MRI Criteria of Developmental Lumbar Spinal Stenosis Revisited

Deep S. Chatha, M.D., F.R.C.P.C., and Mark E. Schweitzer, M.D.

Abstract

Purpose. It is somewhat surprising that radiographic criteria for lumbar stenosis have been transposed from radiography and CT to MR without scientific validation. As these radiographic criteria were developed via population studies with criteria defined by two standard deviations from the mean, we sought to perform the same methodology via MR.

Methods. The study was approved by the institutional review board; the requirement for informed consent was waived. One-hundred patients referred for possible metastatic disease, aged 4 to 94 were studied. Measurements were obtained on a midline sagittal T2-weighted (6000/120) image at each disc level, as well as at the mid-vertebral level. The distributive mean, and standard deviations were calculated and -2 SD was used as a “cutoff” for spinal stenosis. To assess for interobserver variation, 20% of the measurements were repeated by a second observer. To assess for intraobserver variation, another 20% of the measurements were repeated a second time at a minimum of a two month interval.

Results. The spinal canal was narrowest at L5-S1 (mean: 1.16 cm), and widest at L1-L2 (mean: 1.56 cm). Overall the narrowest measurements were at the intervertebral disc space and were narrower at the lower disc spaces. In our population, the lowest cutoff limit (two standard deviations below the mean) had a range between 0.38 cm at the L3-L4 disc space and 0.9 cm at the L1 vertebral level. Notably at the L3 level the size range was from 0.77 to 1.75 cm.

Conclusion. Traditional measurements of canal diameters may be too large when applied to soft tissue analysis on MR. We suggest using a cutoff of smaller than 0.90 cm for developmental stenosis.

It has been over 50 years since primary lumbar spinal stenosis was first described.1-4 Lumbar stenosis may be classified as acquired or developmental. 5 Acquired, or degenerative, stenosis is usually readily visible on imaging, since the changes are centered at the disc space.6 Developmental stenosis is more difficult to diagnose, since it is diffuse by definition and does not include the readily visible hallmarks of disc-centered pathology.7,8

A large amount of interest in imaging has concentrated on degenerative lumbar stenosis and the grading of the stenosis of the central canal. Eisenstein’s two large anatomic studies of skeletons found the lower anteroposterior diameter of the spinal canal in adults to be 12 mm and 13 mm.9,10 Other studies have shown values closely resembling these values.11-14 These criteria for stenosis were transposed, often without adaptation, from radiography to myelography, computed tomography (CT), and more recently magnetic resonance (MR) imaging. Myelographic and smaller CT scan measurements of the lumbar spine demonstrated a mean anteroposterior canal diameter between 12 mm and 14 mm, with a measurement of 11.5 mm considered small.15-19 Less data is available using MRI to quantitate developmental stenosis20 and no study (outside of the the pediatric population21) has sought to determine a normal distribution for canal diameter. Thus in clinical practice, developmental stenosis is often regarded as an anteroposterior spinal diameter of less than 12 mm. We sought to address this deficit in the literature.

Stenosis is a quantitative diagnosis that is made when the measurement of an individual is outside the range of normal. Therefore, the criteria for stenosis should be developed from an analysis of a normative distribution of measurements.
within a population. As has been shown in other areas of the musculoskeletal system, traditional radiographic measurements were often made because of the ease of identification of osseous landmarks. One advantage of MR is that direct measurements can be made of the soft tissue in question. This has led to modification of several skeletal measurements in the era of MR. Therefore, criteria for spinal stenosis on CT and radiography cannot be assured to be directly applicable to MR. Consequently, we sought to study the “normative” distribution of spinal canal measurements at various anatomic points on MR. This was hypothesized as an attempt to develop a distribution of spinal canal measurements and potential MR criteria for developmental spinal stenosis.

**Methods**

Our retrospective study was approved by the hospital’s institutional review board and was compliant with the Health Insurance Portability and Accountability Act (HIPAA). A waiver of informed consent was obtained.

