

Clinical Study

The utility of magnetic resonance imaging results in physician decision-making before initial lumbar spinal injection

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Received 1 March 2018; revised 15 April 2019; accepted 17 April 2019

Abstract

BACKGROUND CONTEXT: The need for advanced imaging before spinal intervention is an area of ongoing debate. Many studies have demonstrated the accuracy of magnetic resonance imaging (MRI) results in evaluating structural pathology in the lumbar spine, but few have addressed how frequently MRI findings change clinical management. A randomized controlled trial showed that viewing MRI results did not impact outcomes in patients with radiculopathy undergoing epidural steroid injection (ESI). The results suggested ESIs that correlated with both imaging and clinical findings experienced slightly more benefit than the blinded cohort, although statistically insignificantly.

PURPOSE: Three related studies were conducted to (1) increase understanding of the opinions of interventional spine physicians regarding the utility of viewing imaging before injection and (2) evaluate the impact of viewing MRI results on injection planning (retrospective and prospective analyses).

STUDY DESIGN: Survey, prospective, and retrospective analysis.

PATIENT SAMPLE: Patients presenting to a university-based spine center for initial evaluation of back or leg pain who were candidates for spinal intervention.

OUTCOME MEASURES: Self-reported measures from a clinical practice questionnaire distributed to interventional spine physicians to determine rates and rationale for utilization of MRI before spine injection, physiologic measures including MRI results, functional measures including physician decision-making regarding type and location of injection performed.

METHODS: This study was funded by the University of Colorado Health and Welfare Trust. A survey was sent to interventional spine physicians to assess their utilization of MRI results before spine procedures. A retrospective analysis of patients who were candidates for ESI was conducted to evaluate how initial injection plan compared with the postviewing of MRI results on injection performed. In a prospective analysis, injection plans pre- and post-MRI were compared among patients presenting for initial evaluation of low back or leg pain.

RESULTS: Survey responses showed that specialists order MRI studies to correlate with physical exam (91%) and to detect the presence of synovial cysts (68%), whereas tumor/infection (93%) was most likely to cause a change in their approach. In the retrospective review, the physician's planned approach before viewing the MRI was concordant with the actual procedure 49% of the

FDA device/drug status: Not applicable.

Author disclosure: **VA:** Grant: University of Colorado Health and Welfare Trust (E); **AM:** Grant: University of Colorado Health and Welfare Trust (E); **JS:** Nothing to disclose; **SB:** Nothing to disclose; **SL:** Grant: University of Colorado Health and Welfare Trust (E); **RB:** Grant: University of Colorado Health and Welfare Trust (E); **BS:** Nothing to disclose; **JF:** Grant: University of Colorado Health and Welfare Trust (E); Consulting: MCG Health (A); **WS:** Grant: University of Colorado Health and Welfare Trust; Trips/

Travel: North American Spine Society (B); Board of Directors: North American Spine Society (B).

Funding Source: This study was funded by the University of Colorado Health and Welfare Trust.

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time. A different type of procedure was performed in 15% of planned injections. In such cases, the initial treatment plan was altered (ie, same procedure at a different or additional level or side) in 35% of planned injections. In the prospective data collection, 43% of injections were different from the initial physician decision. The most common reasons for altering the injection was different level affected (36%), facet pathology (22%), and different nerve root affected (16%).

CONCLUSIONS: In clinical practice, MRI before injection frequently changes management decisions in the planning and delivery of lumbar spine injections. © 2019 Elsevier Inc. All rights reserved.

Keywords: Epidural steroid injection; Facet injection; Interventional spine procedure; Low back pain; Lumbar spine; Magnetic resonance imaging; Physician decision-making; Radicular pain

Introduction

The need for advanced imaging before spinal interventions is an issue of ongoing debate [1]. Magnetic resonance imaging (MRI) results are used to confirm diagnosis, to rule out systemic disease (such as cancer and infection), and to plan spinal procedures and surgery. However, overutilization of advanced imaging may lead to increased cost of care without increased efficacy [2]. Many studies have demonstrated the accuracy of MRI results in evaluating structural pathology in the lumbar spine [1], but few have addressed how frequently MRI findings change clinical management. Thus, the role of MRI in the planning of spinal injections remains controversial.

