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Retrospective analysis of accuracy and positive predictive value of preoperative lumbar MRI grading after successful outcome following outpatient endoscopic decompression for lumbar foraminal and lateral recess stenosis

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ABSTRACT

Objectives: The aim of this study was to analyze the accuracy and positive predictive value (PPV) of preoperative lumbar MRI grading for successful outcome after outpatient endoscopic decompression for lumbar foraminal and lateral recess stenosis. Lumbar MRI is commonly employed in preoperative decision making to identify symptomatic pain generators amenable to surgical decompression. However, its accuracy and positive predictive value for successful postoperative pain relief after endoscopic transforaminal decompression for sciatica-type back and leg pain has not been reported.

Patients and methods: A retrospective study of 1839 consecutive patients with a mean follow-up of 33 months that underwent lumbar endoscopic transforaminal decompression at 2076 lumbar levels was conducted. The sensitivity, specificity, accuracy, and positive predictive value of preoperative MRI grading correctly identifying the symptomatic surgical level were calculated based on the recorded intraoperatively visualized pathology and clinical outcomes assessed by both Macnab criteria and VAS score reduction.

Results: Of the 1839 patients evaluated, 1750 had intraoperatively visualized stenosis in the lateral recess at the surgical level whereas 89 patients did not. Analysis of radiologist grading of exiting nerve root compression in the lumbar MRI reports in patients with visualized compressive pathology: true positive (1196), false negative (554); as compared with patients without visualized compressive pathology showed: false positive (30), and true negative (59); and allowed for calculation of sensitivity (68.34%), specificity (68.29%), accuracy (68.24%) and the positive predictive value (97.38%) in relation to successful clinical outcome of the subsequent endoscopic decompression surgery. Sensitivity (87.2%), specificity (73.03%), and accuracy (86.51%) improved when the treating surgeon graded same MRI scan for traversing nerve root compression. Taking different spinal stenosis classification systems by the radiologist and surgeon into consideration, Kappa statistic assessment of agreement between radiology and surgeon reporting of stenosis showed different degrees of concordance for extruded herniated disc ($\kappa = 0.42$; 331 patients), contained disc herniation ($\kappa = -0.01$; 648 patients), and stenosis ($\kappa = 0.25$; 860 patients). Disagreement ($\kappa = 0.216$; 440 patients) predominantly existed in grading the relevance of foraminal stenosis in the entry- ($\kappa = 0.18$; 278/440 patients), mid- ($\kappa = -0.036$; 121/440 patients), and less so in the exit zone ($\kappa = -0.036$; 41/440 patients) associated with contained ($\kappa = -0.10$; 178/440 patients), extruded disc herniations ($\kappa = 0.4$; 62/440 patients), and stenosis ($\kappa = 0.25$; 200/440 patients).

Conclusion: The grading of a preoperative MRI scan for lumbar foraminal and lateral recess stenosis may significantly differ between radiologist and surgeon. The endoscopic spine surgeon should read and grade the lumbar MRI scan independently to aid in appropriate patient selection for successful transforaminal endoscopic

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decompression surgery. More contemporary MRI reporting criteria are needed to describe the surgical anatomy in the neuroforamen and lateral recess relevant during the minimally invasive endoscopic transforaminal decompression.

1. Introduction

Minimally invasive and endoscopic transforaminal decompression techniques have become popular in spinal surgery due to technological advances [1–4]. There has been a substantial increase of these types of procedures being carried out in an ambulatory surgery center (ASC) [5,6]. The advantages of endoscopic transforaminal decompression are fewer postoperative complications, a shorter interval for return to work and social reintegration [7], less postoperative narcotic independence, and an overall reduced utilization of painkillers [8]. The latter problem is of significance in light of the opiate abuse epidemic in the United States [9–12], more rigorous medical necessity assessment, and a demand for value-based health care measures to serve the aging baby-boomer population [13–15]. In this context, a conclusive preoperative diagnostic workup of lumbar radiculopathy is crucial as decompression is often limited to a small area of one affected neuroforamen and lateral recess [16–18].

