Severity and Location of Lumbar Spine Stenosis Affects the Outcome of Total Knee Arthroplasty

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Abstract

Background

Recent studies have noted that patients with pre-existing lumbar spinal stenosis (LSS) have lower functional outcomes after total knee arthroplasty (TKA). Given that LSS manifests heterogeneously in location and severity, its influence on knee replacement merits a radiographically targeted analysis. We hypothesize that patients with more severe LSS will have diminished knee mobility following TKA.

Methods

This retrospective study assessed all TKAs performed at our institution for primary osteoarthritis from 2017-2020. Preoperative lumbar magnetic resonance image (MRI) with no prior lumbar spine surgery were necessary for inclusion. Stenosis severity was demonstrated by (1) anterior-posterior (AP) diameter of the dural sac and (2) morphological grade. TKA outcomes in 103 cases (94 patients) were assessed by measuring preoperative and postoperative arc of motion (AOM), postoperative flexion contracture, and need for manipulation under anesthesia.

Results

Patients with mild stenosis did significantly better in terms of postoperative knee AOM. As AP diameter decreased at levels L1-2, L2-3, L3-4, and L4-5, there was a significant reduction in preoperative-AOM ($p<0.001$ for each), with a 16 degree decrease when using patients' most stenotic level ($p<0.001$). The same was noted with respect to increased morphological grade ($p<0.001$), with a 5 degree decrease for patients' most stenotic level ($p<0.001$).

Conclusion

Severe LSS, which is readily demonstrated by a reduction in the AP diameter of the dural sac or increased morphological grade on MRI, correlated with a significant reduction in preoperative-AOM that was not improved after TKA. Persistent postoperative reductions in AOM may contribute to reduced patient satisfaction and recovery.

Level of Evidence: Level 4

Background

The knee, hip, and spine connection has recently received greater attention, with pathology in one location often manifesting over time as pain, deformity, or degeneration in another [1–5]. The rising incidence of knee and hip arthroplasty [6] in an aging population has provided an opportunity to further characterize these relationships and their effect on outcomes after corrective surgery [7–10]. As the prevalence of lumbar spinal stenosis (LSS) is higher in these populations, there has been increased interest in how LSS affects total hip (THA) and knee (TKA) arthroplasty outcomes when performed for primary osteoarthritis (OA) [8, 10–13].

In patients undergoing THA, those with concomitant LSS appear to have worse functional outcomes, patient satisfaction scores, and activity levels than patients without stenosis [11]. Additionally, there is evidence that in patients who undergo both THA and surgery for LSS, those who undergo lumbar decompression prior to THA have higher health related quality of life (HRQOL) scores than those who undergo THA prior to addressing LSS [12]. TKA is also affected by prior diagnosis of LSS. Patients with stenosis who underwent TKA were found to have lower Knee Society objective and function scores [13]. Prior TKA was also identified as an independent risk factor for poor outcome 1-year after surgery for LSS [9].

While the aforementioned studies elucidate a strong relationship between LSS and outcomes in lower extremity arthroplasty, they fail to explore whether the heterogeneity in severity and location of LSS differentially contributes to these poor reported results. Specifically, LSS can vary in morphology (central or lateral), present at any level of the lumbar spine, and differ in radiographic severity [14, 15]. Given this clinical variability, a more targeted examination may improve prognostic accuracy, allowing surgeons to better inform their patients' expectations pre-operatively and to understand the potential consequences post-operatively [16, 17].

The purpose of this study was to therefore address this deficit and expand upon potential relationships between pathology in the lumbar spine and TKA. We hypothesized that in patients undergoing TKA, decreases in both pre- and post-operative clinical outcomes would directly correlate with increasing severity of LSS.

Methods

Study Design

After Institutional Review Board approval, all TKAs at a single health care system between 2017 and 2020 were identified. 933 consecutive TKAs in 845 patients were performed for OA [3]. Of this cohort, we identified 103 TKAs performed in 94 patients who met the following inclusion criteria: pre-operative lumbar MRI, no prior history of lumbar spine surgery, pre and post-operative knee mobility measurements and at least 3-months of postoperative follow-up. Patients were excluded for not possessing preoperative lumbar spine MRI (706), prior lumbar spine surgery (57), inadequate follow up with pre- and post-operative knee mobility measurements (30), and for presence of severe scoliosis or suspected secondary OA based on chart review (37).

