Eur Spine J (2012) 21 (Suppl 6):S760–S764
DOI 10.1007/s00586-011-1857-8

ORIGINAL ARTICLE

Is spinal stenosis assessment dependent on slice orientation? A magnetic resonance imaging study

Lucy Henderson · Gerit Kulik · Delphine Richarme · Nicolas Theumann · Constantin Schizas

Received: 21 March 2011 / Accepted: 21 May 2011 / Published online: 8 June 2011

Abstract
Introduction Lumbar spinal stenosis (LSS) treatment is based primarily on the clinical criteria providing that imaging confirms radiological stenosis. The radiological measurement more commonly used is the dural sac cross-sectional area (DSCA). It has been recently shown that grading stenosis based on the morphology of the dural sac as seen on axial T2 MRI images, better reflects severity of stenosis than DSCA and is of prognostic value. This radiological prospective study investigates the variability of surface measurements and morphological grading of stenosis for varying degrees of angulation of the T2 axial images relative to the disc space as observed in clinical practice.
Materials and methods Lumbar spine TSE T2 three-dimensional (3D) MRI sequences were obtained from 32 consecutive patients presenting with either suspected spinal stenosis or low back pain. Axial reconstructions using the OsiriX software at 0°, 10°, 20° and 30° relative to the disc space orientation were obtained for a total of 97 levels. For each level, DSCA was digitally measured and stenosis was graded according to the 4-point (A–D) morphological grading by two observers.
Results A good interobserver agreement was found in grade evaluation of stenosis ($k = 0.71$). DSCA varied significantly as the slice orientation increased from 0° to +10°, +20° and +30° at each level examined ($P < 0.0001$) (−15 to +32% at 10°, −24 to +143% at 20° and −29 to +231% at 30° of slice orientation). Stenosis definition based on the surface measurements changed in 39 out of the 97 levels studied, whereas the morphology grade was modified only in two levels ($P < 0.01$).
Discussion The need to obtain continuous slices using the classical 2D MRI acquisition technique entails often at least a 10° slice inclination relative to one of the studied discs. Even at this low angulation, we found a significantly statistical difference between surface changes and morphological grading change. In clinical practice, given the above findings, it might therefore not be necessary to align the axial cuts to each individual disc level which could be more time-consuming than obtaining a single series of axial cuts perpendicular to the middle of the lumbar spine or to the most stenotic level. In conclusion, morphological grading seems to offer an alternative means of assessing severity of spinal stenosis that is little affected by image acquisition technique.

Keywords Lumbar spinal stenosis (LSS) · Imaging · MRI · Lumbar spine · Diagnostic

Introduction

The diagnosis and radiological assessment of lumbar spinal stenosis (LSS) is currently undertaken by most clinicians using dural sac cross-sectional area (DSCA) measurement on magnetic resonance imaging (MRI) studies. A DSCA of <100 mm^2 has been suggested to represent relative stenosis, whilst a DSCA of <75 mm^2 gives an absolute radiological diagnosis of stenosis [15]. A new 4-point grading system for the radiological diagnosis of LSS has been proposed, based on the morphology rather than DSCA as judged on axial T2 MRI images [12]. This morphological classification has been shown to carry a prognostic value with grades A and B being

L. Henderson · G. Kulik · D. Richarme · N. Theumann · C. Schizas (✉)
Site Hôpital Orthopédique, Centre Hospitalier Universitaire Vaudois (CHUV), University of Lausanne, Avenue Pierre-Decker 4, 1011 Lausanne, Switzerland
e-mail: cschizas@hotmail.com

less likely to need surgery during a 4-year follow-up period. Our aim was to study the variability of surface measurements and morphological grading of stenosis for varying degrees of angulation of the T2-axial images relative to the disc space as observed in clinical practice.

Materials and methods

Lumbar spine MR images were obtained on a 3-T scanner (Verio or Trio, Siemens Medical Systems, Erlangen, Germany) with an isotropic T2-weighted 3D TSE sequence with a variable flip-angle distribution (SPACE: Sampling Perfection with Application optimised Contrasts using different flip-angle Evolution). Parameters for 3D SPACE sequence were repetition time = 1,500 ms, echo time 125 ms, voxel size of 0.9 mm to obtain an isotropic resolution, flip-angle = 100°, matrix = 320 × 320, field of view = 28 cm). Acquisition time was 6 min 15 s with a sagittal slab orientation [1, 7, 10].