Prior studies have demonstrated limited utility of MRI in patients with low back pain with or without radiculopathy when symptoms fail to improve with conservative measures over 6 weeks and are potential candidates for spinal interventions or surgery, or when these patients are deemed high-risk for progressive or irreversible neurological injury, infection, fracture, or cancer [3].

Another randomized controlled trial sought to examine whether advanced imaging improves outcomes in patients undergoing epidural steroid injections (ESI) for patients with lumbar radiculopathy [4]. The results suggested that patients who received an ESI that correlated with both imaging and clinical findings experienced slightly greater benefit than patients who underwent ESI without review of imaging, though differences in outcome did not reach statistical significance.

Examining the role of MRI in clinical decision-making has the potential to decrease the overall cost of care and expedite the delivery of care to patients initially presenting with low back pain [5]. We conducted three related studies to increase understanding regarding how MRI results impact physician decision-making when planning a spinal injection. Data was collected using a survey of interventional physicians, a retrospective chart review of patients who underwent initial lumbar spine injections, and prospective study to evaluate physician decision-making when initially evaluating patients for spinal intervention.

The aims of our study were to: (1) solicit the opinions of interventional spine physicians regarding the use of MRI for injection planning, (2) perform retrospective chart

review to quantify the concordance of the pre-MRI injection plan with the injection that was performed, and (3) prospectively observe physicians' injection plans before and after MRI review to quantify the incidence of altering the initial injection approach based on MRI findings.

Materials and methods

Institutional Review Board approval was obtained before this study. Part 1 was a survey of interventional spine physicians. Part 2 was a retrospective chart review of new consults entering a university spine center practice. Part 3 was a prospective study of patients referred to a university spine center practice for evaluation of low back or leg pain.

Part 1

An electronic survey was sent to 2,960 members of the Spine Intervention Society (SIS), which is comprised of a variety of disciplines. Physicians were told that the data would contribute to knowledge of utilizing advanced imaging in spinal interventions. The survey tool obtained clinical demographic data including primary specialty of the physician and the number of spine injections performed and spine MRI evaluated per week. The survey focused on three core elements pertaining to: (1) the reasons providers would order an MRI before injections; (2) which findings would potentially alter their approach, and (3) their estimated rates of observing certain findings on imaging (eg, central/lateral recess stenosis, tumor, infection, and others).

Part 2

A retrospective review of medical records was performed for initial consultations referred to a university spine center for low back and/or leg pain between January 1, 2009 and December 31, 2011. Of the 1,019 charts reviewed, 486 (47.6%) patients had an MRI in planning for possible lumbosacral spine intervention. Of these, 240 had symptomatic relief with noninterventional treatment or did not return for follow-up and 11 were cervical injections, which were excluded. The remainder of the patients (235) were included in the study. Inclusion criteria were age between 18 and 99 years, chief complaint of low back and/

or leg pain with or without weakness, an order placed for MRI after initial evaluation, and patient returning for a spine injection. Patients were excluded if they had undergone lumbar spine injection(s) within the past year, recent MRI results that they shared with the clinician, or evidence of serious neurologic deficits or myelopathy (eg, bowel/bladder involvement, upper motor neuron signs, and inability to perform tandem gait). Demographic data including age and gender was recorded for each patient. Based on the physician documentation, pattern of pain (axial or radicular), and planned approach for lumbosacral epidural or facet injections were recorded. Sacroiliac joint (SIJ) injections were not included in this study caused by the fact that many practitioners consider this an extra-spinal spinal structure and do not routinely obtain MRI before SIJ injections. MRI findings were recorded for each patient, as well as time elapsed between initial consultation, MRI, and injection appointment. Data from the injection were obtained including site and type of injection and this was compared with the injection plan from the initial consultation. Primary outcomes were to determine whether the pre-MRI injection plan was the same as the injection performed. Secondary outcomes evaluated any disparities in side or level of procedure, additional procedure, or different structural target. This allowed for retrospective analysis of the association of MRI and clinical decision-making for spinal injection approach.

