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P. Neumann
Y. Wang
J. Kärrholm
H. Malchau
A. Nordwall

Determination of inter-spinous process distance in the lumbar spine

Evaluation of reference population to facilitate detection of severe trauma

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P. Neumann (✉) · Y. Wang
J. Kärrholm · H. Malchau · A. Nordwall
Department of Orthopaedics,
Sahlgrenska University Hospital,
S-41345 Göteborg, Sweden
Tel.: +46-31-342 1000,
Fax: + 46-31-82 55 99

Abstract Fracture of a spinal segment with minimal or no compression of the vertebral body can be highly unstable. Screening for such an injury in the lumbar spine is often obstructed in a multi-injured patient, because of difficulty in obtaining adequate sagittal radiographs. The position of the spinous processes in relation to each other is the key for proper evaluation of the status of the posterior stabilising structures. The amount of separation or axial rotation of the posterior part of the vertebra that can occur before failure of the posterior structures has not been unambiguously defined. Despite this, it can be assumed that severe separation of the spinous processes indicates a more or less pronounced loss of mechanical support. An analysis of how the posterior spinous processes relate to each other on an anteroposterior (AP) radiograph could obviate this problem. A new, simple and reproducible radiographic tool is presented for screening of an eventual rupture of posterior structures of the lumbar spine. This method is based on measurements of the variation in interspinal process distance between adjacent levels in lumbar spine in a normal population. Two hundred normal AP radiographs of non-injured thoracolumbar spine were studied. The interspinal process distance was measured as the distance between the cranial ends of the adjacent projections of spinous processes on AP radiographs. The mean values and 99% confidence limits for changes in the interspinal process distances between adjacent spinal levels were determined and analysed in relation to age, gender and spinal segment level. An upper limit of a normal difference in distance between the spinous processes at two adjacent levels was determined to be 7–10 mm, depending on age and location in the lumbar spine. A difference in interspinal process distance exceeding 7 mm between two adjacent lumbar levels should alert a surgeon to severe and unstable injury.

Key words Lumbar spine · Trauma · Instability · Radiography

Introduction

A key factor in the evaluation of lumbar spine trauma is the position of the spinous processes in relation to each other as an indication of the status of the posterior stabilising structures. More or less severe separation of the spinous processes can result in a loss of mechanical support from the posterior spinal structures, and consequently in potential instability of the injured spinal segment. The exact amount of separation of the posterior elements that indicates such an injury on conventional radiographs is, however, not known. The increase in interspinal process distance at the location of an injury of a lumbar spinal segment should be compared with the "normal" interspinal process distance at adjacent levels in the lumbar

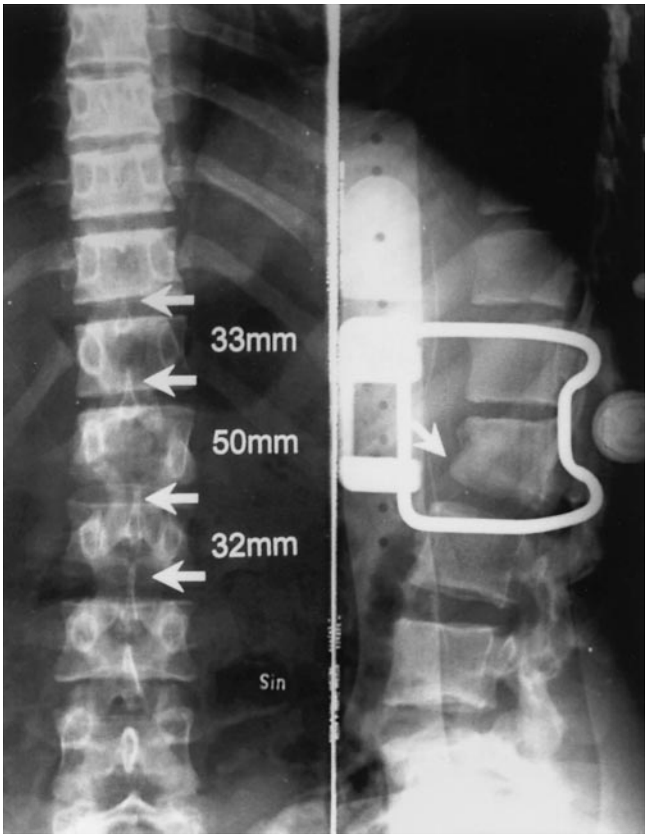

Fig. 1 Radiographs of a lumbar spine demonstrating difficulties in visualising the relation between spinous processes on a lateral projection in an acute situation. However, the anteroposterior (AP) view shows an obvious injury of the posterior structures, as reflected by increased distance between the projection of the adjacent spinous processes

