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Observational Cohort Study

Comparison of the Effects of Lumbar Spine Flexion on the Acoustic Windows Between Young and Elderly Patients

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Background: The effects of lumbar flexion on posterior longitudinal ligament (PLL) length as an acoustic window for neuraxial block in older patients have not been fully elucidated.

Objective: This study aimed to compare changes in PLL length during lumbar spine flexion in young and old patients.

Study Design: Observational cohort study.

Setting: Tertiary University Hospital.

Methods: Forty young and older adult patients were placed in the lateral decubitus position. To flex the lumbar spine, patients were asked to flex their hips and knees and then their neck and shoulder toward their knees as much as they could (fetal position). An assistant pushed the patients' abdomen to the back and held their neck and legs to help them maintain position. To obtain an optimal ultrasound view, lumbar spinal ultrasonography was performed from L5/S1 to L2/L3 using a paramedian oblique sagittal plane. PLL lengths were measured on the ultrasound image before fetal position, after unassisted fetal position, and after assisted fetal position.

Results: PLL lengths increased after lumbar spine flexion in both young and older adult patients, except at the L3-L4 level in old patients. The change in PLL length during lumbar spine flexion was significantly lower in old patients than in young patients at the L5-S1 and L3-L4 levels ($P = 0.0028$ and $P = 0.0134$, respectively). After lumbar spine flexion, the PLL length was significantly different between the spinal levels in older patients ($P = 0.0392$).

Limitations: First, we measured the PLL length as an acoustic window for neuraxial block using lumbar spinal ultrasonography. Second, the researcher who obtained the spinal ultrasound view was not blinded to the patient's group and position. However, the researcher who measured the PLL lengths on ultrasonography was blinded. Third, all participants had no history of surgery, trauma, or congenital abnormalities of the spine, regardless of age.

Conclusion: Lumbar spine flexion can increase PLL length in young and old patients. However, lumbar spine flexion is less effective in increasing the PLL length in old patients than in young patients.

Key words: Lumbar flexion, posterior longitudinal ligament, lumbar spinal ultrasonography, acoustic window, neuraxial block

Clinical Trial Registration: The study was registered with the Clinical Research Information Service (registration number: KCT0005479).

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Lumbar neuraxial anesthesia, such as spinal and epidural anesthesia, is widely used for surgeries involving the lower abdomen and lower extremities. Its analgesic effects are achieved by injecting local anesthetics or opioids into the subarachnoid or epidural space. To reach the subarachnoid or epidural space, the needle should advance between the lumbar vertebrae and puncture the dura mater or ligamentum flavum. The wider the space between the vertebrae, the easier it is for the needle to pass through (1,2). The position of the patient is important to secure a wide interlaminar space by flexing the lumbar spines. Patients are asked to assume the fetal position to flex the lumbar spine. Proper positioning for lumbar neuraxial block can increase the success rate and prevent block-related complications (2-4).

With the increase in the population of older adults, lumbar neuraxial block is increasingly used. Lumbar neuraxial block may be beneficial in old patients to avoid complications of general anesthesia, such as postoperative respiratory problems or cognitive dysfunction (5,6). In a previous study, aging was found to be an independent predictor of the difficulty of spinal anesthesia due to anatomical degenerative changes (7). Aging has been reported to reduce lumbar lordosis and the range of motion in flexion and extension of the lumbar spine (8,9). However, little research has been conducted on the effects of aging on spine flexion for lumbar neuraxial block (6).

Ultrasonography can be used for various purposes in neuraxial blockade. It can help physicians identify the intervertebral level, estimate the depth to intrathecal space, and evaluate interlaminar spaces (10-13). The posterior longitudinal ligament (PLL) lies within the anterior part of the vertebral canal and supports the vertebral column (14,15). The PLL length of the spine measured by ultrasound represents the amount of space available for the passage of the ultrasound beam from the laminae to the PLL, anterior dura, and cord (Fig. 1). In a previous study, PLL length was proven to be a dimension of the acoustic target window for neuraxial blockade on ultrasonography (11,12,16).

This study aimed to evaluate the effects of spine flexion on acoustic target window in old patients and compare the change in PLL lengths during lumbar spine flexion in young and old patients in the lateral decubitus position.