Part 3

Consecutive patients were prospectively assessed at a university-based spine center between September 2013 and May 2015 for initial evaluation of low back pain and/or leg pain and were determined to be candidates for injection and underwent a lumbar MRI. Patients were included in the study protocol if they were at least 18 years of age, had complaints of axial low back and/or radicular pain, and if they went on to have a spine injection. Patients were excluded from the study protocol if they had recent (within 1 year) MRI or CT scan of the lumbar spine, recent (within 1 year) lumbar spine injection, evidence of infection (febrile, leukocytosis, rash, erythema), or evidence of malignancy (night pain, fevers/chills, unintentional weight loss). At the initial visit, physicians recorded assessment, diagnosis, and planned spinal intervention including side(s), level(s), and rationale for planned approach. Patients then obtained an MRI and the same physician who performed the initial consultation interpreted the MRI results and performed the spinal intervention. At the time of injection, the physician recorded the actual procedure performed and the rationale for the procedure, particularly if it was altered from the initial decision.

All injections were performed at the University Spine Center under fluoroscopic guidance by the senior author and two other interventional physiatrists.

Results

Part 1

The questionnaire was sent to 2,960 members of SIS and a total of 249 (8.4%) responded. The majority (47.0%) of the respondents were experienced practitioners (>15+ years) in private practice (71.9%). There was a broad mix of specialties represented with physiatrists and anesthesiologists making up 86% of the total, although remaining respondents were from interventional radiology and other spine intervention practices. Respondents were more likely to always obtain an MRI before cervical (64%) and thoracic (54%) injections compared with lumbar injections (33%) (Fig. 1).

Physicians reported that diagnoses for which MRI is most beneficial are nerve root compression, cervical myelopathy/cord compression, cauda equina syndrome, and to rule out a tumor. The diagnosis for which MRI is of least benefit is SIJ pathology (Table 1). Table 2 outlines physician reported anatomic reasons for altering planned injection, which include (1) different nerve root affected than anticipated; (2) foraminal disc herniation or foraminal stenosis; (3) morphology of disc; (4) facet morphology; and (5) presence of synovial cyst.

Part 2

The retrospective data collection included 235 patients. Baseline demographics are reported in Table 3. The majority of planned injections (90.2%) were transforaminal epidural steroid injections (TFESI). The average time between initial evaluation and first injection was 40.5 days. The results of the retrospective analysis are shown in Table 4. The physician's planned injection before viewing the MRI results matched the actual procedure exactly 49.8% (n=117) of the time. A different type of procedure (ie, TFESI to facet injection) was performed in 15.3% (n=36) of planned injections. The procedure was altered (ie, same

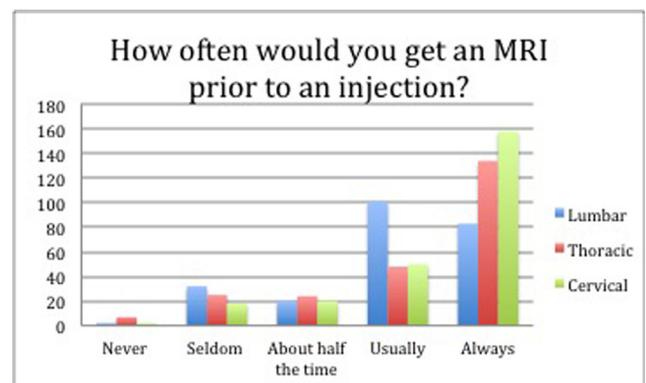


Fig. 1. Self-reported MRI use patterns of interventional spine physicians.

