Implications of the Precise Anatomical Location of Lumbar Stenosis for Minimally Invasive Decompressive Lumbar Surgery

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Objective: The purpose of this study was to characterize an observation that the most severe lumbar stenosis is often displaced from the disc. Methods: A retrospective magnetic resonance (MRI) review of displacement and causes of lumbar canal stenosis, was undertaken. Lumbar MRIs (n=3000) were reviewed for stenosis defined as a canal diameter of ≤8 mm. Displacement of maximal stenosis from the disc was measured; measurements inferior to the disc were assigned negative values. Defined causes were: ligamentous hypertrophy, facet hypertrophy, lipomatosis, spondylolisthesis, synovial cyst, or adjacent segment disease. Results: Lumbar stenosis levels (n=1,042) identified in 749 patients were; L1-2 (3.8%), L2-3 (20.1%), L3-4 (35.3%), L4-5 (37.7%), and L5-S1 (3.2%). Of these levels 20.8% were attributed to facet hypertrophy, 29.8% ligamentous hypertrophy, 31.1% epidural lipomatosis, 12.9% spondylolisthesis, 5.6% adjacent segment disease, and 1.5% synovial cyst. Mean displacement stenosis (mm) was; synovial cyst (-0.3; range 7 to -5), epidural lipomatosis (-1.1; 5 to -13), ligamentous hypertrophy (-3.5; 5 to -13); facet hypertrophy (-3.9; 7 to -11), adjacent segment disease (-4.7; 7 to -11), and spondylolisthesis (-4.9; 11 to -12). Sub-group analysis revealed a predominantly negative displacement for spondylolisthesis, adjacent segment disease, facet hypertrophy, and ligamentous hypertrophy. Conclusion: The site of maximal lumbar stenosis is at or near the center of the disc with lipomatosis or synovial cyst, but significantly inferiorly displaced when ligamentous or facet hypertrophy, spondylolisthesis, or adjacent segment disease is the major cause. Lipomatosis as a cause of stenosis is more common than previously reported.

Key Words: Lumbar stenosis, Minimally invasive spine surgery, Epidural lipomatosis

INTRODUCTION

Lumbar spinal stenosis requiring surgical decompression is a very common spine condition1-5. Open surgery has in part been supplanted by minimally invasive procedures, often via tubular retractors or endoscopes6. When the operating corridor is thus confined, it is important that an access device be directed at the critical pathology points so that stenotic areas do not remain rostral or caudal to the field of view. The first author has noted (personal observation over 20 years of minimally invasive spine surgery experience) that the most severe site of lumbar stenosis is often displaced from the disc space itself, and, therefore, care must be taken to direct the tubular retractor toward the most severe area of stenosis. The primary purpose of the study was to characterize the observation noted above. Therefore, we undertook a radiographic review, at a single institution, over 2 years, to quantify the location, cranial/caudal displacement, and causes of lumbar canal stenosis as determined retrospectively by lumbar magnetic resonance imaging (MRI).

MATERIAL AND METHODS

1. Study Design

A retrospective review was undertaken of 3,000 lumbar MRIs performed at a single institution in 2017 and 2018. Review was conducted by a neurosurgeon (DAR), a neuroradiologist (JMP), a radiology resident (MC and NPL) and 2 medical students (JE and MS). Only cases of routine spondylosis were included. Cases of trauma, neoplasm, or infectious conditions were excluded. Cases with disc protrusions as the major contributor to spondy-
lotic stenosis were excluded as most surgeons are likely to be aware that disc fragments can migrate and routinely direct the surgery to the site of the imaged fragments. Levels previously operated upon were also excluded.

2. Lumbar Magnetic Resonance Imaging Review

Sagittal and axial T2 weighted images were inspected looking for areas with a midline anterior posterior (AP) canal diameter of \( \leq 8\, \text{mm} \). A central ray was drawn through the most proximate disc space on the sagittal view. Rostral or caudal displacement of the site of maximal stenosis from this central ray was measured on the sagittal image in millimeters, with measurements inferior to the disc space assigned negative values. Note was made of the major cause of the stenosis, we defined the cause of stenosis as that which if corrected would enlarge the canal cross sectional area the most, and classified stenosis as ligamentous hypertrophy, facet hypertrophy, epidural lipomatosis, spondylolisthesis, synovial cyst, or adjacent segment disease associated with a prior fusion at an immediately adjacent level. It was recognized that in many cases, more than one factor contributed to the stenosis (as several of these result simultaneously from primary disc degeneration), but only one factor was assigned as the major cause (Figure 1). All scans were reviewed by the senior author (DAR) and any discrepancies in interpretation were reviewed and adjudicated by the neuroradiologist (JMP). The study was approved by the institutional review board and was performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

