fractures with 50% or more spinal canal compromise of their mid sagittal diameter and neurological involvement.

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Source of Support: Nil. **Conflict of Interest:** None Declared.

Cite this article as: Ashwini Bakde, Amit Disawal. Computed Tomographic Evaluation in Spine Trauma with Neurological Correlation in Thoracolumbar Burst Fractures. Int J Med Res Prof. 2017; 3(1):116-23. DOI:10.21276/ijmrp.2017.3.1.022