Table 1
Physician reported diagnoses most beneficial for MRI

	Frequency	Percent	Mean	SE	95% CI
Nerve root compression	108	43.9%	3.58	0.22	(37.8, 50.0)
Cervical myelopathy/spinal cord compression	108	43.9%	3.71	0.22	(37.4, 50.4)
Cauda equina	81	32.9%	4.26	0.22	(26.8, 39.0)
Rule out tumor	75	30.5%	4.26	0.2	(25.2, 36.2)
LSS with neurogenic claudication	54	22.0%	4.29	0.2	(16.7, 27.2)
Rule out infection	71	28.9%	4.62	0.2	(23.2, 34.9)
Compression fracture	51	20.7%	4.84	0.2	(15.9, 26.0)
Spondylolisthesis subtypes	18	7.3%	5.53	0.18	(4.1, 10.6)
Prior injury	14	5.7%	6.06	0.18	(3.3, 8.5)
Facet-mediated pain	14	5.7%	6.48	0.19	(2.8, 8.5)
Sacroiliac joint	22	8.9%	7.59	0.22	(5.7, 12.2)

Respondents were asked to rank the above diagnoses for which MRI is most (1) to least (11) beneficial. The mean indicates the average ranking each item received, so that the diagnosis with the lowest mean was ranked highest.

SE, standard error; LSS, lumbar spinal stenosis.

procedure at a different or additional level or side) in 34.9% (n=82) of planned injections. All altered procedures were TFESIs. Of altered procedures, 67.1% (n=55) were performed at a different level than planned, 34.1% (n=28) were performed on an additional side (ie, unilateral injection changed to bilateral injection), 8.5% (n=7) were performed at an additional level, and 3.7% (n=3) were performed on the opposite side than planned. Information regarding why a different approach was used was not consistently documented.

Part 3

The prospective data collection enrolled 100 participants, 58.0% female and 42.0% male. Of those participants enrolled, 37.0% of the patients had only radicular pain and

49.4% had both radicular and axial low back pain (Table 5). The most common planned injection was transforaminal ESI (67%) whereas the remaining 33% of injections included facet, interlaminar, caudal, and others (Fig. 2).

Of planned injections, 43% were altered from the initial physician decision (Table 6). The most common reasons for altering the injection plan was a different level affected than suspected (36%), presence of facet/synovial cyst (16%), and a different nerve root affected than suspected (16%). Other radiologic reasons for altering the injection plan are shown in Fig. 3. Eleven injections were changed for clinical rather than radiologic reasons. Of these six were caused by different clinically affected level than suspected initially and one was caused by change in symptoms. The most common radiologic reason for changing a TFESI to a

Table 2
Physician reported reasons for altering planned injection

	Frequency	Percent	95% CI
Spontaneous improvement	193	77.50%	(72.3, 82.1)
Symptoms have changed	182	73.10%	(67.9, 78.7)
Different clinically affected level	157	63.10%	(57.0, 69.1)
Patient did not stop blood thinner	164	65.90%	(59.8, 71.9)
Anatomic reasons	99	39.80%	(33.3, 45.8)
Clinical safety reasons	158	63.50%	(57.4, 69.5)
Physician reported anatomic reason for altering planned injection			
Different level than suspected	153	61.4%	(55.4, 67.5)
Different nerve root affected	117	47.0%	(40.6, 53.8)
Foraminal disc location	45	18.1%	(13.3, 23.3)
Morphology of disc herniation	37	14.9%	(10.8, 19.7)
Foraminal stenosis	37	14.9%	(10.4, 20.1)
Angle of entry for transforaminal injection	30	12.0%	(8.0, 16.9)
Transitional vertebrae	26	10.4%	(6.8, 14.5)
Arachnoiditis	25	10.0%	(6.4, 14.1)
Facet spurs into lateral recess of foramen	16	6.4%	(3.6, 9.6)
Synovial cyst	16	6.4%	(3.6, 9.6)
Angle of entry for facet injection	14	5.6%	(2.8, 8.4)
Tarlov cyst preventing flow	11	4.4%	(2.0, 7.2)
Prominent superior recess of facet joint	9	3.6%	(1.6, 6.4)
Calcified ligamentum flavum	8	3.2%	(1.2, 5.6)
Epidural lipomatosis	7	2.8%	(0.8, 4.8)
Conjoined nerve root	6	2.4%	(0.8, 4.4)

