Surg Radiol Anat (1989) 11 : 233-239

Surgical and Radiologic Anatomy
Journal of Clinical Anatomy

Radiological anatomy

Radiologic study of the influence of zygapophyseal joint orientation on spinal injuries at the thoracolumbar junction

KP Singer[1], J Willen[2], PD Breidahl[3] and RE Day[4]

[1] Department of Anatomy and Human Biology, The University of Western Australia, Nedlands WA 6009, Australia
[2] Department of Orthopaedics, Sahlgren Hospital, University of Göteborg, Sweden
[3] Visiting Radiologist, [4] Bioengineering Division, Royal Perth Hospital, Perth WA 6000, Australia

Summary. The change from coronal to sagittal plane orientation of the zygapophyseal (facet) joints at the thoracolumbar junction, coupled with differences in lumbar and thoracic spine mobility, may predispose the T10 to L2 segments to injury. To test for an association between the level of injury and variations in orientation of the zygapophyseal joints, CT investigations of 44 spinal injured patients were studied. Of these, 28 sustained burst/compression fractures and 16 demonstrated a rotation injury with disruption to one or both zygapophyseal joints. Injuries were examined to determine whether more congruent "mortice" joints localised the segmental level of trauma. The Chi-square statistic was used: to compare the transitional characteristics of 44 clinical cases with a "normal" patient database (n=630); to examine differences in transition patterns between the "compression" and "rotation" injury groups; and to compare the incidence of mortice joints between the clinical and normal series. A significant difference between the transition patterns of the clinical and normal series ($p < 0.001$) appeared to account for the higher frequency of abrupt transitions in the 44 injury cases. No significant differences distinguished the transition patterns of the two injury groups. A higher incidence of mortice joints was demonstrated in the injury group compared with the normal population ($p < 0.02$). These findings suggest that individuals with an abrupt transition have a greater predisposition to injures at the thoracolumbar junction.

Etude radiologique de l'influence de l'orientation des processus articulaires de la jonction thoraco-lombaire au cours des traumatismes rachidiens

Résumé. Les variations d'orientation des facettes articulaires de la charnière thoraco-lombaire du plan coronal au plan sagittal associées aux différences de mobilité des rachis lombaire et thoracique, prédisposent aux traumatismes des segments T10 à L2. Pour vérifier l'existence d'une relation entre le niveau lésionnel et l'orientation des facettes, une étude tomodensitométrique a été réalisée chez 44 traumatisés du rachis. Parmi eux, 28 présentaient une fracture avec éclatement ou écrasement, et 16 étaient porteurs d'une lésion d'un, voire de 2 processus articulaires. Les lésions furent étudiées pour déterminer si une articulation « mortaise » plus congruente était à l'origine du niveau de la lésion. Un test de χ^2 fut pratiqué : pour comparer les caractéristiques de la charnière chez les 44 patients avec celles d'une population normale (nb : 630); pour préciser les différences anatomiques entre le groupe des lésions par compression et le groupe des lésions par rotation; pour comparer l'influence des facettes « mortaises » entre les 2 séries de sujets normaux et de traumatisés. Il existe une plus grande fréquence de « transition brusque de la charnière » entre les groupes normaux et traumatisés ($p < 0,001$). Il n'existe pas de différence significative selon le type du traumatisme. On constate avec une plus grande fréquence l'existence d'articulations « mortaises » dans le groupe des traumatisés vis-à-vis du groupe des

---

Offprint requests : KP Singer

Presented at the 27th Annual Scientific Meeting of the International Medical Society of Paraplegia, Perth 10-12 May, 1988

sujets normaux (p <0,02). Ces résultats suggèrent que les sujets présentant une transition brusque au niveau de la charnière ont une plus grande disposition au traumatisme.