Methods

After approval was obtained from the institutional review board, the study was registered with the Clinical Research Information Service (registration number: KCT0005479). This prospective study was conducted on 40 patients aged 20-40 years (young group) and over 65 years (old group). The inclusion criteria were an American Society of Anesthesiologists' physical status I or II and planned spinal anesthesia for elective surgery. The exclusion criteria were a body mass index greater than 35 kg/m^2; neuromuscular disease and history of surgery, trauma, or congenital abnormalities of the spine; and allergy to ultrasound gel. If disc degenerative disease was confirmed on lumbosacral spine radiography preoperatively, patients were excluded. The age, gender, weight, and height of enrolled participants were recorded.

Each patient was placed in the lateral decubitus position on an operating table with a pillow under his/her head. Lumbar spine flexion was performed in 2 steps. In the first step, the patient was instructed to adopt a fetal position without assistance. To this end, the patients were first asked to flex their hips and knees and subsequently their neck and shoulder toward their knees as much as they could. In the second step, the patient adopted the fetal position guided by an assistant investigator who pushed the patient's abdomen to the back and held their neck and legs to help them maintain the position during lumbar spinal ultrasonography.

Spinal ultrasonography was performed in the lateral decubitus position 3 times (before fetal position, after unassisted fetal position, and after assisted fetal position) using a 2- to 5-MHz curvilinear transducer of an ultrasound system (Viamo c100, Canon Medical Systems Co., Otawara, Japan) by a single experienced investigator. Optimal images were obtained to identify anatomical structures around the lumbar spine, such as the ligamentum flavum, dura mater, and PLL on the paramedian sagittal oblique plane view. After identification of the sacral plateau, the transducer was moved cephalad to identify lumbar interlaminar spaces from L5/S1 to L2/L3. To obtain the paramedian sagittal oblique view, the transducer was placed 1-2 cm lateral from the midline of the spinous processes to an operating table and slightly tilted medially to locate the widest part of the interlaminar space. In this view, the laminae of the lumbar vertebrae produced a "sawtooth" pattern. The ligamentum flavum and posterior dura were seen as a hyperechoic line in the paramedian interlaminar space. In the deeper interlaminar space between the anterior

