J Anesth (2014) 28:413–419
DOI 10.1007/s00540-013-1726-1

ORIGINAL ARTICLE

A randomized controlled trial of preinsertion ultrasound guidance for spinal anaesthesia in pregnancy: outcomes among obese and lean parturients

Ultrasound for spinal anesthesia in pregnancy

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Received: 15 November 2012 / Accepted: 1 October 2013 / Published online: 20 October 2013

Abstract
Purpose The present study was conducted to examine if preinsertion lumbar ultrasound scanning helps with performance of spinal puncture, as a tool for decreasing the number of puncture attempts and spinal procedure time and increasing the success rate. We hypothesized that ultrasound can facilitate neuraxial blockade, particularly in pregnant women with difficult topographic anatomy.
Methods One hundred (50 lean, BMI <30 kg/m^2, and 50 obese, BMI ≥30 kg/m^2) parturients scheduled for cesarean delivery were divided into ultrasound and control groups. Subarachnoid block was performed with prepuncture ultrasound examination in lean parturients (group 1, $n = 25$) and in obese parturients (group 2, $n = 25$), and subarachnoid block was performed without prepuncture ultrasound examination in lean parturients (group 3, $n = 25$) and in obese parturients (group 4, $n = 25$). The number of puncture attempts and puncture levels were recorded.
Results A lower number of puncture attempts and fewer puncture levels were detected in ultrasound (US) groups ($p < 0.001$). First attempt success rate under US guidance was 92 % in comparison to 44 % using a conventional technique in obese parturients ($p < 0.001$). In 52 % of the lean patients and in 54.2 % of the obese patients, the intercristal line was at the L3–L4 and at the L2–L3 interspace, respectively. The duration of spinal procedure was shorter in US groups (22 vs. 52 s, $p = 0.031$). We found a high correlation between ultrasound and needle depth ($r = 0.709$, $p < 0.001$).
Conclusions We found a high level of success in the prepuncture ultrasound-determined insertion point. The ultrasound imaging technique can be a reliable guide to facilitate spinal anesthesia, especially in obese parturients.

Keywords Anaesthesia · Obstetric · Anesthetic techniques · Spinal · Equipment · Ultrasound · Pregnancy

Introduction

Pregnancy is associated with tissue edema and weight gain, resulting in difficulty in finding epidural and subarachnoid spaces (SS). Also, flexion may be difficult in pregnant patients receiving neuraxial anaesthesia. The American Society of Regional Anesthesia recommends that anesthesiologists should be aware of the limitations of physical examination to determine the puncture level, especially in pregnant and obese patients [1].

Ultrasound imaging techniques have become an increasingly popular procedure among anesthesiologists to facilitate neuraxial blockade [2–5]. This facilitation is particularly advantageous in pregnant women with difficult topographic anatomy: hyperlordosis, progressive pelvic rotation over the long axis of the spinal column, weight gain, and edema. These factors can potentially interfere with the palpation of lumbar spine landmarks and may position the intercristal line in a more cephalad relationship

This study was presented at the Annual ESRA Congress, September 2011, Dresden, Germany.

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with the vertebral column. Ultrasound imaging has been shown to be superior to the landmark palpation technique in accurate identification of lumbar interspinous spaces [6, 7].

The present study was conducted to examine if preinsertion lumbar ultrasound scanning helps with performance of spinal puncture, as a tool for decreasing the number of puncture attempts and spinal procedure time and increasing the success rate. We hypothesized that ultrasound (US) can facilitate neuraxial blockade, particularly in pregnant women with difficult topographic anatomy.

Our secondary outcome measures were to determine whether identification of the L4–L5 space by physical examination differs from that of ultrasound, to determine the relationship between ultrasound and needle depth, and to determine whether ultrasound can reduce the complications in obese and nonobese parturients.

Materials and methods

After Kocaeli University Ethics Committee (2011/31 KAEK 4/8, 07.02.2011) approval and signing of informed consent by the patients, 100 [50 lean patients with body mass index (BMI) <30 kg/m^2, and 50 obese patients with BMI ≥30 kg/m^2] parturients scheduled for elective cesarean delivery were prospectively studied. BMI was measured by using term pregnancy weight. The degree of obesity for pregnant patients was determined according to the classification of body mass index of the World Health Organization.