Key words : Thoracolumbar transition — Zygapophyseal joints — Computed tomography — Vertebral column — Mortice joint — Spinal injuries-mechanism of injury

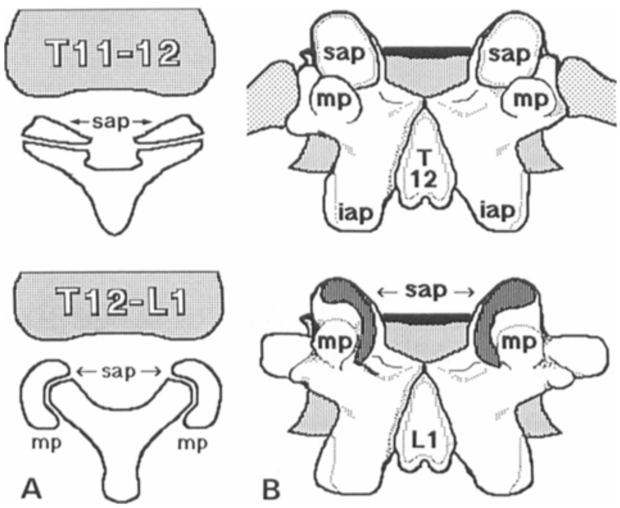

Fig. 1 A, B
A Schematic illustration of an abrupt transition from T11-12 to T12-L1, comparing the articular planes of the paired zygapophyseal joints from a transverse section parallel to and through the superior end-plate. The superior articular processes of T12 are directed in the coronal plane and the inferior articular processes are oriented in the sagittal plane. **B** A mortice joint is demonstrated by the medial projection of the mammillary processes which encloses the inferior articular processes of the vertebra above. Compare with Fig. **A.** *iap* inferior articular process *sap* superior articular process *mp* mammillary process

A Illustration schématique d'une transition de type brusque au niveau T11-T12 et T12-L1 comparant le plan des 2 processus articulaires selon un axe transverse parallèle au plateau vertébral supérieur. La facette articulaire supérieure de T12 est dirigée dans un plan coronal et la facette articulaire inférieure est orientée dans un plan sagittal. **B** Une articulation de type « mortaise » est réalisée par projection médiale du processus mamillaire qui vient recouvrir le processus articulaire inférieur de la vertèbre sus-jacente. Comparer avec la fig. **A.** *iap* processus articulaire inférieur *sap* processus articulaire supérieur *mp* processus mamillaire

The transitional regions of the human spine often have clinical significance due to the prevalence of morphological variation and dysfunction [18]. The change from coronal to sagittal plane orientation of the zygapophyseal joints at the thoracolumbar (T-L) junction is commonly described as occurring abruptly between T11-12 to T12-L1 [8, 9, 11] (Fig. 1a). However, in a preliminary study, variations were frequently observed in the location of the transitional level and the majority of individuals demonstrated a gradual change from coronal to sagittal plane zygapophyseal joint orientation [20]. A feature of the T-L junction posterior elements in some individuals are highly congruent mortice-like zygapophyseal articulations, in which the mammillary and superior articular processes enclose the inferior articular processes of the cranial vertebra [24] (Fig. 1b). Davis [2] proposed that a "locked" T-L mortice joint would increase the susceptibility to vertebral compression fractures during rapid flexion and axial compression deceleration. However, this speculation has not been examined critically.

The vertical orientation of the transitional level and upper lumbar zygapophyseal joints limit torsional movements [4], and according to Panjabi and White [15] and Pearcy and Tibrewal [16] allows approximately two degrees of axial rotation per segment (Fig. 2). In a study of in vivo segmental axial rotation at the T-L junction, least movement occurred at the transitional level and further limitation was evident in subjects with a mortice joint [22].

The T-L junction accounts for a high proportion of all spinal trauma [17] with severe injuries often resulting in paraplegia [1, 7]. Anatomical and biomechanical features of this region may contribute to this incidence. These include: the change from coronal to sagittal zygapophyseal joint orientation [10], differences between lumbar and thoracic segmental mobility [15, 22], the presence of congruent "mortice" joints which may "lock" in certain postures, particularly from compression loads [2], and the change in thoracolumbar curvature from kyphosis to lordosis [12, 23].