spine. In the multiply injured patient with a combination of thoracic, abdominal and skeletal injuries, adequate lateral radiographic examinations visualising these posterior structures (Figs. 1, 2) are difficult to obtain. The spinal injury in such situations is very often initially missed (Fig. 3) [5, 9–11, 14, 17, 27].

Because of the absence of normal radiographic data on the variation of interspinal process distance between two adjacent lumbar segments in the literature, we decided to determine this parameter in a normal population. The antero-posterior (AP) radiographic projection of the lumbar spine was chosen because it can easily visualise the relationship between the spinous processes in an acute situation.

Materials and methods

The definition of a normal AP radiograph of lumbar spine in this study is based on analysing both AP and lateral radiographs. Radiographs with obvious pathological changes such as reduction of disc height, arthrotic changes in the facet joints, abnormal lordosis or kyphosis, signs of pathological bone structure such as tumours, infections, etc, were discarded.

Two hundred AP supine radiographs (T12–L5) of such “normal” non-injured thoracolumbar spines were studied. The material was subdivided into five “decade” age groups: 20–29, 30–39,

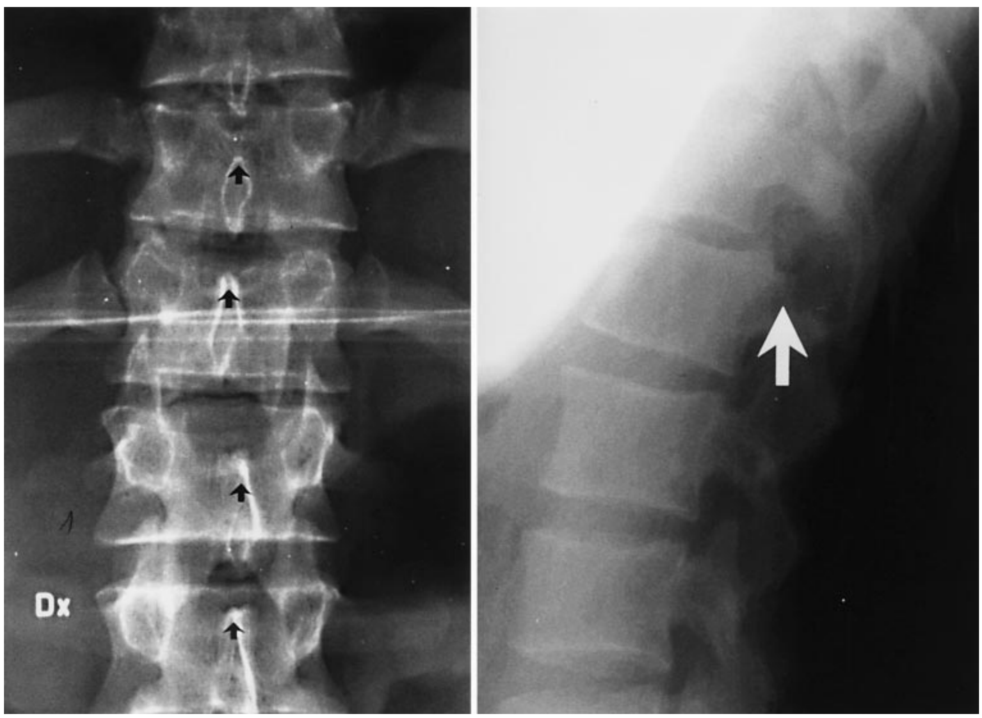

Fig. 2 This lateral radiograph shows discrete changes (slight spondylolisthesis T12–L1), but does not visualise the posterior structures of the spinal segment. The AP projection shows, however, an obvious increase in the interspinous process distance as a sign of severe injury of the stabilising posterior structures. At surgery, we noted bilateral luxation of the facet joints and total rupture of the posterior ligaments starting from the ligamentum flavum to the supraspinous ligament

