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Araştırma/*Research Article*

The Effect of Preoperative Ultrasonography Imaging Method on Success in Patients with Thoracal Epidural Procedure

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Torakal Epidural Uygulanacak Hastalarda Ultrasonografi ile Görüntüleme Yönteminin Başarıya Etkisi

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ABSTRACT

Objective: *To determine the actual measurement of skin-epidural distance in patients in whom epidural anesthesia would be applied at lower thoracic vertebral, and to examine the correlation of epidural space measurements made preoperatively with ultrasonography, and tomography with anthropometric values.*
Methods: *Our prospective, randomized controlled study was realized with 96 ASA I-III adult patients who would undergo epidural anesthesia applied through epidural spaces between 9.-12. thoracic vertebras. Neck and waist circumferences, and BMIs of the patients were recorded. The thoracic level to be used was determined by the anesthesiologist, and marked after verified by USG. From the same thoracic level the distances between skin-spinous process, and skin-ligamentum flavum were measured with USG . After the procedure epidural needle was marked, and obtained values were recorded. Distances between skin- spinous process, and skin-lig. flavum were measured from CTs recorded in the archival files of the same patient.*
Results: *In all three groups of patients (T 9-10 [n=35], T 10-11 [n=30 and T 11-12 [n=31]) skin-lig. flavum distance measured with USG was statistically shorter than that measured with CT, and length of the epidural needle inserted through all levels (p<0,001). Only in the T9-10 group. skin-lig.flavum distance measured in CT was statistically significantly shorter than the length of the needle inserted.*
Conclusion: *With this study, it is shown for the first time in the literature that ultrasonography, CT and anthropometric measurements such as BMI, neck and waist circumference may be useful to estimate the skin-epidural depth before the epidural procedures performed at the lower thoracic levels (T9-12).*

Keywords: *Thoracic epidural, antropometric measurements, epidural distance, ultrasound, Computed tomography*

ÖZ

Amaç: *Alt torakal vertebra seviyelerinde epidural anestezi uygulanacak hastalarda cilt-epidural mesafenin gerçek ölçümünü saptamak, girişim öncesi yapılan ultrasonografi ve tomografide ölçülen epidural mesafenin antropometrik değerler ile korelasyonunu incelemektir.*
Yöntem: *Prospektif, randomize kontrolü çalışmamız torakal 9-12 aralıktan epidural anestezi uygulanacak ASA I-III erişkin 96 hastada gerçekleştirildi. Hastaların boyun ve bel çevresi vücut kitle indeksi (VKI) kaydedildi. İşlem yapılacak seviye anestezist tarafından belirlendi ve USG ile doğrulanarak işaretlendi. Aynı seviyeden USG ile cilt-spinöz çıkıntı ve cilt- ligamentum flavum derinliği ölçüldü. İşlem sonrası epidural iğne işaretlenerek değerler kaydedildi. Aynı hastaya ait arşivimizde bulunan torakal BTdeki cilt-spinöz çıkıntı ve cilt-lig. flavum mesafeleri ölçüldü.*
Bulgular: *Üç grup hastada (T 9-10 (n=35), T 10-11 (n=30) ve T 11-12 (n=31)) USG cilt-lig.flavum ölçümü; BT ile ölçülen cilt-lig. flavum ölçümü ve epidural iğne boyundan istatistiksel olarak daha kısa bulunmuştur (p<0,001). BT ile ölçülen cilt-lig. flavum mesafesi iğne boyu ölçümünden sadece T9-10 grubunda istatistiksel olarak daha kısa bulundu. İğne boyu ile tüm seviyelerde USG, BT ile ölçülen epidural mesafe ve kilo, bel, boyun çevresi arasında korelasyon bulundu.*
Sonuç: *Bu çalışma ile literatürde ilk defa alt torakal seviyelerde (T9-12) epidural girişim öncesi cilt-epidural derinliği tahmin etmek için ultrasonografi, BT nin yanısıra hastanın kilo, bel ve boyun çevresi gibi antropometrik ölçümlerinin de faydalı olabileceği gösterilmektedir.*