This author has previously published his clinical outcomes, readmission-, reoperation-, and complications rates with the transforaminal decompression procedure for the conditions mentioned above [19–21]. During a nine-year study on 1839 patients, this author noticed that the preoperative MRI report in some cases did not call for any stenosis at the surgical level in spite of the patient having a successful surgical outcome. Two case examples of this problem are illustrated in Fig. 1. This prompted him to retrospectively analyze the accuracy and positive predictive value (PPV) of preoperative lumbar MRI reporting by the radiologist and surgeon grading of the MRI images in relation to successful clinical outcome [22–27] after the transforaminal decompression surgery and intraoperatively visualized surgical pathology [28–33] as gold standard references.

2. Materials and methods

In 2006, the Center for Advanced Spine Care of Southern Arizona established an outpatient spinal surgery program for the treatment of lumbar herniated disc and spinal stenosis.

2.1. Patient population

All patients in this case series provided informed consent. This retrospective study included 1839 consecutive patients seen in our clinic who underwent percutaneous endoscopic foraminotomy and microdiscectomy at 2076 levels between 2006 and 2015. The mean follow-up was 33 months ranging from 24 to 85 months at the time this study was concluded. The inclusion and exclusion criteria for this study have been published elsewhere [19–21].

2.2. Preoperative work up and surgical decision making

Patients were worked up with a thorough history, physical examination, and imaging studies as described below. Patients were subjected to an interventional diagnostic workup with lidocaine containing transforaminal epidural steroid injection (TESI) under biplanar fluoroscopic image intensifier guidance using established protocols [34–36]. A TESI was considered diagnostic if the patient reported an immediate (within 15 min) VAS scale reduction > 50%. [37,38]. Patients with conclusive diagnostic workup with matching clinical symptoms, MRI findings, diagnostic TESI response, and supporting history and physical examination were ultimately deemed appropriate surgical candidates for the endoscopic transforaminal decompression procedure.

2.3. Clinical follow-up

Radiographs and MRI images were obtained preoperatively and graded as described below for all surgical patients. Primary clinical outcome measures were reductions in the VAS for leg pain ranging from no pain (0) to worst pain (10) and the Macnab criteria [39].

2.4. Radiologic evaluation of stenosis and classification

Lee's classification of foraminal and lateral recess stenosis causing traversing nerve root compression was employed by the author [40] to grade the MRI scan by defining the location of the offending pathology within the neuroforamen by dividing it from medial to lateral into entry (dura to pedicle; zone 1), middle (medial pedicle wall to center pedicle; zone 2), and exit zone (center pedicle to lateral border of the facet joint; zone 3) [40]. Foraminal and lateral recess stenosis were stratified according to the main offending pathology [41]. The heights of the posterior intervertebral disc and lumbar foramina were evaluated according to Hasegawa [42], who described a lumbar neuroforaminal height of 15 mm or more as normal and reduced posterior intervertebral disc height of 3 to 4 mm as suggestive of spinal stenosis. Only patients with a neuroforaminal width of 3 mm or less on the sagittal MRI cuts or lateral recess height of 3 mm or less on the axial MRI cuts were considered "stenotic" and treated surgically. The degree of lumbar intervertebral disc degeneration was graded using the MRI classification system published by Pfirrmann et al. [43]. The MRI reporting was graded using categories of the exiting nerve root compression of the Lee classification published in 2010. Grade 0 refers to normal

