Observational Study

Evaluation of Contralateral Oblique and Lateral Views for Mid-Thoracic Epidural Access: A Prospective Observational Study

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Disclaimer: This work was presented in part as D-H Kim's PhD dissertation at the University of Ulsan College of Medicine (2021). There was no external funding in the preparation of this manuscript.

Conflict of interest: Each author certifies that he or she, or a member of his or her immediate family, has no commercial association (i.e., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted manuscript.

Manuscript received: 08-03-2020 Accepted for publication: 08-21-2020

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Background: The mid-thoracic region has been known to be the most difficult area when accessing epidural space despite using fluoroscopy. Contralateral oblique (CLO) view has been considered for use; however, it has not been evaluated in the mid-thoracic region.

Objective: To evaluate the CLO view for mid-thoracic epidural access (TEA).

Study Design: A prospective observational study.

Setting: The study took place at a single pain clinic within a tertiary medical center in Seoul, Republic of Korea.

Methods: A total of 30 patients participated in this study. After securing the mid-thoracic (T4–8) epidural space, fluoroscopic images were obtained. The needle tip location relative to the ventral interlaminar line (VILL), and the needle tip and laminar visualization were measured and analyzed on the CLO views at 40, 50, 60 degrees, and measured angle, and the lateral view.

Results: The needle tip was clearly visualized in all CLO views, compared with the lateral view (100% vs. 36.7%, $P < 0.001$). The visualization of the laminar margin and the needle tip location on (or just anterior to) VILL using the CLO measured angle were significantly clearer compared with those in the CLO view at 40 and 50 degrees and the lateral view (laminar margin: 40˚, 56.7% vs. 3.3%, $P < 0.001$; 50˚, 56.7% vs. 26.7%, $P = 0.012$; 90˚, 56.7% vs. 26.7%, $P = 0.035$; needle tip location: 40˚, 96.7% vs. 26.7%, $P < 0.001$; 50˚, 96.7% vs. 63.3%, $P = 0.002$; 90˚, 96.7% vs. 66.7%, $P = 0.012$). There was no difference in these values between the CLO view at 60 degrees and CLO measured angle.

Limitations: Subjective and ambiguous criteria of evaluation may induce bias despite final measured values based on the consensus of an independent investigator.

Conclusion: A CLO view at 60 degrees and CLO measured angle view can provide clearer visualization and more consistent needle tip location than the lateral and other CLO angle views for mid-TEA. A CLO view at 60 degrees and CLO measured angle views could be used to identify the needle location and achieve success in mid-TEA.

Key word: Chronic pain, contralateral oblique view, fluoroscopy, lateral view, mid-thoracic, pain management, epidural analgesia, ventral interlaminar line

Trial registration number: NCT03789955

Pain Physician 2021: 24:E51-E59

A thoracic epidural access (TEA) including epidural block, blood patch, or catheter insertion has been a widely used intervention to reduce chronic pain or acute postoperative pain after chest and upper abdominal surgery (1-3). Accuracy in TEA is needed in order to achieve success in these procedures (4). However, TEA is known to be relatively difficult, compared with cervical or lumbar epidural

access, as the spinous process of the thoracic vertebrae is longer and steeper, the epidural space is smaller due to an acute angle, and the distance between the skin and the epidural space is longer (5). These properties are more prominent in the mid-thoracic region (T4-8) (6,7). According to the evidence available, failure rates of TEA can be up to 32%, which increase at the mid-thoracic region (4,8). Previous studies have demonstrated that the mid-thoracic region is the most difficult area from which to approach the epidural space (6,9).

Although the use of fluoroscopy improves accuracy of TEA (10), this technique still has significant drawbacks, such as false loss of resistance (LOR) and difficulty in assessing the depth of the needle tip in lateral views in relation to the epidural space (11). To overcome this issue, TEA using the contralateral oblique (CLO) view was introduced (12).