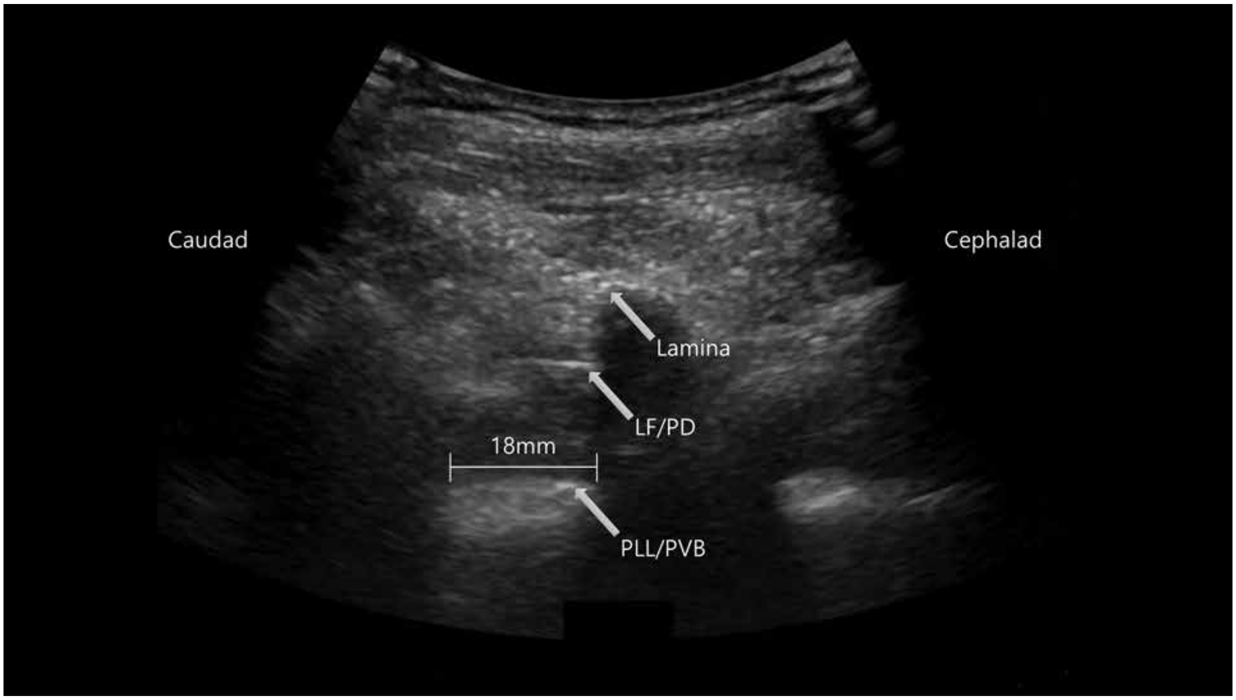

Fig. 1. *Paramedian longitudinal ultrasonography image showing the lamina, ligamentum flavum (LF)/posterior dura (PD), and posterior longitudinal ligament (PLL)/posterior vertebral body (PVB) between the laminae of L5 and S1.*

dura and posterior vertebral body, PLL was identified as a hyperechoic linear structure. When the anterior dura, PLL, and posterior border of the vertebral body were not distinguishable, the anterior complex view, which comprised the anterior dura, PLL, and posterior border of the vertebral body, was considered as PLL (17). Spinal ultrasonography was recorded and saved as a video file; PLL length was measured using the ultrasound view obtained by another anesthesiologist who was blinded to the group and position of each patient. Measurements of PLL length were performed 3 times using the caliper tool on ultrasonography. The mean PLL length was then calculated and used for statistical analysis.

The sample size was estimated based on the results of previous exploratory studies using ultrasonography; 15, 16, and 20 patients were randomly selected for each age group. Statistical analyses were performed using SAS version 9.4 (SAS Inc., Cary, NC). All data are expressed as mean (standard deviation), median (interquartile range [IQR]), or numbers (proportion [%]), as indicated. For continuous data, normality was tested using the Kolmogorov-Smirnov test and Shapiro-Wilk test, and the data between groups were compared using the t test or Mann-Whitney U test based on data normality. Categorical data are presented as numbers and percentages and were compared using Pearson's chi-squared or Fisher's exact test. By changing the position of patients, the changes in PLL lengths were compared between the 2 groups using a linear mixed model. The PLL lengths in the assisted fetal position were compared between the spinal levels using a one-way analysis of variance. Correction for multiple comparisons was performed using the Bonferroni method. A P-value < 0.05 was considered statistically significant.

Results

A total of 40 patients were enrolled in this study. There were no significant differences between the groups in demographic characteristics (gender, weight, and height) (Table 1).

The median (IQR) age of patients in the young group (32.0 [4.0] years) was significantly lower than that of patients in the older group (72.0 [10.0] years). The PLL length was measured on 480 paramedian sagittal oblique views (12 views per patient). The measured PLL lengths are described in Table 2.

At all spinal levels in both young and old patients, the PLL lengths before the fetal position were significantly different from those obtained in the assisted fetal position, except for the length in the L3-L4 level in old patients. There were significant differences in the change of mean PLL length between the young and old groups with the change in position at the L5-S1 and L3-L4 levels ($P = 0.0028$ and $P = 0.0134$, respectively). A post-hoc analysis between the young and old groups revealed a significant difference in the change of mean PLL length before and after unassisted fetal position at the L5-S1 level ($P = 0.0024$). There was also a significant difference in the change of mean PLL length before and after assisted fetal position at the L3-L4 level ($P = 0.0034$). At the L4-L5 and L2-L3 levels, there was no difference in the change in mean PLL length between the young and old groups due to the change in position. Furthermore, there was no difference in the PLL length between the spinal levels in the young group ($P = 0.1508$). In contrast, the PLL length was significantly different between the spinal levels in the old group ($P = 0.0392$). In the old group, the post-hoc analysis showed that the PLL lengths at the L4-L5 and L5-S1 levels were significantly different from each other ($P = 0.0330$).