Anahtar kelimeler: *torakal epidural anestezi, antropometrik ölçümler, epidural mesafe, ultrasonografi, Bilgisayarlı tomografi*

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INTRODUCTION

The use of ultrasonography (USG) for neuraxial blocks goes 40 years back . Cork had performed the first successful ultrasonographic measurement of the epidural space in the 1980s, and ligamentum flavum was recognized in the 1990s. While ultrasonography was initially considered for neuraxial anesthesia in patients with challenging anatomy, it has been suggested to be used in all patients by the National Institute for Health and Care Excellence (NICE)in 2008. [1]

Insertion of the thoracic epidural catheter is one of the most challenging regional anesthesia techniques due to "blinded" identification of the narrow intervertebral foramen by a needle. The rates of epidural intervention-related paresthesia and blood aspiration were reported as 0.16% and 0.67%. Significant nerve damage is quite rare, and the rate of epidural hematoma is less than 1/150.000. On the other hand, occurring complications may be catastrophic. [2]

USG has been frequently used to assess neuraxial structures as a noninvasive, reliable, and rapidly performed imaging method. It enables the anesthetist to preview the spine anatomy, determine the midline, find a specific intervertebral level, to predict the depth of the epidural space accurately, and identify the most suitable location and trajectory regarding needle insertion. [3,4,5] Numerous studies have reported that USG measurement of the skin-epidural depth was compatible to a great extent with the actual depth measured during the lumbar and thoracic epidural interventions. [2,5] All thoracic levels (upper, middle, and lower) have been generally assessed in studies that used USG to measure the thoracic epidural distance. However, since thoracic vertebral anatomy is different in the upper, middle, and lower levels, the results may also be different. [1,3,4,5] Our literature survey has not encountered any study comparing the epidural distance and USG measurement regarding lower thoracic vertebrae only.

Studies conducted up to this day have also investigated the relationships of epidural distance with genetic characteristics, race, ethnicity, geographic origin, age, gender, body weight and height, body mass index (BMI), waist circumference and foot size, abdominal fat thickness, and vertebral space. [6,7]

Our study has aimed to make actual measurements of the skin-epidural space distance (the length of the needle that intervention was performed with) and investigate its correlations with pre-procedural USG findings, the epidural distance measured with computed tomography (CT), and the anthropometric values (neck circumference, waist circumference, BMI, body weight, and height) in patients undergoing epidural anesthesia at lower thoracic vertebral (T9-12) levels.

MATERIAL and METHODS

After approval of the Ethics Committee of Adnan Menderes University Training and Research Hospital (Ethics Committee Decision 2018- 13) and obtaining the patients' written informed consent, this study was conducted on patients undergoing epidural anesthesia between January 2018 - September 2019. The patients were divided into three groups (T9-10, T10-11, T11-12 groups) using the lot-drawing randomization method. ASA I-III patients aged between 18-80 years, undergoing epidural anesthesia for elective surgery were included in the study. Patients in whom epidural anesthesia was contraindicated, patients whose CT images could not be retrieved from our system, patients in whom needle length measurement could not be obtained because of the inability to perform an epidural intervention, and those with uncompleted records, pregnant women, and emergency cases were excluded from the study. Standard monitoring (ECG, pulse oximetry, non-invasive blood pressure) was used in patients taken to the operating room. Neck and waist circumferences of the patients were measured, and BMI was calculated.

Then, ultrasonographic images were obtained with a console-type convex (1-8 MHz) ultrasonography device using a linear probe (3-22 MHz) (Esaote MyLab Five digital ultrasound, DesMoines, Iowa). The USG measurement process was completed while the patient was in a sitting position (with the elbows placed on the thighs), taking care that the total duration of process should not exceed ten minutes. Both the USG and palpation methods were used to assess the intervertebral level, and the cutaneous needle insertion site was marked with a marker pen.

