Contralateral Oblique View is Superior to Lateral View for Interlaminar Cervical and Cervicothoracic Epidural Access

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Abstract

Objective. The purpose of this study was to compare the reliability of the lateral fluoroscopic view and several contralateral oblique (CLO) views at different angles in visualizing and accurately predicting the position of the needle tip at the point of access in the posterior cervical and cervicothoracic epidural space.

Design. After the epidural space was accessed but before confirmation with contrast fluoroscopy, we prospectively obtained fluoroscopic images at eight different angles. Subsequent contrast injection confirmed epidural spread. Needle tip visualization and location of needle relative to bony landmarks were analyzed.

Results. The needle tip was clearly visualized in all CLO projections in all 24 subjects. CLO view at 50 degrees and at obliquity measured on magnetic resonance imaging (MRI) images provided the most consistent needle tip location. In these views, the epidural space was accessed at or just beyond the ventral laminar margin at the ventral interlaminar line or within the proximal half of the predefined CLO area in all patients. The needle tip was poorly visualized in the lateral view and the location of the needle tip was less well defined and independent of the needle location in the anteroposterior (AP) view.

Conclusions. This study provides evidence that during cervical and cervicothoracic epidural access, the CLO view at 50 degrees and at MRI-measured obliquity is superior to the lateral view for the purpose of needle tip visualization and in providing a consistent landmark for accessing the epidural space. This article also introduces the concept of zones to describe needle position in the cervical and cervicothoracic spine in AP, lateral, and oblique views.

Key Words. Epidural (Injection Space); Fluoroscopy

Introduction

The cervical and cervicothoracic epidural space is frequently accessed for therapeutic spine interventions such as an epidural steroid injection. Fluoroscopy is now commonly used in clinical practice with the premise that it improves safety. It is also likely to improve accuracy of needle placement [1]. Despite the introduction of imaging technology, epidural interventions are not without risk. In an American Society of Anesthesiologists closed claims analysis for cervical procedures from 2005 to 2008, there were 20 reported cases of direct spinal cord injury during interlaminar cervical epidural access [2]. In the same study, it was reported that fluoroscopy was employed in 76% of the procedures that were associated with injury. It is clear that major cord injuries continue to occur, even with the use of fluoroscopy.

Accurate and precise visualization of the needle tip is critical to avoid trauma to the spinal cord. The optimal use of fluoroscopy to meet this end has not been studied. Visualization of the needle tip in the lateral view in the lower cervical and cervicothoracic area is often impaired. Various maneuvers such as adjusting the fluoroscope, caudad manipulation of the shoulders, and the swimmer’s view have been suggested in order to improve the quality of needle tip imaging [3]. The clinical success of these manipulations has not been evaluated.
Any last-second patient manipulation with a needle so close to the spinal cord is not desirable.

In addition to the ability to accurately visualize the needle tip during epidural access, it is also critical to have a reliable radiological landmark to guide how far the needle can be safely inserted. Any view that attempts to look at the relationship of the needle tip with bony landmarks must be tangential to the curvature of the epidural space at that point. Given the circumferential nature of the epidural space, the lateral view is topographically inappropriate to visualize the position of the needle tip in the epidural space [4].

Given the limitations of the lateral view, the contralateral oblique (CLO) view has been advocated for epidural needle placement, but has not been rigorously studied. It is advocated because it lends to better visualization of the needle tip and provides a reliable radiographic landmark for the location of the posterior epidural space [4–10].

An image of a needle in epidural space with accompanying contrast spread appeared in a technical piece by Johnson et al. [5]. No further specifics were provided. Whitworth, in an observational study of 10 consecutive patients employing an angle of 30 degrees oblique from lateral view, reported successful entry into the epidural space at the posterior foraminal line [6]. In a letter to the editor, Vaisman observed that at 40 degrees CLO, the tip of the needle invariably overlaps the anterior aspect of the corresponding neural foramen [7]. In a technical report, Zhu et al. reported the use of this view for cervical spinal cord stimulator lead placement [8]. In this article, the obliquity was dependent upon the cross-sectional view of the lamina, and could range anywhere from 30 degrees to 60 degrees. Landers et al. discussed the theoretical basis for the use of the CLO view based upon cadaveric illustration and analysis of three cases drawn from clinical practice recommending an obliquity such that the superior articular process above and below the lamina are co-aligned (around 40 degrees from the lateral in most patients), and further stated that the needle not be advanced beyond the posterior foraminal line [4].