The CLO is the angle in which the x-ray beam runs parallel to the slope of the target lamina. It can be obtained by first identifying the target lamina to which the needle tip is related and then focusing the image intensifier away in an oblique contralateral direction from the lamina (13). The advantages and optimal angle of CLO view in the cervical or lumbar have been systematically and specifically studied (14-17); however, the use of the CLO view in the mid-thoracic region has not yet been investigated. Therefore, this study was designed to compare needle tip and lamina visualization in the lateral fluoroscopic view with several CLO views at different angles when accessing the mid-thoracic epidural space. In addition, we investigated the optimal angles in the CLO fluoroscopic view to identify the most reliable needle tip location to access the mid-thoracic epidural space.

Methods

Study Design and Patients

This prospective observational study was conducted at the Asan Medical Center, University of Ulsan College of Medicine, Seoul, Korea from February 2019 to November 2019. This study was approved by the institutional review board of the Asan Medical Center (2018-1551) and was registered at ClinicalTrials.gov (number of registration: NCT03789955) on December 31, 2018. Patients were enrolled from February 22, 2019 to November 7, 2019. Written informed consent was obtained from each participant before inclusion in this study. All patients scheduled for mid-thoracic (T4-T8) epidural block, blood patch, and catheter insertion were assessed for eligibility. Patients were included if they were aged 20–79 years and available for thoracic magnetic resonance imaging (MRI) or computed tomography (CT). Patients were excluded if they had an allergy to local anesthetics and contrast dye or steroids, infection at the insertion site, neurological or psychiatric disorders, or prior spine instrumentation. Patients who were pregnant, had coagulopathy, or had used anticoagulants or antiplatelet medication, were also excluded.

TEA Protocol

No sedatives were administered before the intervention. Patients were placed on an operating table with a pillow to optimize prone positioning and were monitored with noninvasive blood pressure, pulse oximetry, and 3-lead electrocardiogram. Fluoroscopy (Ziehm Vision RFD, Ziehm, Nuremburg, Germany) was employed to identify the thoracic vertebrae level. An insertion site ranging from T4 to T8 was selected and sterilized. According to a previous study, the needle entry point was determined to be at the junction between the midline of the pedicle paralleled to the midline of the inferior vertebral body (IVB) to the target interlaminar space and the lower border of IVB on an anteroposterior (AP) fluoroscopic view (6). The AP fluoroscopic view was set to line up with the plane of the lower endplate of IVB. A 22-gauge Tuohy needle (Green Medical Supply Co., Seoul, Korea) or 18-gauge Tuohy needle (Perifix, B. Braun Melsungen AG, Melsungen, Germany) was used to access the epidural space. After local infiltration with 1% lidocaine, the Tuohy needle was advanced with an angle of approximately 10–15 degrees medially until it reached halfway through the vertebrae body. Then, fluoroscopy was used to obtain the CLO measured angle and it was subsequently advanced further until it was in the epidural space using a LOR-to-air technique. The CLO measured angle was previously determined by measuring the angle of the superior lamina with the midsagittal plane on MRI or CT before the procedure. Picture archiving and communication system (PACS) in Asan Medical Center (PetaVision, version 3.1, Seoul, Korea) was used to measure the angle on the axial image at the cut where the lamina, pedicle, and the spinous process were well visualized. Based on the midpoint between the 2 pedicles, a first line was drawn from this point, to pass through the exact midline of the spinous process. A second line was drawn parallel to the ventral lamina through the middle. Subsequently, the angle between the 2 lines was calculated. Once LOR was achieved, 6 fluoroscopic views were obtained: AP, CLO at 40 degrees, 50 degrees, 60 degrees, the measured angle, and

lateral views (Fig. 1). Correct epidural access was confirmed by the injection of contrast medium (Omnipaque 300, GE Healthcare, Little Chalfont, UK) in AP, multiple CLO views, and lateral views (Fig. 1). The procedure was performed by 2 physicians with more than 10 years of experience in TEA following identical protocols.