Identifying the Intervertebral Level

The anesthesiologist determined the level planned to be intervened before the USG examination, and the identified T9-10, T10-11, or T11-12 levels were marked, and confirmed by USG. Our console-type ultrasonography device was used during this process (Esaote MyLabFivedigital Ultrasound, DesMoines, Iowa). The identified level was confirmed by placing the probe at the 12th rib level, in the sagittal plane, 2 cm lateral to the midline, and directing it towards upper thoracic levels. During the procedure, these marks were considered as reference points. After that, the depth of the ligamentum flavum was measured,turning a linear (3-22 MHz) or convex (1-8 MHz) transducer medially and using a transverse median approach.

Measuring the Skin-Epidural Space Distance

The distance between the skin and epidural space at the specified level was determined by measurements made up to the posterior complex involving the dura mater and the hyperechoic line of the ligamentum flavum. The best acoustic window was searched by moving the probe 2-3 mm at the intervertebral space or angling it for 5-10°until the characteristic bright echo of the ligamentum flavum was visualized.

We could not obtain images with the linear probe, particularly in patients whose ligamentum flavum was located deeper than 4cm. Therefore, we used the convex probe in these patients, which shows deeper tissues at a higher resolution. Then, the distance between the skin, and spinous process was measured in the sagittal plane and recorded. The measurements were made after freezing the images, and the entire procedure lasted for a maximum of ten minutes. (Figures 1, 2, and 3).

Our hospital's radiologist made the skin-spinous process and skin-ligamentum flavum measurements from the same patient's thoracic CT images using the iSitePacs software. The ligamentum flavum localized on the mid-sagittal line, was used as an anatomical landmark. The recorded measurements were used as the data for statistical and correlation analyses.

Epidural Catheterization and Needle Length Measurement

The epidural technique was performed using the hanging drop technique with an 18G Tuohy needle through a median approach while the patient was in the sitting position, with the elbows kept over the knees. The Perican® epidural needle, Tuohy epidural needle (diameter 1.30X80 mm, 18G), and the Perifix® standard epidural catheter (radiopaque catheter with three lateral holes, 1000 mm, 20G) were used for the application. The skin-level point on the inserted epidural needle was marked with a sterile pen. The marked point was measured after the procedure and recorded as the actual depth.

The obtained values were written on the data collection sheet. The patient's chart number, age, gender, body weight, height, and BMI were written on the datasheet in addition to these values. The neck and wrist circumferences of the patient were measured with a measuring tape and recorded.

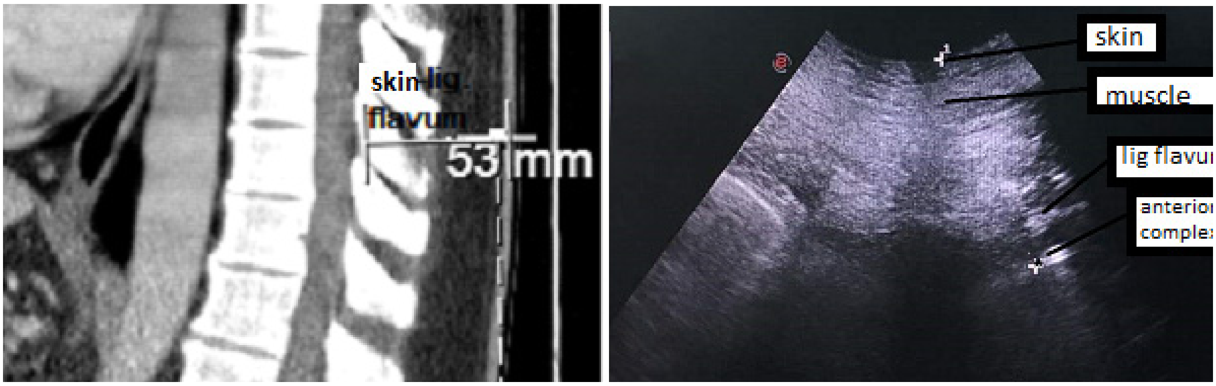

Figure 1. The CT measurement of skin-ligamentum flavum distance in the sagittal plane at the T9-10 level and the image of ligamentum flavum at the T9-10 level in the transverse median window acquired with the convex probe in the same patient