In summary, there is no consensus among these reports as to the angle to be used for the CLO view and as to a radiographic landmark for the posterior boundary of the epidural space. The variability in the angle ranges from 30 to 60 degrees and the location of the epidural space reported anywhere from the ventral laminar line to the anterior foraminal line.

The present study has five purposes: The first is to assess and compare the reliability of known radiological landmarks in accurately predicting the location of the needle tip at the point of accessing the posterior epidural space, in multiple CLO and lateral views. The second is to define the angles in CLO view that provide the least variability of needle tip location at the point of accessing the epidural space. The third is to analyze the relationship of the needle tip in lateral view to the needle location in the antero-posterior (AP) view. The fourth is to compare needle tip visibility in lateral vs CLO view at the point of entering the epidural space. The fifth is to introduce anatomical classification to describe the location of a needle in different fluoroscopic views during the performance of a cervical or cervicothoracic epidural steroid injection.

Materials and Methods

In this study, we evaluated needle position and visualization at several angles in images obtained by fluoroscopy in patients undergoing cervical and cervicothoracic epidural steroid injections. The study was approved by the institutional review board and conducted in an outpatient pain clinic of an academic medical center. The inclusion criteria for the study were adult patients who were undergoing therapeutic cervical or cervicothoracic epidural steroid injection with fluoroscopic guidance. Thus, standard exclusion criteria that apply to elective epidural steroid injections, such as pregnancy, were automatically enforced. Additional exclusions included nonavailability of magnetic resonance imaging (MRI) images pre-procedure, prior posterior cervical spine surgery, and hypersensitivity to contrast agent. The injections were performed under local anesthesia with occasional supplementation with nurse-administered sedation. The procedure was performed by either resident or fellow physicians under the supervision of one of the study investigators. The fluoroscopy unit employed was OEC 9900 Elite (OEC Medical Systems, Salt Lake City, UT, USA). Informed written consent to participate in the study was obtained from all study subjects. The patients were placed in the prone position with a pillow under the chest, and the neck was slightly flexed. The arms were tucked under the thighs so as to caudally displace the shoulders.

A 20-gauge Tuohy needle was used for interlaminar epidural access. The epidural space was accessed under fluoroscopic guidance and with loss of resistance to saline technique. There was no specific protocol regarding the views used for accessing the space. It is however the standard practice for all the investigators in this study to use the CLO view as the preferred view for accessing the epidural space. If the needle was deemed to be in the epidural space when loss occurred, then a true AP view was obtained. The fluoroscope and the bed were adjusted in order to obtain a true AP, and all oblique and lateral rotations were made based upon this as a zero-degree reference point. The needle was assigned a laterality by the attending physician, including nearly midline needles, based upon close observation.

Then, eight fluoroscopic views were obtained: AP, lateral, and CLO at 30 degrees, 40 degrees, 45 degrees, 50 degrees, the isointense angle, and the measured angle. The isointense angle was determined by the angulation at which the ventral and dorsal margins of the laminae were of equal radiographic intensity, thus theoretically representing true coaxial view through the lamina. The measured angle was determined by measuring the angle of the superior lamina with the midsagittal plane on MRI (Figure 1). Centricity PACS software (GE Healthcare, Barrington, IL, USA) was used to measure the angle in the following fashion. The angle was
among three reviewers (study investigators) determined with effort), or 3 (not visualized). The majority vote visualized without ambiguity), 2 (poorly visualized or visualized with effort), or 3 (not visualized). The majority vote among three reviewers (study investigators) determined the grade. Wilcoxon signed-rank test was used to compare the needle tip visualization in CLO view with the needle tip visualization in the lateral view.

In order to objectively describe and demarcate the final needle position in the AP, lateral, and oblique views, three zones were created for each view.

The AP view of the interlaminar space was divided into three zones. AP Zone 1 (APZ1) extends within the lateral margin of the spinous process from one side to the other. The area from the lateral margin of the spinous process to the lateral margin of the interlaminar opening measured at its maximum width was divided into two equal zones, AP Zone 2 (APZ2) medially and AP Zone 3 (APZ3) laterally (Figure 3). AP Zone X was lateral to APZ3.

In the oblique view, the area anterior to the ventral interlaminar line (VILL) and posterior to the line joining the uncinate processes (along ventral margin of the foramen) was equally divided into three zones. Oblique Zone 1 (OZ1) is far posterior, while Oblique Zone 3 (OZ3) is most anterior with Oblique Zone 2 (OZ2) lying in the middle (Figure 4). The area ventral to OZ3 represented Oblique Zone X.