Lumbar spine MR images were obtained from 32 consecutive patients presenting with either suspected LSS or LBP. Mean patient age was 59.5 years, SD 15.3 years (22–88 years). The male/female ratio was 0.75.

The raw 3D DICOM data were imported in the OsiriX software and axial 2D reconstructions were obtained at 0°, +10°, +20°, and +30° relative to the plane of the disc (Fig. 1). The four cranial lumbar intervertebral disc levels were analysed. The L5–S1 level was not studied because morphological grades other than A are rarely encountered in clinical practice given the lesser rootlet content at that level.

A total of 128 axial images were obtained. From these, 31 were omitted due to inadequate quality giving a total of 97 images to analyse. For each image, the DSCA was digitally measured by a single observer. Each image was also assigned a severity grade according to the 4-point morphological grading (Fig. 2) [12] by two observers, one senior and one junior. The latter had been given a short oral tuition detailing the grading system, shown in Fig. 2 and a practice test prior to starting the study. Disc level and patient's presenting symptoms were blinded.

Intra- and interobserver variability for DSCA measurement were not tested, being found to be non-significant in a previous study [12].

Lumbar lordosis was also measured twice between the caudal end pate of T12 and cranial end plate of S1.

Outcome measures

1. Number of levels demonstrating morphological grade change.
2. Number of levels changing stenosis severity as defined by Schonstrom [14]. That is severe stenosis (<75 mm^2) changing to moderate stenosis (75–100 mm^2) and moderate stenosis (75–100 mm^2) changing to absence of stenosis (>100 mm^2). In addition to the above criteria, only those levels demonstrating a minimum of 10% DSCA increase were included.

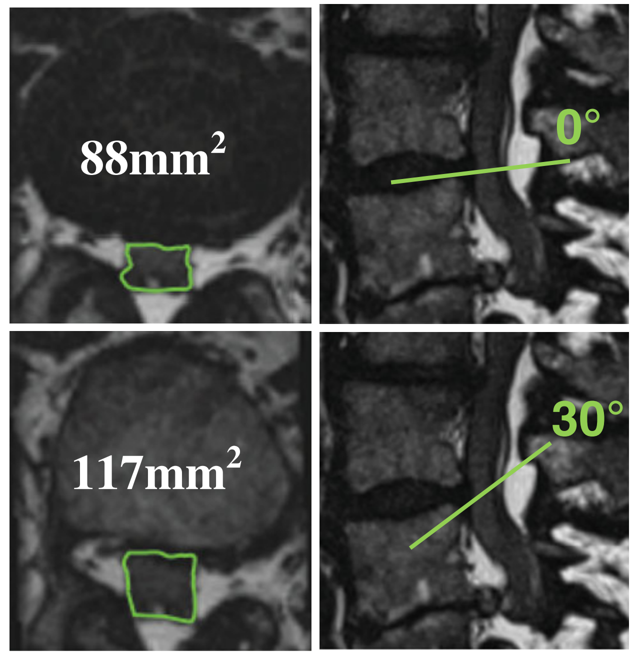

Fig. 1 *Top*. Dural sac cross-sectional surface at a reconstruction angle parallel to endplates of adjacent vertebral body (*line drawn on sagittal slice*). The vertebral level is L4–L5. The morphological stenosis grade is 'C'. *Bottom*. Dural sac cross-sectional area with slice reconstruction angle +30°

Statistical analysis

Weighted kappa test was used to assess interobserver reliability [4]. Paired two-tailed t test and Fisher's exact test were applied where appropriate.

Results

The interobserver agreement for the morphological grading was found to be substantial (κ score of 0.71). Average lordosis was found to be of 47° (23°–71°). When comparing DSCA at each level between the 0° slice and the +10°, +20° and +30° slice orientation, respectively, a significant increase in mean surface area was found at each angulation ($P < 0.0001$). Distribution of DSCA variation according to slice orientation expressed in percentages can be seen in Table 1.