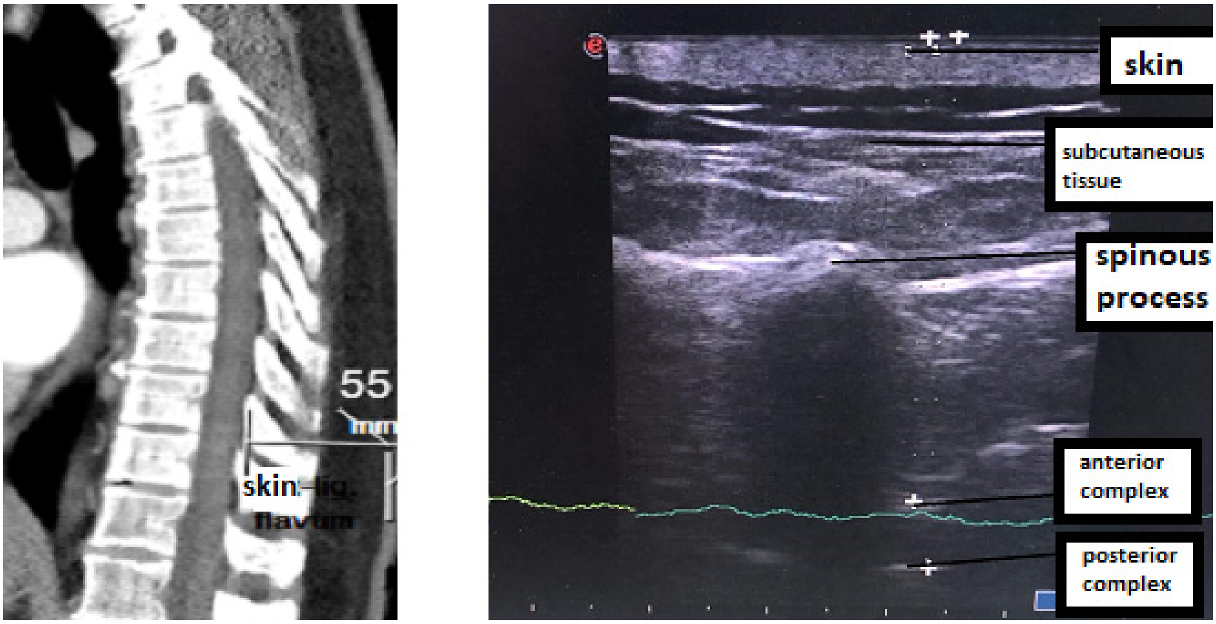

Figure 2. The CT measurement of skin-ligamentum flavum distance in the sagittal plane at the T10-11 level and the USG image of anatomical structures at the T10-11 level in the transverse median window acquired with the linear probe in the same patient