In the lateral view, the area extending from spinolaminar line to the posterior articular pillar line was equally divided into Lateral Zone 1 (LZ1) and Lateral Zone 2 (LZ2) from posterior to anterior. Lateral Zone 3 (LZ3) extended from posterior articular pillar line to the posterior vertebral line (Figure 5). The region anterior to LZ3 represented Lateral Zone X.

The location of the needle or needle tip in each of the zones was determined by consensus among three investigators. In the oblique view for the needle tips that were seen in Zone 2 at CLO 50 and CLO measured, assessment was also made as to whether they lay in the proximal half or distal half of the entire CLO area (all three zones). At CLO 50 and CLO measured, the incidence of the needle tip laying on the VILL was analyzed. If less than half of the needle bevel jutted forward, then this was considered to be on the line. Spearman rank correlation coefficient was used to estimate the correlation between needle position in the AP and lateral views. The dispersion of the needle tip in lateral and oblique zones in all 24 patients was analyzed, and these data are presented in tabular form. Exact confidence intervals (CIs) for proportions were calculated for needle position for CLO 45, CLO 50, and CLO measured views based on the F distribution using the method of Brownlee. We used exact McNemar tests to compare the proportion of needles visualized in Zone 1 in CLO 45, CLO 50, and CLO measured.

The proportion of needles localizing to the two posterior zones at CLO 50 and lateral view was also compared using Fisher exact test. Reliability of co-alignment of the superior articular process with inferior lamina as predictive of the correct angle was also analyzed. Contrast spread patterns in the epidural space were also analyzed and these data will be presented separately.

**Figure 1** The 53-degree line is drawn parallel to the ventral margin of the lamina and represents the measured angle. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

The midpoint between the two articular pillars was located. A line was drawn from this point and to pass through the exact midline of the spinous process. In case of a bifold spinous process, the line was drawn through the middle of the bifid processes. A second line was drawn parallel to the lamina on the side the angle was being calculated. This line was drawn parallel to the lamina through the middle. If there were any discrepancy between the dorsal and ventral laminar angulation, then the line was drawn parallel to ventral laminar margin. The angle of intersection of the two lines was then measured by the Centricity software. At the time of data analysis, the anatomically correct angles from C5-6 to T1-T2 were measured. The angle of the superior lamina at the level of intervention was again independently measured to see if the original value would be reproducible. At the time of measurement, the investigator was blinded to the original value. The lateral view was optimized with fluoroscopic adjustments only, e.g., collimation, increase peak kilovoltage (kVP), height adjustment, or cephalocaudad motion; no position changes requiring patient motion were performed. The injection of contrast medium (Isovue-M 300, Bracco Diagnostics Inc, Princeton, NJ, USA) confirmed epidural spread in AP, multiple CLO, and lateral views. All of the images were electronically stored for analysis.

All of the views taken in each patient are presented in Figure 2.

**Data Analysis and Statistical Method**

The oblique and lateral images were analyzed for needle tip visualization subjectively graded as 1 (clearly visualized without ambiguity), 2 (poorly visualized or visualized with effort), or 3 (not visualized). The majority vote among three reviewers (study investigators) determined the grade. Wilcoxon signed-rank test was used to compare the needle tip visualization in CLO view with the needle tip visualization in the lateral view.

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The proportion of needles localizing to the two posterior zones at CLO 50 and lateral view was also compared using Fisher exact test. Reliability of co-alignment of the superior articular process with inferior lamina as predictive of the correct angle was also analyzed. Contrast spread patterns in the epidural space were also analyzed and these data will be presented separately.
The thickness of the ligamentum flavum (LF) at the level of intervention was also measured in all subjects employing the axial cut on pre-procedure T2-weighted MRI image. LF thickness was measured at its widest, anterior to the lamina, at the axial cut where the spinous process was visualized along with the lamina (Figure 6). The measured angle was obtained from MRI for all available spinal levels extending from C5 to T1 bilaterally, and the data are presented in tabular form. The width of the neural foramen visualized by the CLO view was measured on the corresponding T2-weighted axial cuts of the cervical spine MRI. The axial cut with maximal foraminal width was measured at its narrowest span from the uncinate process to the superior articular process (Figure 6). The width of the zones was calculated as explained in Figure 7.

