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Retrospective Study

Needle Depth and Angle for Lumbar Interlaminar Epidural Injection Using Magnetic Resonance Imaging and C-Arm Measurements

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Background: Interlaminar epidural injection (ILEI) is used to relieve low back pain, with or without radiating pain. The distance from the skin to the epidural space determines the needle depth and may be influenced by the patient's body measurements.

Objectives: The objective of this study was to investigate the correlation between needle depth for ILEI and patients' body profiles, including weight, height, and body mass index (BMI), using magnetic resonance imaging (MRI) and also to compare the needle depth and angle between MRI and C-arm fluoroscopic images of ILEI.

Study Design: This was a retrospective study.

Setting: This study was conducted at a single Department of Anesthesiology and Pain Medicine of Konkuk University Medical Center.

Methods: This retrospective study reviewed patients who underwent MRI and ILEI. The needle depth and caudal angle were measured on the sagittal view of MRI and C-arm images for L3–L4, L4–L5, and L5–S1 ILEI.

Results: Overall, 386 patients were reviewed. For MRI, the mean value of the needle angle given caudally was 14.70, 12.06, and 11.33 for L3–4, L4–5, and L5–S1 ILEIs, respectively. Mean values of needle depth were 52.17, 52.09, and 47.91 mm for L3-4, L4-5, and L5–S1 ESIs, respectively. Height combined with weight and BMI had a higher correlation with needle depth than weight and height. In the comparison between MRI and fluoroscopy, needle depth at L5–S1 and caudal angle at L3–4 and L4–5 were significantly correlated.

Limitations: This study was a retrospective study conducted at a single center.

Conclusion: Height combined with weight and BMI can help estimate the optimal needle depth from the skin to the epidural space. Needle depth in L5–S1 and caudal angle in L3–4 and L4–5 of MRI were correlated with those of fluoroscopy of ILEI.

Key words: Body mass index, epidural depth, obesity, morbid, injections, epidural, magnetic resonance imaging, C-arm fluoroscopic images, low back pain, umbosacral pain

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In medical practice, epidural steroid injections have long been used as a treatment option for patients with lower back pain, with or without radiculopathy (1). Interlaminar epidural injection (ILEI) and transforaminal epidural injection (TFEI) are the 2 basic methods for this type of approach. In the United States, the number of patients undergoing nonsurgical spinal interventional procedures has significantly increased between 2000 and 2008 (2). Currently, the transforaminal approach seems to be performed more frequently than the interlaminar approach because many practitioners believe that the former delivers the injected drug directly into the ventral epidural space closer to the irritated spinal nerve (3). However, the efficacy of these 2 methods remains controversial. In a systematic review by Manchikanti et al (3), both ILEI and TFEI were effective in relieving lumbosacral radicular pain and improving functional scores, and there was no clinically significant difference in the efficacy of pain relief.

Prompt and precise placement of a needle into the desired site can minimize patient discomfort. Lumbar ILEI is performed with a patient lying in the prone or lateral decubitus position on a firm mattress. Therefore, patients may be extremely uncomfortable if the duration of the procedure is too long. Prolonged procedure time with fluoroscopic guidance may also increase the radiation exposure of patients, practitioners, and other assistants in the operating room.

The skin-to-epidural depth may be correlated with the patient's body measurements. Algrain et al reported that body mass index (BMI) was positively correlated with epidural depth in a prospective analysis of cervical interlaminar epidural steroid injections (4). Lumbar epidural depth may increase positively with BMI in the same manner. In some obese patients, the commonly used needle is not sufficient in length. If the skin-to-epidural depth can be estimated before the procedure, it would be helpful for a practitioner to prepare a needle with the proper length and complete the procedure effectively.

We hypothesized that needle depth and patient body measurements correlate with each other. The relationship between the needle depth expected from the MRI scan and patients' height, weight, and BMI was investigated in this study. Additionally, epidural needle depths were measured using C-arm fluoroscopic images. Finally, we compared the measurements from the MRI and C-arm fluoroscopic images and investigated the correlation between them.