Stenosis severity based on surface measurements as defined in the methods section changed in a total of 39

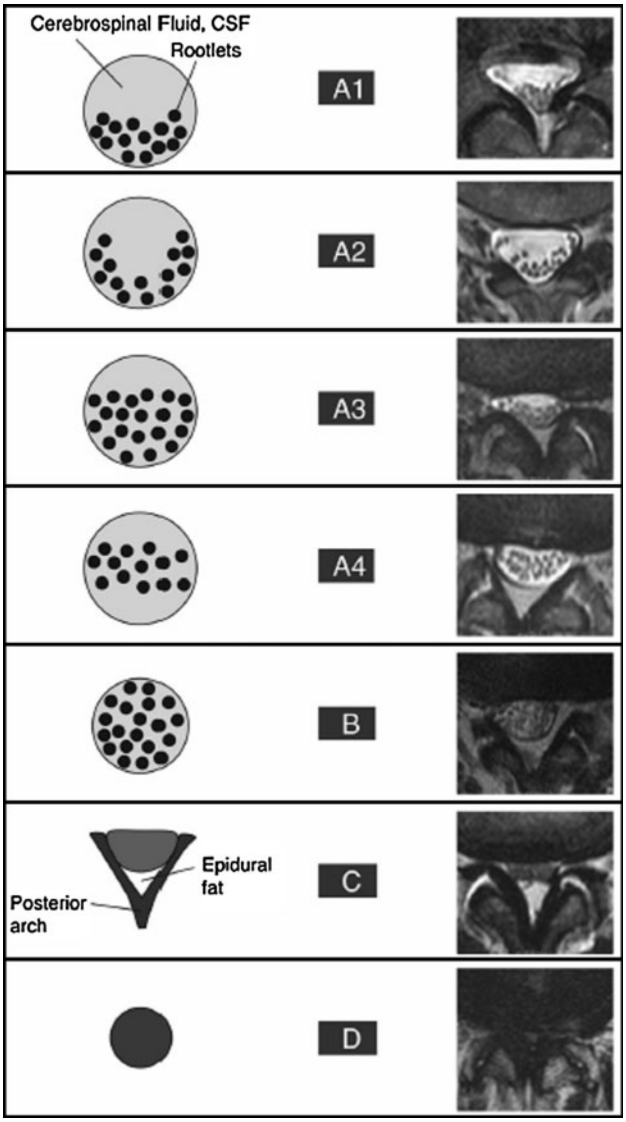

Fig. 2 The 4-point morphological grading used to assign a severity grade to each image, as published by Schizas et al. in: Qualitative grading of severity of lumbar spinal stenosis based on the morphology of the dural sac on magnetic resonance images published in Spine 2010; 35(21):1919 [12]. Reproduced with permission from Lippincott Williams and Wilkins Editors

levels. In contrast, the morphological grade changed in only two levels (Table 2). They were both encountered at 30° angulation, changing from grades C to B. The difference between number of levels changing morphological grade and surface based severity of stenosis was highly statistically significant for the 20° and 30° angulations and significant at 10° angulation.

Discussion

Our results suggest that using DSCA to determine the severity of spinal stenosis can be significantly affected by

Table 1 Change in dural sac cross-sectional area based on the slice orientation expressed in percentage

Percentage change in DSCA	0 versus +10	0 versus +20	0 versus +30
Mean	+5.38	+16.03	+32.16
SD	+18.40	+20.45	+26.52
Range (min)	−15.48	−24.0	−29.35
Range (max)	+31.89	+143.82	+231.13

Table 2 Changes in morphological grade and stenosis severity judged by surface measurements at each angulation

DSCA change from 0°	10° slice	20° slice	30° slice
Absolute: >relative stenosis	3	4	5
Relative: >no stenosis	5	9	13
Total	8	13	18
Morphology grade changes	0	0	2
Fisher's exact test	$P = 0.0067$	$P = 0.0002$	$P = 0.0001$

the slice orientation, whilst using a morphological grading system appears to give reliable outcomes despite any increase in the angle of slice orientation.

In clinical practice, the radiological assessment of spinal stenosis relies heavily on the availability of good quality images and the appropriate technology to aid analysis. Whilst myelography and computed tomography myelography (CTM) has been regarded as the gold standard in terms of imaging in cases of suspected spinal stenosis [9], MRI offers a valuable non-invasive alternative that gives excellent soft tissue delineation [17].

