NLP-powered Analysis of a Large-scale Lumbar Spine MRI Reporting Archive for Characterizing Severity Distribution of Lumbar Spine Degenerative Disease

Walter F. Wiggins, MD, PhD, Brigham and Women's Hospital; Michael T. Caton, MD; Stuart R. Pomerantz, MD; Katherine P. Andriole, PhD, FSIIM

Introduction
Lumbar spine degenerative disease (LSDD) is highly prevalent and a significant driver of healthcare costs. Characterizing LSDD severity has significant clinical implications, as surgical intervention is typically considered for LSDD of at least "Moderate" degree. Useful insights can be extracted using a large-scale ("Big Data") approach to our institutional reporting archive. Radiologists' reporting of LSDD generally follows a patterned semantic structure making it tractable to natural language processing (NLP) analysis. We sought insights into the anatomic and epidemiologic distribution of LSDD severity, by applying NLP to this resource.

Hypothesis
We expected LSDD to increase in prevalence as age increases and predicted that clinically significant (i.e. at least Moderate) spinal canal and foraminal stenosis would be most frequent at the L4-5 level. Foraminal LSDD was presumed to be symmetric. Prevalence of disease was not expected to vary greatly by gender.

Methods
A total of 43,255 lumbar spine MRI (LSMRI) reports acquired from 2007-2017 at a single institution were parsed with a customized regular-expression-based NLP algorithm developed by our group. The various free-text LSDD descriptors extracted from the radiology reports were categorized according to a 6-point scale: 0 = "Normal" …3 = "Moderate" …5 = "Severe" with intermediate grades interposed (e.g. 2 = "Mild-to-Moderate"). To investigate clinically relevant LSDD, we calculated the prevalence of LSDD characterized as 3 ("Moderate") or greater on the 6-point scale. Clinically significant LSDD prevalence was displayed as an anatomically intuitive heatmap for all patients (Fig 1A) with odds ratios for laterality differences in foraminal stenosis (FS) prevalence (Fig 1B). Heatmaps were then generated to evaluate subpopulations, including the effects of gender (Fig 2) and age group (Fig 3).

Results
Pooled analysis of all cases (n = 43255) is shown in Fig 1. We observed a progressive caudal gradient from T12-L1 to L4-5 for prevalence of spinal canal stenosis (SCS) with relative sparing of L5-S1 at the lumbo-sacral junction. FS followed a similar pattern, with highest prevalence at L4-L5. FS was more prevalent than SCS at each level. Overall prevalence of FS was greater on the left at L2-L3 and L5-S1 (Fig 1B, $p < 0.001$). Sub-analysis by gender (Fig 2) shows similar patterns of SCS in both groups though FS was more prevalent in men. Fig 3 shows prevalence of LSDD by age group. Overall, LSDD increased with age. Though FS was overall more prevalent at L4-5, in the > 50 age group, the highest prevalence occurred at L5-S1.

Conclusion
Heatmaps of LSDD prevalence showed two unexpected patterns. First, in the < 50 age group, FS prevalence peaked at L5-S1, despite lower overall prevalence of LSDD. This accelerated degeneration at the lumbo-sacral junction may reflect stresses from various anatomico-pathologic factors such as relative segmental instability, lumbo-sacral angle, transitional anatomy, scoliosis, and spondylolysis. Our findings also show higher prevalence of FS in men, despite a similar pattern of

SCS in both genders. The interplay of gender, weight, occupational stressors with such anatomic considerations as listed above can be further explored.