METHODS

This study was conducted retrospectively and reviewed patients who visited the pain clinic between July 1, 2005, and March 31, 2020. It did not require informed content. This study included patients who underwent lumbar MRI scanning before C-arm fluoroscopy-guided ILEI. The study was conducted at a single university hospital, and permission to conduct the study was granted by the Institutional Review Board of Konkuk University Hospital (IRB file No. 2020-04-011).

Patients who underwent MRI were included in this study. The exclusion criteria were as follows: 1) existence of a spinal implant as a result of spine surgeries or procedures such as vertebroplasty and kyphoplasty; 2) history of lumbar spine compression fracture; and 3) lack of information about the patient's height and weight 6 months before or after the date of MRI scanning.

We collected the following data: gender, age (years), height (cm), weight (kg), BMI (kg/m^2), and depth (mm) and angle (degree) for ILEI on MRI and C-arm fluoroscopy of real ILEI. The depth from the skin to the dura was measured using the sagittal view of T1-weighted MRI, which contains spinous processes. First, the skin entry point was determined. For example, for the L3–4 level, we found the most prominent point of the spinous processes of L3 and L4, and the midpoint of these points was defined as the skin entry point. We then drew a line starting from the skin entry point to the posterior epidural space and passing through the midline between the lower border of the upper spinous process and the upper border of the lower spinous process. We measured the length of the line and the caudal angle from this line to the horizontal line. The length is the needle depth for ILEIs, and the angle is the needle angle during ILEIs. The same processes were performed for the ILEIs L4–L5 and L5–S1. Similarly, skin-to-epidural needle depths and needle angles at L3–4, L4–5, and L5–S1 were also measured using C-arm images in patients who underwent ILEI procedures after MRI evaluation.

Statistical analyses were performed using SPSS version 17.0 (SPSS Inc., Chicago, IL). Data from MRI measurements were assessed using linear regression analysis to evaluate the correlation between needle depth and patients' body measurements, such as height, weight, and BMI. The coefficients of determination were calculated for each independent variable. After the coefficient of determination was compared for each parameter, an equation for this dependent variable was obtained by selecting a dependent variable whose coefficient of determination was close to 1. We also investigated whether there was any relationship between needle depth and needle angle measured from MRI and C-arm images using Pearson correlation analysis and linear regression analysis. In this study, a P value < 0.05 was considered to indicate statistical significance.

RESULTS

A total of 550 patients (199 men and 351 women) initially participated in this study. Among these patients, 386 (156 men and 230 women) were ultimately included because the others met the exclusion criteria. The mean age (standard deviation [SD]) of the participants was 63.15 (15.85) years. Their mean height, weight, and BMI (SD) were 161.30 (9.18) cm, 63.14 (10.90) kg, and 24.22 (3.40) kg/m^2, respectively (Table 1).

Linear regression analysis was performed to determine the correlation between needle depth and patient age, height, weight, BMI, and height combined with weight. Based on the analysis, the R-squared values of (1) BMI and (2) height and weight combined were higher than those of age, height, and weight (Table 2).

From the results of linear regression analysis, we established an equation to explain the relationship between needle depth and BMI at the L3–4 level; needle depth (mm) = 1.504 × BMI (kg/cm^2) +15.4 (Table 3).

The equation for the relationship between needle depth, height, and weight combined for L3–4 level was also established. The equation was as follows: needle depth (mm) = -0.401 × height (cm) + 0.594 × weight + 79.0 (Table 3). Similarly, equations for the correlation of needle depth with BMI and height and weight combined for 3 different levels were developed (Table 4). Therefore, needle depth had a positive correlation with BMI at 3 different levels (Fig. 1).

Using these equations, we were able to determine the exact BMI of patients who required an epidural needle of more than 80 mm in length. According to the equation in Table 4, the needle depth (mm) = 1.504 × BMI (kg/cm^2) +15.4 for a neural blockade at the L3–4 level. Assuming that the needle depth was 80 mm, the corresponding BMI was 42.95. Therefore, patients with BMI > 42.95 needed a longer than usual epidural needle. Likewise, patients with BMI over 43.80 and 49.23 needed longer needles for L4–5 and L5–S1 levels, respectively.