Fluoroscopic Finding Review and Outcome Measurement

All fluoroscopic images obtained were reviewed by 3 investigators who did not participate in the procedure. In the CLO and lateral views, each grade and location of the needle tip and laminar visualization were defined from prior studies with some modifications (14,15). Needle tip visualization was categorized as Grade 1 (clearly visualized without ambiguity), Grade 2 (poorly visualized or visualized with effort), or Grade 3 (indicated nearly not or not visualized). Laminar margin visualization was also categorized as Grade 1 (clearly visualized with complete demarcated laminar), Grade 2 (fairly visualized with incomplete demarcated laminar), Grade 3 (poorly visualized with incomplete demarcated laminar), or Grade 4 (nearly not or not visualized with incomplete demarcated lamina) (Fig. 2). The ventral

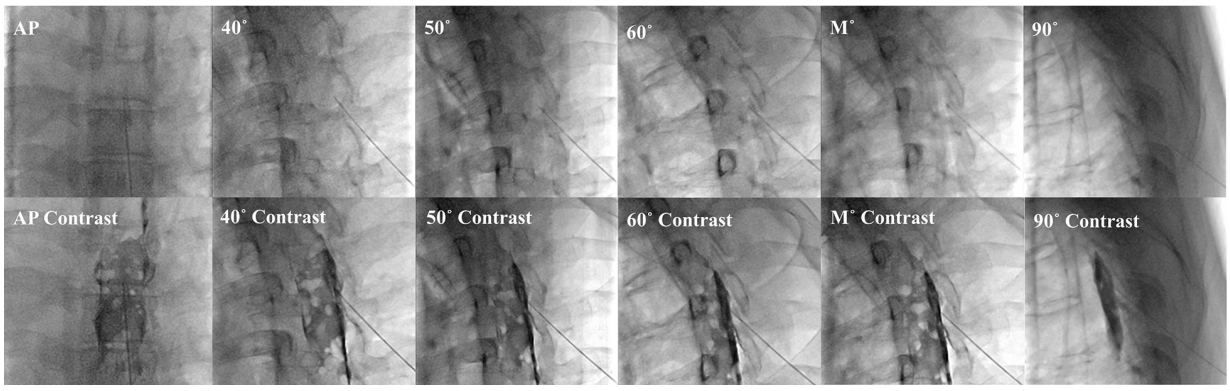

Fig. 1. *After accessing the mid-thoracic epidural space, 12 images were obtained at 6 different angles before and after the contrast medium injection. AP: anteroposterior view; 40°, 50°, and 60°: each angle of the CLO view; M°: measured angle of the CLO view; 90°: lateral view; AP–90°: AP, multiple angles of CLO view, and lateral view after contrast medium administration.*