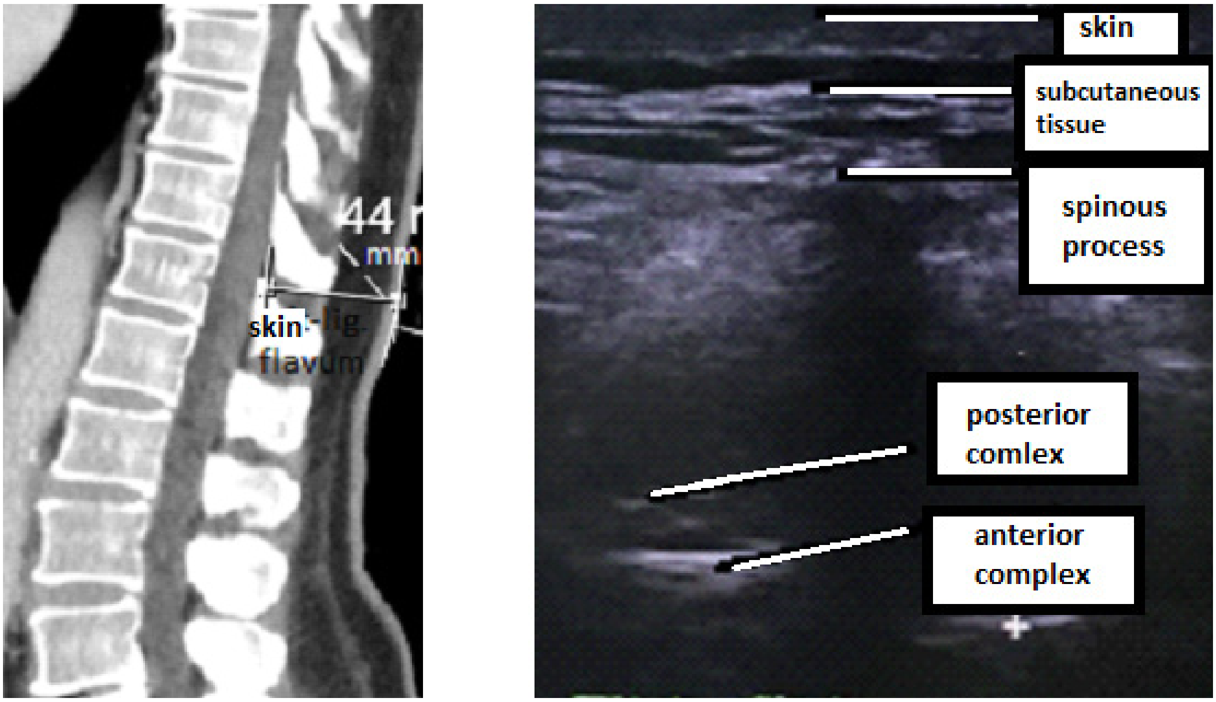

Figure 3. The CT measurement of skin-ligamentum flavum distance in the sagittal plane at the T11-12 level and the USG image of anatomical structures at the T11-12 level in the transverse median window acquired with the linear probe in the same patient

Other diseases, ASA score, type of operation, intervened thoracic level, and number of attempted punctures were also recorded.

Statistical Analysis

The Kolmogorov - Smirnov test analyzed the conformity of quantitative variables with a normal distribution. Independent groups were compared by one-way variance analysis (ANOVA) regarding normally distributed variables, whereas the Kruskal - Wallis test was used for variables with non-normal distribution. Dependent measurements with normal distribution were compared using the paired T-test, whereas Wilcoxon T-test or Friedman test was used for comparison of non-normally distributed dependent measurements. Relationships among quantitative variables were analyzed using the Pearson or Spearman correlation analysis. Descriptive statistics of qualitative variables were expressed as frequency (%). P<0.05 was considered statistically significant.

RESULTS

Among 136 patients participating in the study, 37 were excluded since the epidural space could not be visualized either by CT or USG, whereas three patients were removed from the study due to the failure to perform epidural anesthesia., The mean values for the age (61.79 ± 11.60 years), height (1.66 ± 0.09 m), body weight (73.80 ± 14.34 kg), and BMI (26.63 ± 4.63 kg/m^2), neck (40.24 ± 4.49 cm) , and waist (97.06 ± 15.16 cm) circumferences of the remaining 96 patients were determined. The average skin-spinous process distance and the average skin-ligamentum flavum distance measured with pre-procedural USG and CT performed in all patients, together with the mean post-procedural needle length, are presented in Table 1. When the three groups (T9-10, T10-11, T11-12) were compared, the USG value of skin-spinous process distance at the T9-10 level was found significantly longer than the T11-12 level. No significant difference was found among the groups regarding the skin-spinous process distance values measured by computed tomography (Table 2).