**Results**

A total of 27 subjects were recruited for the study. Of these, three subjects were excluded. One patient had vasovagal symptoms and the injection was not completed. The second patient could not lie down in the prone position and the injection was not initiated. The third patient could not remain still for the additional necessary images required for the study and these could not be obtained.

**Patient Demographics**

There were 15 men and 9 women in the study. The age range was from 36 to 76 years of age with a mean of
Three of the twenty-four subjects cervical spine surgery. Nine injections were performed at C6-7 and 15 injections at C7-T1.

Accuracy of Needle Tip Placement in the Epidural Space

Accuracy of needle tip placement in the epidural space was 100% as confirmed by the contrast spread pattern on lateral and multiple oblique projections. The post-contrast study images were reviewed by the three study investigators, and there was unanimous agreement for epidural spread of contrast.

Needle Tip Visualization

The data for needle tip visualization are presented in Table 1. As is apparent from this table, the needle tip at C7-T1 was poorly visualized in majority of the patients and not visualized in 4/15. At C6-7, the tip was visualized in all cases but visualization remained poor in a third. In contrast, the needle tip was well visualized in all subjects in all CLO projections. By the Wilcoxon signed-rank test to compare needle tip visualization in the CLO view to the lateral view, the CLO view proved to be superior with \( P \) value < 0.0001.

Needle Location in the Lateral View (Table 2)

The data for needle location in the lateral view as a function of where the needle was placed in AP view are presented in Table 2. Most needles were placed in APZ1 or APZ2. The needles were seen to localize to all three lateral zones. The Spearman rank correlation coefficient for the 20 needle tips that were visualized was calculated to be 0.19, \( P \) value 0.42, hence suggesting very weak to negligible correlation.

Needle Location in the CLO View (Table 3)

The distribution of the needle tip position in the three oblique zones is presented as a function of the angle of obliquity (from AP) used to visualize the needle tip. It is clear that with increasing angle of obliquity, the needle tip appears to move posteriorly from OZ3 to OZ1. Thus, at 30 degrees, most of the tips appeared to lie in OZ3, whereas at 50 degrees 20/24 were visualized in OZ1. Using the measured angle, 22/24 needle tips were seen to lie in OZ1. The probability of needle tip localizing to OZ1 at CLO 50 was 83% (95% CI 63–95%). The probability of needle tip localizing to OZ1 at CLO measured was 92% (95% CI 73–99%). By McNemar tests, there was no statistically significant difference in needle tip location in OZ1 between CLO 50 and CLO measured with \( P \) value of 0.5. The probability of needle tip localizing to OZ1 at CLO 45 was 38% (95% CI 19–59%). By McNemar tests, there was statistically significant difference in needle tip location in OZ1 between CLO 50 and CLO 45 with \( P \) value of 0.001, and \( P \) value for statistical difference between CLO 45 and CLO measured was 0.001. The needle tip is in Zone 2.
0.0002. All needles that were seen to lie in OZ2 at CLO 50 and CLO measured were midline needles in AP view. All needles that were seen in OZ2 at CLO 50 and CLO measured were within the proximal half of the entire CLO area. At CLO 50, the needle tip was on the VILL in 11/24 patients. At CLO measured, the needle tip was on the VILL in 14/24 patients.

The laminar cross-sectional view and the VILL were poorly visualized in several patients at CLO 30 (Figure 8), but well outlined in all patients in the more oblique CLO projections. The relationship of the CLO isointense to the needle tip location in the oblique zone was not further studied because of the subjectivity of the angle as the isointense appearance could be seen at multiple angles (Figure 2). The superior articular process (SAP) was also co-aligned or ventrally projecting beyond the lamina in multiple oblique projections and lacked objectivity (Figure 2).

Comparison of Needle Tip Location in CLO 50, CLO Measured, and the Lateral View

The number of needle tips localizing to the two posterior most zones was 24/24 for the CLO 50 and CLO measured view, and 13/24 for the lateral view. By Fisher’s exact test, this was statistically significant with a P value of 0.0002.

Angle of the Lamina and LF Thickness at the Point of Intervention (Table 4)

The mean CLO angle measured from C5-C6 to T1-T2 ranged from 52 degrees to 55 degrees. The mean CLO measured used at C6-7 was 53 degrees with range from 48 degrees to 56 degrees. The mean CLO measured used at C7-T1 was 52 degrees with range from 50 degrees to 57 degrees. There were no major disparities between the right and the left side or between the levels. Repeat measurements of CLO measured varied less than 5 degrees from the originally measured values.