Quantitative/Qualitative grading of MRIs

Measurements of LSS severity were performed on lumbar MRIs by 2 researchers independently. Severity was evaluated by (1) decreased AP diameter of the dural sac [16, 18–20], demonstrated in **Fig. 1**, and (2) increased morphological grade from L1-S1 as described by Guen et al. and demonstrated in **Figs. 2–5** [17, 21]. Interrater reliability for (1) was assessed by calculating a correlation coefficient (0.96) and for (2) using Cohen's kappa, which was almost perfect (kappa = 0.82, $p < 0.05$) [22].

Demographics

Patient demographics including age, sex, body mass index (BMI) were noted. Potential pre-operative confounders were also obtained for regression analyses including knee mobility, opiate use, and concurrent comorbidities including: diabetes, hypertension, osteoporosis, osteopenia, and nicotine use. Presence or absence of symptomatic LSS was identified through retrospective chart review for documented history of unilateral or bilateral "sciatica", "back pain", and/or lower extremity "radiculopathy". Patients with no symptoms were included in the analysis given the lack of defined correlation between imaging and symptom severity [23].

TKA Outcomes

Primary TKA outcomes measured by attending surgeons, orthopedic residents, and physician assistants during pre- and post-operative office visits were gathered during retrospective chart review, including: need for subsequent MUA, pre- and post-operative AOM (defined as the magnitude in degrees of knee flexion minus knee extension), presence of a flexion contracture, and the difference between pre-operative and post-operative AOM (⊗AOM).

Statistical Analysis

Incidence of the aforementioned comorbidities were reported as averages with 95% confidence intervals (CI). Multivariate regression was used to explore the functional relationship between AP diameter, morphological grade, and the outcomes of interest while controlling for other variables. Significance was determined as $p < 0.05$. Analysis was carried out in R version 3.3.1. (R Core Team. R Foundation for Statistical Computing. Vienna, Austria).

Results

Demographics

A total of 94 patients (103 operated upon knees) who underwent TKA for primary OA were included. Of these, the majority were female (73 females to 21 males), with an average BMI of 30.7%, and mean age of 71.3 years. Regarding comorbidities, 22% of patients had diabetes mellitus, 73% had hypertension, 79% had osteopenia or osteoporosis, 4% were tobacco smokers, and 38% used opioids pre-operatively (**Table 1**). Average follow up was 32 weeks (95% CI 27-36 weeks). In total, 23 patients had history of bilateral sciatic and lower back pain, 54 had unilateral sciatic and lower back pain, 21 had isolated lower back pain, and 5 were asymptomatic.

MRI Measurements

Average dural sac AP diameter measured at intervertebral levels L1-2, L2-3, L3-4, L4-5, and L5-S1 were 1.43, 1.29, 1.12, 1.12, and 1.38 centimeters respectively (**Table 2**). Regarding morphological grade of stenosis, at L1-2: 77 MRIs were grade 0, 20 were grade 1, and 6 were grade 2. No patients had grade 3 stenosis at this level. At L2-3: 64 MRIs were grade 0, 26 were grade 1, 12 were grade 2, and 1 was grade 3. At L3-4: 51 MRIs were grade 0, 20 were grade 1, 28 were grade 2, and 4 were grade 3. At L4-5: 59 MRIs were grade 0, 21 were grade 1, 19 were grade 2, and 4 were grade 3. At L5-S1: only 1 MRI was grade 1, the rest were grade 0 (**Table 3**).

TKA Outcomes

The mean preoperative AOM was 111.9 degrees (95% CI 109.5-114.4), while the mean postoperative AOM was 117.5 (95% CI 115.3-119.7). The mean ⊗AOM was 10.7 degrees (95% CI 8.41-13.0) (**Table 5**). A total of 9 (8.74%) knees required MUA and 20 (19.42%) knees had flexion contracture (**Table 6**). Patients with flexion contracture averaged 109.6 degrees of postoperative AOM (95% CI 104.78-114.32). Patients underwent MUA for difficulty with full range of flexion (7 of 9 patients, 77.78%), and difficult with both flexion and extension (2 of 9 patients, 22.23%).

Regression Analysis

Using the worst level of stenosis (classified by AP diameter), linear models accounting for preoperative use of opioids, BMI, age, sex, presence of osteopenia, hypertension, or diabetes mellitus (DM) showed a slightly higher incidence of MUA in patients with worse AP diameter (OR 7.11, 95% CI 1.03, 49.15, p = 0.045), and a higher postoperative AOM if patients' worst level of stenosis was less severe (regression coefficient: 9.13, p =0.037; **Table 6**).

There were no significant relationships between ⊗AOM and AP diameter at any level (**Table 7**). However, comparing preoperative AOM and AP diameter demonstrated significant correlation at all levels except L5-S1 (**Table 8**).