The influence of variations in the transitional level and orientation of the zygapophyseal joints on thoracolumbar injury patterns was investigated in this study to determine whether, abrupt or gradual transition patterns were more frequently represented in individuals with spinal injuries compared to a normal population; different transition patterns were more prevalent in either compression or rotation injury cases and; "mortice" joints were demonstrated more frequently in injury cases compared to a normal population.

Methods

Routine CT investigations of the thoracolumbar spine or abdomen

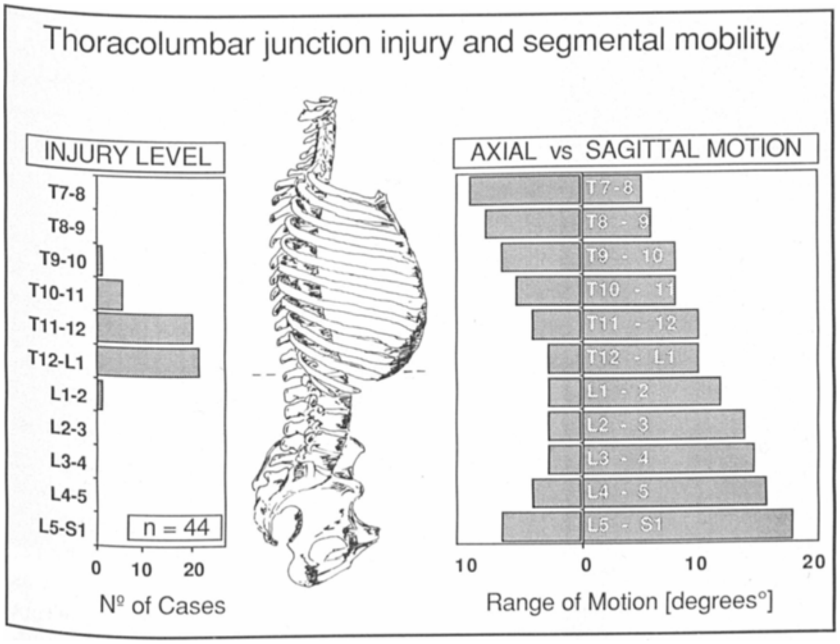

Fig. 2
Histogram of injuries located at the thoracolumbar junction recorded from 44 cases of burst/compression fractures and rotation injuries. Representation of the change in sagittal and axial mobility occurring between thoracic and lumbar segments (modified from Panjabi and White [15])

Histogramme des lésions siégeant au niveau de la jonction thoraco-lombaire chez les 44 cas de fracture par compression et rotation. Représentation des modifications de la mobilité axiale et sagittale survenant entre les colonnes thoraciques et lombaires (modifié à partir des travaux de Panjabi et White [15])

Table 1. Patient data for thoracolumbar junction torsional injuries

Sex	Age	Transition level	Injury level	Aetiology	Classification	Neurological status
M	23	A11-12	T10-11	Fall	# Disloc T10-T11	C↓T11
M	22	A12-1	T12-1	Fall	Denis D, T12-1	C↓T12
M	40	A11-12	T10-11	Struck	Denis D	C↓T10
M	22	A12-1	T11-12	MVA	Denis D-E	C↓T12
F	32	G11-12	T9-10	MVA	Denis D	n/a
M	34	A12-1	T11-12	MVA	# Disloc T11-12	C↓T12
M	20	A12-1	T12-1	Fall	Denis D, T12-1	n/a
M	18	A12-1	T11-12	MVA	Denis D	n/a
M	37	A11-12	T11-12	MVA	# Disloc T12-L1	C↓T11
M	62	G11-12	T10-11	Fall	# Disloc T10-11	C↓T11
F	32	G11-12	T11-12	Fall	# Disloc T11-12	C↓T12
M	31	A12-1	T12-1	MVA	# Disloc T12-1	n/a
M	19	A11-12	T11-12	MVA	Denis D, T11-12	C↓T11
M	50	A12-1	T12-1	Fall	Denis D	C↓L2
M	24	A12-1	T11-12	Fall	Denis D, T11-12	C↓T12
F	13	A12-1	L1-2	MVA	# Disloc T12-1	C↓L2