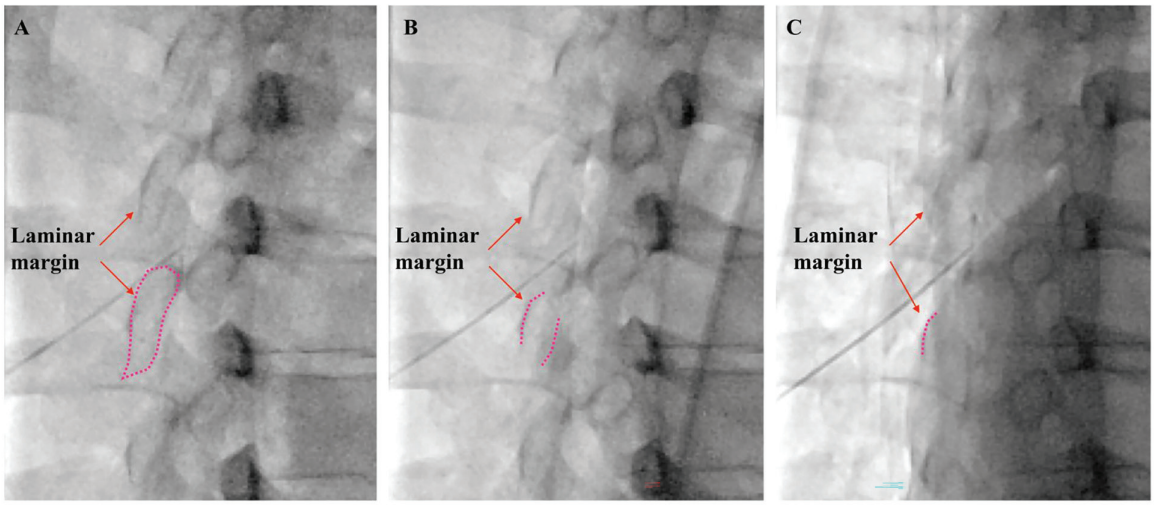

Fig. 2. *Grades of visualization of the laminar margins in the CLO view. A: Grade 1, clearly visualized with complete demarcated lamina; B: Grade 2, fairly visualized with incomplete demarcated lamina; C: Grade 3, poorly visualized with incomplete demarcated lamina.*

interlaminar line (VILL) refers to an imaginary line connecting the ventral laminar margins. Location of the needle tip in the CLO and lateral views was defined as: Grade -2 (significantly posterior to VILL), Grade -1 (just posterior to VILL), Grade 0 (on VILL), Grade 1 (just anterior to VILL), Grade 2 (significantly anterior to VILL), and Grade U (undetermined grade; needle tip location was not able to be evaluated due to lack of visualization) (Fig. 3). A grade of visualization and location of needle tip, and laminar visualization were determined by consensus among 3 investigators.

Statistical Analysis

The sample size was based on a previous study and limited to reduce radiation exposure of patients (14). Data are expressed as mean ± standard deviation, median (interquartile range), and number (proportion), as appropriate. The McNemar test was used to compare the needle tip size and lamina visualization, and needle tip location in the multiple CLO views and lateral view. Multiple groups were divided into Grade 1 and other grades (e.g., Grade 1 vs. Grade 2 plus Grade 3). We considered the location of the needle tip on the VILL or just anterior to the VILL to be ideal for safe and structured TEA. Hence, in the analysis of needle tip location, we compared Grade 0 plus Grade 1 and other grades (Grade -2, -1, 2, and U). Statistical significance was set at a P value of < 0.05.