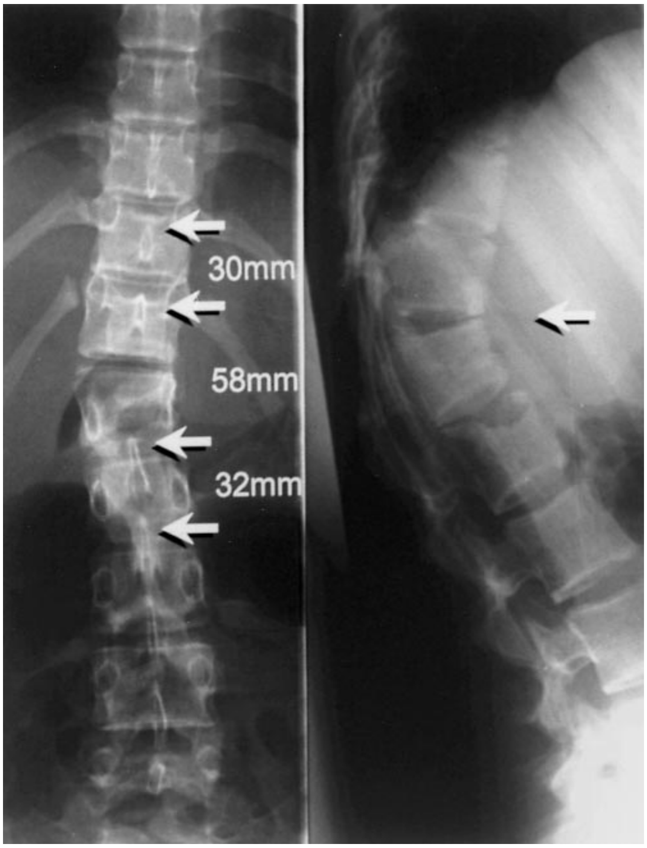

Fig. 3 These radiographs, exposed 6 months after the injury, demonstrate an initially missed flexion distraction injury in the thoraco-lumbar juntion. The patient had concomitant abdominal and thoracic injuries

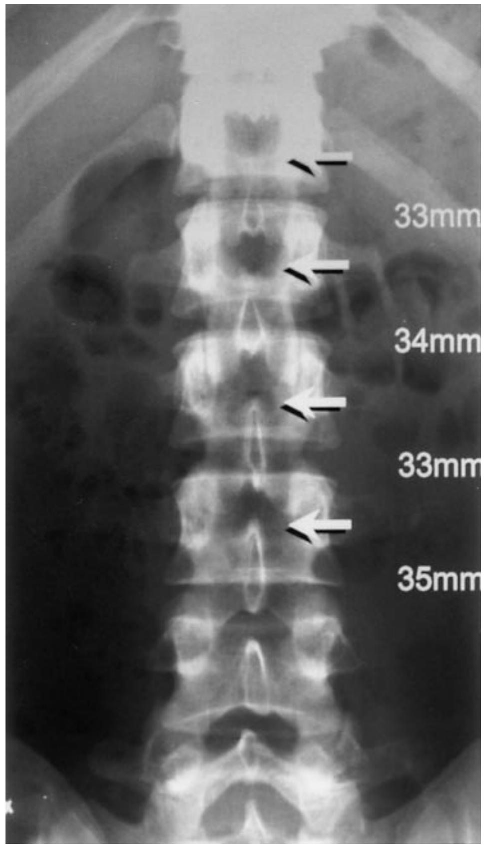

Fig. 4 A normal AP radiograph of lumbar spine showing the relation between the projection of the spinous processes. The measurements of the interspinal process distance should be done between the cranial ends of the "tear drops", at the confluence of the inner cortices

40–49, 50–59 and 60–69 years of age. Younger "decades" were omitted because of variations in the maturity of the spine at the age. For each age there were radiographs from two males and two females resulting in 40 AP radiographs in each decade group.