The skin-ligamentum flavum distance measured by USG was statistically significantly shorter when compared to both the CT measurement of skin-ligamentum flavum distance and the epidural needle length in all three groups (p<0.001). The CT measurement of skin - ligamentum flavum distance was statistically significantly shorter than the needle length measurement only in the T9-10 group (Table 3). While there was a positive correlation between needle length and weight, BMI, neck circumference, waist circumference, USG, and CT measurements, any correlation between the needle length and age was not detected (Table 4).

Table 1. The data related to USG and CT measurements and epidural needle values of all patients participating in the study (n=96)

Variable (mm)	Mean±standard deviation	Min-max
USG Skin-spinous process	11.0±5.3	4.8-29.6
CT Skin-spinous process	18.1±7.7	5.0-36.0
USG Skin-lig. Flavum	37.35±9.2	22.9-61.7
CT Skin-lig. Flavum	44.31±8.2	27.0-66.0
Needle length	47.33±10.0	3.0-74.0

Table 2. Statistical comparison of the groups regarding USG, CT measurements, and needle length

Variable	T9-10	T10-11	T11-12	p
USG Skin-spinous process	11.3 (8.0-15.4)**	9.6 (6.9-12)	8.6(6.4-10.0)**	0.024
CT Skin-spinous process	19.4±7.7	18.0 ±8.3	16.8 ±6.7	0.299

*** The USG skin-spinous process distance of the T9-10 group is statistically significantly different compared to the value of the T11-12 group only.*

Table 3. The results of USG and CT measurements of skin-lig. flavum distance and needle length according to the groups

GROUP	USG skin-lig. flavum	CT skin-lig. flavum	Needle length
T 9-10 (n=35)	36.1* (30.8-45.8)	43 $^{\alpha}$(39-50)	51 (44-56)
T 10-11 (n=30)	33* (30.8-37.9)	43.5 (39-51.2)	46 (37-48.2)
T 11-12 (n=31)	36.3* (32.2-40.0)	42.5 (38-49.2)	44 (40-52)

** p<0.001 (In all three groups) USG skin-lig. flavum different from CT skin-lig. flavum and needle size.*
α p=0.001 (In T9-10 group) Difference between CT skin-lig. flavum and needle length

Table 4. Intragroup evaluation of correlations of needle length with USG / CT measurements and anthropometric data

	T9-10		T10-11		T11-12	
	R	P	R	p	R	P
USG skin-spinous process	0.451	**0.002**	0.699	**0.001**	0.795	**0.001**
CT skin-spinous process	0.361	**0.033**	0.493	**0.006**	0.599	**0.001**
USG skin-lig. flavum	0.571	**0.001**	0.684	**0.001**	0.879	**0.001**
CT skin -lig.flavum	0.552	**0.001**	0.604	**0.001**	0.730	**0.001**
Age	0.162	0.288	0.058	0.703	0.022	0.886
Height	0.085	0.579	0.400	**0.006**	0.061	0.699
Body weight	0.644	**0.001**	0.607	**0.001**	0.828	**0.001**
BMI	0.596	**0.001**	0.485	**0.001**	0.447	**0.003**
Neck circumference	0.409	**0.005**	0.731	**0.001**	0.698	**0.001**
Waist circumference	0.623	**0.001**	0.579	**0.001**	0.644	**0,001**

DISCUSSION

As far as we know, this study has been the first in the literature comparing ultrasonographic, CT, and anthropometric measurements to predict the skin-epidural depth before epidural intervention at lower thoracic levels (T9-12). The skin-epidural space distance measured with USG was shorter than the CT skin-ligamentum flavum distance, and needle length measurements in all patients. Besides, positive correlations of the epidural needle length with anthropometric measurements (body mass index, neck and waist circumferences) and skin-epidural space distance measured with USG and CT were determined.