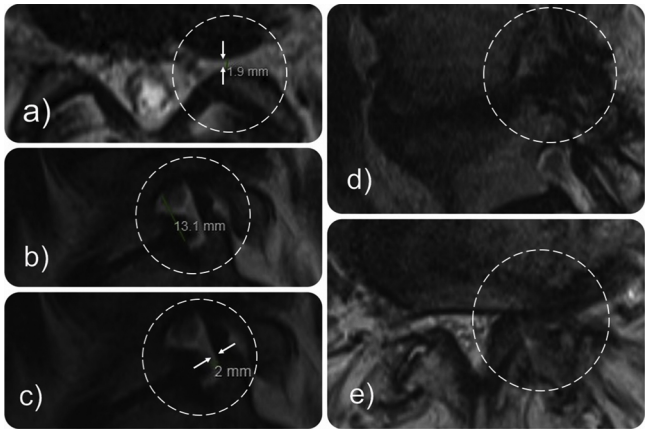

Fig. 1. Representative axial and sagittal lumbar T2-weighted images of the lumbar spine without intravenous contrast of two distinct patients. Patient one panel a-c: a) axial cut through the L5/S1 level showing foraminal stenosis in the foraminal entry and mid zone with foraminal width measured at 1.9 mm on the symptomatic left side, b) sagittal cut through the same left-sided L5/S1 neuroforamen with measured neuroforaminal height of 13.1 mm, and c) width of 2 mm. According to Lee et al. [45] and Hasegawa et al. [47] these MRI images resulted in surgeon grading of *MRI Positive* (criteria: neuroforaminal width of less than 3 mm, and height of less than 15 mm).[45, [47] The same findings were graded by the radiologist as "mild foraminal narrowing" (criteria absence of perineural fat obliteration from more than 2 sides) [49]; i.e., *MRI Negative*. Panel D-e: Sagittal (d) and axial (e) cuts through the L4/5 level of patient two who was ranked as MRI Positive by both the radiologist and surgeon. Both patients underwent endoscopic transforaminal decompression and improved.

neuroforamen, Grade 1: mild foraminal stenosis showing perineural fat obliteration in two opposing directions, Grade 2: moderate foraminal stenosis showing perineural fat obliteration in four directions, and Grade 3: severe foraminal stenosis showing morphologic changes in the nerve root [44]. Patients with MRI reporting (by radiologist) of Grades 2 and 3 were classified as *MRI Positives*.

2.5. Surgical techniques & postoperative rehabilitation

All surgical procedures employed the endoscopic transforaminal approach using the "outside-in" technique [45,46] and employs a foraminoplasty in patients with or without lateral stenosis for the treatment of herniated disc. An example of a completed endoscopic transforaminal decompression is given in Fig. 2. The author has published the details of the surgical decompression of this study group of patients elsewhere [19–21]. Most patients did not require postoperative rehabilitation and supportive care requirements. The patients were treated for postoperative irritation of the dorsal root ganglion with nonsteroidal anti-inflammatories, gabapentin, and TESI to treat any dysethetic leg pain syndromes.

2.6. Visualized pathology

The visualized compressive pathology was recorded by zone location [43] for each patient and described either as 1) herniated disc or 2) bony spinal stenosis. For this purpose, a 2-mm diameter flexible neural probe was attempted to be passed into the lateral recess through the safe zone [47,48] to determine the extent of the stenotic lesion underneath the facet joint complex. Illustrative examples of the intraoperative determination of location of the stenotic process under the facet joint complex in the entry, mid, and exit zone are given in Fig. 3. The inability to pass the 2-mm diameter probe into the lateral recess was considered intraoperative evidence of lateral recess stenosis as described by Hasegawa [42].

2.7. Correlative analysis of MRI, visualized pathology and surgical outcomes

For the clinical outcome analysis, descriptive statistics (mean and standard deviation), cross tabulation statistics and measures of association were computed for two-way tables using IBM SPSS Statistics software, Version 25.0. The Pearson χ [2] and the likelihood-ratio χ [2] tests were used as statistical measures of association. Intraobserver reliability between the surgeon grading of the zone classification of the preoperative MRI images and the intraoperatively observed and recorded zone location of the compressive pathology was done by intraclass coefficient (ICC) calculation. A bivariate correlation matrix test was done as an additional measure of agreement between preoperative MRI grading by the surgeon with intraoperatively recorded zone location of compressive pathology. This was done by calculating the Pearson R correlation coefficient using a two-tailed test using an alpha of 0.01. A measure of agreement between radiologist's grading of the preoperative MRI scan deducted from the MRI report and the surgeon's assessment of foraminal stenosis Cohen's kappa, κ, was calculated from the observed and expected frequencies on the diagonal of a square contingency table.

The MRI sensitivity of accurately grading and detecting symptomatic nerve root compression (true positive rate; TP) responsive to surgical decompression (defined as improved by Macnab outcome criteria *Excellent, Good, and Fair*) was calculated for both grading by the radiologist and surgeon as the percentage of patients (*MRI Positives*) among the radiculopathy patients who were correctly identified by MRI as having symptomatic neural compression confirmed by direct intraoperative visualization (visualized pathology). False negatives (FN) were patients with intraoperatively visualized neural compression whose preoperative MRI grading was negative for stenosis (*MRI Negatives*). Therefore, diagnostic MRI sensitivity for predicting a successful clinical outcome from the endoscopic transforaminal decompression procedure was calculated as follows:

$$\frac{\textit{MRI Positives}\text{ with visualized pathology responsive to decompression (TP)}}{\text{TP}+\textit{MRI Negatives}\text{ with visualized pathology responsive to decompression (FN)}}$$