We tried to determine if there was any relationship between the measurements from MRI and C-arm images by Pearson correlation analysis (Table 5). There was a statistically significant correlation between the caudal angles at L3–4 (P = 0.005) and L4–5 (P = 0.008), and needle depth at the L5–S1 level (P = 0.003).

The correlation coefficients were 0.191, 0.177, and 0.438, respectively. Thus, the caudal angle of the C-arm images in L3–4 and L4–5 and the needle depth of the C-arm images in L5-S1 were positively correlated with that of MRI. Therefore, the larger the needle depth in MRI, the larger the needle depth in C-arm images.

Table 1. *Demographic data of patients.*

Variable			
Gender	386		
Male, n (%)	156 (40.4%)		
Female, n (%)	230 (59.6%)		
	Range	Mean	SD
Age (years)	21-95	63.15	15.855
Height (cm)	138.50-187.00	161.30	9.18
Weight (kg)	34.10-108.00	63.14	10.90
BMI (kg/m^2)	15.80-35.26	24.22	3.40

SD, standard deviation
BMI, body mass index

Table 2. *R-squared values, F and significant F change of age, height, weight, body mass index, and height and weight combined in 3 different levels of lumbar epidural space.*

		R squared	F	Sig. F change
L3–4	Age	0.004	1.427	0.233
	Height	0.000	0.153	0.696
	Weight	0.195	92.905	0.000
	BMI	0.281	149.834	0.000
	Height and weight	0.288	77.358	0.000
L4–5	Age	0.000	0.079	0.779
	Height	0.001	0.214	0.644
	Weight	0.141	63.060	0.000
	BMI	0.235	118.120	0.000
	Height and weight	0.237	59.550	0.000
L5–S1	Age	0.004	1.603	0.206
	Height	0.001	0.437	0.509
	Weight	0.184	86.383	0.000
	BMI	0.502	129.065	0.000
	Height and weight	0.261	67.623	0.000

Sig. F change, Significant F change; BMI, body mass index

Finally, additional linear regression analysis was performed for the caudal angle in L3–4 and L4–5 and for the needle depth in L5–S1 (Table 6). By using the coefficient and intercept, the relationship was explained using a linear equation. For example, at the L5–S1 level, the needle depth of C-arm images (mm) = 0.460 × [needle depth of MRI (mm)] +31.777.

DISCUSSION

In this study, caudal angles and skin-to-epidural depths for ILEI were measured using MRI and compared with C-arm images. The mean needle angle on MRI was

Table 3. *Coefficients for the equation of needle depth related with body mass index, and height and weight combined in 3 different levels.*

Level	Model	Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	Std. error	Beta		
L3–4	Constant	15.433	3.006		5.135	0.000
	BMI	1.504	0.123	0.530	12.241	0.000
	Constant	78.992	7.735		10.212	0.000
	Height	-0.401	0.057	-0.381	-7.069	0.000
	Weight	0.594	0.048	0.669	12.430	0.000
L4–5	Constant	17.104	3.232		5.293	0.000
	BMI	1.436	0.132	0.485	10.868	0.000
	Constant	84.946	8.347		10.177	0.000
	Height	-0.425	0.061	-0.387	-6.948	0.000
	Weight	0.562	0.052	0.607	10.900	0.000
L5–S1	Constant	16.017	2.799		5.721	0.000
	BMI	1.300	0.114	0.502	11.361	0.000
	Constant	68.782	7.195		9.560	0.000
	Height	-0.334	0.053	-0.347	-6.330	0.000
	Weight	0.516	0.044	0.636	11.604	0.000

Std. error, standard error
Sig., significance
BMI, body mass index

Table 4. *Equations of needle depth at 3 different levels.*

	Needle depth (mm)
L3–4	$1.504 \times \text{BMI}$ (kg/cm^2) + 15.4 or $-0.401 \times$ height (cm) + $0.594 \times$ weight + 79.0
L4–5	$1.436 \times \text{BMI}$ (kg/cm^2) + 17.1 or $-0.425 \times$ height (cm) + $0.562 \times$ weight + 84.9
L5–S1	$1.3 \times \text{BMI} + 16.0$ or $-0.334 \times$ height (cm) + $0.516 \times$ weight + 68.8

