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Variations in zygapophyseal joint orientation and level of transition at the thoracolumbar junction

Preliminary survey using computed tomography

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Summary. Variation in zygapophyseal joint orientation at the thoracolumbar transitional junction was investigated using computed tomography (CT). The study population (N=214) comprised 176 cases of abdominal scans, 9 thoracolumbar junction referrals and 29 cadaveric vertebral columns. Scans through the superior endplates of T11, T12, L1 and L2 were selected and joint angles calculated using a computer aided digitiser. Analysis revealed 29 % of cases presented coronally orientated superior and sagitally orientated inferior joint processes at T12. This pattern occurred in 16 % of cases at T11 and 0.5 % at L1. A gradual transition occurred in 54 % of cases and involved the adjacent inter-segmental joints of T11 and T12. Articular tropism (>20°) was most frequent at T11-12 (21 %), followed by T12-L1 (9 %).

Variations de l'orientation des articulations zygapophysaires et niveau transitionnel de la jonction thoraco-lombaire : étude préliminaire par tomographie computérisée

Résumé. La variation de l'orientation des articulations zygapophysaires a été explorée au niveau de la jonction transitionnelle thoraco-lombaire par tomographie computérisée (CT). L'effectif étudié (N=214) a comporté 176 tomodensitométries abdominales, 9 jonctions thoraco-lombaires de référence et 29 colonnes vertébrales cadavériques. Les coupes tomodensitométriques pratiquées au niveau des plateaux supérieurs de Th11, Th12, L1 et L2 ont été sélectionnées, et les angles articulaires ont été calculés par digitalisation assistée. L'analyse a révélé que dans 29 % des cas Th12 présentait des facettes crâniales d'orientation frontale et des facettes caudales d'orientation sagittale. Cette disposition a été retrouvée dans 16 % des cas en Th11 et dans 0,5 % en L1. Une transition progressive a été rencontrée dans 54 % des cas, impliquant les articulations intervertébrales adjacentes à Th11 et Th12. La déviation angulaire articulaire (>20°) a été plus souvent notée en Th11-Th12 (21 %), puis en Th12-L1 (9 %).

Key words : Thoracolumbar transition — Zygapophyseal joints — Computed tomography — Vertebral column — Tropism

The junction between thoracic and lumbar segments is of clinical importance due to the high proportion of spinal injuries which are localised to this region (Holdsworth 1970). While extensive investigation has been conducted on zygapophyseal joint orientation at the lumbosacral junction (Farfan and Sullivan 1967; Cihak 1970; van Schaik et al 1984), comparatively little quantitative investigation on the thoracolumbar [T-L] transition has been reported. Anatomical descriptions typically suggest that the twelfth thoracic vertebra has coronally directed superior, and sagittally directed

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inferior, zygapophyseal joint processes (Testut and Latarjet 1948; Terry and Trotter 1953; Kapandji 1974; Hoppenfeld 1977; Romanes 1981) although departures from these patterns have been documented (Whitney 1926; Lanier 1939). Kazarian (1981) has indicated that this transition may occur between T9 and L1, however no data on the incidence of these variations in orientation pattern have been reported.

A prospective survey of CT cases was initiated to provide baseline data on the variations and patterns of joint orientation for the T10-L2 spinal levels prior to commencing histological and biomechanical studies on this region.

Methods

Records from one radiology practice were reviewed and 185 suitable studies selected. Cases comprised 176 routine abdominal investigations and 9 referrals for T-L scans where no abnormalities were demonstrated. In addition, 29 cadaveric spines were scanned prior to histological examination. Collectively these individuals were aged from 15 to 92 years and the sample consisted of 97 females and 115 males (Fig. 1). Scans were conducted using a Philips Tomoscan 310/350 and selected images were enlarged in bone window settings for optimal demonstration of the posterior joints. Apart from the cadaveric spines, where whole spine plain films were taken, the T10 to L2 segments were determined in the patient series from either antero-posterior or lateral scanograms. As there were no complete spine views available for the latter group, some reservation is noted concerning the precise segmental labelling, as variation in the number of vertebrae is more common in the thoracic and lumbar regions (Willis 1929; Delmas and Catritsis 1949; Wigh 1980).