The MRI specificity (true negative rate; TN) of accurately detecting the absence of symptomatic nerve root compression as visualized intraoperatively during spinal endoscopy was calculated as the percentage of patients correctly identified as not having symptomatic neural compression (visualized pathology) and not responsive to surgical decompression Macnab outcome: Poor). False positive (FP) were defined as *MRI Positives* without endoscopically visualized compressive pathology and *Poor* clinical. Therefore, diagnostic MRI specificity of predicting a successful clinical outcome from the endoscopic transforaminal decompression procedure was calculated as follows:

$$\frac{\textit{MRI Negatives}\text{ without visualized pathology unresponsive to decompression (TN)}}{\text{TN}+\textit{MRI Positives}\text{ without visualized pathology unresponsive to decompression (FP)}}$$

The PPV of a diagnostic preoperative lumbar MRI scan for a successful clinical outcome following a transforaminal endoscopic decompression procedure was calculated as follows:

$$\frac{\textit{MRI Positives}\text{ with endoscopically visualized pathology responsive to decompression}}{\text{TP}+\text{FP}\ \textit{MRI Positives}\text{ without visualized pathology unresponsive to decompression}} = \frac{\text{TP}}{\text{TP}+\text{FP}}$$

Disease prevalence due to symptomatic neural compression was calculated as the percentage of the patient study group with intraoperatively confirmed, endoscopically visualized compressive pathology:

$$\text{Disease Prevalence} = \frac{\text{TP}+\text{FN}}{\text{TP}+\text{FN}+\text{FP}+\text{TN}}$$

As a measure of statistical bias, the accuracy (ACC) of a diagnostic preoperative lumbar MRI scan for a successful clinical outcome was calculated as follows:

$$\text{ACC} = \frac{\text{TP}+\text{TN}}{\text{TP}+\text{FN}+\text{FP}+\text{TN}}$$

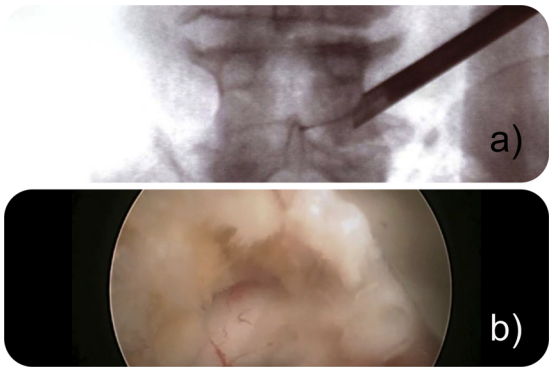

Fig. 2. a) AP intraoperative fluoroscopic view after completion of decompression and removal of compressive pathology at L4/5 level, where the probe could be advanced beyond the lateral recess into the spinal canal below the dural sac. b) intraoperative endoscopic view of a decompressed traversing L5 nerve root at the L4/5 level.

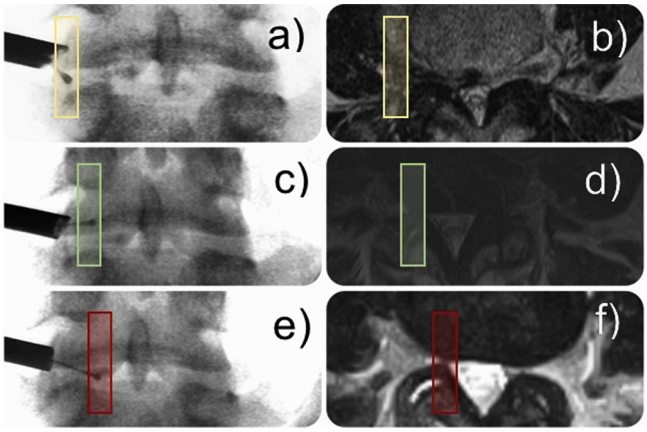

Fig. 3. Representative AP intraoperative fluoroscopic view (a, c, and e) paired with the corresponding axial lumbar T2-weighted images of the lumbar spine without intravenous contrast of three distinct patients who underwent endoscopic transforaminal decompression at the L4/5 level. Panel a and b: showing foraminal stenosis in the foraminal entry zone (yellow shading). The probe could not be passed under the facet joint. Panel d and d): showing stenosis in the foraminal mid zone (green shading). The probe could only be passed under the mid-portion of the facet joint. Panel e and f: showing stenosis in the foraminal entry zone (red shading) with the probe being advanced to the lateral recess but not around the L5 pedicle (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

The confidence intervals for the likelihood ratios were calculated using the "log method" according to Altman et al. [49]. The confidence interval for the PPV are the standard logit confidence intervals as described by Mercaldo et al. [50]. The sensitivity, specificity, PPV, disease prevalence, and accuracy parameters were calculated separately for radiologist and surgeon-reported MRI findings for comparison.