In the study conducted by Rasolian A. et al. [2], an epidural intervention was performed at levels of T5-9 in 20 patients, and the needle lengths were compared to skin-ligamentum flavum distances measured with CT and USG. It was reported that the USG and CT measurements were shorter than the needle length (the mean needle length was 55±7 mm). In our study, an epidural intervention was performed at T9-12 levels in 96 patients, and the needle length was found as 47.14±10 mm. The cause of this significantly longer needle length used at the T9-10 level (51 mm) compared to the other groups (T10-11 and T 11-12) might be the more angled approach used for epidural intervention in higher-level thoracic vertebrae, similar to the study conducted by Rosalian et al. In our study, we also found that longer needle length was used compared to USG measurements at all levels. The cause of this result might be that, due to its curved tip, the Tuohy needle we used might have pushed the dura a little after piercing ligamentum flavum, and this distance might have been added to our measurement. In their study, Rosalian A. et al. found that USG measurements were 4.49 mm shorter than CT measurements. In our study also, the epidural distance measured by USG was significantly shorter than the CT measurement at all levels. This result might have been related to a decrease in distance due to compression of the skin and subcutaneous tissues by the USG probe and changing thickness of ligamentum flavum while measuring the skin-epidural distance with USG.

Three approaches are commonly used at one vertebral level in conventional ultrasonography: transverse, median longitudinal, and paramedian longitudinal. We obtained the best images with the median transverse approach and measured the ligamentum flavum distance using this approach in all patients. In the study conducted by Grau T. et al. [8] , USG was performed using all three approaches at the L3-4 level, and the widths, epidural spaces, and the images of ligamentum flavum were compared in 60 patients. As a result, it was reported that the highest visibility of the ligamentum flavum and dura was achieved through the widest window using the paramedian approach. On the other hand, studies in the literature have reported successful results with the transverse approach, supporting our study. [9,10,11] Chauhan A. K. et al. [9] compared epidural depth measurement by USG performed in the transverse plane with epidural needle lengths and concluded that taking measurements from the needle insertion site increased the quality and success rate of the procedure.

Similarly, other studies have reported that simultaneous USG-guided interventions in transverse and paramedian sagittal oblique windows were possible and comfortable. [10,11] Another study conducted by Salman et al. [12] in 2011 investigated the usability of USG at levels of mid-lower thoracic vertebrae by approaching in the paramedian sagittal oblique plane. Patients who were planned to undergo upper abdominal surgery were included in the study. Images were obtained in the paramedian sagittal oblique plane, and the skin- epidural space distance was measured in all patients. In that study, it was concluded that for mid-lower level thoracic vertebrae (T6-7), performing USG in the paramedian sagittal oblique plane would be beneficial regarding the prediction of skin - epidural space distance. We also performed USG for lower-level thoracic vertebrae and determined its strongest correlation with the needle length, particularly at the T11-12 level, in the transverse median plane. Thus, we can suggest that a transverse median window is a practical approach for predicting the skin-epidural space distance in lower-level thoracic vertebrae. The relative anatomical similarity of lower-level thoracic and lumbar vertebral structures might have been significant regarding the visualization of ligamentum flavum in the transverse approach. In neuraxial anatomy, caudal angling of spinous processes of upper thoracic vertebrae and narrow interspinous and interlaminar spaces in the mid-thoracic region might have led to the formation of a narrow acoustic window during the transverse USG approach and thus, limited visibility. [4] However, we still think that selection between the transverse and paramedian approaches depends on the experience, and skill of the performer.

Our study used superficial anatomy and confirmation with USG to determine the thoracic vertebral levels. Besides, similar to the literature [13], we did not confide in the information about considering the vertebral level corresponding to the lower scapular tip as T7. We determined the level by palpating upwards, starting from the 12th rib level, and rapidly confirmed this level with USG, significantly reducing the error margin.