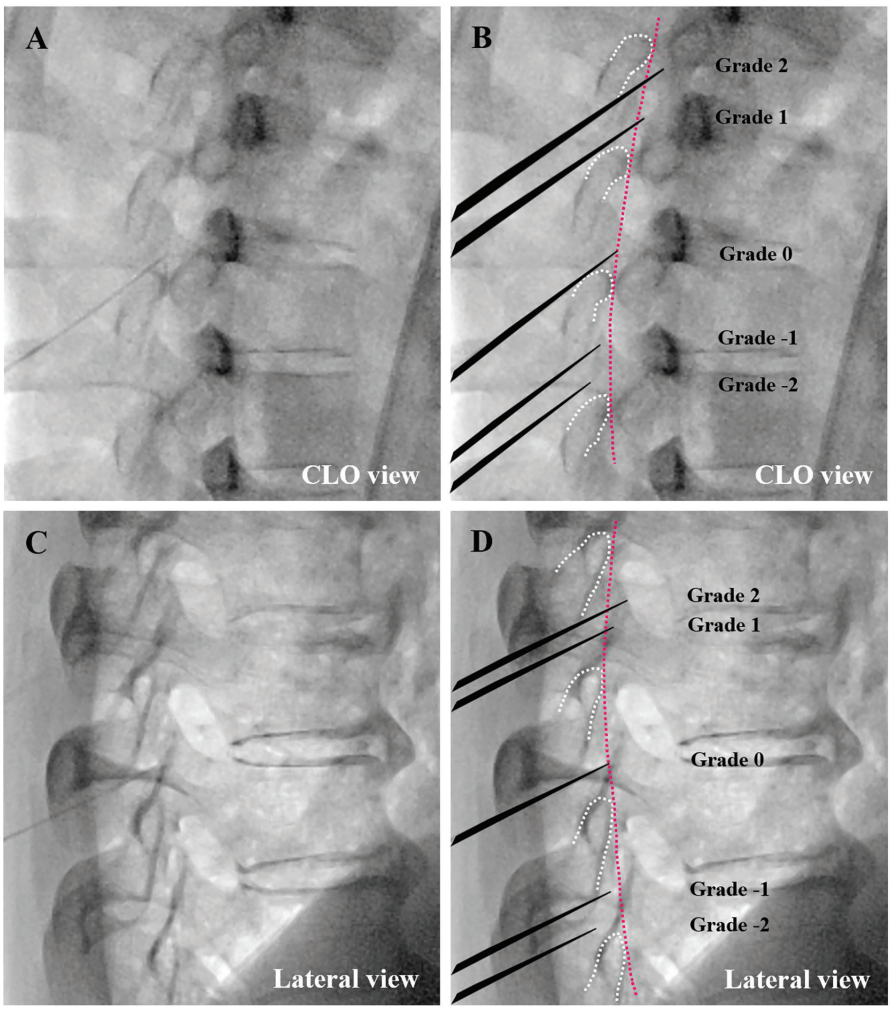

Fig. 3. *Original fluoroscopic and schematic views for describing the grade of needle tip location in the CLO view (A and B) and lateral views (C and D). White dot lines indicate the laminar margin. Red dot lines indicate the ventral interlaminar line (VILL). Grade -2, significantly posterior to VILL; Grade -1, just posterior to VILL; Grade 0, on VILL; Grade 1, just anterior to VILL; Grade 2, significantly anterior to VILL.*

Results

Patient and Procedural Characteristics

A total of 30 patients were enrolled in this study. There were no excluded patients. Mean age was 57.2 ± 16.4 years, with 50.0% being men (Table 1). In our cohort, postherpetic neuralgia and intercostal neuralgia (23.3% and 20%) were the most common reasons to perform TEA. The mid-TEA was conducted at the interlaminar spaces of T4–T5 (20%), T5–T6 (20%), T6–T7 (26.7%), and T7–T8 (33.3%). The median value of CLO angle measured from T4–T5 to T7–T8 ranged from 54.0 degrees to 63.5 degrees. The mean and standard deviation of CLO angle measured from the whole mid-thoracic region was

58.8 ± 5.5 degrees. The CLO measured angle seemed to gradually increase, corresponding to decreasing thoracic vertebra level in the mid-thoracic region. All needle tips were successfully placed in the epidural space, which was confirmed by contrast dispersion on AP, lateral, and various oblique views.

Visualization of needle tip

The needle tip in all CLO views was clearly visualized without ambiguity (i.e., Grade 1) compared with that in the lateral view (100% vs. 36.7%, $P < 0.001$, in Grade 1 vs. Grade 2 plus Grade 3, respectively) (Table 2). In the lateral view, 16 (53.3%) and 3 (10.0%) needle tips were categorized to Grade 2 and Grade 3, respectively. The visualization of needle tips in Grade 2 and 3 were not observed in all CLO views.

Visualization of Laminar Margin

The visualization of the laminar margin using the CLO measured angle was significantly clearer (Grade 1) compared with that in the CLO view at 40 and 50 degrees and the lateral view. (40˚, 56.7% vs. 3.3%, $P < 0.001$; 50˚, 56.7% vs. 26.7%, $P = 0.012$; 90˚, 56.7% vs. 26.7%, $P = 0.035$ in Grade 1) (Table 3). There was no difference in the visualization of the laminar margins between the CLO view at 60 degrees and CLO measured angle (63.3% vs. 56.7%, $P = 0.688$); 23.3% of cases in the lateral view were visualized in Grade 3 and 4, but none in the CLO view at 60 degrees and CLO measured angle view.

Table 1. *Patient characteristics*.

Demographics	Total patients (n = 30)
Age (years)	57.2 ± 16.4
Gender (male), n (%),	15 (50)/15 (50)
Body mass index (kg/m^2)	24.1 ± 3.8
Underlying diseases	
Chronic post-thoracotomy pain	3 (10.0)
Postherpetic neuralgia	7 (23.3)
Intercostal neuralgia	6 (20.0)
Cancer pain	5 (16.7)
Spontaneous intracranial hypotension	5 (16.7)
Compression fracture	4 (13.3)
Target level/CLO angle measured	
T4–T5	6 (20.0)/54.0 (50.0–56.0)
T5–T6	6 (20.0)/59.0 (55.0–62.0)
T6–T7	8 (26.7)/58.0 (54.5–63.0)
T7–T8	10 (33.3)/63.5 (61.0–65.0)

CLO angle measured, contralateral oblique angle measured based on imaging modalities; Data are expressed as number (%) or median (interquartile range).