BMI, body mass index

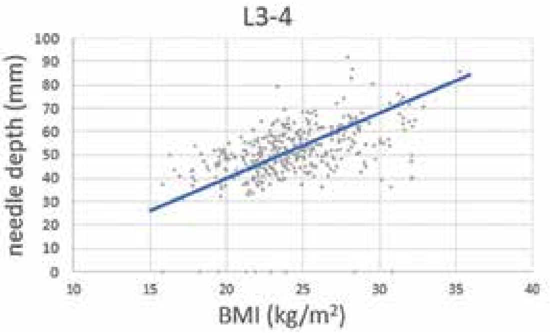

Fig. 1. *Correlation between epidural needle depth and body mass index at L3-4 level.*

14.70, 12.06, and 11.33 for the L3–4, L4–5, and L5–S1 levels, respectively. The mean needle angles in the C-arm images were 20.09, 15.90, and 10.18 for the L3–4, L4–5, and L5–S1 levels, respectively. Among various body measurements from a patient, BMI and height combined with weight correlated with skin-to-epidural needle depth. Through linear regression analysis, the equation for the relationship was established: needle depth (mm) = a × BMI (kg/cm^2) + b, and needle depth (mm) = c × height (cm) + d x weight + e, where "a," "c," and "d" were constants and "b" and "e" were regression coefficients. The constants and coefficients differed between the lumbar levels. The epidural needle used for ILEI in our center was a Tuohy-type needle 80 mm in length. Therefore, a longer needle must be prepared if patients with BMI over 42.95, 43.80, and 49.23 kg/m^2 are going to have ILEIs at the L3–4, L4–5, and L5–S1 levels, respectively.

Lumbosacral pain with radiculopathy is a common symptom experienced by individuals regardless of age (5). Low back pain is now the leading cause of disability globally (6).

Minimally invasive interventions such as therapeutic injections have increased dramatically in the treatment of low back pain, with or without lower extremity pain (7). Epidural steroid injections are the most widely used interventional procedure (8). Most clinicians perform epidural injections via either the interlaminar or

Table 5. *Results of Pearson correlation analysis between measurement of C-arm and magnetic resonance imaging.*

	Mean	**SD**	**Correlation coefficient**	***P* value**
Needle depth of L3–4 on C-arm Needle depth of L3–4 on MRI	57.51 52.17	8.65 9.60	0.050	0.742
Needle depth of L4–5 on C-arm Needle depth of L4–5 on MRI	57.67 52.09	8.67 10.07	0.249	0.095
Needle depth of L5–S1 on C-arm Needle depth of L5–S1 on MRI	53.99 47.91	10.60 8.89	0.438	0.003
Needle angle of L3–4 on C-arm Needle angle of L3–4 on MRI	20.09 14.70	5.65 6.17	0.191	0.005
Needle angle of L4–5 on C-arm Needle angle of L4–5 on MRI	15.90 12.06	5.25 5.64	0.177	0.008
Needle angle of L5–S1 on C-arm Needle angle of L5–S1 on MRI	10.18 11.33	5.14 6.82	0.123	0.067

SD, standard deviation
MRI, magnetic resonance imaging

transforaminal approach to direct the needle into the dorsal and ventral epidural spaces, respectively. Sencan et al (9) reported significantly lower 3-month numerical rating scale scores in the ILEI group than in the bilateral TFEI group, and a higher percentage of the decrease in the pain score between the baseline and the third month in the ILEI group. In addition, Husseini et al (10) reported that inadvertent intravascular injections occurred with a higher frequency of transforaminal epidural injections than interlaminar epidural injections. Furthermore, the interlaminar approach is superior to the transforaminal approach in patients with multiple levels of spinal pathology because it facilitates the spread of injected drugs through the epidural space (11). If the patient has an enlarged articular process due to degenerative changes in the spine, epidural steroid injection via the transforaminal route may be extremely difficult (12). Therefore, ILEI is still regarded as an effective method to treat lumbosacral radiculopathy.