3. Results

Of the 1839 patients that underwent outpatient decompression between 2006 and 2015 (Table 1), *Excellent* and *Good* results according to the Macnab criteria were obtained in 82.2% of patients with extruded disc fragment (331/1839). In this group, the mean VAS score decreased from 5.9 ± 2.5 preoperatively to 2.4 ± 1.8 at the final follow-up ($P < 0.01$). Patients with contained disc herniations (648/1839) had *Excellent* and *Good* results 69.7% at the time. In this group, the mean VAS score decreased from 7.2 ± 1.6 preoperatively to 3.1 ± 1.5 at final follow-up ($P < 0.01$). In the spinal stenosis group (860/1839), 75% of patients had *Excellent* to *Good* results, and the mean VAS score decreased from 6.5 ± 1.8 preoperatively to 2.3 ± 1.4 at final follow-up ($P < 0.001$). There were no major approach or anesthesia-related problems. As published elsewhere [19–21], there were few clinical complications including two incidental durotomies, two patients with foot drop, and nine reherniations (2.7% recurrence rate). Reherniations were associated with preserved disc height of > 6 mm ($P < 0.02$). Postoperative sequelae occurred in an additional 69 patients extravasations of irrigation fluid into the subcutaneous tissues (3.8%), and another eight patients developed spinal headaches (0.4%). There were additional patients with failure of pain relief without significant improvement of walking endurance: 39 of the 860 patients with bony stenosis in the central canal, lateral recess, and entry zone of the neuroforamen (4.5%) and in 41 of the 648 patients with contained disc bulges (6.3%). The latter subset of patients with contained disc herniation had advanced degenerative changes (Pfirrmann Grade V and some Grade IV). Dysesthetic leg pain due to DRG irritation occurred in 229 patients (12.4%) and was unrelated to case frequency but was associated with severe foraminal stenosis ($P < 0.01$).

Analyzing the frequency of diagnostic *MRI Positive* grading of exiting nerve root compression by the radiologist in patients with visualized compressive pathology: true positive (1196); false negative (554); as compared with an *MRI Negative* grading by the radiologist in patients without visualized compressive pathology: false positive (30 patients); and true negative (59 patients) allowed for calculation of sensitivity (68.34%), specificity (66.29%), and the PPV (97.55%) of preoperative diagnostic lumbar MRI scan in relation to successful clinical outcome of the subsequent endoscopic decompression surgery (Table 2). The accuracy of the preoperative lumbar MRI grading by the radiologist report in relation to successful clinical outcome of the subsequent endoscopic decompression surgery was determined to be 68.24% (Table 3).

The same analysis of surgeon diagnostic *MRI Positive* grading of traversing nerve root compression on the preoperative lumbar MRI scan in patients with visualized compressive pathology revealed: true positive (1526); false negative (224); as compared with an *MRI Negative* grading by the surgeon in patients without visualized compressive pathology: false positive (24 patients); and true negative (65 patients) allowed for calculation of sensitivity (87.2%), specificity (73.03%), and the PPV (98.45%) of preoperative diagnostic lumbar MRI scan grading in relation to successful clinical outcome of the subsequent endoscopic decompression surgery (Table 3). The respective accuracy of the preoperative lumbar MRI grading of traversing nerve root compression by the surgeon in relation to successful clinical outcome of the subsequent endoscopic decompression surgery was determined to be 86.51% (Table 4).