The average thickness of LF at the level of intervention was 1.85 mm. The median was 1.8 mm and the range was 1.2 mm to 3 mm. The data are also presented in Table 4. There was no correlation found between LF thickness and the needle tip. Thus, for three of the four needle tips seen to lie in Zone 2 at CLO 50, the corresponding LF thickness was less than the mean and was 2 mm in the fourth.

Width of the CLO Zones

The mean foramen size was 6.36 mm at C7-T1 and 5.8 mm at C6-C7. Using the foramen to oblique zone ratio on fluoroscopy, we calculated the mean size of CLO 50 and CLO measured oblique zones for each subject. No difference was found in mean zone width between these two CLO projections. Each oblique zone

Figure 5 In the lateral view, the area extending from spinolaminar line to the posterior articular pillar line was divided into Zone 1 and Zone 2 from posterior to anterior. Zone 3 extended from posterio articular pillar line to the posterior vertebral line. Zone X is anterior to Zone 3. The needle is at the junction of Zone 1 and 2.

Figure 6 C7 vertebral level axial T2-weighted scan. Ligamentum flavum measured anterior to lamina at the level where spinous process is visible. Arrow A points to where the foramen size was measured.
The foramen width was averaged 2.26 mm wide with a range from 1.67 mm to 3.3 mm. In 14/24 patients, the foramen was equal to the size of three zones combined, and in the remaining cases the foramen was smaller.

### Discussion

This was a pilot study to analyze the position of the needle tip at the point when it accesses the posterior cervical and cervicothoracic epidural space. The needle tip was visualized in lateral and multiple CLO projections. In addition to needle tip position, the clarity of visualization of the tip was also analyzed in lateral and multiple CLO projections. Given the pilot nature of the study and extra radiation exposure to the study subjects, the sample size was restricted by the institutional review board. However, the results of the study provide clinically meaningful answers as to the position of the needle tip placed in the posterior epidural space when visualized in different views. The study also attempts to answer the question as to what views and angles provide the highest degree of consistency in the location of the needle tip at the point of accessing the epidural space. The number of times the needle tip was not well visualized or not visualized at all in the lateral view is concerning. The lack of correlation

### Table 1

<table>
<thead>
<tr>
<th>Needle Tip Visualization</th>
<th>Grade 1</th>
<th>Grade 2</th>
<th>Grade 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>C6-7</td>
<td>6</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>C7-T1</td>
<td>2</td>
<td>9</td>
<td>4</td>
</tr>
</tbody>
</table>

The clarity of the needle tip was subjectively graded as 1 (clearly visualized without ambiguity), 2 (poorly visualized or visualized with effort), or 3 (not visualized). The majority vote among three reviewers (study investigators) determined the grade.

### Table 2

The locations of needle tips in lateral zones are depicted for each AP zone

<table>
<thead>
<tr>
<th>AP Zone 1 (N = 9)</th>
<th>AP Zone 2 (N = 13)</th>
<th>AP Zone 3 (N = 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral zone 12</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Lateral zone 24</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Lateral zone 32</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Not visualized</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

AP = anteroposterior view.

### Table 3

The number of needles in each oblique zone as a function of the angle of obliquity

<table>
<thead>
<tr>
<th>Oblique zone</th>
<th>30°</th>
<th>40°</th>
<th>45°</th>
<th>50°</th>
<th>Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oblique zone 1</td>
<td>0</td>
<td>3</td>
<td>9</td>
<td>20</td>
<td>22</td>
</tr>
<tr>
<td>Oblique zone 2</td>
<td>3</td>
<td>10</td>
<td>10</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Oblique zone 3</td>
<td>20</td>
<td>10</td>
<td>5</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Oblique zone x</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>VILL*</td>
<td>11</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Needle tips located at the ventral interlaminar line (VILL) was analyzed only for 50 degrees and the measured angle view.
between needle position in the AP and lateral zones in this sample size was also surprising.