Scans in the horizontal plane closest to the superior end-plates of T11, T12, L1 and L2 were selected, as this level typically corresponds to the mid-joint section of the zygapophyseal joints (van Schaik et al 1984). A 35 mm transparency produced from each image was back projected onto a digitising tablet (Digi-Pad 5, GTCO Corporation, Rockville, MN 20850) for data collection using software developed for a 9836 C Hewlett-Packard computer.

The median sagittal reference line was determined by digitising the circumference of the vertebral end-plate and computing the centroid position; then the junction of the spinous process and laminae was visually selected with the aid of the screen grid and the line between these 2 points connected. From this midline, the intersection between the anteromedial and posterolateral borders of each superior articular process defined the posterior joint angles. This schema is represented in Fig. 2.

In a preliminary study, accuracy of this method was determined through repeated measurement (10 trials) of selected scans and a schematic vertebral model. This produced a mean variation of between 1.3 and 0.6 % which indicated acceptable measurement sensitivity. The difference was considered to represent errors due to partial volume effect.

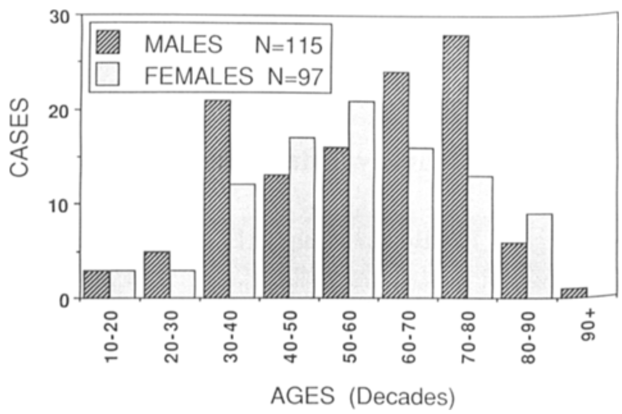

Fig. 1
The age and sex distribution of the study population

Distribution de la population étudiée selon l'âge et le sexe

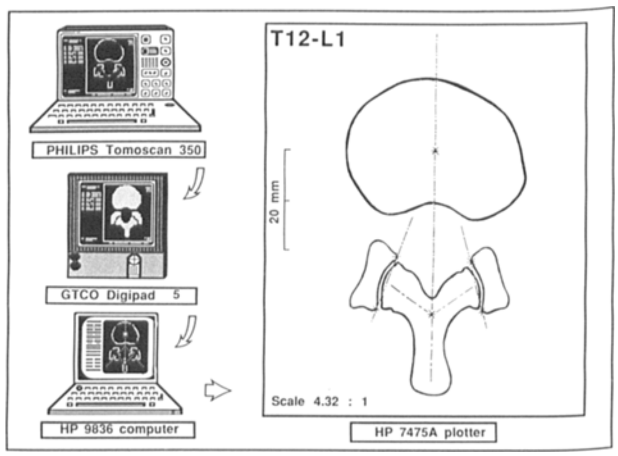

Fig. 2
Selected CT images were back projected onto a digitising tablet, the median sagittal line constructed through the centroid of the vertebral body and centre of the spinolaminar junction. Right and left zygapophyseal joint angles correspond to anteromedial and posterolateral points of the superior articular processes intersected with the midline

Les images tomidensitométriques sont projetées sur une table de digitalisation. La ligne médiane passe par le centre du corps vertébral et le point de jonction entre le processus épineux et les lames. Les angles articulaires droit et gauche sont formés par l'intersection de la ligne médiane et d'une ligne passant par les bords antéro-médial et postéro-dorsal de la facette supérieure

Images were rejected if the resolution was inadequate to determine the joint margins or if structural/organic pathology was evident. In some cases, not all levels were available for study, therefore, the final, analysis reflected varying sample sizes.