**Patients**

One-hundred patients (36 males and 64 females) ranging in age from 4 to 94 (mean: 61.9 years of age) were studied. Patients who were referred for possible metastatic disease and who had no evidence of secondary spinal tumors were evaluated.

Selecting the patient population for a “normal” distribution is difficult. Healthy volunteers were not imaged, since they may not provide a broad distribution that is likely to be skewed to the left. Similarly, we chose not to evaluate patients referred with spinal symptoms, since that would skew the distribution to the right. We selected patients who were undergoing screening for possible metastatic disease, since they approximate the general population imaged in age and usually have non-specific symptoms. Although this is an imperfect group, we felt that it was similar to that used in prior, non-MR studies of spinal stenosis.

**MR Imaging and Measurements**

Patients were scanned at 1.5 T (Siemens, Erlangen, Germany). The following measurements were obtained on sagittal T2-weighted (6000/120) images. At each disc level (L1-L2, L2-L3, L3-L4, L4-L5, and L5-S1) and at the mid-vertebral level (L1, L2, L3, L4, and L5), a perpendicular line was drawn on a midline image from the posterior aspect of the spinal canal to the anterior aspect of the canal using electronic calipers (Magic View, Siemens, Erlangen, Germany), and the diameter was measured. Measurements were performed in centimeters (cm), to the nearest hundredth (Fig. 1).

The distributive mean and standard deviations were calculated. The mathematical definition of a musculoskeletal spine anomaly is outside two standard deviations. Consequently, -2 SD was used as a “cutoff” for spinal stenosis.

**Interobserver and Intraobserver Variation**

To assess for interobserver variation, 20% of the measurements were repeated by a second observer. To assess for intraobserver variation, another 20% of the measurements were repeated a second time at a minimum of a 2 month interval. The measurements were analyzed using the Pearson correlation, intra-class correlation coefficient, and 95% limits of agreement.

**Results**

**Measurements of the Lumbar Spine**

Our normative measurements are presented in Table 1.

Figure 2 demonstrates the distribution of the anteroposte-
rior dimensions of the lumbar spinal canal with accompanying upper and lower limits for each level.

As would be expected, the spinal canal was narrowest at L5-S1 (mean 1.16 cm) and widest at L1-L2 (mean 1.56 cm). Overall, the narrowest measurements were at the disc space level and were narrower at the lower disc spaces. This is also intuitive.

The greatest standard deviation was at L3-L4, with a standard deviation of 1.00 cm. The smallest standard deviation was found at L2, with a deviation of 0.44 cm.

The smallest cutoff of two standard deviations below normal was at L3-L4, with 0.38 cm. The widest measurement with two deviations above normal was at L2-L3, at 2.43 cm. The measurements of the lower limits of each level are compared to those of five other prior studies (Fig. 3). These measurements are presented in a normative distribution curve (Fig. 4).

In our population, the lowest cutoff limit (two standard deviations below the mean) had a range between 0.38 cm at the L3-L4 disc space and 0.93 cm at the L1 vertebral level.

**Interobserver and Intraobserver Agreement**

There was good interobserver and intraobserver agreement at the mid-vertebral levels where developmental stenosis would be a factor. The intraclass correlation ranged between 0.68 and 0.87. Conversely, there was relatively weak correlation and wide limits of agreement observed for the intervertebral disc levels where acquired stenosis is the predominant factor. Intraclass correlation was poor at these levels ranging between 0.18 and 0.84. There was strongest agreement at L5, and the least agreement was at L1-L2.

**Discussion**

Spinal stenosis should not be considered an actual measurement but rather a manifestation of a continuum of various canal sizes. This same concept is applied to other areas of the musculoskeletal system, such as the height of the patella and the length of the ulna, among many others. In the situation where there is a continuum of measurements without an external reference, two standard deviations has been used as the definition of an anatomic outlier. This criteria of two standard deviations has been used in other investigations on the imaging of spinal stenosis. Thus, we used two standard deviations as our criteria for outliers of our normative measurements.