There were no significant relationships between the incidence of MUA or flexion contracture and grade of stenosis in linear models accounting for preoperative use of opioids, BMI, age, sex, presence of osteopenia, hypertension and DM.

There were no significant relationships between postoperative AOM and morphological grade at any level (**Table 9**). Looking at ⊗AOM, patients with higher (worse) morphological grade of stenosis had better postoperative ⊗AOM at L2-3, and a trend in the same direction at their worst level of stenosis (**Table 10**).

As with AP diameter, for preoperative AOM, there was strong correlation with higher morphological grade (worse stenosis) at every intervertebral disc space except L5-S1 (**Table 11**).

Discussion

This study demonstrates a link between severity of lumbar spine stenosis and preoperative knee mobility in a cohort of patients who subsequently underwent total knee arthroplasty for primary osteoarthritis. In elucidating this relationship, it gives credence to the variability of spinal stenosis by utilizing radiographic measures to stratify LSS in severity and location (specific lumbar intervertebral disc space), providing a more targeted analysis.

For both measures of stenosis severity, namely 1) increasing morphological grade and 2) decreasing AP diameter, patients demonstrated reduced preoperative AOM at all levels of the lumbar spine aside from L5-S1. This previously undocumented relationship between stenosis severity and poor pre-operative knee mobility was most significant when assessing each patient's worst/most stenotic level (**Tables 8** and **Table 11**), further supporting our hypothesis that this deficit was related to LSS. Looking at L5-S1 in our cohort revealed a lack of stenosis by both utilized measures, which can be explained by increased anatomical size of the spinal canal at this level on average, and less nerve rootlets within the dural sac [17,20].

Though postoperative AOM outcomes were not affected by LSS at a statistically significant level in this group (aside from at their most stenotic level measured by AP diameter), the effect demonstrated on preoperative knee AOM is of great interest. Reduced preoperative knee mobility has previously been shown to be associated with decreased functional outcomes following TKA [24]. However, there is limited data on the effect of optimizing preoperative knee mobility in the sagittal plane prior to TKA [25], and so this study emphasizes the importance of evaluating patients for the presence of factors (including LSS) that may contribute to decreased preoperative AOM. Additionally, in our cohort, patients did not improve significantly from the preoperative AOM assessment, regaining less than 6 degrees (**Table 4**). This result emphasizes that determining the etiology of poor preoperative AOM is paramount, as these deficits may not be correctable by TKA alone.

While we did find that patients had worse postoperative AOM with increasing severity of their worst level of stenosis (**Table 6**) there were no other significant relationships between this variable and LSS in our cohort. Furthermore, in a seemingly counterintuitive manner, patients with worse grade of stenosis at L2-3 had better recovery of knee mobility following TKA (**Table 10**). Stenosis at this level may have had less effect on the quadricep and hamstring muscles, allowing for better postoperative rehabilitation.

While prior work in this area is limited, there are important comparisons to be made with our study that may guide future investigations. Pivec et al. investigated outcomes of TKA (Knee Society objective scores, function scores, range of motion, radiographic outcomes, and implant survivorship) in 115 patients with LSS, finding significantly lower mean postoperative Knee Society function and objective scores compared to control patients without stenosis [13]. Similar to the current study, they found no postoperative difference in knee range of motion between study groups, however, they also found no pre-operative difference between LSS and non-LSS cohorts. This incongruity may be attributed to differences in selection criteria used for their study, which required patients in the LSS cohort to have an official diagnosis of LSS or prior surgery for LSS, possibly enhancing preoperative knee range of motion [13].

This study excluded patients with prior surgery for LSS for a few reasons. Corrective surgery for lumbar degenerative disease (LDD) has been shown to increase failure rates in TKA above that observed in patients with LDD alone [8]. Further, our study relied heavily on MR image analysis, and so we attempted to negate postoperative MR image degradation as well as occult postoperative epidural scarring that could confound our findings [26]. This approach allows for a more nuanced investigation of the isolated effect of LSS on knee mobility surrounding TKA.

Limitations to this study include the retrospective design of this study, which relies on chart review for collection of data on patient symptoms, lack of a prospective imaging protocol, lack of patient reported outcome measures to correlate clinical outcomes to the study's findings, and relatively short average post-operative follow-up. While heterogeneity in MRI quality and formatting of axial slices exists due to studies obtained at outside facilities, the near perfect interrater reliability provides confidence in the MRI measurements.