To establish the level and type of transition (abrupt/gradual), the segment with coronally directed superior, and sagittally directed inferior, joint processes was noted. In the case of the transition spanning several levels, the intermediate segment was recorded. Descriptive statistics were used to represent the data and scattergrams were plotted to assess the relationship between paired zygapophyseal joint angles.

Differences between gender and across age ranges (decades) were assessed using the Student 't' test with significance accepted at the $p < 0.05$ alpha level.

Results

There were no significant differences between joint angles for either sex, therefore CT data were combined for subsequent presentation. Similarly there were no significant age related changes in joint orientation. The mean, standard error of the mean (SEM) and 95 % confidence intervals for the zygapophyseal joint angles of the 4 levels are presented in Table 1.

Symmetry for the paired angles at each level was examined from the scattergrams and variability depicted with the use of percentiles (Fig. 3). The change from thoracic to lumbar orientation occurred predominantly within the last two thoracic and first lumbar segments, however, there was inconsistency in the primary level marking this transition and in joint angles at each level. This feature is responsible for the wide variation in data recorded at T11-12 and T12-L1.

Table 1. Descriptive data on zygapophyseal joint angles at the thoracolumbar junction

Level	N°	Left joint angle *		Right joint angle *	
T10-11	117	101.5 [0.70]	(100.1-102.9)	103.1 [0.75]	(101.7-104.6)
T11-12	184	69.0 [2.06]	(64.9-73.1)	71.2 [2.10]	(67.1-75.3)
T12-L1	202	31.3 [1.13]	(29.1-33.6)	33.0 [1.08]	(30.9-35.2)
L1-2	92	24.6 [0.72]	(23.1-25.9)	26.5 [0.66]	(25.2-27.8)

* Mean [SEM] (95 % confidence intervals)

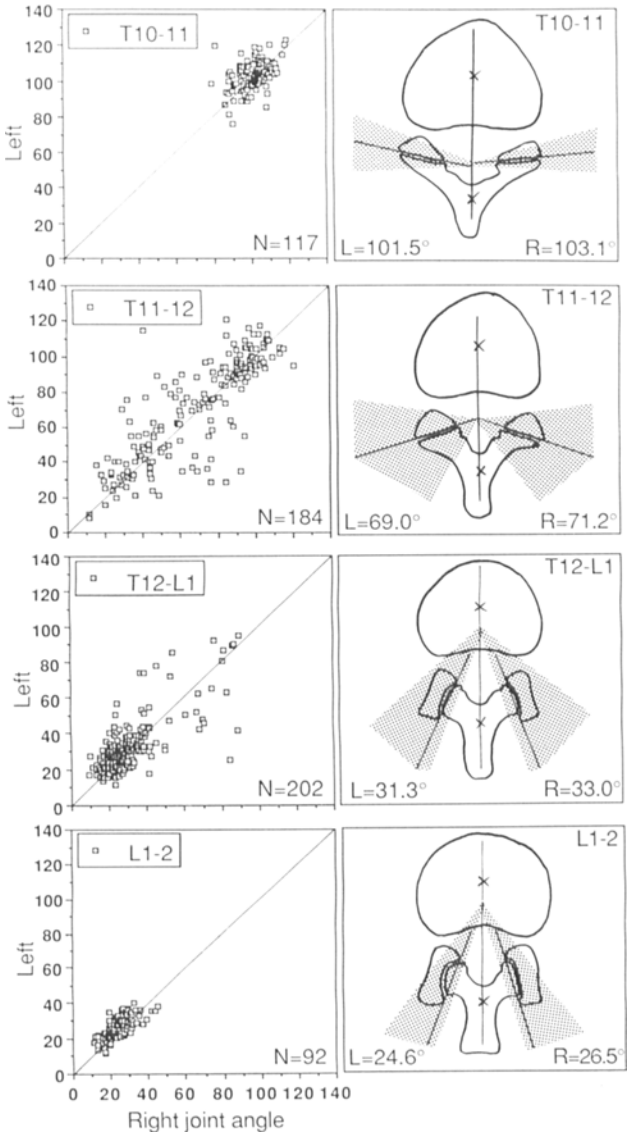

Fig. 3
Scattergrams for the T-L paired zygapophyseal joints indicate greater incidence of asymmetry and range in angles at T11-12 and T12-L1. Variability at these levels is also depicted by 10th and 90th percentiles. The T10-11 and L1-2 levels were more consistent and symmetrical