The interspinal process distance was measured on AP radiographs as the distance between the cranial ends of the adjacent "tear-drops", and for the purposes of measurement, the confluence of the inner cortices was used (Fig. 4). To delineate the true anatomic location for this landmark, a true dry bone preparation of the lumbar spine was used (Fig. 5). Metallic markers were attached to two different parts of the spinous processes on the specimen, which thereafter was X-rayed. The smaller markers were attached to the cranial end of the posterior part (tip) of the spinous processes, whereas the larger ones were attached to the cranial end of the base of the spinous processes. The "tear-drop" on an AP radiograph corresponds to the projection of the tip of the spinous process as demonstrated by the position of the smaller markers fastened on the dry skeleton (Fig. 5). The cranial end of the "tear drop" on the AP radiographic picture coincides with the projection of the confluence of the inner cortices (of the cranial part) of the spinous processes (Figs. 4, 5). The cranial end of the "tear-drop" was chosen because it was found to be easy to identify. The projection of the larger markers fastened on the cranial part of the base of the spinous processes coincides with the confluence of the outer cortices of the spinous processes, and this point was more difficult to identify because of its indistinct delineation. Change of projection by 30° of the X-ray beam changed the position of the markers attached to the tip of the spinous process by only 2–3 mm (Fig. 6). This tilted position between the vertebrae L1–L2 on the same dry skeleton as in Fig. 4 simulates the clinical situation of facet joint luxation (Fig. 6). This implies that the confluence of the inner cortices of the cranial part of the "tear-drop" on an AP radiograph can be utilised as a measuring point, even in situations with severe dislocation of the lumbar spine segments. At our radiography department the spinous process film distance may vary between 0 and 150 mm, depending on examination technique. The corresponding focus table distance is routinely set at 1000 mm. The corresponding variability of the magnification up to 10% was not corrected for.

After indicating the proximal ends of the tear-drops on the AP radiographs, the distances between T12–L1, L1–L2, L2–L3, L3–L4 and L4–L5 were measured on a digitising table connected to a personal computer (Research Metrics, Ortho Graphics Inc., Salt Lake City, Utah). A total of 999 interspinal process distances were measured and 799 differences in the interspinal process distance between adjacent levels were calculated and subsequently used in the statistical calculations. One case had to be rejected because of anatomic anomaly at the most distal level (Table 1).

The interobserver variability was evaluated by two observers (P.N. Y.W.). The intra-observer variability was evaluated by repeated measurements of the same radiographs with an interval of 2 weeks. In both intra- and interobserver evaluations the indications of the landmarks on the radiographic film were removed between the two measurements.