As studies correlating clinical LSS to stenosis of particular areas within the canal are sparse [27], we were unable to reliably use patient symptoms to better localize stenosis within this population, leaving room for future studies to further enhance our more targeted approach to this problem. The effects of patient reported LSS symptoms severity on TKA outcomes is an important future direction. While there are a number of studies offering methodologies for radiographic grading of LSS [15,17,28-30] and attempting to define population parameters [21], there is a lack of consensus regarding MRI measurements and their true significance as prognostic indicators [16,23,31,32]. Regarding the particular methodology we utilized in grading LSS, the authors found some deficiencies in its use. Namely, some patients have mild decrease in anterior CSF space (very little to no obliteration), but do have some clumping of the cauda equina, making it difficult to distinguish Grades 1 and 2 as currently defined by Guen, Y. L. et al. [17].

In conclusion, this study supports careful evaluation of patients prior to TKA for any symptoms of LSS and/or prior imaging of the lumbar spine. Patients with LSS may have poor preoperative knee AOM, and are at risk for reduced patient satisfaction, function, and overall recovery after TKA. Our findings suggest that preoperative lumbar spine evaluation may be useful in properly selecting patients who will be candidates for optimal recovery of knee functionality after TKA, as well as adequately discussing expectations and goals with patients before surgery.

Abbreviations

LSS: Lumbar Spinal Stenosis; TKA: Total Knee Arthroplasty; MRI: Magnetic Resonance Imaging; AP: Anterior-Posterior; AOM: Arc of Motion; THA: Total Hip Arthroplasty; HRQOL: Health Related Quality of Life; OA: Osteoarthritis; BMI: Body Mass Index; MUA: Manipulation Under Anesthesia; ΔAOM: Difference Between Preoperative and Postoperative AOM; DM: Diabetes Mellitus; Cerebrospinal Fluid (CSF)

Declarations

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Author Contributions

Conceptualization, DYP, WLS, AAS; Methodology, KMM and WLS; Software, WLS; Validation, WLS, KMM, and AUB; Formal Analysis, WLS, AS and AUB; Investigation, DYP; Resources, DYP and AAS; Data Curation, KMM, GB, AS and WLS; Writing – Original Draft Preparation, HYP, KMM and WLS; Writing – Review & Editing, WLS, DYP, GB, HYP and KMM; Visualization, DYP and AAS; Supervision, DYP; Project Administration, DYP; Funding Acquisition, not applicable.

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Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available due to the regulations by our Institutional Review Board, but can be made available from the corresponding author by request.

Ethics approval and consent to participate

This study was conducted in accordance with the University of California Los Angeles' clinical research guidelines and with approval from the institutional review board (IRB) of UCLA Health Systems.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Tables

Table 1: Demographics

Demographics and Comorbidities	
Average Age (years)	71.3
Male (%)	24.5
Average BMI (kg/m^2)	30.7
Diabetes Mellitus (%)	22.3
Hypertension (%)	72.3
Osteoporosis/Osteopenia (%)	21.2
Current Smoker (%)	4.3
Preoperative Opioid Use (%)	38.3

Table 2: AP diameter

Level	Mean (cm)	SD (cm)	95% CI (cm)
L1-2	1.43	0.25	1.39-1.48
L2-3	1.29	0.31	1.23-1.35
L3-4	1.12	0.32	1.04-1.17
L4-5	1.12	0.36	1.05-1.19
L5-S1	1.38	0.37	1.31-1.45

Table 3: Morphological Grade

Level	Grade 0	Grade 1	Grade 2	Grade 3
L1-2	77	20	6	0
L2-3	64	26	12	1
L3-4	51	20	28	4
L4-5	59	21	19	4
L5-S1	102	1	0	0

Table 4: TKA Outcomes (continuous)

	Mean (degrees)	SD (degrees)	95% CI (degrees)
Preop Arc of Motion	111.9	12.42	109.5-114.3
Postop Arc of Motion	117.5	11.21	115.3-119.7
D Arc of Motion	10.7	11.74	8.41-13.0

Table 5: TKA Outcomes (categorical)

	Number of Knees
MUA	9
Flexion Contracture	20

Table 6: Postoperative Arc of Motion vs AP diameter

Intervertebral Level	Regression coefficient (p value)
L1-2	5.21 (0.32)
L2-3	3.22 (0.45)
L3-4	7.67 (0.055)
L4-5	3.75 (0.27)
L5-S1	2.23 (0.47)
Worst Level of Stenosis	9.13 (0.037)**

**Statistically significant

Table 7: D Arc of Motion vs AP diameter

Intervertebral Level	Regression coefficient (p value)
L1-2	-8.33 (0.15)
L2-3	-7.41 (0.14)
L3-4	-2.51 (0.60)
L4-5	-4.95 (0.23)
L5-S1	-1.20 (0.76)
Worst Level of Stenosis	-4.18 (0.42)

