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Prevalence of Anatomic Impediments to Interlaminar Lumbar Epidural Steroid Injection

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Abstract

Objective—To determine the prevalence of anatomic impediments to interlaminar lumbar epidural steroid injection (LESI) in a community-based population.

Design—Cross-sectional observational study.

Setting—Community-based.

Participants—Older adults (N=333) sampled irrespective of back pain status.

Interventions—Not applicable.

Main Outcome Measures—Computed tomography evaluation of 5 potential anatomic impediments to interlaminar LESI at the L2-S1 spinal levels, including (1) ligamentum flavum (LF) calcification, (2) interspinous ligament (ISL) calcification, (3) spinous process (SP) contact, (4) the absence of epidural fat in the posterior epidural space, and (5) the presence of fat density superficial to the LF in the midsagittal plane. Independent variables included age, sex, body mass index (BMI), and current smoking.

Results—LF and ISL calcifications were prevalent in 3% to 7% and 2% to 3% of spinal levels, respectively, without significant differences by spinal level. SP contact was most common at the L4-5 level (22%). Absence of posterior epidural fat was very common at L5-S1 (65%), but infrequent at other levels. The presence of midline fat density superficial to LF was most common at L5-S1 (55%). The prevalence of LF calcification, ISL calcification, and SP contact increased with age, but the prevalence of absence of posterior epidural fat and the presence of a midline fat density superficial to LF did not. Sex and smoking status were not associated with the prevalence of anatomic impediments, but higher BMI was associated with a lower prevalence of absence of posterior epidural fat.

Conclusions—Anatomic impediments to interlaminar LESI were common in this community-based population, particularly at the L5-S1 spinal level. Because of the high overall prevalence of anatomic impediments, and differences in prevalence by spinal level, knowledge of the

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distribution and frequency of these impediments may aid in aspects of decision-making for the interventional spine physician.

Keywords

Injections; epidural; Low back pain; Pathological conditions; anatomical; Rehabilitation; Spine

Lumbar epidural steroid injections (LESIs) are a common treatment for radicular pain with or without low back pain. Rates of LESI in the U.S. Medicare population quadrupled between 1994 and 2001.¹ More recent reports suggest that this trend in utilization has continued over the past decade.^{2,3}

In the United States, LESI is performed most commonly via the interlaminar route.⁴ Interlaminar LESIs were performed without fluoroscopic guidance early in their history (ie, using the “blind” technique).⁵ The performance of blind interlaminar LESI often relies on the “loss of resistance” experienced by the operator when the ligamentum flavum (LF) of the posterior spinal structures is penetrated. However, studies⁶⁻⁸ have demonstrated rates of inaccurate needle placement outside the epidural space with blind interlaminar LESI relying on the loss of resistance technique ranging from 25% to 30%, and improper spinal level placement up to 50% of the time. Although fluoroscopy is generally thought to improve needle placement,^{6,9,10} only 70% of LESIs in 2006 were performed with fluoroscopic guidance.⁴ A wide variety of other factors may influence the choice of LESI technique for a specific operator or clinical situation, including the procedural training of the operator, type of epidural performed, and findings on cross-sectional spinal imaging.

Several anatomic impediments have been postulated to decrease the accuracy of the blind technique for interlaminar LESI.¹¹ Whitworth et al¹¹ outlined 4 such impediments, including (1) LF calcification, (2) interspinous ligament (ISL) calcification, (3) spinous process (SP) contact, and (4) absence of epidural fat in the posterior epidural space. Bartynski et al⁶ described a fifth potential impediment—a false loss of resistance superficial to the epidural space resulting from fat posterior to the LF. Even when fluoroscopy is used, each of these 5 factors may require minor adjustments in procedural planning or execution. These may include altering patient positioning, changing technique or target level, the need for close correlation with cross-sectional imaging, or even the simple expectation that a procedure may take longer than average to complete. Better knowledge of the epidemiology of these anatomic impediments may therefore provide useful information for the interventional spine physician. However, the prevalence of these anatomic impediments to epidural steroid injection placement in the lumbar spine is unknown.

We designed a study to examine the prevalence of these 5 anatomic impediments to interlaminar LESI in a community-based population. We hypothesized that the prevalence of these anatomic impediments would vary by spinal level. Furthermore, we expected that the prevalence of these anatomic impediments would increase with age.