Poor fluoroscopic imaging of the needle tip in lower cervical and cervicothoracic level is well described [3]. This technical limitation may contribute to spinal cord injuries following interlaminar epidural needle insertion. No prior study has attempted to quantify the incidence of this technical shortcoming. In this study, at C7-T1 level, the needle tip was not visualized in nearly a fourth of the cases and was clearly visualized in only 2/15 of the cases. An important point is that the aforementioned incidences of poor needle tip visualization were determined in the absence of patient manipulation. Methods used for optimizing the view in lateral projection included fluoroscope repositioning (excluding altering obliquity or tilting) as well as collimation and deployment of higher kVP. The other adjustments could have included attempts to pull the arms down to decrease the impact of the shoulders and the swimmer’s view as well as real-time tilting and rotating the C arm. If these methods had been employed, then it is possible that the visualization of the needle tip may have improved. It is however important to keep in mind that these maneuvers are suboptimal. Specifically, it is preferable that patient motion be minimized with a needle so close to the spinal cord. Additionally, a true lateral image is likely to be compromised when excessive C arm tilting and rotation are performed. In contrast to the dismal needle tip visualization in the lateral view, the CLO view provided a crisp image of the needle tip at all angles in all patients. Based upon the results of this study, it can be stated that lateral view is often inadequate and cannot be relied upon in providing good needle tip visualization whereas the CLO view provides consistently good needle tip visualization.

The breaching of the spinolaminar line marks the potential beginning for a change in tissue impedance and therefore a “loss of resistance” may follow. It is anticipated that with a midline needle, the epidural space will be accessed just ventral to the spinolaminar line in LZ1, and with a laterally placed needle, the epidural space would be accessed slightly deeper, just posterior to the articular pillar line in LZ2. Lastly, the epidural needle inserted far lateral in APZ3 would translate to LZ3. In this study, this assumption did not hold true and we found that the needle tip position in lateral view had very weak or negligible correlation with the needle position in the AP zone.

There are several possible explanations for the lack of correlation of the needle tip location in lateral view to the zone of insertion in the AP view. The epidural space is slightly anterior to the spinolaminar line to account for the thickness of the LF, which is attached to the ventral part of the lamina. Hence, the epidural space is most likely to be accessed in LZ2 even when inserted in APZ1. The epidural space is at its widest in the midline not tightly bounded by the dura mater, allowing the needle to have some anterior mobility. Just a few millimeters of motion can make the needle appear significantly deep. The AP distance from the base of the spinous process to the posterior articular pillar line depends on the angle of the lamina and may be as small as few millimeters. The third and very important reason is the difficulty in visualizing the needle tip and its relationship with the bony landmarks in the lower cervical and upper thoracic area. As a result of poor visualization of both the bony landmarks and the needle tip, a true assessment of the relationship of these can be challenging. In addition, a true lateral view can also be difficult to obtain at these levels. These factors in various combinations result in the lack of reliable prediction of the needle tip location in the lateral view based on the AP needle zone insertion. Given the results of this study, even if a larger study were to reveal an association for needle position between the AP zone and the lateral zone, it is unlikely that this association would be so strong that it could be clinically relied upon. Hence, loss of resistance should be started at the spinolaminar line or earlier if the spinolaminar line is not visualized with the knowledge that the loss may occur anywhere from the spinolaminar line to beyond the posterior articular pillar line irrespective of the AP zone insertion.

Because we describe the CLO area, an important point to discuss is the reliability of the width calculation of this area. The CLO width at CLO 50 and CLO measured

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**Figure 8** Lamina is not well-formed and ventral interlaminar line (VILL) not clearly visualized in this patient at 30 degrees. Dotted lines showing margins of lamina are incomplete.
### Table 4  
Angle of the lamina with the sagittal plane at different levels, ligamentum flavum size, and the size of the ipsilateral foramen at the level of intervention

<table>
<thead>
<tr>
<th>Patient</th>
<th>C5-C6 (R)</th>
<th>C5-C6 (L)</th>
<th>C6-C7 (R)</th>
<th>C6-C7 (L)</th>
<th>C7-T1 (R)</th>
<th>C7-T1 (L)</th>
<th>T1-T2 (R)</th>
<th>T1-T2 (L)</th>
<th>Angle Used</th>
<th>LF*</th>
<th>Foramen†</th>
<th>Zone Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50</td>
<td>50</td>
<td>51</td>
<td>48</td>
<td>50#</td>
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*Ligamentum flavum was measured at the level of intervention in axial T2-weighted cuts (Figure 6).
†Ipsilateral foramen size was measured from base of superior articular process (SAP) to uncinate process at the level of intervention on the visualized side (Figure 6).
‡Patients where needle transgressed into Zone 2 at 50 degrees.
§Patients where needle transgressed into Zone 2 at measured angle.
#Level and side used for each case are marked.
L = left; R = right.
was found to be comparable. Even though we did not have the ability to directly measure the width of the oblique zone on the fluoroscopic image given lack of scale, the indirect method used by us should provide a reliable estimate for the following reasons. We measured foramen width on MRI and assumed that the foramen width at CLO measured is the same. From the foramen width, we calculated the total CLO width as described in Figure 7. Our results of the foramen width on the MRI measurement are in close agreement with what has previously been described by computed tomography (CT) measurements [11]. Additionally, an angle of 52 degrees has been shown to be an appropriate obliquity to look at the foraminal area, and the foramen size on X-ray images has been shown to match well with foramen size measured on CT [11,12]. Hence, our method should provide a fairly reliable estimate of the actual width of the CLO area.