Table 3
Retrospective demographics (n=235)

	Mean	SD	
Age	58.1	17.3	
	Number	Percent	95% CI
Pain			
Axial	4	1.7%	(0.1, 3.3)
Radicular	89	37.9%	(31.8, 43.9)
Both	3	1.3%	(-0.1, 2.7)
Planned injection			
TFESI	213	90.6%	(87.0, 94.3)
Ilesi	1	0.4%	(-0.4, 1.2)
Caudal ESI	16	6.8%	(3.7, 10.0)
Facet injection	3	1.3%	(-0.1, 2.7)
MBB	2	0.9%	(-0.3, 2.0)

TFESI, transforaminal epidural steroid injection; Ilesi, interlaminar epidural steroid injection; ESI, epidural steroid injection; MBB, medial branch block.

different TFESI was a different level affected than suspected. The most common radiologic reasons for changing a TFESI to a facet injection were facet pathology and absence of nerve root impingement (Fig. 4).

Discussion

Spine injections are often planned based on information gained from MRI. Our study quantifies the direct impact of MRI on spine injection planning, demonstrating that

Table 4
Retrospective procedures - planned vs. actual (n=235)

	Number	Percent	CI
Same procedure	117	49.8%	(45.4, 56.0)
Different procedure	36	15.3%	(10.8, 19.8)
Altered procedure*	82	34.9%	(28.9, 40.8)
Opposite side	3	3.7%	(1.3, 6.0)
Different level	55	67.1%	(61.2, 72.9)
Additional level	7	8.5%	(5.0, 12.0)
Additional side	28	34.1%	(28.2, 40.1)
Procedures changed after MRI			
TFESI	113	96.6%	(86.3, 93.7)
Facet injection	2	1.7%	(2.2, 7.7)
Caudal ESI	2	1.7%	(2.2, 7.7)
Ilesi	1	0.9%	(-0.3, 2.0)
TFESI to TFESI	82	72.6%	(67.0, 78.1)
TFESI to Ilesi	9	8.0%	(4.6, 11.3)
TFESI to caudal ESI	9	8.0%	(4.6, 11.3)
TFESI to SIJ	7	6.2%	(3.2, 9.2)
TFESI to facet injection	6	5.3%	(2.5, 8.1)

TFESI, transforaminal epidural steroid injection; Ilesi, interlaminar epidural steroid injection; ESI, epidural steroid injection; SIJ, sacroiliac joint injection.

Same procedure – same target, level, and side as planned.

Different procedure – different target structure (ex, TFESI to facet injection).

* All altered procedures were TFESI.

Table 5
Prospective demographics (n=100)

	n
Gender	
Male	42
Female	58
Pain	
Axial	11
Radicular	30
Both	40
Planned procedure	
TFESI	67
Ilesi	9
Caudal	6
SI joint	4
Facet	16

TFESI, transforaminal epidural steroid injection; Ilesi, interlaminar epidural steroid injection; ESI, epidural steroid injection; SIJ, sacroiliac joint injection.

injections are frequently altered based on MRI findings, most often caused by a different nerve root or level affected, the presence of facet pathology or synovial cysts, or the absence of nerve root impingement. In addition to targeting the precise level of pathology before a spine injection, MRI is often used to rule out systemic disease and to evaluate the anatomy to ensure a safe injection approach.