n/a information unavailable, *C or IC* ↓ complete or incomplete neurological lesion/level, *A* abrupt transition from coronal to sagittal orientation of the zygapophyseal joints involving 2 adjacent segmental joints, *G* gradual transition from coronal to sagittal orientation involving 3 adjacent segmental joints, *# Disloc* fracture-dislocation, *MVA* motor vehicle accident, *MCA* motor cycle accident

from 630 "normal" individuals were used to document joint orientation patterns at T10-11, T11-12, T12-L1 and L1-2 and provide baseline data for the incidence of abrupt and gradual transition patterns [21]. The change from coronal to sagittal orientation plane of the zygapophyseal joints was defined as appearing abruptly between the superior and inferior articular processes of one vertebra, or more gradually between the articular processes of two adjacent vertebrae. A detailed account of the methodology developed for this study has been reported previously [20].

In addition, CT and plain radiographs from 44 patients with thoracolumbar injuries, admitted to 3 regional Spinal Injury Units between 1983 and 1988, were studied. These cases comprised 34 males and 10 females with a mean age of 32 years [SD±13]. In addition to axial CT scans, antero posterior and lateral radiographs were used to categorise the spinal injuries according to the three column spine classification of Denis [3]. These cases were subdivided into 2 groups consisting of compression fractures and burst fractures (Denis Type A and B) and fracture—dislocations and burst—rotation injuries (Denis type D). Inclusion in this study depended on the availability of scans above and below the primary level of injury from which joint orientation and the type of transition could be determined. In some cases involving torsional injury to the posterior elements, it was more difficult to assess joint orientation; however, classification of the transition patterns as abrupt or gradual according to the adjacent segments was always possible.

Antero posterior and lateral radiographs were used to identify the primary injury level (Fig. 3). Descriptive data relating to the two groups were listed according to: injury type and primary level, tran-

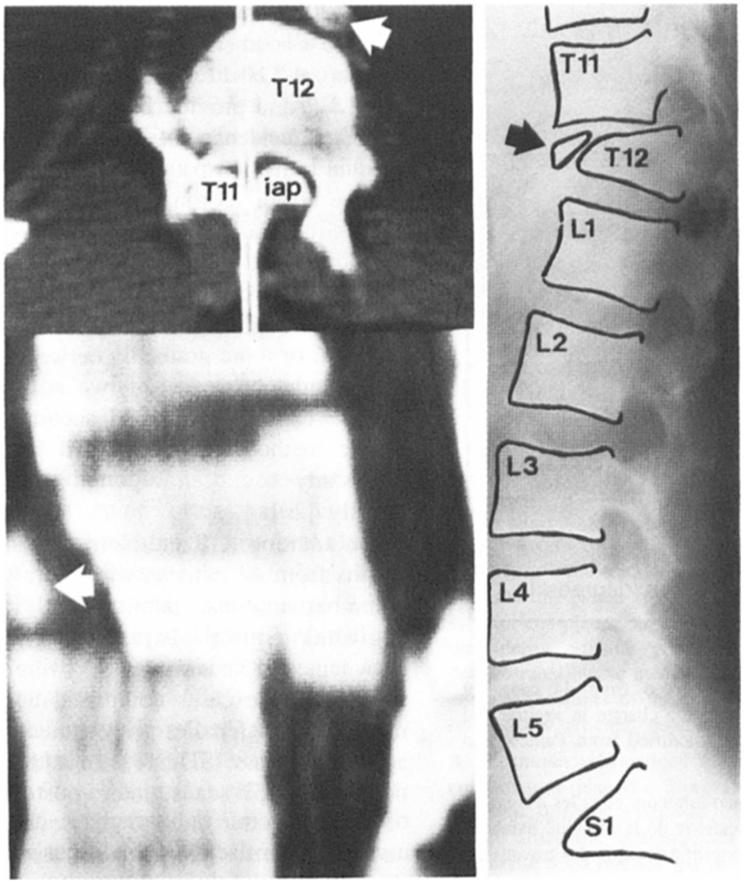

Fig. 3
Lateral plain radiograph and para-sagittal CT reconstruction of a fracture/dislocation at T11-12. Scans of adjacent levels indicated that this injury was located at the transitional level. *Arrows* indicate a bone fragment at T12

Radiographie de profil et reconstruction para-sagittale tomodensitométrique d'une fracture par dislocation au niveau T11-T12. Les coupes tomodensitométriques des niveaux adjacents montraient que cette lésion était située au niveau transitionnel. Les *flèches* montrent un fragment osseux au niveau T12

sition pattern, injury classification [3] and neurological status on admission (Tables 1, 2).