Precise targeting and fine needling are essential for a successful intervention with the least complications and discomfort to the patients, as well as radiation exposure. A skilled pain physician can minimize the duration of the procedure, and time is one of the most essential considerations for radiation safety (13,14). The proper length of the needle is important. If the needle is too long for the patient, its precise management may be difficult. If the needle is too short for the patient, the needle tip will not be able to reach the target epidural space, and a second attempt with another needle is inevitable. The patient's discomfort increases due to the pain arising from reinsertion of the needle, as well as from prolonged duration of the procedure. Galbraith et al (15) reported that radiation dose exposure and fluoroscopy screening time also increased with increasing BMI in patients. Therefore, preparation of the spinal needle with proper length is especially important for both patients and practitioners when the patient's BMI is relatively high.

Table 6. *Linear regression analysis for needle depth and caudal angle of C-arm.*

Variable	**Coefficient**	***P* value**	**R^2**
Intercept Caudal angle of L3–4, MRI	17.565 0.173	0.000 0.005	0.037
Intercept Caudal angle of L4–5, MRI	13.919 0.164	0.000 0.009	0.031
Intercept Needle depth of L5–S1, MRI	31.177 0.460	0.000 0.003	0.192

MRI, magnetic resonance imaging

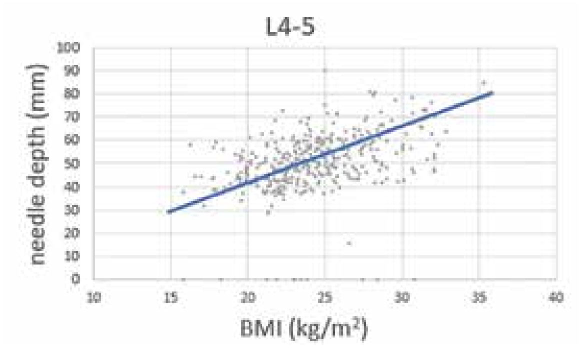

Fig. 2. *Correlation between epidural needle depth and body mass index at L4-5 level.*

Before performing spinal epidural injection, many clinicians order an MRI examination because it is useful for visualizing the anatomy and pathology of the patient. A systemic review by Brinjikji et al showed that

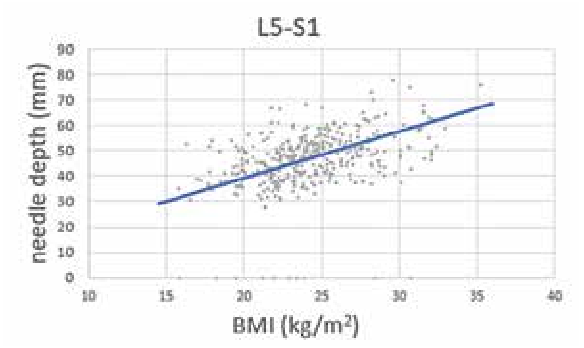

Fig. 3. *Correlation between epidural needle depth and body mass index at L4-5 level.*

a few MRI findings were strongly associated with low back pain, such as Modic type 1 change, disc bulging, disc extrusion, and spondylolysis (16). Sometimes, the treatment plan is changed substantially according to unexpected MRI findings (11), for example, spinal cancer (17). Thus, pre-intervention MRI scans may be important for the proper management of low back pain. The images can then be used to measure the epidural depth before conducting epidural injections, as in this study.

A correlation between needle depth and BMI in epidural injection procedures has already been reported. However, most studies have been conducted on lumbar TFEI and cervical ILEI (4,15,18-22). Therefore, we investigated the relationship between needle depth and the patient's body measurements, such as weight, height, and BMI, for lumbar interlaminar epidural steroid injections. Among these parameters, BMI and height combined with weight were significantly correlated with needle depth.