Clinical guidelines from the American College of Physicians and the American Pain Society from 2007 recommend using MRI to evaluate patients with persistent low back pain and signs or symptoms of radiculopathy or spinal stenosis if they are potential candidates for ESI or surgery. These guidelines also highlight the importance of specialist clinical correlation with imaging [6]. Similarly, the American College of Radiology recommends MRI for acute, sub-acute, or chronic low back pain or radiculopathy with suspicion of cancer, infection, or immunosuppression or if the patient is a surgical or intervention candidate with worsening or persistent symptoms during or following 6 weeks

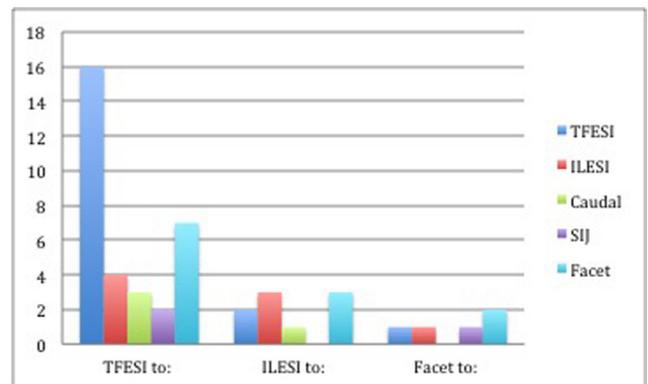


Fig. 2. Modifications to target of spine injection based on MRI results in the prospective analysis.

TFESI, transforaminal epidural steroid injection; Ilesi, interlaminar epidural steroid injection; SIJ, Sacroiliac joint injection.

Table 6
Prospective procedures - planned vs actual (n=100)

	Number	Percent	CI
Same procedure	57	57.0%	(50.8, 63.2)
Different procedure	24	24.0%	(18.7, 29.3)
Altered procedure	19	19.0%	
Different level	15	15.0%	(10.5, 19.5)
Different side	0	0.0%	
Additional level	3	3.0%	(0.9, 5.1)
Additionas Side	1	1.0%	(-0.2, 2.2)
Procedures Changed after MRI			
TFESI	30	69.8%	(64.0, 75.5)
Ilesi	8	18.6%	(13.7, 23.5)
Caudal	0	0.0%	
Facet	5	11.6%	(7.6, 15.6)
SIJ	0	0.0%	
TFESI to TFESI	16	53.3%	(47.0, 59.6)
TFESI to Ilesi	3	10.0%	(6.3, 13.7)
TFESI to caudal	3	10.0%	(6.3, 13.7)
TFESI to SIJ	2	6.7%	(3.5, 9.8)
TFESI to facet	7	23.3%	(18.0, 28.6)

TFESI, transforaminal epidural steroid injection; Ilesi, interlaminar epidural steroid injection; ESI, epidural steroid injection; SIJ, sacroiliac joint injection.

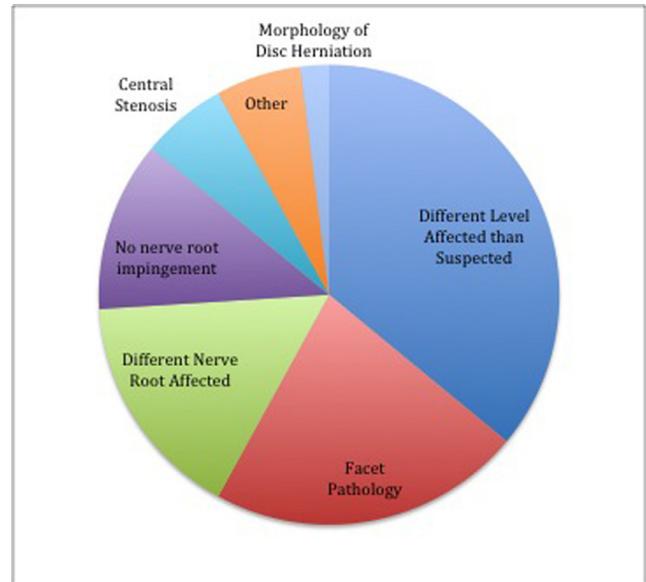


Fig. 3. Radiologic reason for altering injection based on MRI results in the prospective analysis.

of conservative treatment [7]. However, concern among practitioners has developed over the indiscriminate use of MRI for nonspecific low back pain, particularly in light of several studies demonstrating no difference in outcomes with the use of advanced imaging [4,8,9]. Our survey results demonstrated that spine practitioners do not always order an MRI before performing spine injections. Only one-third (33%) of physicians surveyed said they always order an MRI before a lumbar injection, although 42% said they usually order an MRI. This variation highlights the

lack of consensus in the use of MRI for spine injection planning despite multiple organizations recommending their use [7].