Table 8: Preoperative Arc of Motion vs AP diameter

Intervertebral Level	Regression coefficient (p value)
L1-2	17.64 (0.0003)**
L2-3	13.57 (0.0007)**
L3-4	12.37 (0.0011)**
L4-5	10.93 (0.0007)**
L5-S1	4.47 (0.15)
Worst Level of Stenosis	15.76 (8.18e-05)**

**Statistically significant

Table 9: Postoperative Arc of motion vs Grade of Stenosis

Intervertebral Level	Regression coefficient (p value)
L1-2	-3.48 (0.11)
L2-3	-0.32 (0.86)
L3-4	-2.47 (0.08)
L4-5	-0.39 (0.77)
L5-S1	-9.55 (0.42)
Worst Level of Stenosis	-1.36 (0.31)

Table 10: D Arc of motion vs Grade of Stenosis

Intervertebral Level	Regression coefficient (p value)
L1-2	2.38 (0.36)
L2-3	4.84 (0.02)**
L3-4	1.75 (0.28)
L4-5	2.87 (0.07)
L5-S1	-6.00 (0.69)
Worst Level of Stenosis	2.82 (0.06)

**Statistically significant

Table 11: Preoperative Arc of Motion vs Grade of Stenosis

Intervertebral Level	Regression coefficient (p value)
L1-2	-7.18 (0.0005)**
L2-3	-6.76 (4.20e-05)**
L3-4	-5.06 (6.44e-05)**
L4-5	-4.24 (0.0009)**
L5-S1	-4.67 (0.70)
Worst Level of Stenosis	-5.20 (1.22e-05)**