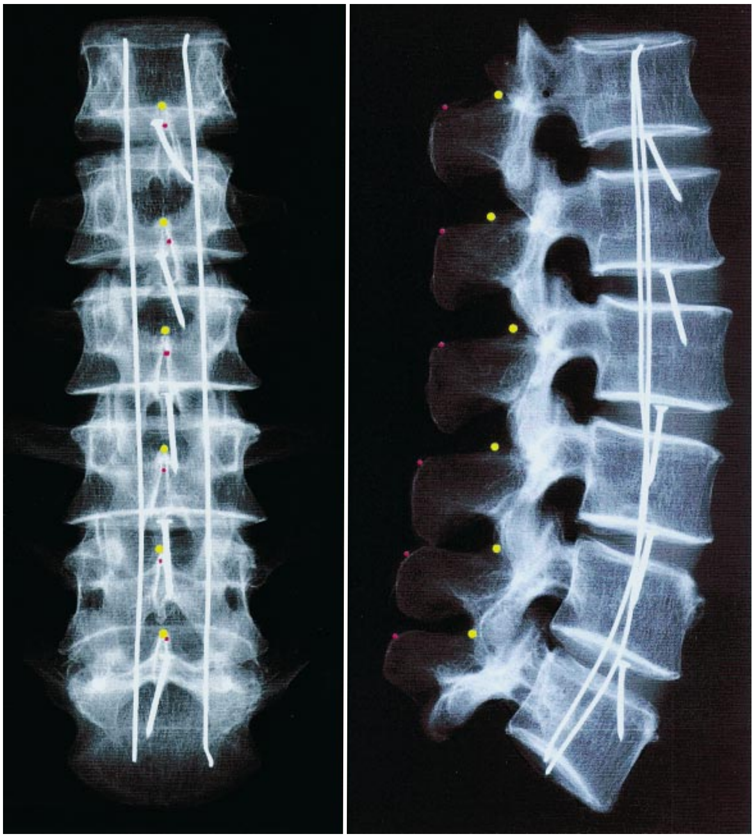

Fig. 5 These dry skeleton radiographs show that the cranial end of the most posterior part (the tip) of the spinous processes is projected as the cranial end of a "tear-drop" on the AP radiograph, as demonstrated by the projection of the smaller metallic markers *(red)*. This point coincides with the projection of the confluence of the inner cortices of the cranial part of the spinous processes. The larger metallic markers *(yellow)* are attached to the cranial end of the most proximal part (the base) of the spinous processes. Their projection coincides with the confluence of the outer cortices of the spinous processes. (The metal objects except the markers on the spinous processes are artefacts in the construction of the spinal model, and should not be considered)

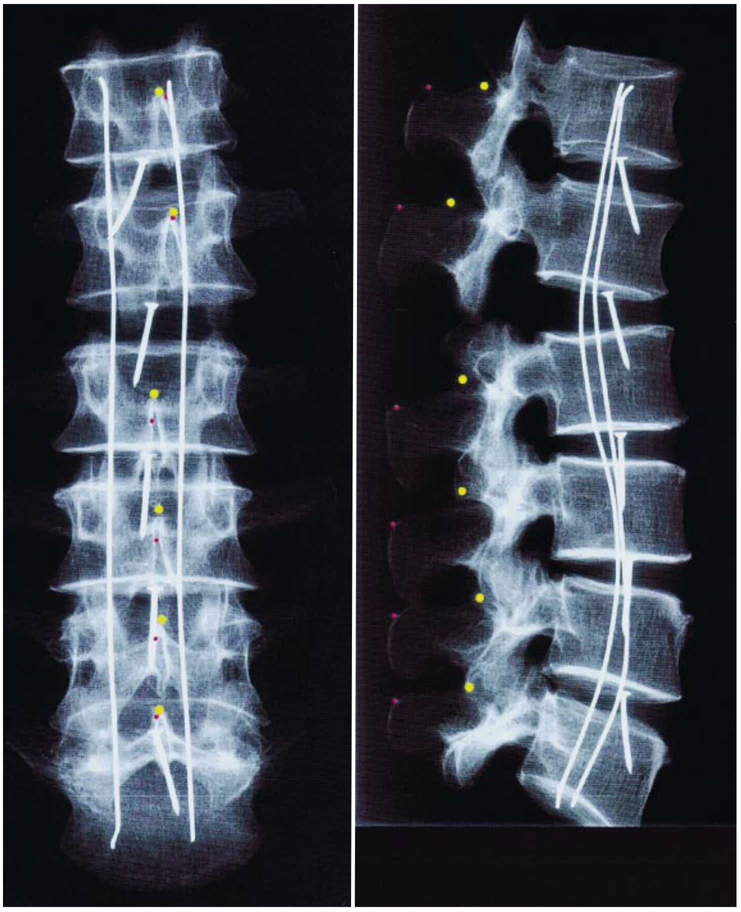

Fig. 6 Radiographs of a dry skeleton (position of the markers as in Fig. 5) simulating a luxation of facet joints between the L1 and L2 vertebrae. As compared to Fig. 5, the position of the small *(red)* and large *(yellow)* markers on the spinous process of L1 (AP radiographs) coincide, because the central X-ray beam is more parallel to the cranial part of the spinous process of L1, which has dislocated cranially. The centre of rotation for the dislocation is located comparatively far anteriorly, which means that the change of projection of the spinous process on the A-view will be small. (The metal objects except the markers on the spinous processes are artifacts in the construction of the spinal model and should not be considered)

Table 1 Mean value, standard deviation and 99% confidence intervall (CI) for the different age groups and locations. Statistics refer to one-way ANOVA with post-hoc test (Bonferroni)