Table 1. *Demographic characteristics of participants.*

	Young group (n = 20)	Old group (n = 20)	*P*-value
Gender (men/women)	11/9	11/9	1.000
Age (years)	32.0 (4.0)	72.0 (10.0)	0.0001
Height (cm)	170.6 ± 9.3	165.9 ± 7.6	0.084
Weight (kg)	65.9 ± 12.6	69.6 ± 11.9	0.330

Data are presented as number, median (interquartile range), or mean ± standard deviation.

Discussion

In this study, we compared the change in PLL length as an acoustic window for neuraxial block between young and old patients during lumbar spine flexion in the lateral decubitus position. Lumbar spine flexion increased PLL length from the L2-S1 level in both young and old patients, except for the L3-L4 level in the old patients. However, the change in PLL length by lumbar spine flexion at the L5-S1 and L3-L4 levels was less in old patients than in young patients. In the future, research should be conducted to determine the clinical impact of the increase in PLL length during lumbar spine flexion, especially in old patients.

The PLL length measured in this study does not indicate the actual length of PLL, and the increase in PLL length during lumbar spine flexion does not indicate the lengthening of PLL. PLL has very limited extensibility, and its main function is to limit the flexion of the spine and inhibit posteromedial disc protrusion or extrusion (14). The PLL length measured on ultrasonography indicates the space through which the ultrasound beam can pass without being obstructed by any bony structure between the interlaminar spaces. The block needle is also expected to easily advance to the epidural or subarachnoid space (10,11). Thus, the

Table 2. *Effects of position change on PLL length (mm).*

	Before fetal position	After unassisted fetal position	After assisted fetal position	*P*-value*	*P*-value†
Young group					
L5-S1	13.5 ± 1.9	16.7 ± 3.2	17.9 ± 3.8	< 0.0001	
L4-5	13.5 ± 3.0	15.5 ± 3.5	16.0 ± 3.6	0.002	
L3-4	13.5 ± 3.3	14.2 ± 3.9	15.8 ± 3.2	0.005	
L2-3	13.3 ± 2.5	15.2 ± 3.8	15.4 ± 4.2	0.010	
P-value‡			0.1508		
Old group					
L5-S1	13.1 ± 2.5	13.7 ± 2.2	14.1 ± 2.3	0.011	0.0028
L4-5	11.5 ± 2.4	12.2 ± 1.8	12.4 ± 1.6	0.025	0.0847
L3-4	12.5 ± 2.4	13.5 ± 2.3	13.3 ± 2.2	0.069	0.0134
L2-3	12.5 ± 1.8	13.0 ± 1.9	13.7 ± 1.8	0.004	0.2177
P-value‡			0.0392		

PLL, posterior longitudinal ligament.
Data are presented as mean ± standard deviation.
**P*-value before fetal position vs. after assisted fetal position, as compared by the paired t-test.
†*P*-value in the young group vs old group, as compared by the linear mixed model for the change of PLL length.
‡*P*-value of PLL lengths at the assisted position between the spinal levels, as compared by a one-way analysis of variance.

use of PLL as an acoustic target window for neuraxial block has been validated in several studies, and poor PLL visualization is associated with technical difficulties intraoperatively (12,13,20). Because older individuals have more osteophytes in their vertebrae (21), the length of PLL can better reflect the difficulties in the neuraxial block in the lumbar region.

In this study, the PLL length after the assisted fetal position was significantly greater than the PLL length before the fetal position in both groups at all lumbar spinal levels for neuraxial block, except for one spinal level in the group of older patients. This indicates that the PLL lengths increased after lumbar spine flexion in both old and young patients at almost all spinal levels, suggesting that lumbar spine flexion may also be effective in increasing the acoustic window for neuraxial block in old patients. However, the changes in PLL lengths during lumbar spine flexion at 2 levels were less in old patients than in young patients. The difference in the changes in PLL lengths between the old and young patients can be due to a reduction in overall flexion as a loss of the elasticity of the interspinous and supraspinous ligaments and ligamentum flavum and additional degenerative changes in old patients, preventing the ultrasound beam from passing through the spinal canal (22).