In our prospective data collection, 43% of injections were changed based on the results of the MRI and in our retrospective data collection, 50% were changed. These findings are consistent with Cohen et al., who found that in 66% of cases the injection plan was the same with and without viewing the MRI whereas in 34% of cases a different injection was performed. Consistent with our results, most

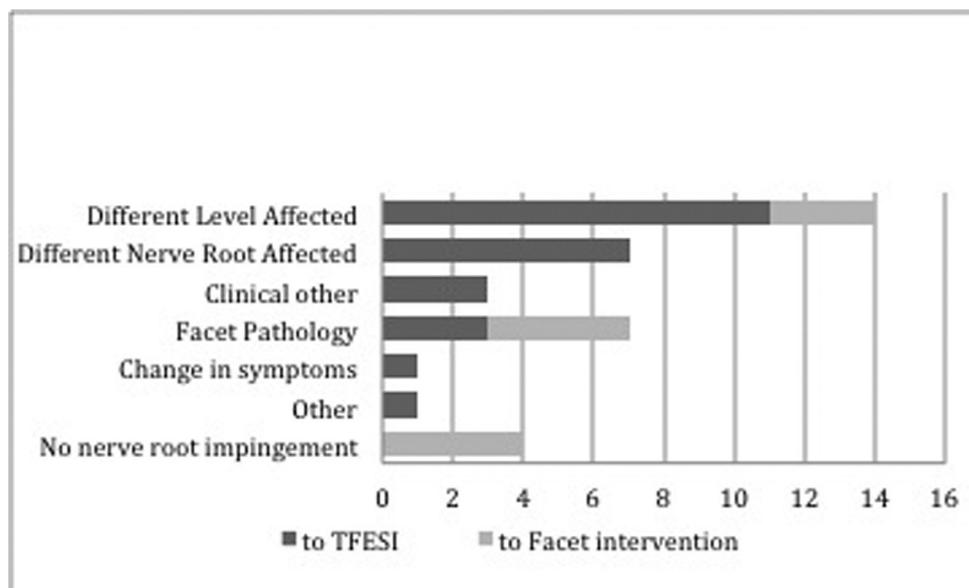


Fig. 4. Reason for altering injection from a planned transforaminal epidural steroid injection to either a different epidural injection or facet injection in the prospective analysis.

often (82%) the planned ESI was altered to a different ESI, and less frequently a completely different injection was performed [4]. In both our retrospective and prospective analysis, the most common reason for altering a planned injection following MRI review was a different nerve root or level affected than suspected based on the initial evaluation. This was also the reason most cited in the interventional spine physicians survey for altering a planned injection, highlighting the limitations of the physical exam in precisely localizing level or nerve root affected in the lumbar spine. At least in cases of paracentral lumbar disc herniations, prior studies suggest that an ESI is more likely to be effective when the injectate reaches the affected pre-ganglionic nerve in the ventral epidural space [10,11], and radicular pain patterns are often insufficient to identify the affected nerve root [12,13]. Furthermore, the anatomical location of nerve compression (eg, lateral recess versus foraminal) impacts injection approach decision-making. Further studies are needed to determine the most effective approach in lateral recess, foraminal, or multifocal degenerative stenosis [14]. Variations in lumbosacral anatomy, presence of transitional segments, and overlapping dermatomal distributions confound vertebral enumeration and contribute to varying clinical presentations of nerve root impingement at a specific vertebral level [13].