A mortice joint was defined as the presence of prominent mammillary processes (MP) which provided a recessed enclosure to the inferior articular processes of the vertebra above. This recess varied according to the extent to which the MP's projected medially behind the IAP's (Fig. 1a,b). Mortice joints appeared either symmetrically (Fig. 4a) or unilaterally (Fig. 4b). The presence and type of any mortice joints were classified according to a previous report [19].

After pooling the data for gradual and abrupt transitions from both groups, the Chi-square statistic was used to: compare transitional frequencies of the 44 clinical series with a "normal" patient database reported previously [21]; test for differences between transition patterns of the "compression" and "rotation" injury groups; and compare the incidence of mortice joints between the normal and clinical series.

Results

Burst fractures were demonstrated in 26 of the 44 patients. There were 7 Denis type A and 21 Denis type B fractures, 8 of whom presented radiological features of a crush cleavage injury [13]. The remainder showed compression fractures with little displacement. Sixteen cases showed radiological signs of a rotation injury with disruption to one or both zygapophyseal joints. Of these, 9 were Denis type D, burst-rotation injuries. A significant difference in T-L transition patterns was demonstrated between the "normal" and clinical series ($\chi^2=30.12$, $p<0.001$). This difference was attributed to the frequency of abrupt transitions, which comprised 68% of the 44 clinical cases compared with 29% in the normal population (Table 3). There were no conclusive differences in the transition patterns between either fracture group ($\chi^2=1.916$, ns).

Two thirds of the 44 spinal injury cases showed some form of mortice joint (Fig. 4a,b). In 19 cases, the mortice joint was associated with the injury level while the remainder were identified either above or below the injury site. Nine out of the 16 rotational injury cases showed a mortice joint, with 6 of these located at the primary level of injury. In the 28 cases of compression/burst fractures, 20 demonstrated a mortice joint and of these, 13 were identified at the same level as the injury. Fifteen cases did not demonstrate any mortice joint on the scans available for study.

There was a significantly greater number of patients with mortice joints compared with a larger CT series [19] ($\chi^2=5.612$, $p<0.02$) (Table 4).