The needle tip in the CLO view was visualized at multiple angles in order to identify the angle that provided the most posterior and consistent location for needle tip position. The epidural space was not accessed before the VILL in any patient in any CLO view. The measured angle approach provided the most posterior and most consistent location for the needle tip at the point where the epidural space was accessed. The mean measured angle was 53 degrees at C6-C7 and 52 degrees at C7-T1. We tried to minimize the subjectivity in this regard by using electronic software and defining a specific method for measurement of the angle. Repeat measurements were within 5 degrees of the original measurement. Furthermore, our results are consistent with what has been previously shown—a mean of 52 degrees has previously been shown to be an appropriate angle of obliquity to measure the foraminal size in a cervical radiograph [12]. A full view of the foramen will only be obtained if the fluoroscope is parallel to the lamina and the foramen (Figure 1). At this angle, the needle tips lay mostly in OZ1. At measured angle, the probability of needle localization in the most posterior zone was 22/24 or 92% (95% CI 73–99%). The results at 50 degrees were statistically similar with this sample size with 20/24 needles in OZ1, giving the probability of needle location to the posterior most zone at 83% (95% CI 63–95%). In both CLO 50 and CLO measured, the needle tip lay in the two most posterior zones in 24/24 subjects and none of the needle tips traversed more than 50% of the CLO area. All needles that were seen to lie in Zone 2 at CLO 50 and CLO measured were midline needles, and this is well explained on the basis of Figure 9. In the midline, the epidural space is the widest in AP dimension as opposed to the paramedian epidural space, which is tightly bounded anteriorly by the diameter (Figure 6). A midline needle can therefore have some forward motion when the space is accessed, but the
paramedian needle is restricted from any forward motion by the dura mater. Geometrically, a midline needle that traverses the AP length of the epidural space will appear in Zone 2 (Figure 9). Furthermore, slightest deviation of the needle tip to the ipsilateral site immediately makes the needle tip look anterior (Figure 9).

The maximum angle of obliquity that we chose to test was 50 degrees. Fifty degrees is very close to the angle of the lamina with the sagittal plane and also close to the maximal obliquity that most full-size fluoroscopy units can provide in both directions. To investigate angles with greater obliquity, we chose to use CLO measured to look straight through the ventral margin of the lamina and get a true assessment of the needle depth beyond the bone in each subject. As expected, the results for 50 degrees are very close to the results for CLO measured. The question arises as to whether further obliquity would have localized all needle tips to Zone 1 oblique. We think that this is unlikely as two needle tips lay in Zone 2 at CLO measured of 54 and 56 degrees (Table 4). Increasing obliquity further can overestimate the depth of the lamina and consequently the epidural space can be accessed before Zone 1 oblique, seriously undermining the utility of this view. This phenomenon is illustrated in Figure 10.

With decreasing angle of obliquity, needle tip appeared to move anteriorly from predominantly OZ1 at 50 degrees to OZ3 at 30 degrees as explained in Figures 9 and 11. Additionally, with decreasing angle of obliquity, the line of view starts going through the lamina rather than parallel to it (Figure 11). This line therefore also cuts through the part of foramen and the end result is that the CLO width decreases, and hence the needle seems to penetrate a greater proportion of the CLO area ending up in Zone 3 at 30 degrees. In addition to anterior location of the needle tip at CLO 30, this view also failed to provide consistently good visualization of the dorsal and ventral laminar margins or the VILL (Figure 8). When using this view, loss of resistance should be started just before the VILL but expected anteriorly in Zone 3 oblique. At CLO 45, needle tips continued to span all three zones with only 9/24 needles tips restricted to the posterior most zone and this was statistically significant, different from CLO 50.