METHODS

Study Sample

This was an ancillary project to the Framingham Heart Study. A total of 3529 participants from the Offspring and Third Generation cohorts of the Framingham Heart Study underwent abdominal multidetector computed tomography (MDCT) to assess aortic calcification. A description of the Offspring and Third Generation cohorts has been previously published.^{12,13} The recruitment and conduct of computed tomography (CT) scanning have also been reported previously^{14,15}; scans were conducted between June 2002 and April

2005. A total of 333 individuals from the MDCT study were sampled irrespective of clinical information. Although most individuals in the MDCT cohort are from the Third Generation Cohort, the Offspring cohort was oversampled in this substudy to enrich the cohort for older adults. We wished to capture a larger sample of older adults because it is this Medicare-age population that has been highlighted in recent reports of increasing LESI utilization, and because we expected these potential anatomic impediments to be more common in older adults. The sample was drawn from the Framingham community irrespective of the presence of back pain and unaware of the hypothesis being tested. This research was approved by the Institutional Review Board of New England Baptist Hospital.

Demographic and Anthropometric Factors

Data on sex and body mass index (BMI) were collected at the contemporaneous Framingham examination. BMI was calculated as weight in kilograms divided by the square of height in meters, and divided into categories according to the classification by the National Heart, Lung, and Blood Institute: underweight/normal (BMI, <25.0kg/m²), overweight (BMI, 25.0–29.9kg/m²), and obesity classes I to III (BMI, ≥30.0kg/m²).¹⁶

Smoking status was defined by a report of having smoked cigarettes regularly within the past year.

CT Evaluation of Anatomic Impediments

Study participants were imaged with an MDCT scanner using methods that have been reported elsewhere,¹⁷ and the lumbar spinal structures were evaluated using eFilm Workstation (version 2.0.0) software.^a The prevalence of LF calcification, ISL calcification, SP contact, absence of epidural fat in the posterior epidural space, and the presence of fat density superficial to the LF in the midsagittal plane was evaluated on CT scans at the L2-S1 spinal levels. CT scans were evaluated in a blinded fashion with respect to personal and clinical data. The L2-3 through L5-S1 intervertebral levels were reviewed for each patient, using both bone and soft tissue windows. Axial views and sagittal multiplanar reformatted views were evaluated. The presence or absence of LF calcification was assessed in the axial plane at each level of the lumbar spine using bone windows. The presence or absence of ISL calcification and SP contact was evaluated in bone windows using precise alignment along the midsagittal plane, which was defined by a line connecting the midanterior vertebral margin with the spinous process. In situations where SP alignment was clearly asymmetric, the midsagittal plane was defined instead by a line connecting the midanterior vertebral margin with the base of the SP. The depth and width of the posterior epidural fat was measured in soft tissue windows at each lumbar interspace in the midsagittal plane and axial planes, respectively. The absence of epidural fat posterior to the epidural space was treated as a dichotomous variable. Although accepted standards do not exist for what constitutes a relative absence of posterior epidural fat, we defined absence of epidural fat as either having 1mm or less of posterior epidural fat width in the axial plane, or essentially no epidural fat depth in the midsagittal plane. The presence of fat density superficial to the LF in the midsagittal and axial planes was evaluated on CT scans in soft tissue windows. Figure 1 presents examples of these typical anatomic impediments to interlaminar LESI.

Reliability of CT Readings

All CT scans were evaluated by a single physician reader. This reader was a physiatry resident, who was extensively trained in assessment of these anatomic impediments by a fellowship-trained interventional spine specialist. The spine specialist has substantial clinical

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experience in the interpretation of lumbar spinal imaging relevant to the performance of LESI, as well as experience in prior research studies of lumbar spine CT imaging.¹⁷⁻¹⁹ A reading protocol was developed to measure concordance between the reader and the spine specialist in a subset of CTs that were interpreted by both individuals, as an assurance of the validity of the primary reads. Before the start of formal reads, an initial set of CTs was reviewed by both the physician reader and the spine specialist to ensure consistency of evaluations. At the start of formal reads, interrater reliability was calculated. Formal reads then continued, and reliability was reassessed in a structured manner at the midpoint and conclusion of formal reads to determine whether “reader drift” had occurred. The initial set of previously analyzed CTs was available as needed to the primary reader during formal reads to maintain calibration, akin to the common use of an imaging atlas in imaging studies to promote standardization. Interrater reliabilities assessed with the κ statistic²⁰ approached or met “almost perfect” agreement beyond that expected by chance²¹: .76 for LF calcification, .86 for ISL calcification, .84 for SP contact, .77 for absence of posterior epidural fat, and .82 for midline fat density superficial to the epidural space. No substantial reader drift was noted during the reading process. Throughout formal reads, any anatomic features that were indeterminate according to the primary reader were checked directly by the spine specialist; where reads were discordant, the results were coded according to the spine specialist's impression.