3. Statistical Analysis

To evaluate for factors potentially contributing to the amount displacement of the most severe lumbar stenosis from the corresponding disc space, univariate associations were first examined using Pearson’s correlation for continuous variables, Spearman correlation for ordinal variables, and Pearson Chi-Square for nominal variables. Factors with statistically significant associations were entered in the multi-variate model as well as their corresponding interaction terms. Iterative grouping of the categorical variables were also performed to maximize associations between the merged variable and the displacement measurements. Factors with significant contributions to displacement measurements in the multi-variate model underwent further ANOVA analysis followed by post hoc Turkey multiple comparisons to determine potential group characteristics. Data is presented as ±standard deviation (SD).

RESULTS

1. Demographics and Stenosis Level

Of the 3,000 original lumbar MRIs, 1,042 levels in 749 separate patients were identified as meeting inclusion criteria. Studies were excluded when there was no significant stenosis at any lumbar level, demonstrated recent trauma, infection, or neoplasm, showed a disc protrusion as the major cause of stenosis, were postoperative, were redundant, or were of poor quality. Age range was 40 to 89 years (mean 65.6±10.7 years). Of the 1,042 levels there were 474 females and 568 males, and 39 cases (3.8%) were at L1-2, 209 cases (20.1%) at L2-3, 368 cases (35.3%) at L3-4, 393 cases (37.7%) at L4-5, and 33 cases (3.2%) at L5-S1.

2. Classification and Cause of Stenosis

Of the 1,042 levels: 217 (20.8%) were classified as being due to facet hypertrophy, 310 (29.8%) to ligamentous hypertrophy, 324 (31.1%) levels to epidural lipomatosis, 117 (11.2%) levels to spondylolisthesis, 58 (5.6%) levels to adjacent segment disease, and 16 (1.5%) levels to a synovial cyst (Table 1). The largest fraction of cases from ligamentous hypertrophy, spondylolisthesis, and synovial cysts was at L4-5, but the largest fraction of lipomatosis, facet hypertrophy, and adjacent segment disease cases was at L3-4.

3. Displacement

Mean displacement from the disc space at levels that were
Table 1. Major cause of cenosis by lumbar level (n=1,042)

| Cause               | Level (n: %) | L1-2 | L2-3 | L3-4 | L4-5 | L5-S1 |
|---------------------|--------------|------|------|------|------|------|
| Lipomatosis         | 324          | 20; 6.2 | 85; 26.2 | 126; 38.9 | 86; 26.5 | 7; 2.2 |
| Ligamentous         | 310          | 4; 1.3 | 42; 13.5 | 111; 35.8 | 143; 46.1 | 10; 3.2 |
| Facet Hypertrophy   | 217          | 11; 5.1 | 54; 24.9 | 83; 38.2 | 61; 28.1 | 7; 3.2 |
| Spondylolisthesis   | 117          | 1; 0.9 | 5; 4.3 | 18; 15.4 | 86; 73.5 | 7; 6.0 |
| Adjacent Segment    | 58           | 3; 5.2 | 20; 34.5 | 26; 44.8 | 8; 13.8 | 1; 1.7 |
| Synovial Cyst       | 16           | 1; 6.3 | 2; 12.5 | 3; 18.8 | 9; 56.3 | 1; 6.3 |

Table 2. Displacement of maximum stenosis from the disc space by major causative factor

| Cause               | Percent | Range of displacement (mm) | Mean displacement (mm) | Absolute displacement (mm) |
|---------------------|---------|---------------------------|------------------------|----------------------------|
| Synovial Cyst       | 1.5     | 7 to -5                   | -0.3                   | 2.8                        |
| Lipomatosis         | 31.1    | 10 to -11                 | -1.1                   | 1.6                        |
| Ligamentous         | 29.8    | 5 to -13                  | -3.5                   | 3.6                        |
| Facet Hypertrophy   | 20.8    | 7 to -11                  | -3.9                   | 4.1                        |
| Adjacent Segment    | 5.6     | 7 to -11                  | -4.7                   | 4                          |
| Spondylolisthesis   | 11.2    | 11 to -12                 | -4.9                   | 5.2                        |

Table 3. A summary of statistical analysis results

| Analysis | Displacement | p-value |
|----------|--------------|---------|
| Univariate | and age | 0.009 |
|          | and cause | <0.001 |
|          | and sex (female) | 0.049 |
|          | and spine level | <0.001 |
| Multivariate | Cause | <0.001 |
|          | Level | 0.003 |