Currently, CT measurement of the skin-epidural space distance has been performed in numerous studies. [7,14] In the studies conducted by Kosturakis et al. [7] and Nathaniel et al. [14], associations of needle length measurements with CT measurements and anthropometric characteristics at levels from T3-4 to T11-12 were investigated. CT measurements were reported to be significantly shorter than needle lengths in both studies. The authors stated that its cause might be the supine position used for CT imaging, leading to compression exerted by skin and subcutaneous tissues. CT measurements were not corrected according to needle insertion angles in these studies.

On the contrary, in the study conducted by Carnie J et al. [15], the actual epidural depth was estimated using the Pythagorean theorem (needle length=the distance measured with CT/the cosine of the insertion angle). However, in the study of Kosturakis [7], et al. ,it was stated that it was not possible to know and calculate the needle angling definitely during the epidural intervention. In our study, a significant difference was present between CT measurements and needle lengths in the T9-10 group only. We also did not correct our USG and CT measurements according to the needle insertion angles, considering that we would not be able to calculate the needle angles definitely and standardize them for 96 patients; however, we determined strong correlations between needle length and our measurements.

The distance of the epidural space from the skin and the width of the epidural space are affected by numerous factors. Studies performed to date have investigated various factors such as race, ethnic and geographical origins, age, gender, body weight, height, foot size, BMI, and BSA (body surface area). [16,17,18,19,20] In the study conducted by Cantürk M et al. [21] on 130 pregnant women, the skin-to epidural space distance was measured with USG at the L3-4 intervertebral space. Then a combined epidural-spinal block was performed through this space, and the waist circumference, BMI, age, height, and body weight were recorded in all patients. The correlation coefficient between the epidural space and waist circumference was calculated as 0.797, and strong correlations with BMI and body weight were also determined. On the other hand, no correlation with either height or age was present.

Similarly, our study determined extraordinarily strong correlations of epidural depth with waist circumference and body weight in all patients, particularly at the T11-12 level; this might be because abdominal fat and weight affect the lower thoracic region. Similar to the study conducted by Cantürk M et al., we were not able to determine the correlation of epidural depth with height and age. Besides, unlike other studies, we determined strong correlations between epidural depth and neck circumference at all levels.

The complication rate is low in central neuraxial blocks, and most of the complications resolve within six months. [22,23,24] In a study that a thoracic epidural block was performed in 2059 patients, accidental dural puncture and inability to place an epidural catheter were found to occur with a rate of 0.7-1.2%, and none of these patients developed neurological sequela. [23] In our study, an epidural intervention was performed in a total of 136 patients, and consistent with the literature, an accidental dural puncture occurred in two (1.4%) patients. Following the dural puncture, the epidural intervention was tried again at the next higher level. No pathology was encountered during the neurological follow-up of these patients.

One limitation of our study might be not to record the total duration of the procedure. We tried to complete the whole procedure involving USG measurement and epidural catheterization in less than ten minutes; however, we did not keep time precisely. Because MR images of our patients were not present in our system, our other limitation was the inability to make MR measurements. If we could have made those measurements, we would be able to compare the epidural depths in CT and MRI. No obese patient was present in our study group. Since most of our study group consisted of cancer patients, we did not have the chance to measure many overweight patients. Another limitation was failure to intervene simultaneously with USG. Since we did not have experience on this subject and did not want to prolong the procedure , we did not prefer simultaneous intervention. Even though use of real-time USG during neuraxial procedures is promising, it would be challenging if performed by a single person and necessitates high-degree hand skill and hand-eye coordination. Besides, the gel used for USG may cause an infection during the neuraxial block.

In conclusion, we can state that in clinical practice, epidural depth at levels of T9-12 can be predicted by pre-procedural USG or CT, and these measurements can be correlated with needle length. Besides, we think that visualization can be performed using the transverse medial approach in lower thoracic vertebrae. We also think that, among anthropometric measurements, neck circumference can also help us to predict the skin-epidural space distance in addition to body weight and waist circumference. In thoracic epidural anesthesia, more studies investigating the use of USG at all levels and the data of a large number of patients are required.

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