The ICC was 0.514 (absolute agreement definition; $p < .000$), average measure = 0.679 (computed without interaction effect; $p < .000$), with a Cronbach's Alpha of 0.758. The surgeon grading of the preoperative lumbar MRI scan was identical to the intraoperative grading of the location of the directly visualized compressive pathology 81.1% (437 patients) of the time for stenosis in the neuroforaminal entry zone, 82.8% of the time (347 patients) for stenosis in the neuroforaminal exit zone, and 86.6% (763 patients) of the time for stenosis in the mid-zone of the surgical neuroforamen totaling 1547 patients. Of these 1547 patients with an absolute agreement between surgeon zone grading of the preoperative lumbar MRI scan was identical to the intraoperative grading of the location, 1462 (94.51%) patients had improved clinical outcomes according to Macnab criteria. A bivariate correlation matrix of agreement between preoperative MRI grading by the surgeon with intraoperatively recorded zone location of compressive pathology showed Pearson Chi-Square = 2126.437, df = 4, $p < .000$, Likelihood Ratio = 1912.289, df = 4, $P < .000$, N of Valid Cases = 1839, with 0 cells (.0%) have expected count less than 5. The Pearson correlation coefficient was 0.628, $p < .000$.

Kappa statistic assessment of agreement between radiology and surgeon grading of stenosis showed different degrees of concordance rates for extruded herniated disc ($\kappa = 0.42$; 331/1839 patients), contained disc herniation ($\kappa = -0.01$; 648/1839 patients), and stenosis ($\kappa = 0.25$; 860/1939 patients). Disagreement ($\kappa = 0.216$; 440/1839 patients) predominantly existed in grading the relevance of foraminal stenosis in the entry- ($\kappa = 0.18$; 278/440 patients), mid- ($\kappa = -0.036$; 121/440 patients), and less so in the exit zone ($\kappa = -0.036$; 41/440 patients) associated with contained ($\kappa = -0.10$; 178/440 patients),

Table 1
Patients by Diagnosis and Outcome (N =1839).

	Macnab Outcome	Improved		Not Improved
Diagnosis		Excellent & Good	Fair	Poor
Extruded	331	272	50	9
Contained	648	471	136	41
Stenosis	860	645	176	39
Subtotal:		1388	362	89
Total:	**1839**			

Table 2
Preoperative MRI* grading of stenosis by radiology report in relation to intraoperatively visualized pathology and postoperative outcome from transforaminal endoscopic decompression.

MRI Grade	Visualized Pathology		No Visualized Pathology	
	Clinically Improved Postoperatively		Clinically Not Improved Postoperatively	
MRI Positive	True Positive	1196	False Positive	30
MRI Negative	False Negative	554	True Negative	59
Subtotal:		1750		89
Total:				1839

* MRI was classified as *MRI Positive* if preoperative lumbar MRI scan report by the radiologist graded the compressive pathology as Grade 2 (moderate), or Grade 3 (severe) according to Lee et al.: A practical MRI grading system for lumbar foraminal stenosis. *AJR Am J Roentgenol* 194: 1095–98, 2010.

Table 3
Sensitivity, specificity, disease prevalence, accuracy, and positive predictive value (PPV)of a preoperative lumbar MRI grading in predicting improved clinical outcome from transforaminal endoscopic decompression.

Grading/Statistical Measure	MRI Report		Surgeon	
	[%]	95% CI	[%]	95% CI
Sensitivity	68.34	66.11 – 70.52	87.20	85.54 – 88.73
Specificity	66.29	55.49 – 75.97	73.03	62.58 – 81.90
Disease Prevalence	95.16	94.08 – 96.10	95.16	94.08 – 96.10
Accuracy	68.24	66.06 – 70.37	86.51	84.87 – 88.04
Positive Predictive Value (PVP)	*97.55*	*96.75 – 98.16*	*98.45*	*97.83 – 98.90*
N =	**1839**			**1839**

Table 4
Preoperative [a]MRI grading of stenosis by surgeon in relation to intraoperatively visualized pathology and postoperative outcome from transforaminal endoscopic decompression.

MRI Grade	Visualized Pathology		No Visualized Pathology	
	Clinically Improved Postoperatively		Clinically Not Improved Postoperatively	
MRI Positive	True Positive	1526	False Positive	24
MRI Negative	False Negative	224	True Negative	65
Subtotal:		1750		89
Total:				1839

[a] MRI was graded by surgeon according to foraminal zone classification by Lee et al.: Lateral lumbar spinal canal stenosis: classification, pathologic anatomy, and surgical decompression. *Spine* (Phila Pa 1976). 1988 Mar;13(3):313–20. The MRI was classified as *MRI Positive* by the surgeon if preoperative lumbar MRI scan showed reduced lateral recess and foraminal width of less than 3 mm due to compressive pathology.

extruded disc herniations ($\kappa = 0.4$; 62/440 patients), and stenosis ($\kappa = 0.25$; 200/440 patients). The overall measurement of agreement for the total group of 1839 patients was calculated as $\kappa = 0.216$ and was statistically significant ($p < 0.001$).