Stafira et al. [16] looked at inter- and intra-observer reliability in comparisons of MRI and CTM images, evaluating the level as well as severity and cause of spinal stenosis. The assessment of severity in their study gave interobserver kappa scores of 0.31 for MRI and 0.26 for CTM. Intraobserver kappa scores were 0.37 for MRI and 0.41 for CTM. Lurie et al. [8] describe a method of morphological assessment in determining the degree of spinal stenosis. Their study involved looking at the impingement on nerve roots in foraminal images—classified as 'none', 'touching', 'displacing' or 'compressing'. The interobserver kappa score obtained in the present study was 0.71 using the morphological grading system. We nevertheless limited the assessment of LSS to one parameter (morphological grade).

In addition, a kappa score of 0.71 compares favourably with intra- and inter-observer values of other classification systems, such as the AO classification of spinal fractures (kappa score 0.45) [18], or the thoracolumbar injury classification and severity score (kappa score 0.189 improving to 0.509 7 months later) [11].

The two parameters analysed, DSCA and morphological grading, do not have the same inter- and intra-observer agreement. Although there is no statistical difference in the variation in DSCA measurements as shown in a previous paper [12], inter-observer kappa score for the morphological grading was 0.7. This would seem to suggest that DSCA has better interobserver agreement than the morphological grading system introducing a possible bias.

A 30° slice angulation might seem excessive at first hand. The need to obtain continuous slices using the classical 2D MRI acquisition technique entails often at least a 10° slice inclination relative to one of the studied disc spaces due to physiological lordosis. In fact, a slice parallel to the mid-lumbar spine could easily reach an average of 25° at the cranial or caudal end of the lumbar spine given that studies have shown an average lordosis of 50° in healthy adults [2], or a range of 45° ± 22.56° (2 SD) in those with lumbar complaints [3] similar to the average value of 49° in our series.

Thirteen percent of DSCA measurements were found to slightly decrease, as the angle of the slice increased. This can be attributed to the fact that the spinal canal is not a uniform cylinder and thus increasing the obliquity of the slice orientation will not always result in an increase in DSCA.

In common with the measurement of DSCA, the use of the morphological grading system did underestimate the severity of LSS in two cases, where grading changed as slice orientation increased to 30°. This could be explained by the fact that the rootlets converge as they travel caudally through a stenotic disc level as they leave the canal at the pedicle level above.

Schonstrom [13] was the first to recognise the importance of obtaining perpendicular CT axial cuts to the affected level in evaluating DSCA in spinal stenosis. He proposed a geometrical model allowing correcting the error, but suggested that this approach would only be valid for thin slices and angulations not exceeding 15°. This model does not take into consideration the shape of the dural sac in a stenotic spine which is funnel shaped and therefore might underestimate the error induced by increase in slice angulation.

Hamanishi [5] recognised the potential for slice orientation to alter the DSCA, although recommended altering the equation for DSCA measurement only if slice orientation were more than 20° over a line parallel to the disc space. We have shown that increases as small as +10° in slice orientation can significantly impact on measurement of DSCA and thus on presumed severity of spinal stenosis.

Another study of a different anatomical region (pelvis) has also underlined the impact of slice acquisition, showing a 4.8–16% variation in actual measurements of the anteroposterior dimension of the levator hiatus when slice orientation was altered [6].

In clinical practice, given the above findings, it might therefore be unnecessary to align the axial cuts to each individual disc level which could be a more time-consuming process than obtaining a single series of axial cuts perpendicular to the middle of the lumbar spine or, even better, to the most stenotic level. At the extremes of the image acquisition, cranially and caudally, even though the images could be distorted through slice angulation, there would be very little risk of misjudging the degree of spinal stenosis using the morphological grading that has been previously described.

If DSCA is to be used as a radiological definition of LSS severity, the significant increase in DSCA demonstrated in this study with increasing obliquity of slice orientation could affect the management decisions and therefore the clinical outcome for the patient.

Conclusion

Morphological grading shows significantly less variability on slice orientation than DSCA measurement, and thus offers a more reliable means for assessing severity of LSS.

Acknowledgments Unrestricted research grant: DePuy Spine Switzerland (J&J).

Conflict of interest None.