For the regression analysis mentioned above, we used equations for needle depth (Table 5). The equation is: needle depth (mm) = a × BMI (kg/cm^2) + b, or needle depth (mm) = [c × height (cm)] + [d × weight (kg)] + e, where "b" and "e" are constants and "a," "c," "d" are regression coefficients. These constants and regression coefficients differ with spine level. Using these equations, we were able to predict the needle depth in patients undergoing ILEIs. In this study, the needle depth of the C-arm images in L5-S1 was positively correlated with that of MRI. At the L5–S1 level, the needle depth of C-arm images (mm) = 0.460 × [needle depth of MRI (mm)] +31.777. Therefore, the value at the time of the procedure using C-arm fluoroscopy can be estimated as the value in the MRI.

In our center, we used a Tuohy-type 20G epidural needle as the first choice of needle (TaeChang Industrial Co., Gongju, Korea, or Becton Dickinson, Franklin Lakes, NJ). The overall length of this needle was approximately 80 mm. Therefore, using the equation of the needle depth and the patient's BMI, we could calculate the BMI, which corresponds to a needle depth of 80 mm. If a patient's BMI exceeds the BMI limit, a needle longer than 80 mm is a better choice and should be prepared before the procedure. As mentioned above, there was a linear correlation between BMI and epidural depth. An alarming increase in the morbidly obese population has also been reported in South Korea (23). The prevalence of class III obesity (BMI $\geq$ 35.0 kg/m^2, categorized by the Korean Society for the Study of Obesity) increased 3.8- and 3.5-fold between 2009 and 2018 in young men and women in Korea (24). Thus, the equations established in our study can be helpful for selecting a proper needle and placing the needle effectively with less discomfort and radiation exposure in patients undergoing ILEI.

This study has several limitations. First, the patient's position may have contributed to the difference between the needle depth measured from the MRI scan and the actual depth during the procedure. MRI scans and ILEIs were performed in different patient positions. Patients lay supine during MRI scans and prone during ILEIs. Different positions may lead to a measurement gap between the MRI and the actual needle depth. Algrain et al reported that estimates of needle depth measured using MRI were consistently greater than the actual needle depth measured using the loss of resistance technique (4). However, the prone position did not influence the positions of the lumbar nerve roots in other studies (25,26). Thus, the measurement disparities arising from different positions may be negligible. Errors may arise from either the patient or investigator. It is not easy for the patient to hold their breath for the entire MRI examination period. Therefore, the breathing cycle of the patient may have influenced the recorded length on the MRI. We presumed that the difference would be subtle and that the equations would still be helpful for predicting the needle depth. In this study, we compared the measured data from MRI and C-arm fluoroscopy, and the caudal angle of C-arm images at L3–4 and L4–5, and the needle depth of C-arm images at L5–S1 was positively correlated with that of MRI. Second, the needle insertion site and angle may differ slightly from radiologic imaging. Therefore, the actual needle length required to reach the target epidural space may be slightly shorter or longer.

Complications of ILEIs may be related to needle placement, infection, or drugs injected (11). Direct puncture of the dura with or without spinal cord trauma may result in symptoms such as headache, nausea, vomiting, dizziness, and vasovagal reactions. Accuracy and efficiency are important to minimize adverse events during ILEI procedures (10,27,28). We reduced the possibility of dural puncture through the preparation of proper needles. Prompt and effective injections also reduce discomfort and radiation exposure in both patients and practitioners. Pain physicians perform various procedures under C-arm fluoroscopy guidance. The C-arm fluoroscope is a type of x-ray equipment, and C-arm fluoroscopy generates radiation when used by a pain physician (14,29-31). A brief episodic radiation exposure may not have critical effects on health. However, several patients visiting general hospitals or university hospitals suffer from intractable pain, and they require periodic interventions. Thus, several pain physicians perform procedures under C-arm fluoroscopy guidance repetitively. Cumulative doses may be detrimental to both physicians and patients even if the radiation dose is small (32,33).

CONCLUSION

In conclusion, body measurements, such as BMI, and combined height and weight, correlated with needle depth in ILEI. Needle depth in L5–S1 and caudal angle in L3–4 and L4–5 of MRI were correlated with those of fluoroscopy of ILEI. The equations of needle depth may help decide the size of epidural needles and prepare proper needles before the procedure.

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