4. Univariate Associations

Significant univariate associations were demonstrated between displacement measurement and patient age (p=0.009, more advanced age associated with more negative displacement), lumbar canal stenosis underlying cause (p<0.001), sex (p=0.049, female sex associated with more negative displacement) and level of disease (p<0.001, lower level associated with more negative displacement). Further evaluation with multi-variate linear regression adjusting for interaction terms among patient age, cause of lumbar stenosis, gender, and level of disease confirmed significant contributions to displacement measurements from cause of lumbar canal stenosis and level of disease (p<0.001 and p=0.003, respectively) but not patient age or sex (p=0.135 and p=0.537, respectively). Iterative grouping of the categorical variables suggested merging of adjacent segment disease, facet hypertrophy, and ligamentous hypertrophy into one group with a group mean contribution of -3.2 mm as well as merging disease at levels L1-2, L2-3, and L3-4 into one group with a group mean contribution of -2.0 mm (Table 3).

4. Univariate Associations

Sub-group analysis showed a common trend of predominantly negative displacement measurements with spondylolisthesis, adjacent segment disease, facet hypertrophy (the synovial joints bilaterally), and ligamentous hypertrophy (the low T2 signal structures internal to the lamina consistent with ligamentum flavum). Epidural lipomatosis (the high T1 and T2 signal internal to the ligamentum flavum and external to the thecal sac) showed a different distribution of displacement values with a significantly higher percentage of stenoses at the level of the disc space (post hoc p<0.01 compared to spondylolisthesis, adjacent segment disease, facet hypertrophy, and ligamentous hypertrophy: p=0.038 compared to synovial cyst). Lumbar stenosis caused by synovial cyst also had a significantly different displacement distribution, evenly distributed among negative, zero, and positive values (post hoc p<0.01 compared to spondylolisthesis, adjacent segment disease, facet hypertrophy, and ligamentous hypertrophy; p=0.038 compared to synovial cyst) (Figure 2).

DISCUSSION

The fastest increasing area of lumbar spine surgery in recent decades is in older patients with lumbar spinal stenosis. Minimally
and found 1,042 levels showing stenosis defined as an AP diameter 5.144 mm. We conducted a retrospective review of 3,000 lumbar MRIs over 2 years, of maximal stenosis in planning the procedure. We have concluded that care must be taken to carry the decompression inferior to the disc space to ensure a complete decompression. In studies suggesting that minimally invasive decompression is not as effective as decompression and fusion, it will be critical to ascertain if the decompression actually reached the area of most severe stenosis, as failure to do so could account for poorer outcomes in patients who were not fused.

Minimally invasive decompression is also effective in segments adjacent to an instrumented fusion. Adjacent segment decompression can be hampered by protruding rods and arthrodesis bone. It is important to accurately assess the location of maximal stenosis and to plan a tubular trajectory which will avoid collision with the hardware.

It is of interest that almost one third of our cases were judged to be due in large part to epidural lipomatosis. This is becoming an increasing problem, likely in association with the obesity epidemic and steroid exposure, but has not been reported to this extent. According to Theyskens, et al., who conducted a report-based search for the term lipomatosis in the radiologist’s reports of 28,902 spinal MRIs, the overall incidence of lipomatosis was 2.5% of which only 0.1% were definitely symptomatic. Lipomatosis was associated with older age, higher modified Charlson comorbidity index, male sex, body mass index >30, Black/African American race, systemic corticosteroid, and epidural corticosteroid injections. In a series of patients operated upon for symptomatic lipomatosis, no correlated factors were found to be significantly different from other spine surgery patients except for a longer duration of symptoms, suggesting that the diagnosis may be delayed. Our study suggests that epidural lipomatosis sufficient to result in stenosis may be more common than previously reported.

1. Limitations

The study is limited by its retrospective nature, by the precise definition of stenosis selected, and by some variability in assigning a major cause of the stenosis, which is often multifactorial. As this study was undertaken with all lumbar MRIs performed in a finite period of time and obtained for a wide variety of reasons, it is not known if any of the findings were symptomatic or if any patients had subsequent surgery of any kind. It was not the intention of this study to correlate the findings with clinical outcomes,
CONCLUSION

In summary, the site of maximal lumbar stenosis is at or near the center of the disc space when the major cause is lipomatosis or synovial cyst, but is often significantly inferiorly displaced from the disc space when ligamentous or facet hypertrophy, spondylolisthesis, or adjacent segment disease is the major cause. Lower lumbar levels and older patients may harbor larger displacements from the disc space. Correctly orienting the access tube for minimally invasive lumbar decompression will help to prevent leaving an undecompressed stenotic segment caudal or rostral to the field of view.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article.

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