References

1. Baumert B, Wortler K, Steffinger D, Schmidt GP, Reiser MF, Baur-Melnyk A (2009) Assessment of the internal craniocervical ligaments with a new magnetic resonance imaging sequence: three-dimensional turbo spin echo with variable flip-angle distribution (SPACE). Magn Reson Imaging 27:954–960
2. Chernukha KV, Daffner RH, Reigel DH (1998) Lumbar lordosis measurement: a new method versus Cobb technique. Spine 23:74–79
3. Fernand R, Fox DE (1985) Evaluation of lumbar lordosis—a prospective and retrospective study. Spine 10:799–803
4. Fleiss JL, Cohen J (1963) The equivalence of weighted kappa and the intrarelation correlation coefficient as measures of reliability. Educ Psychol Meas 33:613–619
5. Hamanishi C, Matukura N, Fujita M, Tomihara M, Tanaka S (1994) Cross-sectional area of the stenotic lumbar dural tube measured from the transverse views of magnetic-resonance-imaging. J Spinal Disord 7:388–393
6. Hoyte L, Ratiu P (2001) Linear measurements in 2-dimensional pelvic floor imaging: the impact of slice tilt angles on measurement reproducibility. Am J Obstet Gynecol 185:537–544
7. Lichy MP, Wietek BM, Mugler JP, Horger W, Menzel MI, Anastasiadis A, Siegmann K, Niemeyer T, Konigsrainer A,

Kiefer B, Schick F, Claussen CD, Schlemmer HP (2005) Magnetic resonance imaging of the body trunk using a single-slab, 3-dimensional, T2-weighted turbo-spin-echo sequence with high sampling efficiency (SPACE) for high spatial resolution imaging—initial clinical experiences. Invest Radiol 40:754–760

8. Lurie JD, Tosteson AN, Tosteson TD, Carragee E, Carrino JA, Kaiser J, Sequeiros RT, Lecomte AR, Grove MR, Blood EA, Pearson LH, Weinstein JN, Herzog R (2008) Reliability of readings of magnetic resonance imaging features of lumbar spinal stenosis. Spine (Phila Pa 1976) 33:1605–1610
9. Morita M, Miyauchi A, Okuda S, Oda T, Iwasaki M (2011) Comparison between MRI and myelography in lumbar spinal canal stenosis for the decision of levels of decompression surgery. J Spinal Disord Tech 24:31–36
10. Mugler JP, Bao SM, Mulkern RV, Guttmann CRG, Robertson RL, Jolesz FA, Brookeman JR (2000) Optimized single-slab three-dimensional spin-echo MR imaging of the brain. Radiology 216:891–899
11. Patel AA, Vaccaro AR, Albert TJ, Hilibrand AS, Harrop JS, Anderson DG, Sharan A, Whang PG, Poelstra KA, Arnold P, Dimar J, Madrazo I, Hegde S (2007) The adoption of a new classification system—time-dependent variation in interobserver reliability of the thoracolumbar injury severity score classification system. Spine 32:E105–E110
12. Schizas C, Theumann N, Burn A, Tansey R, Wardlaw D, Smith FW, Kulik G (2010) Qualitative grading of severity of lumbar spinal stenosis based on the morphology of the dural sac on magnetic resonance images. Spine (Phila Pa 1976) 35(21):1919–1924
13. Schonstrom N (1988) The significance of oblique cuts on ct scans of the spinal-canal in terms of anatomic measurements. Spine 13:435–436
14. Schonstrom N, Bolender NF, Spengler DM, Hansson TH (1984) Pressure changes within the cauda-equina following constriction of the dural sac—an invitro experimental-study. Spine 9:604–607
15. Schonstrom N, Lindahl S, Willen J, Hansson T (1989) Dynamic changes in the dimensions of the lumbar spinal-canal—an experimental-study invitro. J Orthop Res 7:115–121
16. Stafira JS, Sonnad JR, Yuh WTC, Huard DR, Acker RE, Nguyen DL, Maley JE, Ramji FG, Li WB, Loftus CM (2003) Qualitative assessment of cervical spinal stenosis: observer variability on CT and MR images. Am J Neuroradiol 24:766–769
17. Straub R, Mack MG, Jacobi V, Proschek D, Vogl TJ (2006) Magnetic resonance imaging in orthopaedic medicine. Orthopade 35:626–631
18. Wood KB, Khanna G, Vaccaro AR, Arnold PM, Harris MB, Mehbod AA (2005) Assessment of two thoracolumbarfracture classification systems as used by multiple surgeons. J Bone Joint Surg Am 87A:1423–1429