Les diagrammes de dispersion des valeurs angulaires de paires articulaires montrent une plus grande asymétrie et une plus grande fourchette des valeurs en Th11-Th12 et en Th12-L1. La variabilité à ces niveaux est également illustrée par pourcentage de 10e et 90e. Les niveaux Th10-Th11 et L1-L2 sont plus constants et symétriques

In over 80 % of this series, the level and type of transition could be determined. From this assessment, an abrupt transition from coronal to sagittal orientation occurred in 46 % of cases. Of these, T12 accounted for almost two thirds, while one third demonstrated the change at T11 and 1 case was noted at L1. The remainder (54 percent) presented with a more gradual progression from thoracic to lumbar orientation, this more typical type of transition occurred over three adjoining levels, with an intermediate orientation characteristically centred at T11-12 (Fig. 4).

Asymmetry of paired zygapophyseal joints (articular tropism) was most marked at the T11-12 level (Fig. 5) where 21 % of cases demonstrated differences greater than 20°, compared to 9 % at T12-L1. The adjoining

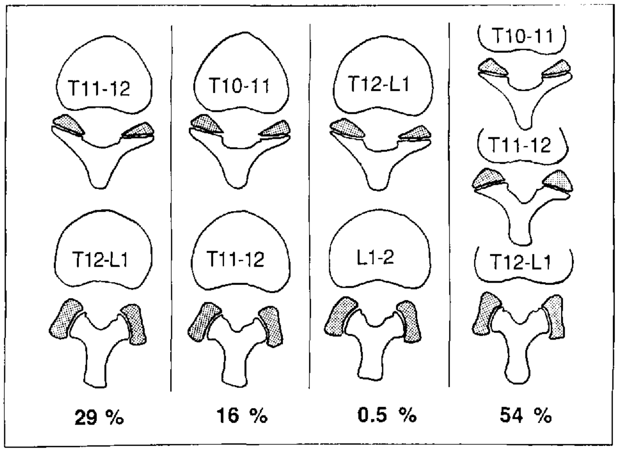

Fig. 4
Schematic representation describing the incidence and patterns of transition from coronal to sagittal orientation at the thoracolumbar junction

Représentation schématique de la fréquence et des types transitionnels fronto-sagittaux à la jonction thoraco-lombaire

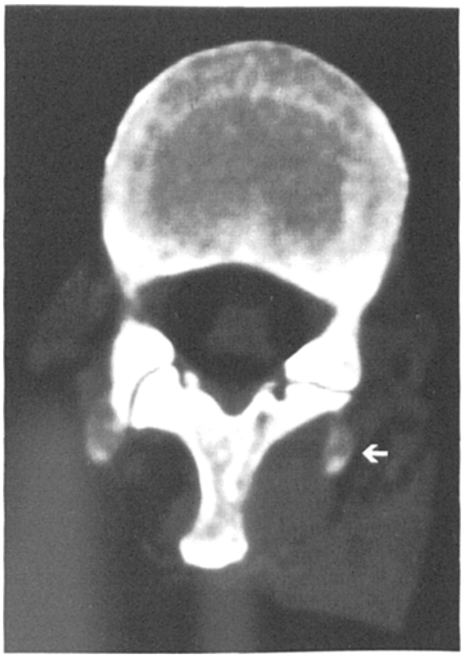

Fig. 5
Example of zygapophyseal joint asymmetry (tropism) at T11-12 from a cadaveric specimen, demonstrating the mammillary process *(arrow)* distinct from the left zygapophysis

Exemple de l'asymétrie articulaire (par déviation angulaire rotatoire), chez un sujet anatomique, montrant le processus mamillaire *(flèche)* séparé du processus zygapophysaire gauche

levels indicated greater symmetry, reflecting the typical coronal and sagittal patterns of the lower thoracic and upper lumbar regions respectively.

