Prevalence of Anatomical Impediments to Epidural Steroid Injection

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ABSTRACT

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

Design: Cross-sectional observational study.

Setting: Community-based.

Participants: Three hundred thirty-three older adults sampled irrespective of back pain status.

Assessment of Risk Factors: Independent variables included age, sex, body mass index, and current smoking.

Main Outcome Measurements: Computed tomography (CT) evaluation of five potential anatomical barriers to LESI at the L2-S1 spinal levels, including: 1) ligamentum flavum (LF) calcification, 2) interspinous ligament (ISL) calcification, 3) spinous process (SP) contact, 4) absence of epidural fat in the posterior epidural space, and 5) the presence of fat density superficial to the LF in the midsagittal plane.

Results: LF and ISL calcifications were prevalent in 3-7% and 2-3% of spinal levels respectively, without significant differences by spinal level. SP contact was most common at the L4-L5 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 presence of a midline fat density superficial to LF did not. Sex and smoking status were not associated with the prevalence of anatomical impediments, but higher BMI was associated a lower prevalence of absence of posterior epidural fat.
Conclusions: Anatomical impediments to LESI were common in this community-based population, particularly at the L5-S1 spinal level. Due to 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 aspects of decision-making for the interventional spine physician.
INTRODUCTION

Lumbar epidural steroid injections (LESI) are a common treatment for radicular pain with or without low back pain. Rates of LESI in the US Medicare population quadrupled between 1994 and 2001. More recent reports suggest that this trend in utilization has continued over the past decade.

In the United States, LESI is performed most commonly via the interlaminar route. Interlaminar LESIs were performed without fluoroscopic guidance early in their history, i.e. utilizing the ‘blind’ technique. The performance of blind LESI relies on the ‘loss of resistance’ experienced by the operator when the ligamentum flavum of the posterior spinal structures is penetrated. However, studies have demonstrated rates of inaccurate needle placement outside of the epidural space with blind LESI ranging from 25-30%, and improper spinal level placement up to 50% of the time. Although fluoroscopy is generally thought to improve needle placement, only 70% of LESIs in 2006 were performed with fluoroscopic guidance. 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 anatomical impediments have been postulated to decrease the accuracy of the blind technique for interlaminar LESI. Whitworth et al. outlined four such impediments, including (1) ligamentum flavum (LF) calcification, (2) interspinous ligament (ISL) calcification, (3) spinous process (SP) contact and (4) absence of epidural
fat in the posterior epidural space. Bartynski described a fifth potential impediment, (5) a false loss of resistance superficial to the epidural space resulting from fat posterior to the ligamentum flavum (LF). Even when fluoroscopy is used, each of these five 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 anatomical impediments may therefore provide useful information for the interventional spine physician. However, the prevalence of these anatomical impediments to epidural steroid injection placement in the lumbar spine is unknown.

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

Study sample:

This was an ancillary project to the Framingham Heart Study. 3529 participants from the Offspring and Third Generation cohorts of the Framingham Heart Study underwent abdominal multi-detector computed tomography (MDCT) to assess aortic calcification. A description of the Offspring and Third Generation cohorts has been previously published.\textsuperscript{12,13} The recruitment and conduct of CT scanning have also been reported previously.\textsuperscript{14,15} Three hundred and thirty eight individuals from the MDCT study were chosen randomly for inclusion in this study; the Offspring cohort was oversampled to enrich the cohort for older adults. The population 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 <25.0 kg/m\textsuperscript{2}), Overweight (BMI 25.0-29.9 kg/m\textsuperscript{2}), and Obesity Classes I-III (BMI 30.0+ kg/m\textsuperscript{2}).\textsuperscript{16} Smoking status was defined by a report of having smoked cigarettes regularly within the past year.
CT Evaluation of Anatomical Barriers:

Study participants were imaged with a MDCT scanner using methods that have been reported elsewhere\textsuperscript{17}, and the lumbar spinal structures were evaluated using eFilm Workstation (Version 2.0.0) software. The prevalence of ligamentum flavum (LF) calcification, interspinous ligament (ISL) calcification, spinous process (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 were 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 were evaluated in bone windows using precise alignment along the midsagittal plane, which was defined by a line connecting the mid-anterior vertebral margin with the spinous process. In situations where spinous process alignment was clearly asymmetric, the midsagittal plane was defined instead by a line connecting the mid-anterior vertebral margin with the base of the spinous process. Depth and width of posterior epidural fat was measured in soft tissue windows at each lumbar interspace in the midsagittal plane and axial planes, respectively. 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 ≤1 mm posterior epidural fat width in the axial plane, or essentially no epidural fat depth in the
The presence of fat density superficial to the LF in the midsagittal and axial planes was evaluated on CT scans in soft tissue windows.

Reliability of CT readings:

All CT scans were evaluated by a physician reader, who was trained by an interventional spine physician with experience in multiple prior research studies of lumbar spine CT imaging. An initial set of CTs were reviewed in order to develop a reading protocol for evaluation of the anatomical barriers described above, and to achieve consistency of evaluations between the two readers. Using this protocol, inter-rater reliability was calculated for two readers. After initial reliability was determined, reliability was reassessed late during the reading phase. Previously analyzed CTs were periodically reevaluated to “recalibrate” the readings to a standard throughout the reading phase. Inter-rater reliability assessed with the $\kappa$ statistic\cite{18} was 0.76 for LF calcification, 0.86 for IS ligament calcification, 0.84 for spinous process contact, 0.77 for absence of posterior epidural fat, and 0.82 for midline fat density superficial to the epidural space.

Statistical analysis:

The analytic approach was primarily descriptive. The sample was characterized using means and standard deviations for continuous variables, and frequencies and proportions for categorical variables. The prevalence of each anatomical impediment was calculated for each age group. To assess whether the prevalence of these anatomical impediments demonstrated significant differences by spinal level, the chi-square test was used. To assess whether the prevalence of these anatomical impediments increased with
age, the chi-square test for trend was used. All statistical analyses were performed using SAS software.
The study sample (n=333) included an even distribution of men and women in each age group (Table 1), with the majority of individuals over 60 years of age. Table 2 demonstrates the prevalence of different anatomical impediments by spinal level; these differences are also depicted graphically in Figure 1. 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 anatomical 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 anatomical impediments at one 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 over the age of 70, at one or more spinal levels. The prevalence of SP contact also increased substantially by age group, affecting only 9% of individuals with age <50, and 61% of individuals with age ≥ 70 (p=<0.0001). 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 having any anatomical impediment did increase by age group, the vast majority of individuals had at least one anatomical impediment due to the
higher percentage of individuals having absence of posterior epidural fat and presence of a midline fat density superficial to LF at one or more levels.

In analyses examining associations between other clinical factors and these five anatomical impediments, neither sex nor smoking status were associated with any anatomical impediment (data not shown). Higher BMI was significantly associated with a lower prevalence of the absence of posterior epidural fat: 57% for individuals with BMI <25, 53% for individuals with BMI 25-30, and 40% for individuals with BMI >30 (p=0.03). In other words, individuals with a higher BMI also had slightly more fat in the posterior epidural space. There were no other differences in anatomical impediments with respect to BMI (data not shown).
DISCUSSION

To our knowledge, there have been no studies to date that have characterized the prevalence of anatomical factors relevant to interlaminar LESIs in a community-based population. Our findings demonstrate that anatomical 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 anatomical 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-L5 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 anatomical impediments at and above the L4-L5 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 pre-test 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, often irrespective of whether or not fluoroscopy or epidurography is used. For example, the presence of ISL or LF calcification in the needle trajectory may cause increased resistance to needle advancement\textsuperscript{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 spinous processes 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\textsuperscript{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 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\textsuperscript{6}.