In our prospective investigation, the identification of synovial cysts or facet pathology was the second most common reason for altering an injection plan and changing from a TFESI to a facet injection. This finding is probably explained by overlapping clinical presentations between facet-mediated pain with somatic referral to the limb and true radicular pain, along with the lack of validated or specific physical exam maneuvers for identifying primary facet-mediated pain [15–17]. Moreover, when radicular pain is caused by nerve root compression from a facet-related synovial cyst, the injection plan may be altered to attempt to attempt to aspirate the cyst.

The strongest indication for obtaining an MRI before performing an ESI from survey results is to preserve patient safety. This is accomplished both by evaluating for systemic disease and by visualizing spine anatomy to optimize the safety of the injection approach. Although rare, infection, cancer, and inflammatory spondyloarthropathies should be ruled out in the work up of persisting back or leg pain. Injection safety remains an important consideration when planning a spine injection approach. Fluoroscopy used for injection approach images cortical bone but cannot fully evaluate the target epidural space. The MRI is used to ensure adequate epidural space, which may be compromised by critical central or foraminal stenosis. Vulnerable structures such as synovial cysts, conjoined nerve roots, a displaced thecal sac, or meningeal cysts can also be identified and may affect the planned trajectory of the injection. Finally, in patients with prior spine trauma or interventions, preinjection MRI allows identification of adhesive arachnoiditis [18]. Although no cases of arachnoiditis were

identified in this study, failure to make this diagnosis before ESI could have medical-legal ramifications for the interventionalist [19].

This study is not without limitations. Survey responses are influenced by selection bias, likely augmented by the relatively low response rate for this survey (8.4%). Physicians typically have a lower response rate than nonphysicians [20], and have been shown to be less affected by selection bias than general population surveys. Additionally, we did not employ any follow-up measures to improve response rate. The retrospective design of Part 2 of our study was also influenced by selection bias. Of the charts we reviewed, approximately 50% had an MRI for injection planning and approximately 50% of those did not go on to have injections. Presumably, this represents patients who improved without interventional treatments (including medications and physical therapy), those who went on to have surgery, and those who had injections with a provider outside of our spine center. Additionally, there was an average of 40 days between the initial consultation and the injection. It is possible that during this time symptoms may have changed. Therefore, the post-MRI intervention plan may have been confounded by symptom change rather than MRI findings alone. This may be suggested by the results demonstrating that the post-MRI intervention was sometimes changed to a different side or an additional level. For the retrospective analysis, pain distribution (axial vs. radicular) was not always available; however, for those recorded, radicular pain was predominant. It is unclear if axial pain was less likely to be clearly documented or if this pattern was consistent throughout the cohort. In our retrospective analysis, the exact reason for altering the injection plan was not consistently documented and thus, could not be used in analysis. This study also did not evaluate outcomes of the injections, so we are unable to determine if changing the injection plan influenced the outcome for the patient. Additionally, the study was underpowered to detect low prevalence, red-flag spinal pathologies including cancer, infection, or spondyloarthropathies.

Conclusion

An accepted indication for a lumbar MRI is persistent or progressive low back pain or leg pain despite physician-directed conservative treatment for 6 weeks and planned intervention, such as a spinal injection. This study shows there is variability with if and how an MRI is used before a spinal injection. As costs of caring for patients with low back pain are rising, including a cascade of medical expenses initiated with advanced imaging studies, there is an impetus to develop evidence-based guidelines for advanced imaging utilization for spine injections. This study demonstrates that MRI results do frequently alter injection plan, most commonly caused by different spinal level affected, presence of synovial cysts or other facet pathology, or the absence of pathology. This study suggests that

imaging of the lumbar spine before intervention does alter the approach to transforaminal and interlaminar lumbar epidural spinal injections whereas posterior column injections and caudal ESIs are safe to perform without an MRI.

Supplementary materials

Supplementary material associated with this article can be found in the online version at <https://doi.org/10.1016/j.spinee.2019.04.016>.

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