Discussion

Results from this study of 44 cases of thoracolumbar junction injuries

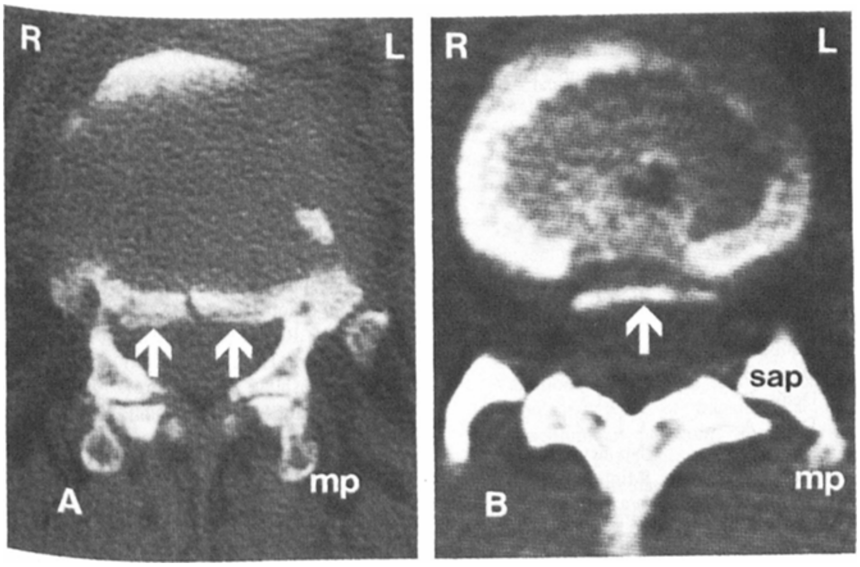

Fig. 4 A, B
Two CT cases illustrating mortice joints at the thoracolumbar junction associated with the level of injury. **A** Example of a compression fracture at T12 showing a retropulsed fragment flattening the normal contour of the spinal canal *(arrows)*. Prominent mammillary processes *(MP)* enclose the inferior articular processes **B** A compression-rotation injury at T11-12 showing wide displacement of the left zygapophyseal "mortice" joint. Note also the posterior rim bone fragment within the vertebral canal *(white arrow)*. *sap* superior process *mp* mammillary process

Deux coupes tomodensitométriques montrant des articulations de type « mortaise » au niveau de la jonction thoraco-lombaire siégeant au niveau lésionnel. **A** Exemple de fracture par compression au niveau T12 montrant un fragment migré en arrière et effaçant le contour normal du canal vertébral *(flèches)*. Un processus mamillaire proéminent *(MP)* recouvre le processus articulaire inférieur **B** Un cas de fracture par compression-rotation au niveau T11-T12 montrant le déplacement important de l'articulation gauche qui est du type mortaise. Noter le fragment osseux postérieur à l'intérieur du canal vertébral *(flèche blanche)*. *sap* processus articulaire supérieur *mp* processus mamillaire

suggest that transitional variations and morphology of the zygapophyseal joints at the T-L junction may influence some patterns of trauma. The clinical cases were significantly different from the "normal" patient population by virtue of the higher incidence of abrupt transitions and mortice joints (Tables 3, 4), which may suggest that these features predispose to T-L junction injuries. Preliminary CT data on patterns of unilateral rotation at the T-L junction showed that normal male subjects with an abrupt transition produced slightly less segmental rotation than those with a gradual transition [22]; therefore, torsional overload may be less well tolerated in individuals with an abrupt transition and this may contribute to the high percentage (81%) of abrupt transitions in the rotation injury group.

The compression group demonstrated greater variation in their levels of trauma compared with the rotation cases whose injuries tended to be located either at the transitional level or below. These patterns appear consistent with several reports on burst/compression and fracture-dislocation injuries [1, 3, 5, 6, 14, 17].

There was no significant difference in the transition patterns between the 26 selected cases with compression trauma compared with the 16 rotational injuries. Clinically however, the rotation injury group tended to show more complete neurological lesions, typically involving high cord levels compared to the burst/compression fracture group (Tables 1, 2).

Davis [2] speculated that a "locked" mortice joint would tend to localise T-L junction vertebral compression fractures during rapid axial deceleration. However, the precise role that the mortice joint plays in the production of vertebral injuries cannot be established unequivocally from this small series, particularly as one third of the mortice joints identified appeared unrelated to the fracture level. Although the mortice joint was demonstrated more frequently in the patient series, the availability of contiguous scans in this group compared to single scans per segment in the larger population [19] might have contributed to this difference.

Given the many variables that combine to produce injuries at the thoracolumbar junction, these preliminary results must be examined with care. A larger sample comprising specific injury classifications (eg: Denis A & B and fracture—dislocation injuries, including Denis D fractures) would be required to consider more accurately the influence of zygapophyseal joint orientation on the location and pattern of trauma. Consideration of the association between anatomy and injury is also dependant upon adequate visualisation of the lesion and a detailed knowledge of the injury biomechanics.

In conclusion, individuals with an abrupt change from coronal to sagittal zygapophyseal joint orientation of the thoracolumbar junction appear to sustain a higher frequency of injuries. In some situations the T-L mortice joint may contribute to the localisation effects of these injuries.