Age interval (years)	Difference in distance between adjacent spinous processes											
	T12–L1/L1–L2			L1–L2/L2–L3			L2–L3/L3–L4			L3–L4/L4–L5		
	Mean	SD	98% CI	Mean	SD	98% CI	Mean	SD	99% CI	Mean	SD	99% CI
20–29	3.1	2.3	10.1	4.4	3.1	13.8a[a]	3.6	2.7	11.8	5.5	3.1	14.9[c]
30–39	2.8	1.7	7.8	2.3	2.0	8.4	2.7	2.3	9.7	4.2	2.4	11.5
40–49	2.7	2.0	8.8	1.7	1.4	5.9	2.4	2.2	9.1	3.1	2.4	10.4
50–59	3.2	2.2	9.9	2.6	2.1	9.1	2.4	2.0	8.5	2.9	1.9	8.4
60–69	3.6	2.9	12.4	3.2	3.0	12.2[b]	3.1	2.2	9.8	3.9	2.3	10.9

[a] Greater difference than age groups 30–39, 40–49, 50–59 ($P < 0.05$)
[b] Greater difference than age group 40–49 ($P < 0.05$)
[c] Greater difference than age groups 40–49, 50–59 ($P < 0.05$)

Statistical analysis

All calculations were based on the absolute values of the differences between adjacent interspinal process distances. Multivariate ANOVA was used to evaluate whether age or gender had any influence on the recorded differences. If so, the divergent levels were identified in the univariate *F*-test. Finally the deviations at these levels were verified in a one-way ANOVA with a post-hoc test (Bonferroni) to account for multiple comparisons. All calculations were done using SPSS 6.0 (SPSS Inc., Chicago, Ill.).

Results

The difference in distance between adjacent inter-spinous processes varied depending on age ($P < 0.0005$), but was not influenced by gender ($P = 0.32$; multivariate ANOVA). The age-related variation concerned the levels L1–L2/L2–L3 and L3–L4/L4–L5 ($P < 0.0005$; multivariate ANOVA, univariate *F*-test). There was a tendency to greater differences between these levels in the youngest age group compared to the age intervals 30–59 years (L1–L2/L2–3) or 30–49 years (L3–L4/L4–L5) (Table 1). The difference between the levels L1–L2/L2–L3 was more pronounced in the age group 60–69 years compared to age group 40–49 years ($P < 0.05$; one-way ANOVA with post-hoc test).

The 99% confidence intervals for “normal” difference between adjacent level in the lumbar spine varied between 5.9 mm (ages 40–49 years: L1–L2/L2–L3) and 14.9 mm (ages 20–29 years: L3–L4/L4–L5), depending on age and location. In the entire material ($n = 799$, disregarding age and location) the corresponding 99% confidence interval reached 9.6 mm. There were nine observations (1.1%) with a difference between adjacent interspinal process distances exceeding 7 mm and three (0.4%) that exceeded 10 mm.

The intra-observer variability of the adjacent spinal level differences varied between 3.4 and 4.6 mm (2 SD) at different levels, while the interobserver variability varied between 3.1 and 5.1 mm (2 SD).

Discussion

Determination of displacements and angulations between the vertebrae has been the focus of interest in many conditions with a potential instability of the spine such as degenerative disease. tumours, infections, traumatic and post-traumatic conditions of the spine [1, 3, 4, 8, 15, 16, 23, 24, 28, 29].

Few studies have investigated the biomechanical effects of rupture of the intersponous process tissues. In an experimental study on the limit of flexion in lumbar motion segment, Adams et al. [2] noted an increase in strain of 33% in the supra/interspinous ligament at first sign of injury. In another experimental study, Dumas et al. [7] stated that the elongation of the inter/supraspinous ligament complex did not exceed 7.4 mm until the first sign of injury occurred. Myklebust et al. [20] studied the posterior spinal ligaments in a similar study and noted that the elongation of inter- and supraspinous ligaments reached 14 and 27 mm, respectively, at failure. Neumann et al. [21] simulated flexion-distraction injury on an intact spinous segment and noted an elongation of 20 mm at first sign of injury. The difference between these studies are most probably an effect of different experimental set-ups and techniques of measurement.