Initially measurements were based on large anatomic studies of lumbar spine diameter in skeletons by Eisenstein. Examining 275 skeletons, with 1,340 lumbar vertebral levels, he found that 12 mm represented the lower limit of anteroposterior dimensions of the spinal canal in adults. In his study, only 1.7% of vertebral levels measured less than 12 mm, and none were less than 11 mm. His larger follow-up study with 443 skeletons and 2,166 vertebral levels demonstrated slightly larger measurements with an

---

**Figure 2** Graph of normative measurement of spinal stenosis in 100 patients.

**Figure 3** Comparison of lower limits of normative spinal canal with the prior literature.

**Figure 4** Bell-shaped curve of measurements demonstrating mean dural sac diameter and standard deviations in 100 patients.
average mid-sagittal diameter of 16 mm and a lower limit of normal of 13 mm. On lumbar radiographs, the lower limit of normal was found to be 15 mm after correction for magnification factor. As these studies were performed on skeletons, they did not take into consideration the soft tissues that are readily seen on MR imaging.

The diameter of the spinal canal was relatively wider at the upper levels than at the lower levels. This is similar in the data of Wildermuth and colleagues and Haig and associates. The data of Hinck and coworkers found much larger spinal cord diameters than the ones in this study. However, their absolute number for two standard deviations was nearly identical. The details of the symptoms of the patients studied were not provided. Eisenstein performed two separate radiographic studies on spinal stenosis. In both of these investigations, he had developed criteria slightly larger than ours, but lower than that of Hinck and coworkers, while evaluating ex-vivo skeletons. He used the previously described smallest radiographic measurement values as a measurement for stenosis (1.2 cm and 1.3 cm). A broad age range of patients was also used. Several studies have shown that although there is minimal increase in the dural sac diameter with age, it is not statistically significant, while other studies have shown that the mid-sagittal growth of the lumbar spine does not change significantly after 4 years of age.

We realize that there are several limitations to this study. First, our population was somewhat limited. Eisenstein used 433 skeletons to make his measurements. In another study by Eisenstein, he used 11 skeletons. The population selected is always open to debate, and we would be the first to acknowledge that although not suboptimal, it was not ideal. Other than selecting a large number of random participants, this was thought to be a useful population. If volunteers were selected, many who might be interested would likely have a history of back problem and might participate because of the secondary gain. Our “clinical” population is, however, not dissimilar to that used in other studies of stenosis, or for that matter patella height or ulna variance. We realize that the population is also diverse with a large age range. Perhaps future studies with populations grouped into age ranges may be useful. However, we believe the eventual answer is related less to patient selection than to the concept of the canal as a three-dimensional construct and, in the future, some type of multi-dimensional shape analysis.

Secondly, evaluation of a much larger population of both symptomatic and asymptomatic patients with analysis of patient demographics and clinical history would be a greater undertaking but would prove useful. That is to say that there are patients with significant symptoms of spinal stenosis and normal sized canals and, conversely, patients with markedly stenotic canals who have little or no symptomatology. In addition, patient size itself, more so than age, may influence the size of the central canal and should be evaluated. Thus a measurement in and of itself, without reference to the patients’ clinical picture, may be of limited use.

Conclusion

Accepting these limitations, we conclude that traditional measurement of canal diameters may be too large when applied to soft tissue analysis on MR. We suggest using a cutoff
of smaller than .90 cm (9 mm) for developmental stenosis. We provide some preliminary data for acquired changes at the disc level, but we suggest that these be viewed with much more caution.

Disclosure Statement
The authors have no financial or proprietary interest in the subject matter or materials discussed, including, but not limited to, employment, consultancies, stock ownership, honoraria, and paid expert testimony.

References
15. Verbeist H. Neurogenic intermittent claudication in cases with absolute and relative stenosis of the lumbar vertebral canal (ASLC and RSCL), in cases with narrow lumbar intervertebral neuroforamina, and in cases with both entities. Clin Neurosurg. 1973;20:204-14.