4. Discussion

Results of this study highlighted a "difference in opinion" in the interpretation of routine lumbar MRI scan between the radiologist and treating surgeon and how it may impact patient selection for the endoscopic transforaminal surgery. Raters on both sides of the equation may use different radiological classification systems during the preoperative diagnostic decision algorithm. The calculation of the sensitivity, specificity, accuracy and PPV of a routine lumbar MRI scan to predict a successful clinical outcome after endoscopic transforaminal decompression surgery for sciatica-type low back and leg pain and to use these clinical outcome measures as the gold reference standard rather than another imaging modality seems highly appropriate for a number of reasons: First, these parameters have been previously reported that way and are suitable for direct comparison to other imaging modalities [28,29]. Second, their use facilitates simple and straightforward communication of expected outcomes to patients, payers, and other healthcare providers. Last, but not least, calculation of the positive predictive value of routine lumbar MRI scan concerning a successful clinical outcome after the endoscopic transforaminal decompression surgery, allows ranking of the lumbar MRI scan regarding its clinical usefulness in comparison to other predictive tests, such as a preoperative selective nerve root block [20].

Since advanced imaging studies including MRI are often used to determine medical necessity of proposed surgical interventions, this author was interested in analyzing how to utilize it more effectively in his modern lumbar spinal endoscopy practice [20–22] considering that its accuracy has recently been called into question in the preoperative assessment of spinal stenosis [51], the integrity of the posterior longitudinal ligament [52], and the facet joint complex [53]. Additionally, the high prevalence of abnormal MRI findings in asymptomatic volunteers [54], and its poor predictive value of the development or duration of low back pain is of concern [55]. Notwithstanding the foregoing, this study on 1839 patients carried out over a nine-year period demonstrated that a small, targeted endoscopic transforaminal foraminoplasty and discectomy procedure performed for sciatica and neurogenic claudication refractory to conservative care can produce improvement of symptoms in most patients exceeding expected success rates [19–21,56] reported for laminectomy to be in the in the 70%–80% range [57–61]. The disease prevalence in our patient cohort was high (95.16%) suggesting that patient selection for surgery was appropriate. Since clinical outcome was used as the gold standard, the disease prevalence and its actual percentage (95.16%) remained the same as the ratio of improved and failed patients remained the same.

Measuring the degree of agreement between the different spinal stenosis classification systems by the reporting radiologist (based on exiting nerve root compression [44]) and surgeon (based on traversing nerve root compression [40]) by Kappa statistic showed different degrees of concordance. The most relevant source of disagreement between radiology reporting of spinal stenosis and surgeon grading of the same scan came from contained (κ = -0.10; 178/440 patients), extruded disc herniations ($\kappa = 0.4$; 62/440 patients), and stenotic lesions ($\kappa = 0.25$; 200/440 patients) predominantly in the entry zone ($\kappa = 0.18$; 278/440 patients) presumably because description of the entry zone hardly ever found any attention in the radiology lumbar MRI reporting. Disagreement in grading compressive pathology in the mid-zone was much less common (κ = -0.036; 121/440 patients). Conflicts in stenosis classification in the exit zone were least frequent. Negative kappa values implied that the disagreements were worse than random and, hence, factual [62].

The methods of assessing in intraobserver reliability employed in this study as a measure of the accuracy of the surgeon grading of the preoperative MRI scan and the intraoperatively recorded zone location of the compressive pathology showed a high percentage of patients having been accurately graded (81.1% for entry-, 83.8% for exit-, and 86.6% for mid zone lesions) with a statistically significant correlation and agreement between the surgeon employed grading methods. The bivariate correlation matrix of agreement between preoperative MRI grading by the surgeon with intraoperatively recorded zone location of compressive pathology showed a Pearson correlation coefficient of 0.628 with a statistical significance level of $p < .000$. Of the 1547 patients in whom the preoperative surgeon MRI zone grading was identical to the intraoperative classification of the location, 1462 (94.51%) patients had improved clinical outcomes according to Macnab criteria.