Statistical Analysis

The analytic approach was primarily descriptive. The sample was characterized using means and SDs for continuous variables, and frequencies and proportions for categorical variables. The prevalence of each anatomic impediment was calculated for each age group. To assess whether the prevalence of these anatomic impediments demonstrated significant differences by spinal level, the chi-square test was used. To assess whether the prevalence of these anatomic impediments increased with age, the chi-square test for trend was used. All statistical analyses were performed using SAS software.^b

RESULTS

The study sample (n=333) included an even distribution of men and women in each age group (table 1), with most individuals older than 60 years. Table 2 demonstrates the prevalence of different anatomic impediments by spinal level; these differences are also depicted graphically in figure 2. Neither LF nor ISL calcification showed significant differences in prevalence by spinal level. SP contact was most common at the L4-L5 (22%) and L3-L4 (17%) levels. Absence of posterior epidural fat was very common at L5-S1 (65%), but infrequent at other levels. The presence of midline fat density superficial to LF was most common at L5-S1 (55%), but was also prevalent to a lesser extent at L2-L3 (27%). The prevalence of any anatomic impediment at the L5-S1 level was 84%, roughly twice that of any other level; this appeared to be driven mainly by the factors of absence of posterior epidural fat and presence of a midline fat density superficial to LF.

Table 3 depicts the prevalence of anatomic impediments at 1 or more of the L2-S1 interspaces, by age group. The prevalence of LF calcification and ISL calcification increased significantly by age group, affecting 17% and 11% of individuals older than 70, at 1 or more spinal levels. The prevalence of SP contact also increased substantially by age group, affecting only 9% of individuals younger than 50, and 61% of individuals 70 years or older ($P<.0001$). In contrast, the prevalence of absence of posterior epidural fat and presence of a midline fat density superficial to LF did not increase with age. Although the prevalence of

^bSAS Institute Inc, 100 SAS Campus Dr, Cary, NC 27513.

having any anatomic impediment did increase by age group, the vast majority of individuals had at least 1 anatomic impediment as a result of the higher percentage of individuals having absence of posterior epidural fat and presence of a midline fat density superficial to LF at 1 or more levels.

In analyses examining associations between other clinical factors and these 5 anatomic impediments, neither sex nor smoking status was associated with any anatomic impediment (data not shown). A higher BMI was significantly associated with a lower prevalence of the absence of posterior epidural fat: 57% for individuals with a BMI less than 25, 53% for individuals with a BMI of 25 to 30, and 40% for individuals with a BMI greater than 30 ($P=.03$). In other words, individuals with a higher BMI also had slightly more fat in the posterior epidural space. There were no other differences in anatomic impediments with respect to BMI (data not shown). Subjects with prior lumbar spinal surgery were more likely to have LF calcification (54.6% vs 11.5%; $P<.0001$) or SP contact (63.6% vs 35.0%; $P=.06$), but there were no differences with respect to the other imaging parameters examined; results of the analyses above were not materially different when individuals with prior spine surgery were excluded.

DISCUSSION

To our knowledge, there have been no studies to date that have characterized the prevalence of anatomic factors relevant to interlaminar LESIs in a community-based population. Our findings demonstrate that anatomic impediments to lumbar epidural placement are common and vary by spinal level. Most notable is the high prevalence of impediments at the L5-S1 level, especially for absence of posterior epidural fat and the presence of a midline fat density superficial to LF. The prevalence of certain anatomic impediments increased with age, as was the case with LF calcification, ISL calcification, and SP contact. In contrast, the prevalence of absent posterior epidural fat and a midline fat density superficial to LF was similar in different age groups.

Although there is wide variation in techniques and standard practices for performing interlaminar LESIs, the L4-5 level is considered to be the most common level for LESI.¹⁰ The findings of our study support this common practice, since the prevalence of anatomic impediments at and above the L4-5 level is substantially lower than the prevalence of impediments at L5-S1. When injection at L5-S1 is warranted, absence of posterior epidural fat and the presence of a midline fat density superficial to LF should be expected.

The data presented in this article provide an idea of the pretest probability of various anatomic impediments at specific levels, allowing the practitioner to anticipate and accommodate for factors related to injection performance. Knowledge of the prevalence of these impediments can aid decision-making at various points in the daily practice of a busy interventional spine physician. For example, the presence of ISL or LF calcification in the needle trajectory may cause increased resistance to needle advancement.¹¹ Although these calcifications are often not visible on fluoroscopy, our findings suggest they should be anticipated in patients older than 60. SP contact should also be expected in older adults, and can be identified by review of imaging studies. SP contact may be accounted for by movement of the lumbar roll so as to increase the space between SPs at the target level; marked SP contact may warrant a change to a paramedian technique or to a different spinal level. Our data suggest that absence of posterior epidural fat should be expected at the L5-S1 level, and can be noted on review of cross-sectional imaging.¹¹ Absent posterior epidural fat may increase the risk of dural puncture, and this risk can be minimized by using fluoroscopy. Lastly, fat posterior to the epidural space also should be expected at the L5-S1 level, and can be noted on review of cross-sectional imaging. This impediment can lead to a

false loss of resistance superficial to the epidural space and incorrect delivery of injectate; these errors may be obviated by the use of fluoroscopy with epidurography.⁶ In this manner, use of fluoroscopy or preprocedure planning using cross-sectional imaging can further refine decision-making and detection of anatomic impediments in a variety of different ways, informed by the pretest probabilities of anatomic impediments presented in this article.