The results of this study regarding PLL lengths should be interpreted based on the clinical situation of the neuraxial block in the lumbar spine. The differences in the PLL lengths before and after lumbar spine flexion were less than 1.0 mm at all spinal levels except at the L2-L3 level in old patients, which is rarely chosen for neuraxial block. In a previous study, a difference of more than 1.0 mm in the PLL length was considered clinically significant because the diameter of the needle used for spinal or epidural block was approximately 1.0 mm (23,24). It is unclear whether an increase of less than 1.0 mm in PLL length in the old patients in this study improved the clinical outcome of the lumbar spinal approach. The PLL length was increased by more than 2.0 mm at all spinal levels in the young group, thus increasing the success rate and preventing complications of neuraxial block. The finding of lower effectiveness of lumbar spine flexion in old patients than in young patients could be attributed to the degenerative changes in the lumbar spine in the former group.

Lumbar spine flexion was performed in 2 steps¬–unassisted fetal positioning and assisted fetal positioning–in this study. Some old patients often showed difficulties in following the instructions to assume the fetal position by themselves due to reasons such as decreased cognitive function, hearing loss, or muscular weakness. To ensure that the fetal positioning, including flexion of the lumbar spine, was properly achieved in old patients, an assistant investigator helped all patients in assuming and maintaining the fetal position. The change in mean PLL length was significantly different between the young and old groups before and after the unassisted fetal position at the L5-S1 level and after the assisted fetal position at the L3-L4 level. Both unassisted and assisted fetal positioning contributed to a difference in changes in PLL lengths between the old and young groups.

After lumbar spine flexion, there was no difference in PLL lengths between the spinal levels in young patients, whereas the PLL lengths between spinal levels were significantly different in older patients. In old patients, the PLL length at the L5-S1 level was significantly greater than that at the L4-L5 level. The spinal level for neuraxial block should be mainly determined by the sensory level required for a particular type of surgery. Furthermore, in old patients, the physician should remember that the acoustic windows for neuraxial block may vary depending on the spinal level. Radiologic findings, including radiography or ultrasonography, may be useful in determining the level for neuraxial block in old patients.

In this study, PLL lengths were measured in the paramedian sagittal oblique plane view because the neuraxial block was performed using the paramedian approach. In old patients, the paramedian approach is often selected for neuraxial block instead of the midline approach due to degenerative changes in their lumbar spines. The calcification of the interspinous ligament or difficulty in flexing the spine decreases the acoustic window in the midline approach (25,26). The applicability of the results of this study to patients undergoing lumbar neuraxial block using the midline approach should be interpreted with caution. For the midline approach, further studies measuring the PLL lengths in the median sagittal plane are required.

In this study, patients were placed in the lateral decubitus position on the operation table. The lateral decubitus position, as well as the sitting position, is widely used for the lumbar spinal neuraxial block. The lateral decubitus position has some advantages and disadvantages compared to the sitting position. The lateral decubitus position is preferred for old patients when they are sedated or hypotension is anticipated after neuraxial block (27). Additionally, the lateral decubitus position for the fixation of a femur fracture is impossible to achieve. The effect of lumbar spine flexion on PLL lengths may vary depending on the position of the patients. Thus, the results of this study may have been different if patients had been in the sitting position.

This study has some limitations. First, we measured the PLL lengths as an acoustic window for neuraxial block using lumbar spinal ultrasonography. Further clinical research using lumbar neuraxial block should be conducted. Second, the researcher who obtained the spinal ultrasonography view was not blinded to the patient's group and position. However, the researcher who measured the PLL lengths on ultrasonography was blinded. Third, all participants had no history of surgery, trauma, or congenital abnormalities of the spine and were not pregnant or obese, regardless of age. Caution is needed when applying the results of this study to patients with an underlying disease of the lumbar spine, pregnancy, or obesity.

Conclusions

Lumbar spine flexion can increase the PLL length as the acoustic target window for neuraxial block in older adult patients. However, the change in PLL length in older people was less than 1.0 mm, which was significantly lower than that in young patients at some lumbar spinal levels. Lumbar spine flexion is less effective in increasing the acoustic target window for neuraxial block in old patients than in young patients.

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