Second, we identified unexpected asymmetry in FS prevalence at L2-L3 and L5-S1, which was significantly greater on the left. To our knowledge, this pattern has not been previously reported. Asymmetric biomechanics due to scoliosis offers one possible mechanism for this finding, though further investigation is planned.
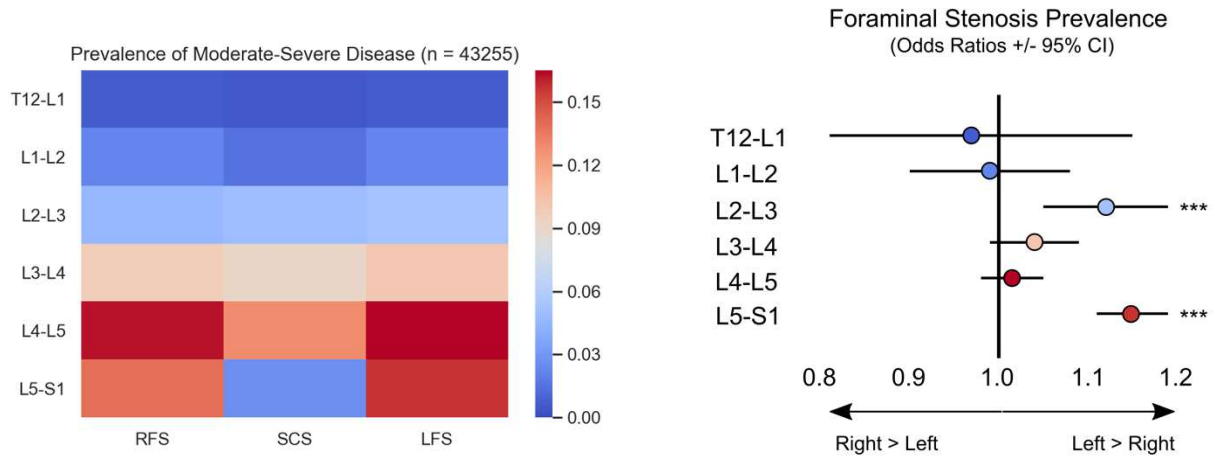
Statement of Impact

Quantification of LSDD using NLP of large-scale free-text radiology reporting archives is feasible. Such a "Big-Data" approach reveals new insights into the epidemiology and pathophysiology of LSDD which could aid individual treatment-planning and prognostication as well as population health decisions.
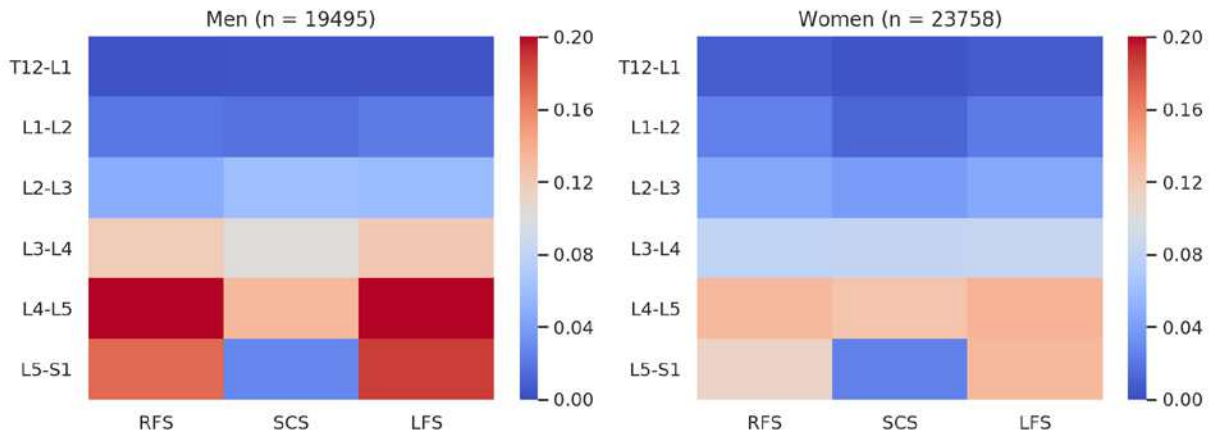
Keywords

lumbar spine, MRI, degenerative disease, spinal stenosis

Figure 1:

Prevalence of Moderate-Severe Disease (n = 43255)

Foraminal Stenosis Prevalence
(Odds Ratios +/- 95% CI)

Figure 2:

Men (n = 19495)

Women (n = 23758)

Figure 3:

< 50yo (n = 16267)

50-70yo (n = 18077)

> 70yo (n = 8911)