Loss of resistance occurred at the VILL in 11/24 subjects at CLO 50 and in 14/24 subjects at CLO measured. This raises the question of how to account for the intervening thickness of the LF. This may be accounted for by the fact that LF has elastic properties and has variable thickness as well as a posterior angulation going superior to inferior. Furthermore, LF may be discontinuous or absent in places [13]. We did not see any correlation between LF size and the needle position in the CLO views. This is because LF thickness demonstrated minimal intersubject variability and was not significant enough to create meaningful difference in needle location.

Figure 10 Diagrammatic axial representation of contralateral oblique (CLO) 60 (the angle of lamina is 53 degrees): the ventral line is drawn connecting the uncinate process to the midsagittal line at 60 degrees. Dorsal line is drawn at 7 degrees to the ventral margin of the lamina. Note midline needles will be in Zone 1, but this also raises the possibility of accessing the epidural space before the ventral margin of the lamina as the true depth of the lamina is now overestimated—this is reverse of what is seen at CLO 30 and can seriously undermine the utility of this technique.
Taken together, it can be stated that at CLO 50 and CLO measured, the epidural space is never accessed before the ventral margin of the lamina or the VILL, and that the loss may occur right on the line or within 1–3 mm (when needle motion is perpendicular to line of view) thereafter in most patients. In the CLO 50 and CLO measured view, the midline needles can appear deeper than the laterally placed needles. Whereas the CLO view at these angles does provide greater consistency in location, it is not accurate enough, hence needle should never be advanced beyond VILL without testing for loss of resistance.

Limitations of this study are that this is a pilot study with a small number of patients and these results must be interpreted in this context. Given the angle of the lamina and the geometry presented in Figure 9, the possibility of accessing the space before the VILL when employing CLO 50 (very close to measured angle) is minimal to none. A larger study could show greater dispersion of the needle tips and that some needle tips enter Zone 3 in oblique view at CLO 50 and CLO measured. In this study, however, none of the needle tips were seen in Zone 3 oblique. A larger study could also show that there is in fact a consistency in where the needle tip is placed in the AP view and where it is seen in the lateral view. It is however unlikely that this relationship would be so strong as to be clinically relied upon. A study that capitalizes on all interventions to improve the quality of lateral view could show that the needle tip is well visualized in the lateral view, but this visualization would still likely be inferior to needle tip visualization in the CLO view.

**Conclusion**

This study shows that the CLO view provides excellent visualization of the needle tip during cervical and cervicothoracic epidural access. The CLO view at 50 degrees and at MRI-measured obliquity provides the most consistent and most posterior position of the needle tip at the point where the epidural space is accessed. In this regard, the
measured angle approach provided the highest consistency but this was not statistically different from that provided by CLO 50. When using these angles of view, most needle tips will be localized to the VILL or to the posterior third of the CLO width (OZ1). Some midline-placed needle tips may, however, extend into the middle third of the CLO area (OZ2), but remain in the posterior half. CLO views at 45, 40, and 30 degrees provide lesser consistency and progressively anterior needle tip position and may be used as needed while keeping these limitations in mind. One advantage of this approach is that the epidural space is not accessed until the VILL is reached, hence allowing needle advancement up to just before the VILL before checking for loss of resistance. This may decrease the risk of false loss of resistance. Secondly, the combination of a more reliably predicted epidural space at or within a few millimeters of the VILL and a clearly visualized needle tip may decrease risk of dural puncture and spinal cord injury. The accuracy of this view is, however, not sufficient enough to place the needle directly at the target, and loss of resistance started before the VILL remains the critical element of the performance of an epidural steroid injection.

The lateral view is less consistent in terms of the position of the needle at the point where the epidural space is accessed and needle tip can lie anywhere from the spinolaminar line to beyond the posterior articular pillar line. Additionally, the needle tip is poorly visualized and may not be visualized at all at C7-T1 level.

This study suggests that CLO view should replace the lateral view as the view of choice for cervical and cervicothoracic epidural access. The lateral view is however important backup view to the CLO view when secondary confirmation is needed and should be used with an understanding of its limitations. A good understanding of all three views is important in the performance of a cervical epidural steroid injection. Furthermore, we propose nomenclature for describing the needle location in different views, which is a useful tool for objective communication between providers. Further work needs to be done to validate the use of the zones described in this article.

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References