Inclusion criteria were as follow: 18 years of age or older, 8 h fasting, and elective cesarean section for term pregnancy under subarachnoid block. Patients were excluded from the study if they were pregnant with twins, contraindicated for subarachnoid block (infection at the puncture site, coagulopathy, patient refusal, hypovolemia, or abnormal spinal anatomy), or were undergoing urgent or emergency cesarean sections. Patients were monitored with pulse oximeter, noninvasive blood pressure, and electrocardiogram, and venous access was established. Using a sealed envelope method, parturients were randomized to one of four study groups:

Group 1 ($n = 25$): subarachnoid block was performed with prepuncture ultrasound examination in the lean patients (US group)

Group 2 ($n = 25$): subarachnoid block was performed with prepuncture ultrasound examination in the obese patients (US group)

Group 3 ($n = 25$): subarachnoid block was performed without prepuncture ultrasound examination in the lean patients (control group)

Group 4 ($n = 25$): subarachnoid block was performed without prepuncture ultrasound examination in the obese patients (control group)

Ultrasonography was performed by the same operator (T.S.) who has extensive experience in ultrasonographic identification of the intervertebral structures in parturients (approximately 150 examinations) in only those patients assigned to an ultrasound group. With the parturient in a sitting position, an anesthesiologist with more than 5 years of experience in obstetric anesthesia identified the L4–L5 space using anatomical references, i.e., the level that an imaginary line connecting both upper iliac crests crossed the spine identified L4 or the L4–L5 space in all patients. This determination was followed by lumbar ultrasound with a Esaote Mylab 30 (Florence, Italy) only in the US groups. A convex transducer of 2–5 MHz was used. Ultrasound visualization in the paramedian longitudinal and transverse planes was performed. The transducer was initially placed on the sacral region on a longitudinal paramedian presentation, 2–3 cm from the midline, angled to the center of the spinal canal. The sacrum was identified as a continuous hyperechoic line. The transducer was moved in a cephalad direction to identify the intervertebral spaces (acoustic windows) and spinous processes (acoustic shadows) of the lumbar vertebrae as a saw-like image (Fig. 1). The ligamentum flavum (LF) and dura mater were identified as an echogenic structure inside the spinal canal. The midpoint of the US transducer was placed over the L4–L5 interspinous space, and the intervertebral level was marked on the skin by marker pen with a transverse line passing through the midpoint of the transducer in the US groups. In the transverse plane, the operator captured the best image

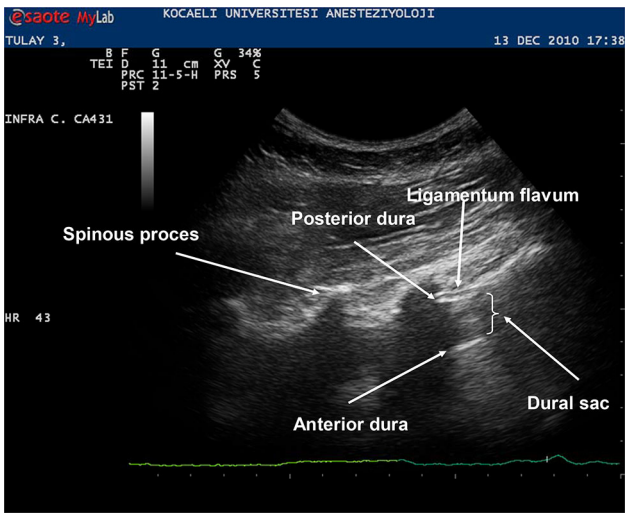

Fig. 1 Paramedian ultrasound of the lumbar spine. Note the posterior epidural space is a hypoechoic area between the hyperechoic ligamentum flavum and the posterior dura

showing the transverse and articular processes, vertebral body, LF, and dura mater. After ultrasonographic imaging of the L4–L5 intervertebral space, the space distance from the skin to the subarachnoid space (just under the dura mater) (ultrasound depth, UD) and the distance from the skin to the LF were measured in the paramedian sagittal plane and transverse plane using built-in calipers. In addition, the diameter of the intrathecal space (the distance between anterior and posterior dura) was measured.