**Statistically significant

Figures

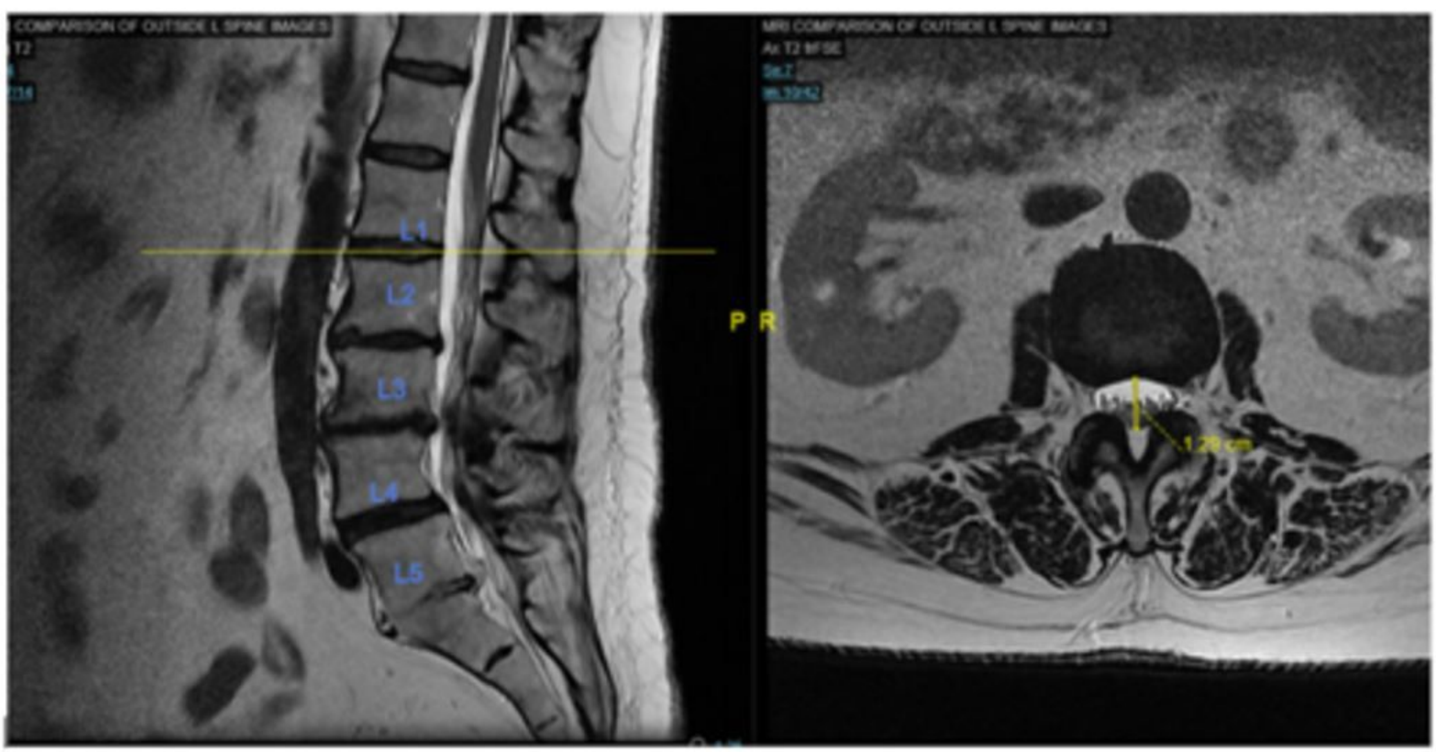

Figure 1

See image above for figure legend

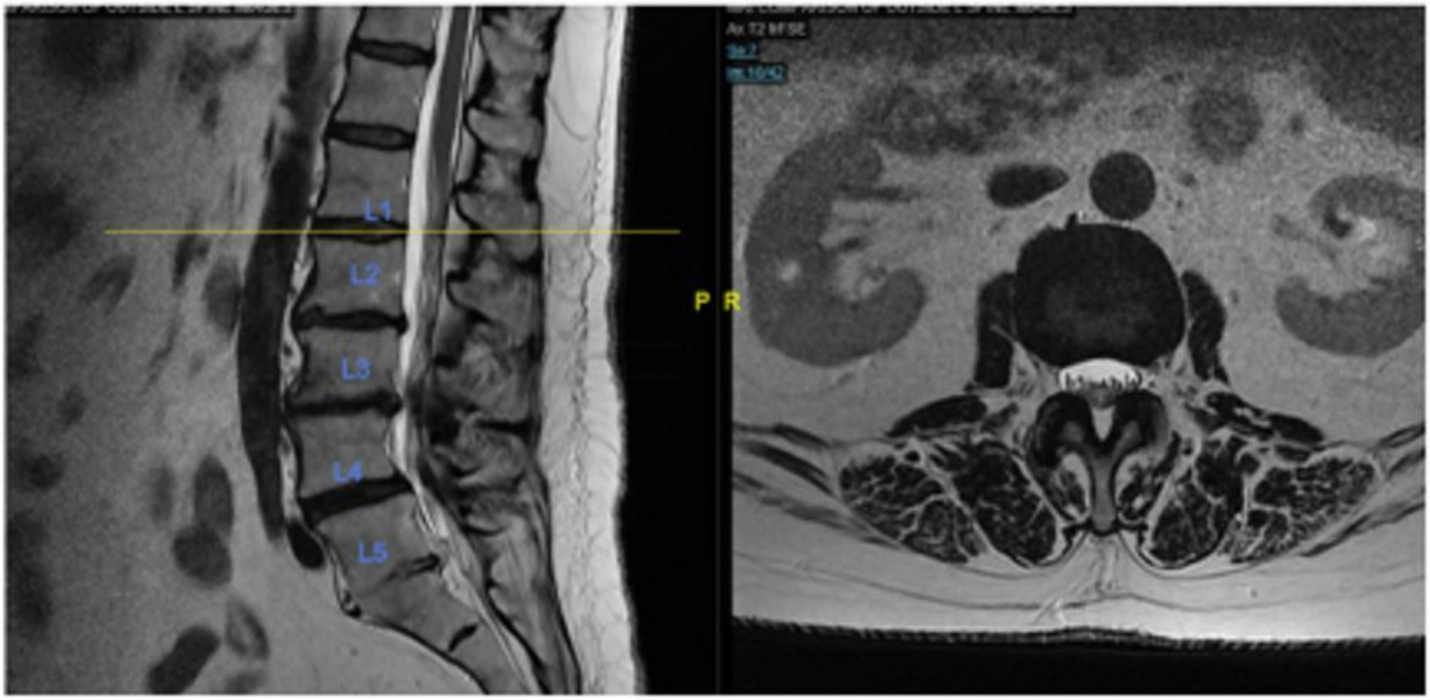