Table 2. *Comparison of needle tip visualization in various degree of CLO views compared to that in the lateral view.*

	CLO view, n (%)				Lateral view
	40 degree	50 degree	60 degree	Measured	90 degree
Grade 1	30 (100)*	30 (100)*	30 (100)*	30 (100)*	11 (36.7)
Grade 2	0 (0)	0 (0)	0 (0)	0 (0)	16 (53.3)
Grade 3	0 (0)	0 (0)	0 (0)	0 (0)	3 (10.0)

CLO, contralateral oblique; Measured, angle measured based on imaging modalities; Grade 1, clearly visualized without ambiguity; Grade 2, poorly visualized or visualized with effort; Grade 3, nearly not or not visualized. *$P < 0.001$ compared with the lateral view (grade 1 vs. entire other grades).

Table 3. *Comparison of laminar margin visualization in various degree of CLO views compared to that in the lateral view.*

	CLO view, n (%)				Lateral view
	40 degree	50 degree	60 degree	Measured	90 degree
Grade 1	1 (3.3)**	8 (26.7)*	19 (63.3)†	17 (56.7)	8 (26.7)*
Grade 2	20 (66.7)	21 (70.0)	11 (36.7)	13 (43.3)	15 (50.0)
Grade 3	9 (30.0)	1 (3.3)	0 (0)	0 (0)	3 (10.0)
Grade 4	0 (0)	0 (0)	0 (0)	0 (0)	4 (13.3)

Measured, angle measured based on imaging modalities; Grade 1, clearly visualized with complete demarcated lamina; Grade 2, fairly visualized with incomplete demarcated lamina; Grade 3, poorly visualized with incomplete demarcated lamina; Grade 4, nearly not or not visualized with incomplete demarcated lamina. * $P < 0.05$, ** $P < 0.001$, and †$P = 0.688$ compared with CLO view at measured (grade 1 vs. entire other grades).

Location of Needle Tip

Table 4 showed the needle tips location in various degrees of CLO views and in the lateral view. The needle tips, which were located on the VILL (Grade 0) or just anterior to the VILL (Grade 1), were significantly more frequently seen in the CLO measured angle view, compared with the CLO views at 40 and 50 degrees, and the lateral view (40°, 96.7% vs. 26.7%, $P < 0.001$; 50°, 96.7% vs. 63.3%, $P = 0.002$; 90°, 96.7% vs. 66.7%, $P = 0.012$ in Grade 0 and 1; Fig. 4). No difference was noted between the CLO view at 60 degrees and CLO measured angle (96.7% vs. 96.7%, $P > 0.999$). In the CLO view, the needle tips were all located on the VILL or just anterior at the VILL and were closer to the VILL as the angle of the CLO view increased. In contrast, in the lateral view, 16.7% of needle tips were located posterior to the VILL and the needle tip locations were not evaluated in 13.3% of cases due to lack of visualization of the laminar margin and needle tip.

Discussion

This study demonstrated 3 main findings. First, the needle tip was clearly visualized at any CLO view, compared with the lateral view in the mid-thoracic region. Second, the laminar margin was significantly well visualized at the CLO view at 60 degrees and the CLO measured angle view in the mid-thoracic region. These properties could aid in visualization of the needle tip on fluoroscopic images to avoid the lamina, improving the accuracy of TEA in the mid-thoracic region. Third, in the CLO view at 60 degrees and CLO measured angle view, needle tips were all located on or just anterior to the VILL in the mid-thoracic epidural space. The ability to confirm the

Table 4. *Comparison of needle tips location in various degree of CLO views compared to that in the lateral view.*