Subsequently, an anesthesiologist (second author: an anesthesia resident with 4 years of experience in performing neuraxial blocks for spinal anesthesia) blinded to the UD located the subarachnoid space through the predetermined insertion point thought to represent the L4–L5 interspace (identified by ultrasound using the paramedian approach) and measured the length of the needle from the marked point of skin to the pinpoint (needle depth, ND) with a ruler. A 25 G Quincke needle (88 and 120 mm) was used, and 8 mg 0.5 % hyperbaric bupivacaine combined with 25 μg fentanil was administered; the anesthesia followed the protocol of the institution. In the control groups, the puncture site was located by only palpation and the subarachnoid space was confirmed by backflow of cerebrospinal fluid. The extent of sensory block was evaluated by cold and the degree of motor block according to Bromage. Subarachnoid block was classified as a failure if the surgical procedure could not begin without the addition of general anesthesia. The duration of spinal procedure (s) was accepted as the time from the handle of spinal needle to observe free flow of cerebrospinal fluid and was measured by an observer with a stopwatch.

The number of puncture attempts (every separate insertion of the needle) and the number of puncture levels (moving to a second interspace after three times insertion of needle) were recorded. A needle requiring withdrawal for redirection for the same intervertebral level was also counted. We compared the ultrasound depth that was measured using the paramedian view and needle depth. All patients were interviewed regarding spinal anesthesia side effects such as paresthesia, backache, and postdural puncture headache.

Before ultrasonography, edema was evaluated on the back just in the iliac crest line by using a 4-point scale (0, none; 1, slight; 2, moderate; 3, severe). The ease of landmark palpation (palpation of the iliac crests and spinous processes) was graded on a 4-point scale: easy = light palpation of iliac crests, spinous processes identified by sight; moderate = light to deep palpation of iliac crests, light palpation of spinous processes; difficult = deep palpation of iliac crests and spinous processes; impossible = iliac crests or spinous processes could not be palpated) [8]. Edema and landmark palpation were evaluated by the first author. The visibility of the LF and dura mater on US was analyzed by a numeric scoring system: 0, not detectable; 1, hardly (cannot define, despite manipulation of probe); 2, well (can define with manipulation of probe); 3, very well (clearly visible) detectable.

Statistical analysis

Analyses were performed using the SPSS 13.0. The calculation of sample size was based on the following: the primary endpoint was the rate of successful puncture at the first puncture site. Based on a previously published study [9], the rate of successful puncture at the first puncture site was 50 % in the palpation group and 90 % in the ultrasound group. With the (two-sided) α error set at 0.05 and β error set at 0.2 (power of 80 %), 19 patients per group were needed. To account for a 25 % loss from potential withdrawals and technical failures, we increased the target sample size to 25 patients per group.

Normality distribution of continuous variables was tested using the Shapiro–Wilk test. The normally distributed

Table 1 Demographic and obstetric data

	Nonobese US (group 1)	Obese US (group 2)	Nonobese control (group 3)	Obese control (group 4)
Age (years)†	31 ± 4.8	32.4 ± 6.6	30.2 ± 4.7	31.6 ± 5.2
Weight (kg)†	69.9 ± 7.3	86.7 ± 10.1	73 ± 7.6	96 ± 15.9
Height (m)†	1.6 ± 0.06	1.5 ± 0.06	1.6 ± 0.05	1.5 ± 0.05
BMI (kg m^{-2})†	26.4 ± 2.2	34.1 ± 3.5	27.2 ± 2	37.3 ± 5.8
Gravida (*n*)†	2.3 ± 1.6	3 ± 2.5	2.5 ± 1.2	2.4 ± 1.1
Parity (*n*)†	0.8 ± 1	1.4 ± 2	1 ± 0.9	1.4 ± 1.1
ASA††				
I	18 (72)	15 (60)	18 (72)	14 (56)
II	7 (28)	10 (40)	7 (28)	11 (44)
Preeclampsia††				
No	24 (96)	18 (72)	23 (92)	20 (80)
Yes	1 (4)	7 (28)	2 (8)	5 (20)
Edema††*				
0	15 (60)	6 (24)	16 (64)	8 (32)
1	7 (28)	13 (52)	9 (36)	14 (56)
2	3 (12)	5 (20)	0 (0)	3 (12)
3	0 (0)	1 (4)	0 (0)	0 (0)
Landmark palpation††**				
0	17 (68)	5 (20)	20 (80)	4 (16)
1	7 (28)	8 (32)	3 (12)	11 (44)
2	1 (4)	9 (36)	2 (8)	8 (32)
3	0 (0)	3 (12)	0 (0)	2 (8)

Data are given as mean ± SD or *n* (%)