Figure 2

See image above for figure legend

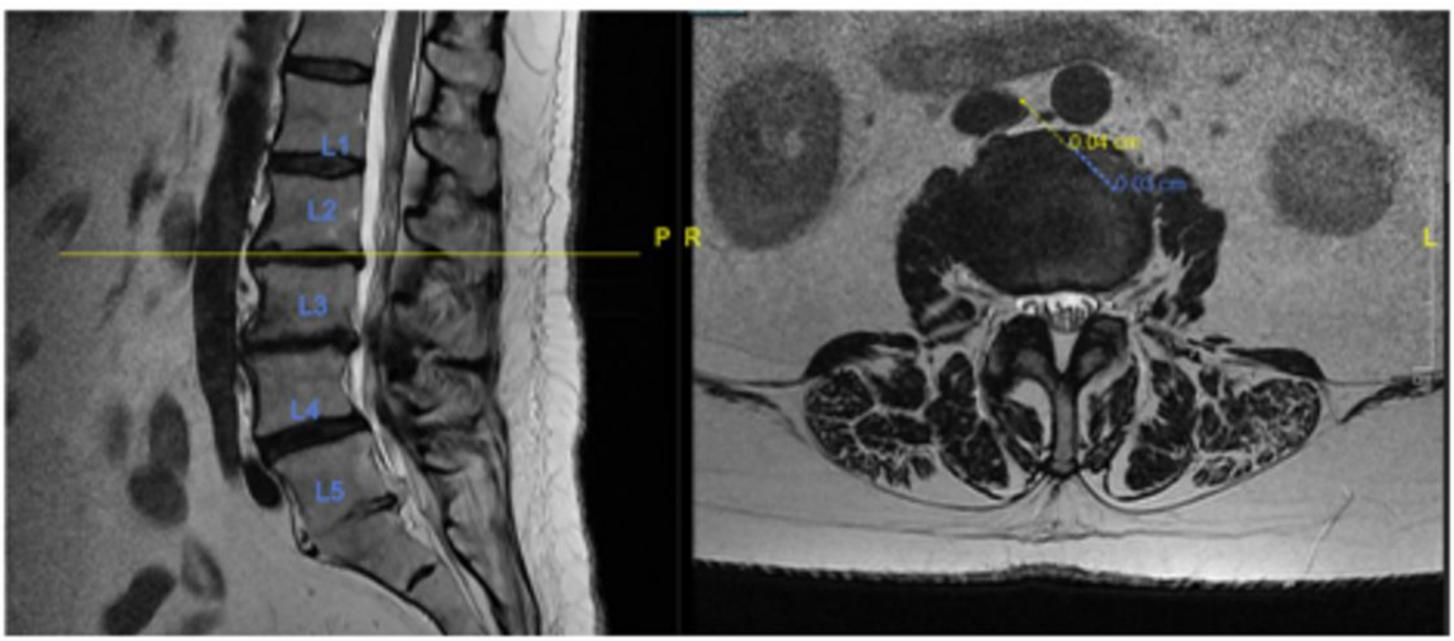

Figure 3

See image above for figure legend