Grade	CLO view, n (%)				Lateral view
	40 degree***	50 degree**	60 degree†	Measured	90 degree*
-2	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
-1	0 (0)	0 (0)	0 (0)	0 (0)	5 (16.7)
0	0 (0)	4 (13.3)	19 (63.4)	16 (53.4)	11 (36.7)
1	8 (26.7)	15 (50.0)	10 (33.3)	13 (43.3)	9 (30.0)
2	22 (73.3)	11 (36.7)	1 (3.3)	1 (3.3)	1 (3.3)
U	0 (0)	0 (0)	0 (0)	0 (0)	4 (13.3)

CLO, contralateral oblique; Measured, angle measured based on imaging modalities; -2, significantly posterior to VILL; -1, just posterior to VILL; 0, on VILL; 1, just anterior to VILL; 2, significantly anterior to VILL; U, undetermined grade - needle tip location was not able to be evaluated because of nearly not visualized laminar margin and needle tip. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, and † $P > 0.999$ compared with CLO view at measured (grade 0 and 1 vs. other grades).

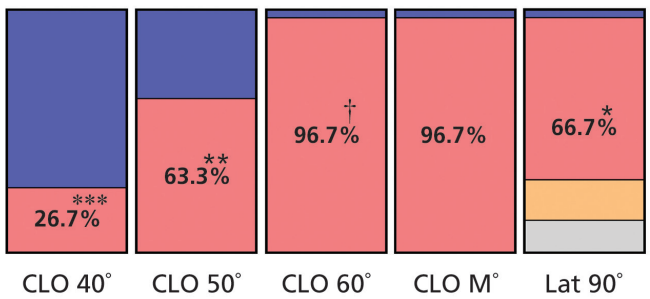

Fig. 4. *Stacked bar plots comparing the proportion of the grade of needle tip location according to various degrees of CLO views and the lateral view. CLO, contralateral oblique; M°, angle measured based on imaging modalities; Grade 2, significantly anterior to the ventral interlaminar line (VILL); Grade 1, just anterior to VILL; Grade 0, on VILL, Grade -1, just posterior to VILL; Grade U, undetermined grade (needle tip location was not able to be evaluated due to lack of visualization). * P < 0.05, ** P < 0.01, *** P < 0.001, and † P > 0.999 compared with CLO view at measured (grade 0 and 1 vs. other grades).*

depth of the needle tip in relation to the epidural space could ensure safe TEA.

When approaching the mid-thoracic epidural space, successful TEA can be difficult to achieve due to the unique anatomical characteristics of the mid-thoracic region, including long and steep spinous processes and a narrow interlaminar space (6). To improve the success rate of TEA in the mid-thoracic region, Nagaro's method of using a pedicle as a landmark on the AP and lateral fluoroscopic view was proposed (5). However, the mid-TEA still remained technically challenging (8,12). The slanted and long spinous processes, the thin lamina of vertebrae and the mediastinal organs in the mid-thoracic region blunts the contrast of the interlaminar space, making its visualization difficult despite the use of fluoroscopy with any projection (5). Moreover, AP and lateral fluoroscopic views cannot accurately assess the depth of the needle tip in relation to the epidural space and discriminate between true and false LOR (11); therefore, explaining why major spinal cord injury continues to occur, even with the use of fluoroscopy (18).

Considering the limitations of conventional fluoroscopic views, the CLO view has been recommended because it leads to better visualization of the needle tip and lamina which provides a reliable radiographic landmark (13,19,20). Through rigorous and precise analyses of the CLO view when accessing epidural space, Gill et al (14,15) suggested that each CLO view at 50 and 45 degrees were superior to the lateral view in the cervical and lumbar epidural region respectively, for improving needle tip visualization and providing a consistent landmark when accessing the epidural space.