US ultrasound, *BMI* body mass index

* Edema: 0, none; 1, slight; 2, moderate; 3, severe

** Landmark palpation: 0, easy; 1, moderate; 2, difficult; 3, impossible

† One-way ANOVA test was used

†† Chi square test was used

Table 2 Ultrasonographic evaluation of lumbar spine and distances

	Nonobese US (group 1)	Obese US (group 2)	*P*
Ligamentum flavum visibility††			
Hardly	7 (28)	9 (36)	
Well	12 (48)	13 (52)	0.519
Very well	6 (24)	3 (12)	
Skin–LF depth (cm)†			
Paramedian approach	4.7 ± 0.6	5.3 ± 0.6	0.002
Transverse approach	4.5 ± 0.6	5.1 ± 0.5	0.002
Ultrasound depth (cm)*†			
Paramedian approach	5 ± 0.6	5.6 ± 0.6	0.001
Transverse approach	4.7 ± 0.6	5.3 ± 0.5	0.006
Needle depth (cm)**†	5.7 ± 0.4	6.5 ± 0.8	<0.001
Epidural space†	0.2 ± 0.04	0.1 ± 0.04	0.652
Intrathecal space†	0.9 ± 0.2	0.9 ± 0.1	0.768
Intercristal line exact space††			
L2	1 (4)	0 (0)	
L2–L3	4 (16)	13 (54.2)	
L3	6 (24)	6 (25)	0.022
L3–L4	13 (52)	4 (16.7)	
L4	1 (4)	1 (4.2)	

Data are given as mean ± SD or number (%)

LF ligamentum flavum

† Student's *t* test was used

†† Chi square test was used

* Ultrasound depth: subarachnoid depth measured by ultrasound

** Needle depth, subarachnoid depth measured by needle

variables were compared using analysis of variance (ANOVA) among the four groups, and the Tukey test was used for post hoc comparison. Skewed continuous variables were compared using the Kruskal–Wallis test. Independent-sample *t* test was used for comparison of continuous variables between the obese and nonobese ultrasound groups. For categorical variables, the chi square test was used. Pearson correlation analysis was used to find the relationship between ultrasound depth and actual needle depth and also between edema and landmark palpation.

A *P* value of 0.05 was considered to be statistically significant.

Results

Patient characteristics and obstetric data are shown in Table 1. All patients enrolled completed the study. No important differences were noted between groups with respect to age, height, ASA classification, presence of preeclampsia, number of pregnancies, and parity (Table 1).

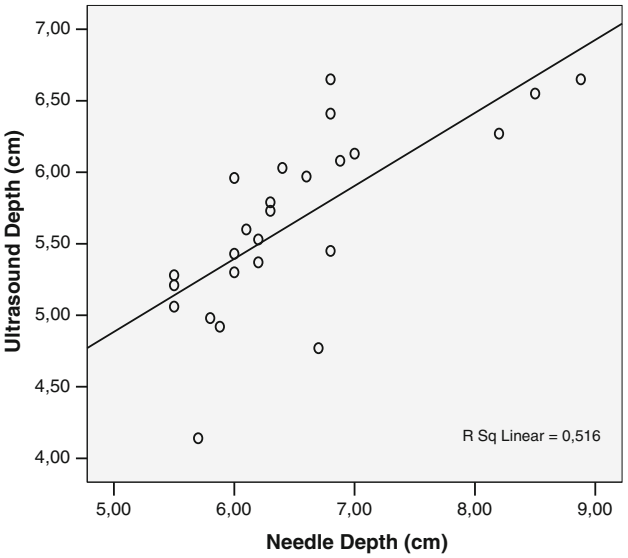

Fig. 2 Scatter plot of ultrasound measured depth and actual needle depth in obese patients

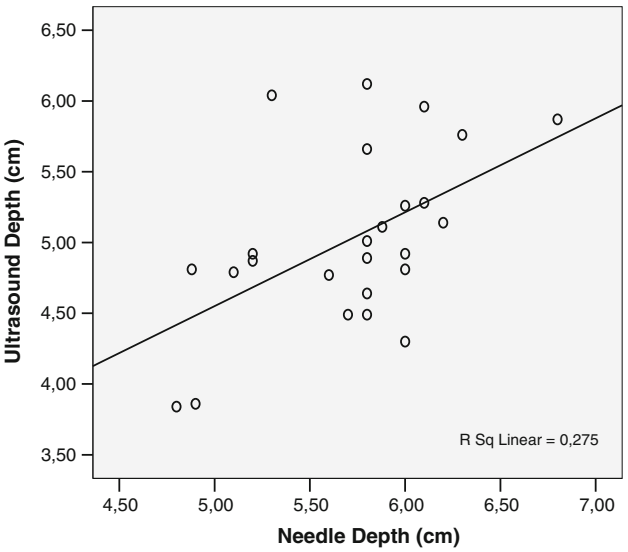

Fig. 3 Scatter plot of ultrasound measured depth and actual needle depth in non obese patients

Edema was more frequent and landmark palpation was more difficult in obese parturients (Table 1).