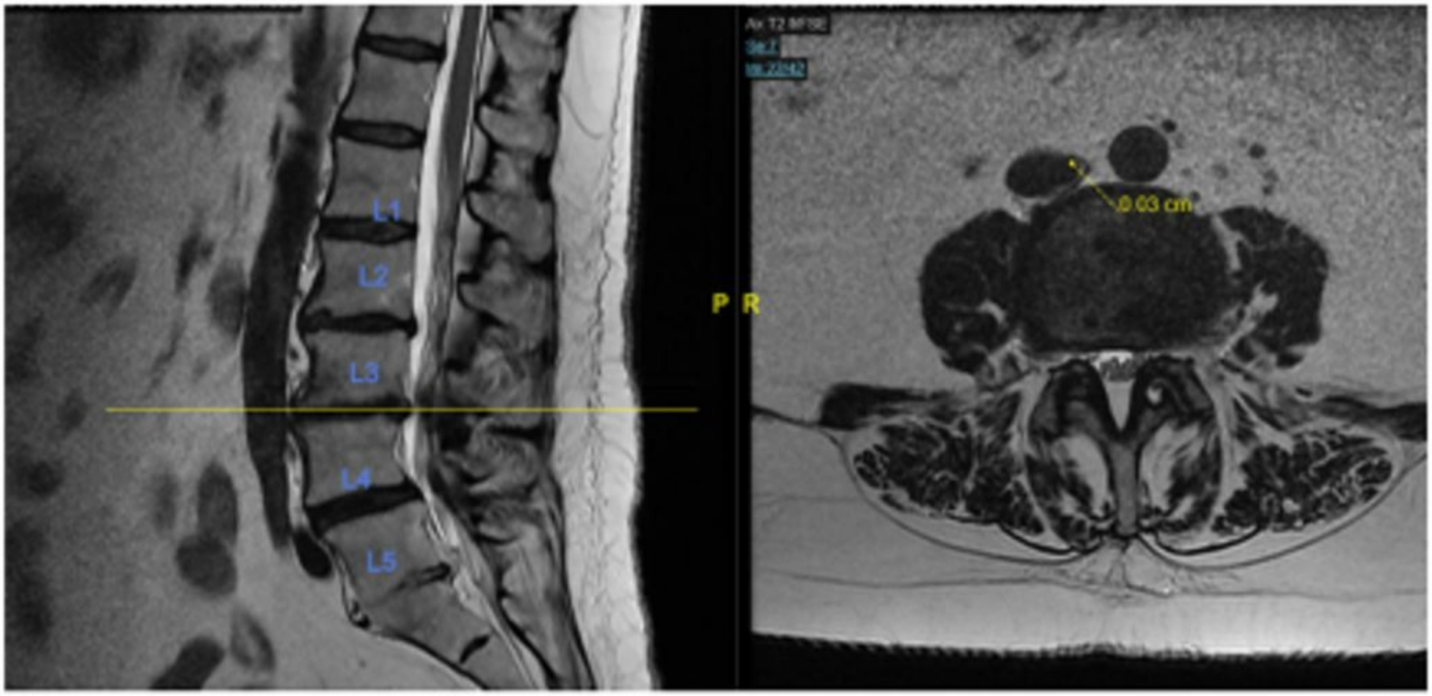

Figure 4

See image above for figure legend

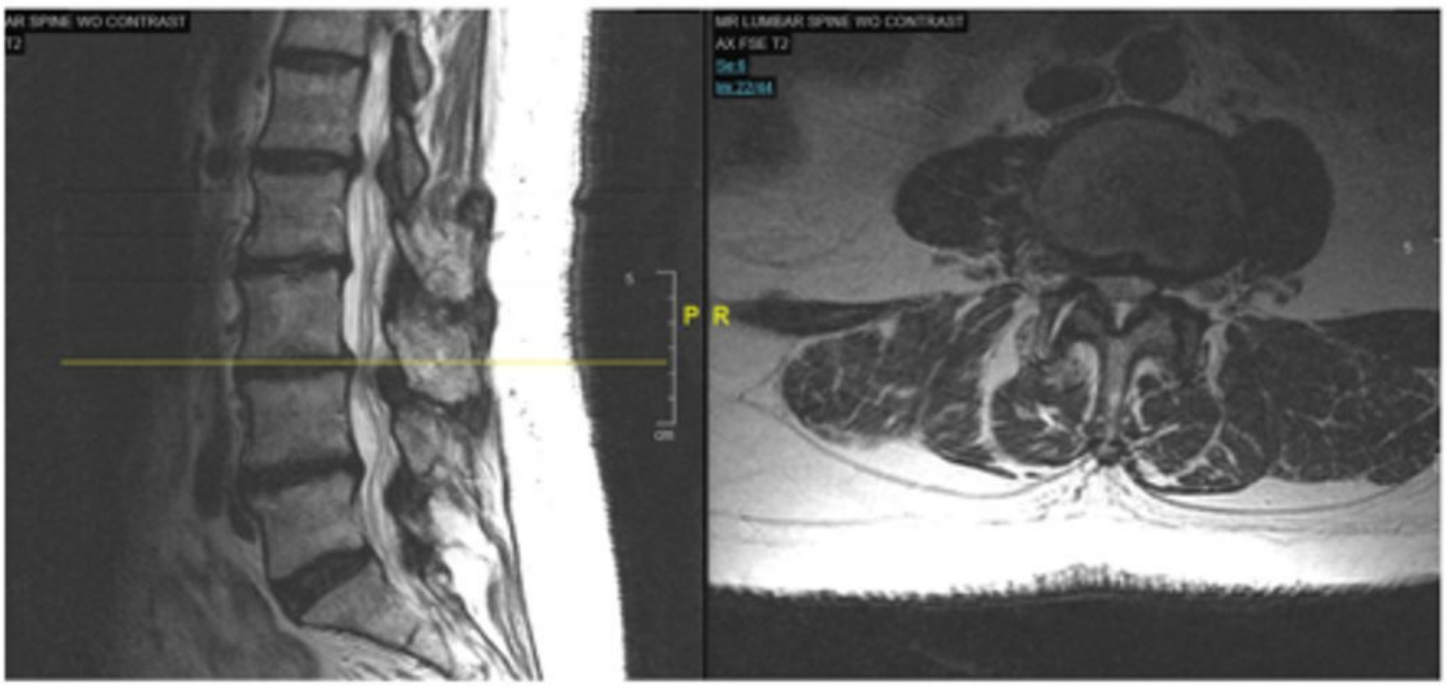

Figure 5

See image above for figure legend