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. It must also be noted that these CTs were obtained while the patient was in a supine position. This fact 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.
Despite these limitations, our study demonstrates that anatomical impediments to LESI are common in this community-based population. Due to 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 anatomical impediments may contribute to inaccurate needle placement or increased technical difficulty when performed without fluoroscopy and epidurography, especially at the L5-S1 level.
Table 1. Descriptive Statistics of the Study Sample (n=333)

<table>
<thead>
<tr>
<th></th>
<th>N (%) or mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td></td>
</tr>
<tr>
<td>&lt;50</td>
<td>64 (19.2%)</td>
</tr>
<tr>
<td>50-60</td>
<td>75 (22.5%)</td>
</tr>
<tr>
<td>60-70</td>
<td>96 (28.8%)</td>
</tr>
<tr>
<td>≥ 70</td>
<td>98 (29.4%)</td>
</tr>
<tr>
<td><strong>Female sex</strong></td>
<td>156 (46.8%)</td>
</tr>
<tr>
<td><strong>Body mass index</strong> (BMI)</td>
<td>28.3 (5.0)</td>
</tr>
<tr>
<td><strong>Smoking</strong></td>
<td>37 (11.1%)</td>
</tr>
</tbody>
</table>

*height (meters)/weight² (kg²)
Table 2. Prevalence of anatomical impediments to LESI by spinal level

<table>
<thead>
<tr>
<th>Impediment</th>
<th>L2-L3</th>
<th>L3-L4</th>
<th>L4-L5</th>
<th>L5-S1</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LF calcification</td>
<td>17 (5.4%)</td>
<td>22 (6.7%)</td>
<td>18 (5.5%)</td>
<td>10 (3.0%)</td>
<td>0.15</td>
</tr>
<tr>
<td>ISL calcification</td>
<td>8 (2.5%)</td>
<td>9 (2.7%)</td>
<td>8 (2.4%)</td>
<td>10 (3.0%)</td>
<td>0.89</td>
</tr>
<tr>
<td>SP contact</td>
<td>26 (8.2%)</td>
<td>57 (17.2%)</td>
<td>71 (21.5%)</td>
<td>29 (8.8%)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Absence of posterior epidural fat</td>
<td>10 (3.2%)</td>
<td>17 (5.2%)</td>
<td>34 (10.4%)</td>
<td>208 (64.6%)</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>
| Presence of a midline fat density superfi
cial 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%) | <.0001  |

LESI = lumbar epidural steroid injection; LF = ligamentum flavum; ISL = interspinous ligament; SP = spinous process

Figure 1. Prevalence of anatomical barriers to LESI by spinal level

LESI = lumbar epidural steroid injection; LF = ligamentum flavum; ISL = interspinous ligament; SP = spinous process
Table 3. Prevalence of anatomical impediments to LESI by age group

<table>
<thead>
<tr>
<th></th>
<th>Age &lt;50</th>
<th>Age 50-60</th>
<th>Age 60-70</th>
<th>Age ≥ 70</th>
<th>p-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n=64</td>
<td>n=75</td>
<td>n=96</td>
<td>n=98</td>
<td></td>
</tr>
<tr>
<td>LF calcification</td>
<td>3 (4.7%)</td>
<td>9 (12%)</td>
<td>14 (14.6%)</td>
<td>17 (17.3%)</td>
<td>0.02</td>
</tr>
<tr>
<td>ISL calcification</td>
<td>0 (0%)</td>
<td>4 (5.3%)</td>
<td>7 (7.3%)</td>
<td>11 (11.2%)</td>
<td>0.005</td>
</tr>
<tr>
<td>SP contact</td>
<td>6 (9.4%)</td>
<td>12 (16%)</td>
<td>41 (42.7%)</td>
<td>60 (61.2%)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Absence of posterior epidural fat</td>
<td>29 (45.3%)</td>
<td>42 (56.0%)</td>
<td>49 (51.0%)</td>
<td>48 (49.0%)</td>
<td>0.94</td>
</tr>
<tr>
<td>Presence of a midline fat density</td>
<td>42 (65.6%)</td>
<td>48 (64%)</td>
<td>66 (68.8%)</td>
<td>71 (72.4%)</td>
<td>0.24</td>
</tr>
<tr>
<td>Any impediment (any of above)</td>
<td>50 (78.1%)</td>
<td>67 (89.3%)</td>
<td>91 (94.8%)</td>
<td>95 (96.9%)</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

LESI= lumbar epidural steroid injection; LF= ligamentum flavum; ISL=interspinous ligament; SP=spinous process
*for trend by age group
REFERENCES