In this study, our results were in line with those of previous studies of CLO views. In the CLO view at 60 degrees and measured angle view, needle tips and lamina were clearly visualized, which has several advantages. Firstly, clear needle tip visualization could help the operator recognize and correct the location of the needle tip, whereas, indistinct needle tip visualization could make it challenging to identify the location of the needle tip and the operator could inadvertently advance the needle into the epidural space causing dura puncture or cord injury. Indeed, only 36.7% of cases showed clearly visualized needle tips at the lateral view. All cases showed clearly visualized needle tips in any CLO view in the present study. Secondly, well demarcated laminar margins could increase the success rate and decrease the procedural time and patient discomfort as the operator could advance the needle without encountering the lamina. In TEA, the epidural needle can frequently encounter the lamina, causing discomfort and pain from periosteal contact, needle redirections, and multiple skin punctures (21). In the present findings, in 50% of cases the laminar margin was clearly visualized with complete demarcated laminar in the CLO view at 60 degrees and measured angle view; none were poorly or not visualized laminar margins. In contrast, 23.3% of cases were poorly or not visualized in the lateral view, which could lead to difficult TEA.

Notably, in almost all cases (96.7%) in the CLO view at 60 degrees and CLO measured view, the needle tips were located on or just anterior to the VILL, achieving successful TEA. These views provided significant consistency in the needle location at the point where the epidural space was accessed. Importantly, the epidural space was not accessed until the needle tip reached or passed the VILL, allowing needle advancement up to just before the VILL and LOR, guiding the operator forward into the epidural space and allowing anticipation of the locus in which the LOR was obtained. Furthermore, this could help discriminate between true and false LOR, and confirm successful TEA through epidurography contrast patterns seen in front of the VILL. If the needle tip was not in the epidural space, contrast spreads posteriorly to VILL. Hence, these virtues of the CLO view at 60 degrees and measured view could improve clinical performance, increase success rate, reduce procedural time, and decrease patient discomfort, while guaranteeing safety when performing mid-TEA. Interestingly, in the lateral view, the needle tip locations were not evaluated in 13.3% of cases as the laminar margin and needle tip were not visualized, and 16.7% of needle tips were located posterior to the VILL. Therefore, the lateral view could not provide consistency of needle location and thus lead to difficult TEA. Hence, the CLO view at 60 degrees and measured view appeared to be superior to the lateral view for mid-TEA.

In the previous study, use of the CLO view at 50 and 45 degrees was recommended for cervical and lumbar epidural access, respectively (14,15). In this study, outcomes of the CLO measured view were not statistically different from that provided by CLO view at 60 degrees. The mean of CLO measured angle on the mid-thoracic region was 58.8 degrees. Therefore, we suggest the use of CLO views at 60 degrees when accessing the mid-thoracic epidural space in clinical situations where thoracic CT or MRI is not available.

This study has some limitations. Firstly, this was a pilot study with a small number of patients, therefore unable to provide conclusive results demonstrating

the superiority of the CLO view over the lateral view and the optimal angle of CLO view when accessing the mid-thoracic epidural space. Secondly, delicate and detailed geometric analysis was insufficient, compared with previous studies (14). However, the essential and fundamental findings were included in our analysis, and additional geometric analysis may not have affected the results of this study. Thirdly, this study followed the methodological protocol of the previous studies (14). However, the subjective and ambiguous criteria of evaluation such as "just anterior" and "significantly posterior" may induce bias despite final measured values based on the consensus of an independent investigator. Further rigorous and precise study using the objective standard criteria should be done. Finally, clinical improvements such as increased success rate, reduced procedural time, and decreased patient discomfort were not included as primary objectives in this study; therefore, evaluation of the clinical usefulness of the CLO view and lateral view is warranted.

Conclusion

In comparison to the lateral view and other CLO angles, the CLO view at 60 degrees and obliquity measured based on CT or MRI can provide consistent needle tip locations and clear visualization of needle tip and lamina. This could potentially be used to identify the needle in relation to epidural space and achieve success in TEA. Without available CT or MRI images, the CLO view at 60 degrees may be considered and selected as the optimal view during mid-TEA.

Acknowledgments

We gratefully acknowledge the statistical support of the Department of Clinical Epidemiology and Biostatistics, Asan Medical Center, and University of Ulsan College of Medicine.

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