Table 2. Patient data for thoracolumbar junction compression injuries

Sexe	Age	Trnsition level	Injury level	Aetiology	Classification	Neurological status
M	16	A12-1	L1	MCA	Denis A	C↓S2
M	54	A11-12	T11	Fall	Denis B	No neuro deficit
F	50	A1-2	L1	MVA	Denis B	IC↓L1
F	16	G11-12	L1	Fall	Denis A	IC↓L3
M	54	G11-12	L1	MVA	Denis A	IC↓L3
M	32	G11-12	L1	Struck	Denis B, C CI	IC↓L5
F	23	A12-1	L1	Fall	Denis B, C CI	IC
M	45	A12-1	T12	MVA	Denis B, C CI	C↓L3
M	32	G11-12	T12	MVA	Denis B, C CI	IC
M	15	G11-12	L1	MCA	Denis B	IC↓L5
M	37	A12-1	L1	Fall	Denis A	C↓T12
M	36	A12-1	T12	Fall	Denis B	No neuro deficit
M	40	A12-1	L1	Fall	Denis A	Minimal deficit
F	33	A12-1	T12	Fall	Denis B	n/a
F	50	A12-1	L1	MVA	Denis B	C↓T12
M	40	G11-12	T12	MVA	Denis A	C↓L1
M	26	G11-12	L1	MVA	Denis A	n/a
M	20	A12-1	T12	MCA	Denis B, C CI	C↓T12
M	19	G11-12	T12	MVA	Denis B, C CI	C↓T12
M	50	A12-1	T12	Fall	Denis B	C↓T11
M	26	A12-1	L1	Fall	Denis B	IC↓T12
F	23	G11-12	L1	Fall	Denis B, C CI	No neuro deficit
M	51	A12-1	T12	MVA	Denis B	n/a
M	17	G11-12	L1	MCA	Denis B	n/a
F	21	A12-1	T12	Fall	Denis B	n/a
M	27	G11-12	L1	Fall	Denis B	n/a
M	53	A12-1	L1	Fall	Denis B, C CI	n/a
M	20	A12-1	T12	MVA	Denis B	n/a

n/a information unavailable, *A* abrupt transition from coronal to sagittal orientation of the zygapophyseal joints involving 2 adjacent segmental joints, *G* gradual transition from coronal to sagittal orientation involving 3 adjacent segmental joints, *C or IC* ↓ complete or incomplete neurological lesion/level, *C CI* crush cleavage fracture, *MVA* motor vehicle accident, *MCA* motor cycle accident

Table 3. Comparison of abrupt and gradual transition patterns at the thoracolumbar junction recorded from 630 "normal" individuals and 44 clinical cases. Data was tested with the χ^2 statistic

Population	Transition type	
	Gradual	Abrupt
"Normal" n=630	450 (71%)	180 (29%)
Patients series* n=44	14 (32%)	30 (68%)

* $\chi^2 = 30.12$, $p < 0.001$
A An abrupt transition from coronal to sagittal orientation of the zygapophyseal joints involving 2 adjacent segmental joints. *A* gradual transition from coronal to sagittal orientation involving 3 adjacent segmental joints

Table 4. Comparison of mortice joint incidence at the thoracolumbar junction recorded from 630 "normal" individuals and 44 spinal injury cases. Data was tested with the χ^2 statistic

Population	Present	Absent
"Normal" n=630	297 (47%)	333 (53%)
Patients series* n=44	29 (66%)	15 (34%)

* $\chi^2 = 5.612$, $p < 0.02$

Acknowledgments. We are grateful to the following individuals for their kind assistance: Sir G Bedbrook, Emeritus Senior Spinal Surgeon, and Mr ER Griffiths, Director of the Spinal Injuries Unit, Royal Perth Rehabilitation Hospital, Perth, WA, Drs G Ungar, Co-director of the Spinal Injuries Unit, the Austin Hospital, Heidelberg, Victoria and J Yeo, Director of the Spinal Injuries Unit at the Royal North Shore Hospital, NSW We also thank: Drs J Hunt, DP Thomas and THM Chakera, Directors of the Radiology Departments at Royal North Shore Hospital, Sydney, NSW, the Austin Hospital, Heidelberg, Melbourne, VIC and Royal Perth Hospital, Perth, WA, for granting permission to review CT cases of thoracolumbar injuries at their institutions. We are grateful to Dr L Schmidt for statistical active and to Sir G Bedbrook for helpful comments on an earlier draft of this manuscript.