Study Limitations

A limitation of this study is that it describes anatomic factors detected on lumbar spine CT only. These factors may or may not result in technical difficulties in the hands of an experienced practitioner. Second, these CTs were obtained while the patient was in a supine position. This position may have resulted in overestimation of the prevalence of SP contact, which may be lower when patients are positioned prone, as they would typically be for a fluoroscopically guided LESI. Third, the primary physician reader was not a radiologist. Nevertheless, the reader was extensively trained, and the accuracy of our CT assessments is confirmed by concordance levels with an expert spine specialist reader approaching or at “almost perfect” levels as measured by the κ statistic. Fourth, some of the anatomic impediments assessed by CT in this study (particularly ligamentous calcifications) may not be as easily detected on magnetic resonance imaging. Last, this study was conducted on a subsample of participants from the Framingham MDCT study. Because of the selection criteria of the parent study and the demographics of Framingham, Massachusetts, these findings may not be strictly representative of the U.S. general population, particularly because most of the MDCT study population was white.

CONCLUSIONS

Despite these limitations, our study demonstrates that anatomic impediments to LESI are common in this community-based population. Because of the high overall prevalence of anatomic impediments, and differences in prevalence by spinal level, knowledge of the distribution and frequency of these impediments may aid in decision-making for the interventional spine physician. The prevalence of these anatomic impediments may contribute to inaccurate needle placement or increased technical difficulty when performed without fluoroscopy and epidurography, especially at the L5-S1 level.

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List of Abbreviations

BMI	body mass index
CT	computed tomography
ISL	interspinous ligament
LESI	lumbar epidural steroid injection
LF	ligamentum flavum
MDCT	multidetector computed tomography

SP spinous process

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Fig 1. Anatomic impediments to interlaminar LESI. (A) Absence of fat in the posterior epidural space. (B) Fat density posterior to the LF. (C) ISL calcification. (D) LF calcification. (E) SP contact.

Fig 2.
Prevalence of anatomic impediments to interlaminar LESI by spinal level.

Table 1

Descriptive Statistics of the Study Sample (n=333)

Characteristics	Values
Age (y)	
<50	64 (19.2)
50–60	75 (22.5)
60–70	96 (28.8)
70	98 (29.4)
Sex (female)	156 (46.8)
BMI *	28.3±5.0
Smoking	37 (11.1)
Prior lumbar spine surgery	11 (3.3)

NOTE. Values are n (%) or mean ± SD.

* Height (m)/weight² (kg²).

Table 2

Prevalence of Anatomic Impediments to Interlaminar LESI by Spinal Level

Anatomic Impediments	L2-3	L3-4	L4-5	L5-S1	P
LF calcification	17 (5.4)	22 (6.7)	18 (5.5)	10 (3.0)	.15
ISL calcification	8 (2.5)	9 (2.7)	8 (2.4)	10 (3.0)	.89
SP contact	26 (8.2)	57 (17.2)	71 (21.5)	29 (8.8)	<.0001
Absence of posterior epidural fat	10(3.2)	17 (5.2)	34 (10.4)	208 (64.6)	<.0001
Presence of a midline fat density superficial to LF	84 (26.6)	50 (15.4)	30 (9.2)	179 (55.4)	<.0001
Any impediment (any of above)	127 (39.8)	122 (36.6)	135 (40.7)	279 (84.0)	<.0001

NOTE. Values are n (%) or as otherwise indicated.

Table 3

Prevalence of Anatomic Impediments to Interlaminar LESI by Age Group

Anatomic Impediments	Age <50 (n=64)	Age 50-60 (n=75)	Age 60-70 (n=96)	Age 70 (n=98)	<i>P</i> [*]
LF calcification	3 (4.7)	9 (12.0)	14 (14.6)	17 (17.3)	.02
ISL calcification	0 (0)	4 (5.3)	7 (7.3)	11 (11.2)	.005
SP contact	6 (9.4)	12 (16.0)	41 (42.7)	60 (61.2)	<.0001
Absence of posterior epidural fat	29 (45.3)	42 (56.0)	49 (51.0)	48 (49.0)	.94
Presence of a midline fat density	42 (65.6)	48 (64.0)	66 (68.8)	71 (72.4)	.24
Any impediment (any of above)	50 (78.1)	67 (89.3)	91 (94.8)	95 (96.9)	<.0001

NOTE. Values are n (%) or as otherwise indicated.

^{*} *P*value for trend by age group.