Levine et al. [17] reviewed 30 cases with bilateral dislocation of the lumbar facet articulations. They observed that the distance between the interspinous processes on the radiographic AP view was increased by 10 mm compared with the normal adjacent segment. Several authors noted an increase in interspinal process distance when analysing radiographs of patients with seat-belt injuries, but did not quantify this increase [6, 12, 14, 27]

None of these studies consistently evaluated the relative displacement of spinous processes based on measurements of adjacent spinous processes, and there is no definition of an abnormal increase and its clinical consequences. The results of the present study are based upon a large sample size and should fairly accurately represent the normal limits in a Scandinavian population. These limits may have to be adjusted in populations with a shorter average height. If so, smaller confidence limits could be expected, which would mean that the “normal” limits found in our material do not represent an overestimation.

A simple radiographic method is of interest to screen for instability in cases with a lumbar spine fracture and/or dislocation in multiply injured patients. In such cases it is often very difficult to perform adequate sagittal radiographs and to record objectively the relation between the spinous processes and indirectly the status of the posterior stabilising structures of the spine. Fracture and/or fracture dislocations of the spinal segment with minimal or no compression of the vertebral body can be highly unstable and can be easily overlooked or missed on casual and inadequate sagittal radiographs (Figs. 1, 2) and even on conventional or helical CT scans [13, 18, 19, 25]. Such fractures are often seen in car accidents and are known as seat-belt injuries [10, 11, 27]. They are very often combined with abdominal and/or thoracic injuries, which initially dominate the clinical picture of the patient [5, 9, 26]. A simple method that can alert the surgeon to an unstable spinal injury before treating the other life-threatening concomitant injuries is therefore desirable.

We think that the AP radiograph of the thoraco-lumbar spine is a simple and useful tool to rapidly discover suspected rupture of the posterior spinal structures. It seems to be reliable according to the comparatively small intra- and interobserver errors. There is a difference depending on the age and level, which results in a variability of the upper “normal” levels. Nevertheless, in routine examination, the use of an upper limit of 6–7 mm difference in distance between spinous processes of two adjacent spinal segments can be used as a sign of serious injury. To avoid delayed diagnosis, further radiographic investigations should be done to delineate a potential unstable spinal injury in multi-traumatised patients. However, this method can only be used to alert the examiner and does not exclude all types of spinal trauma.

Conclusion

The measurement of interspinal process distance variation between adjacent lumbar spinal segments, in terms of changes in the distance between the cranial ends of the projected spinous processes on standard AP radiographs, is a reliable tool to alert the surgeon to a potentially severe injury of the posterior vertebral structures.

An interspinal process distance variation between two adjacent lumbar segments exceeding 7 mm should prompt the surgeon to make further radiographic investigations to map out the exact extent of the lesion.