References

1. Bedbrook GM (1979) Spinal injuries with tetraplegia and paraplegia. J Bone Joint Surgery [Br] 61 : 267-279
2. Davis PR (1955) The thoracolumbar mortice joint. J Anat 89 : 370-377
3. Denis F (1983) The three column spine and its significance in the classification of acute thoracolumbar spinal injuries. Spine 8 : 817-831
4. Farfan HF (1969) Effects of torsion on the intervertebral joints. Can J Surg 12 : 336-341
5. Gellad FE, Levine AM, Joslyn JN, Edwards CC, Bosse M (1986) Pure thoracolumbar facet dislocation : clinical features and CT appearance. Radiology 161 : 505-508
6. Griffith HB, Gleave JRW, Taylor RG (1966) Changing patterns of fracture in the dorsal and lumbar spine. Br Med J 1 : 891-894
7. Holdsworth F (1970) Fractures, dislocations, and fracture-dislocations of the spine. J Bone Joint Surg [Am] 52 : 1534-1551
8. Hoppenfeld S (1977) Orthopaedic neurology. Lippincott, Philadelphia, pp 98-99
9. Kapandji IA (1974) The physiology of the joints. The trunk and vertebral column, vol 3. Livingstone, Edinburgh, p 130
10. Larson SJ (1986) The thoracolumbar junction. In : Dunsker SB, HH Schmidek, J Frymoyer, A Kahn (eds) The unstable spine. Grune and Stratton, Orlando, pp 127-152
11. Last RJ (1963) Anatomy : regional and applied. London, Churchill, p 679

12. Levine AM, Bosse M, Edwards CC (1988) Bilateral facet dislocations in the thoracolumbar spine. Spine 13 : 630-640
13. Lindahl S, Willén J, Nordwall A, Irstam L (1983) The crush-cleavage fracture, A "new" thoracolumbar unstable fracture. Spine 8 : 181-186
14. Nicoll EA (1949) Fractures of the dorso-lumbar spine. J Bone Joint Surg [Br] 31 : 376-394
15. Panjabi MM, White AA (1980) Basic biomechanics of the spine. Neurosurgery 7 : 76-93
16. Pearcy MJ, Tibrewal SB (1984) Axial rotation and lateral bending in the normal lumbar spine measured by three-dimensional radiography. Spine 9 : 582-587
17. Rehn J (1968) Die knöchernen Verletzungen der Wirbelsäule (Bedeutung des Erstbefundes für die spätere Begutachtung. Wirbelsäule Forschung Praxis 40 : 131-138
18. Schmorl G, Junghanns H (1971) The human spine in health and disease. 2nd Am ed. Translated by EF Besemann. Grune and Stratton, New York, pp 55-60, 262-271
19. Singer KP (1989) The thoracolumbar mortice joint : radiological and histological observations. Clin Biomech (in press)
20. Singer KP, Breidahl PD, Day RE (1988) Variations in zygapophyseal joint orientation and level of transition at the thoracolumbar junction. Surg Radiol Anat 10 : 291-295
21. Singer KP, Breidahl PD, Day RE (1989) Posterior element variation at the thoracolumbar transition : a morphometric study using computed tomography. Clin Biomech 4 : 80-86
22. Singer KP, Day RE, Breidahl PD (1989) In vivo axial rotation at the thoracolumbar junction : an investigation using low dose CT in healthy male volunteers. Clin Biomech (in press)
23. Singer KP, Jones TJ, Breidahl PD (1989) A comparison of radiographic and computer-assisted measurements of thoracic and thoracolumbar sagittal curvature. Skel Radiol (in press)
24. Topinard P (1887) Des anomalies de nombre de la colonne vertébrale chez l'homme. Rev Anthropol 6 : 577-649

Received June 5, 1988/Resubmitted February 24, 1989/Accepted March 14, 1989