The extent of the sensitivity (68.34% vs. 87.2%) and specificity

(66.29% vs. 73.03%) gap between grading of radiology MRI reports and surgeon grading of MRI images may create misunderstandings in the communication between the stakeholders involved in patient care and can potentially lead to over-, but more likely under-treatment of symptomatic patients. For example, if the decision for surgical decompression had purely been based on the radiologist's MRI report, 330 patients (difference of MRI FN between radiology and surgeon MRI grading) would not have been treated for their ongoing sciatica-type back and leg symptoms as they were falsely categorized as MRI Negative (FN). However, as evidenced by the Excellent and Good clinical outcomes according to Macnab criteria, these 330 patients benefited from the endoscopic transforaminal decompression and were suffering from stenosis related sciatica-type back and leg pain caused by traversing- and not exiting nerve root compression pain syndromes. Assessment of the clinically more relevant traversing nerve root compression [40] on the MRI images by the treating surgeon improved the accuracy of predicting successful postoperative outcome after the endoscopic transforaminal decompression to 86.5%. Nearly all of the remaining 224 F N patients, who were also graded by the treating surgeon falsely as MRI Negative and still underwent surgical decompression in spite of the surgeon MRI grading being negative for spinal stenosis, had large extruded herniations and underwent endoscopic transforaminal sequestrectomy. Ultimately, these patients were not graded as stenotic contributing to the overall large number of FN patients in this study. The small number of false positive (FP) patients did not differ much, regardless of whether the surgeon or a radiologist did the MRI grading. Some patients may have been merely incorrectly classified due to technical limitations of the MRI as an imaging modality.

The most significant limitation of this single-surgeon retrospective study may have been the impact of affective (unconscious emotional reaction) and cognitive (distortions of thinking) biases in the clinical diagnostic and surgical decision-making process [63,64]. Cognitive biases, such as hindsight or outcome bias, have been shown to be virtually unavoidable in retrospective studies as knowledge of the clinical outcome by the surgeon has been recognized to inflate the predictability of an event after it happened [65–68]. Hindsight cognitive biases may have been less relevant since the extent of disagreement in preoperative lumbar MRI grading by surgeon and radiologist was not known throughout the 9-year study period. Intuition bias 68] may have played a role in patient selection for surgery after the initial set-up phase of the complex clinical protocol after completion of a learning curve.

This study set out to better understand how to utilize the lumbar MRI scan as a prognosticator of favorable clinical outcomes when selecting patients for the endoscopic transforaminal decompression procedure. The variations in the calculated the specificity, sensitivity, accuracy, and positive predictive value of a routine lumbar MRI scan emphasizes the need to use all available clinical information to best understand the context of lumbar spine care and the rationale for surgical decision making at the time when the care is delivered and not to employ the MRI as the only surgical prognosticator to establish the indication for the endoscopic transforaminal decompression surgery.

5. Conclusion

The grading of a preoperative MRI scan for lumbar foraminal and lateral recess stenosis may significantly differ between radiologist and surgeon. Endoscopic spine surgeon should read and grade the lumbar MRI scan independently to aid in appropriate patient selection for successful transforaminal endoscopic decompression surgery. Surgical translational research on the intraoperatively visualized spinal pathology should focus on analyzing the effectiveness of endoscopic surgery interventions in the lumbar spine using state-of-the-art measures of central, lateral recess, and neural foraminal stenosis on MRI to further determine how they impact the prognosis of surgical treatment for neurogenic claudication and lumbar radiculopathy.

Authors Contributions

Study concept and design: Lewandrowski
Acquisition of data: Lewandrowski
Analysis and interpretation: Lewandrowski
Study supervision: Lewandrowski

Disclaimer

The views expressed in this article represent those of the author and no other entity or organization.

Conflict of interest

The author has no direct (employment, stock ownership, grants, patents), or indirect conflicts of interest (honoraria, consultancies to sponsoring organizations, mutual fund ownership, paid expert testimony). This surgeon is not currently affiliated with or under any consulting agreement with any vendor that the clinical research data conclusion could directly enrich. This manuscript is not meant for or intended to push any other agenda other than the associated clinical outcomes and the need for surgeons to review their own MRI scans in addition to the MRI reports. The motive for compiling this clinically relevant information is by no means created and/or correlated to directly enrich anyone due to its publication.

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