References

1. Abumi K, et al (1990) Biomechanical evaluation of lumbar spinal stability after graded facetectomies. Spine 15: 1142–1147
2. Adams MA, Hutton WC, Stott JRR (1980) The resistance to flexion of the lumbar intervertebral joint. Spine 5: 245–253
3. Bernhardt M, Bridwell KH (1989 Segmental analysis of the sagittal plane alignment of the normal thoracic and lumbar spines and thoracolumbar junction. Spine 14: 717–721
4. Boden SD, Wiesel SW (1990) Lumbosacral segmental motion in normal individuals. Have we been measuring instability properly? Spine 15: 571–576
5. Dehner JR (1971) Seatbelt injuries of the spine and abdomen. Am J Roentgenol Radium Ther Nucl Med 111: 833–843
6. Denis F (1983) The three column spine and its significance in the classification of acute thoracolumbar spinal injuries. Spine 8: 817–831
7. Dumas GA, Beaudoin L, Drouin G (1987) In situ mechanical behaviour of posterior spinal ligaments in the lumbar region. An in vitro study. J Biomech 20: 301–310
8. Dvorak J, Panjabi MM, Chang DG, Theiler R, Grob D (1991) Functional radiographic diagnosis of the lumbar spine. Flexion-extension and lateral bending. Spine 16: 562–571
9. Garrett JW, Braunstein PW (1962) The seat belt syndrome. J Trauma 2: 220–238
10. Gertzbein SD, Court-Brown CM (1988) Flexion-distraction injuries of the lumbar spine. Mechanisms of injury and classification. Clin Orthop 227: 52–60
11. Gertzbein SD, Court-Brown CM (1989) Rationale for the management of flexion-distraction injuries of the thoracolumbar spine based on a new classification. J Spinal Disord 2: 176–183
12. Gertzbein SD (1994) Spine update. Classification of thoracic and lumbar fractures. Spine 19: 626–628
13. Handel SF, Lee YY (1981) Computed tomography of spinal fractures. Radiol Clin North Am 19: 68–89
14. Hayes CW, Conway WF, Walsh JW, Coppage L, Gervin AS (1991) Seat belt injuries: Radiologic findings and clinical correlation. Radiographics 11: 23–36
15. Hayes MA, Howard TC, Gruel CR, Kopta JA (1989) Roentgenographic evaluation of lumbar spine flexion-extension in asymptomatic individuals. Spine 14: 327–331
16. Lehmann TR, Wilson MA, Crowninshield RD (1982) Load response characteristics of lumbar spine following surgical destabilisation. Presented at the 28th Annual Meeting of the Orthopaedic Research Society, New Orleans
17. Levine AM, Bosse M, Edwards CC (1988) Bilateral facet dislocations in the thoracolumbar spine. Spine 13: 630–640
18. Link TM et al. (1996) Artificial spine fractures. Detection with helical and conventional CT. Radiology 198: 515–519
19. Manaster BJ, Osborn AG (1987) CT patterns of facet fractures dislocations in the thoraco-lumbar region. AJR 148: 335–340
20. Myklebust JB, Pintar F, Yoganandan N, Cusick JF, Maiman D, Myers TJ, Sances A Jr (1988) Tensile strength of spinal ligaments. Spine 13: 526–531

21. Neumann P, Nordwall A, Osvalder A-L (1995) Taumatic instability of the lumbar spine. A dynamic in vitro study of flexion-distraction injury. Spine 20: 1111–1121
22. Neumann P, Osvalder A-L, Nordwall A, Lövsund P, Hansson T (1992) The mechanism of initial flexion-distraction injury in the lumbar spine. Spine 17: 1083–1090
23. Panjabi MM, Duranceau JS, Oxland TR, Bowen CE (1989) Multidirectional instabilities of traumatic cervical spine injuries in a porcine model. Spine 14: 1111–1115
24. Pearcy M, Portek I, Shepherd J (1984) Three-dimensional x-ray analysis of normal movement in the lumbar spine. Spine 9: 294–297
25. Reid OC, Henderson R, Saboe L, Milles IDR (1987) Etiology and clinical course of missed spine fractures. J Trauma 27: 980–986
26. Rennie W, Mitchell N (1973) Flexion distraction fractures of the thoracolumbar spine. J Bone Joint Surg Am 55: 386–390
27. Smith WS, Kaufer H (1969) Patterns and mechanisms of lumbar injuries associated with lap seat belts. J Bone Joint Surg Am 51: 239–254
28. Stagnara P, DeMAuroy JC, Dran G, Gonon GP, Costanzo G, Dimnet J, Pasquet A (1982) Reciprocal angulation of vertebral bodies in a sagittal plane: approach to references for the evaluation of kyphosis and lordosis. Spine 7: 335–342
29. White AA III, Panjabi MM (1990) Clinical biomechanics of the spine, 2nd eds. JB Lippincott, Philadelphia

REVIEWER’S COMMENT

The more severely ill or injured is the patient, the less time and opportunity will be available for a full radiological examination, and the greater the need for surgeons and radiologists to extract all available information from the scanty initial radiological material, and not to miss unexpected yet essential diagnostic information. The authors of this paper remind us of the importance of looking at interspinal distances on AP projections of the spine, and they provide the reader with practical information on how to reliably distinguish between normal and abnormal distances. Their examples convincingly demonstrate that diagnosis of pathologically increased interspinal distance may provide a timely warning of serious disorder of the spine, which may otherwise be overlooked, with sometimes irreversible consequences.

L. Penning
University Hospital AZG, Room B 1.08, Hanzeplein 1,
Postbox 30.001, NL-9700 RB Groningen, The Netherlands