Discussion

Contrary to typical anatomical textbook descriptions of the T-L junction which suggest that an abrupt change from coronal to sagittal zygapophyseal orientation occurs at T12, over half of the present series showed a more gradual type of transition (Fig. 4). An abrupt change between thoracic and lumbar zygapophyseal joint orientations were variously localised to T12 (29 %), T11 (16 %) and L1 (0.5 %). The suggestion by Kazarian (1981) that the transition may commence from as high as T9-10 was not confirmed in this survey. In the majority of cases the transition progressed through an intermediate stage typically centred at T11-12. This level also accounted for the highest incidence of articular tropism for the 4 segments studied, a finding consistent with previous reports by Whitney (1926), Allbrook (1955) and Malmivaara et al (1987).

Odgers (1933) suggested that T-L transitional asymmetry reflected a functional imbalance of the multifidus muscle attaching to the mammillary processes. He considered that muscular tension exerted at this process stimulated the sagittalisation of the lumbar joints. In some scans, the mammillary process was observed distinct from the coronally directed articulation when compared to the contralateral side (Fig. 5). While this may reflect a developmental disorder between the zygapophysis and the mammillary process, consistent with Odger's theory, other genetic factors may be involved (Reichmann 1971).

Clinical relevance

The incidence of articular tropism and variations in the type of transition, may contribute to spinal dysfunction occurring at the T-L junction. Zygapophyseal joint orientation governs movement in a mobile segment and reciprocally, the nature of the constraint to extremes of motion. Therefore, the manner in which forces are imparted through the T-L junction may be an important factor contributing to degenerative sequelae of these synovial joints and in the development of local/referred pain syndromes (Maigne 1980; Lewit 1986).

In the case of lumbosacral tropism, Giles (1987) noted greater evidence of articular degeneration affecting the more sagittally directed zygapophysis compared to the joint orientated towards the coronal plane. This observation complemented findings by Farfan and Sullivan (1967) who described a marked frequency of intervertebral disc degeneration at the lumbosacral junction consistently on the side of the coronally facing joint. They proposed that axial motion centred towards the coronal zygapophysis induced disproportionately greater unilateral annular torsion which predisposed to disc protrusion.

While intervertebral disc prolapse is less common in the low thoracic segments, a higher frequency of end plate disorders and Schmorl's nodes are demonstrated in this region (Hilton et al 1976; Resnick and Niwayama 1978). A similar pattern of unilateral zygapophyseal degeneration to that recorded by Giles (1987) for lumbosacral tropism has been noted by Malmivaara et al (1987) at the T-L junction. However, it remains unclear whether a relationship exists between tropism and intravertebral disc herniations (Schmorl's nodes) at the T-L junction.

In the case of torsional injuries localised to the T-L junction, variations in the level and type of transition may tend to produce slightly different patterns of injuries. It has been observed by Cyron and Hutton (1980) that resistance to torsional stress within a motion segment is greatest where the zygapophyseal joints are oriented close to the sagittal plane. In a situation where rotational forces are violently dissipated through the axial skeleton, individuals with more abrupt T-L transitions may be predisposed to injury at T12-L1 or L1-2, as these joints conform most closely to the sagittal plane. Similarly, given the higher frequency of zygapophyseal joint asymmetry at T11-12 and the association between tropism and motion segment instability, greater susceptibility to injury may result from abnormal stresses applied to this region.

The extent to which variations in transition characteristics and orientation of the zygapophyseal joints at the T-L junction may influence motion, articular degeneration and spinal injury patterns, is the focus of present investigations.

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