In the US groups, the ligamentum flavum was visible in all patients.

Mean depths from skin to the ligamentum flavum and to the subarachnoid space as measured by longitudinal paramedian and transverse ultrasound planes are presented in Table 2. Pearson's correlation coefficient comparing the transverse ultrasound plane to the longitudinal paramedian ultrasound plane was 0.699. We found a high correlation between ultrasound depth and needle depth ($r = 0.709$, $p < 0.001$) in obese and nonobese patients (Figs. 2, 3).

Table 3 Assessment of subarachnoid block quality

	Nonobese US (group 1)	Obese US (group 2)	Nonobese control (group 3)	Obese control (group 4)	*P*
Number of puncture attempts[†]					
1	23 (92)	23 (92)	18 (72)	11 (44)	≤0.001[a]
2	2 (8)	2 (8)	1 (4)	6 (24)	
≥3	0 (0)	0 (0)	6 (24)	8 (32)	
Number of puncture levels[†]					
1	25 (100)	25 (100)	19 (76)	16 (64)	≤0.001[a]
2	0 (0)	0 (0)	5 (20)	8 (32)	
3	0 (0)	0 (0)	1 (4)	1 (4)	
Requirement of needle redirection[†]					
0	10 (40)	8 (32)	7 (28)	7 (28)	0.001[b]
1	10 (40)	14 (56)	6 (24)	6 (24)	
2	5 (0)	2 (8)	4 (16)	2 (8)	
≥3	0 (0)	1 (4)	8 (32)	10 (40)	
Spinal needle length[†]*					
1	25 (100)	22 (88)	23 (92)	16 (64)	0.004[b]
2	0	2 (8)	0 (0)	6 (16)	
3	0	1 (4)	2 (8)	8 (20)	
Duration of spinal procedure (s)[‡]	23	22	45	52	0.031
Median (min–max)	(5–85)	(10–150)	(6–590)	(8–840)	
[IQR]	[43]	[30]	[65]	[184]	
Spinal success[†]					
Yes	24 (96)	23 (92)	24 (96)	23 (92)	0.868
No	1 (4)	2 (8)	1 (4)	2 (8)	

Data are given as *n* (%) or median (min–max) (IQR)

* Spinal needle length: (1) 88 mm, (2) 120 mm, (3) both were used[‡]: Kruskal–Wallis test was used

[†] Chi square test was used

[a] Ultrasound and control groups were found to be statistically different in the number of puncture attempts and puncture levels

[b] The requirement of needle redirection and the use of both needle sizes were higher in the obese control group than other groups

Skin–ligamentum flavum and skin–subarachnoid distances were significantly different between obese and nonobese patients.

Ultrasound determination of the intervertebral space clinically identified as L4–L5 (intercristal line) was performed in all patients except one in the obese group (Table 2). A wide variation, with statistically significant differences, was observed. In 52 % of the lean patients, the intercristal line was at the L3–L4 interspace; in 54.2 % of the obese patients, the intercristal line was at the L2–L3 interspace.

In the nonobese groups, there were two failed subarachnoid blocks, compared to four in the obese groups (Table 3). Fewer puncture attempts and fewer puncture levels were detected in US groups ($p < 0.001$). First attempt success rate under US guidance was 92 % in comparison to 44 % using a conventional technique in obese parturients ($p < 0.001$). The duration of spinal procedure was shorter in the US groups (22 vs. 52 s, $p = 0.031$) (Table 3).

The requirement of needle redirection and the use of both needle sizes (88 and 120 mm) were higher in the obese control group (Table 3).

In both US groups, subarachnoid space was successfully identified at premarked insertion point by observation of the free flow of cerebrospinal fluid. Punctures were performed only at one intervertebral level in ultrasound groups, whereas in the control group, especially in the obese control group, two or three levels were needed to find the subarachnoid space ($p < 0.001$) (Table 3).

No important differences were noted between groups with respect to adverse effects during and after the subarachnoid block such as paresthesia, backache, and postdural puncture headache (Table 4).

Table 4 Adverse effects in the ultrasound (US) versus the control group

	Nonobese US (group 1)	Obese US (group 2)	Nonobese control (group 3)	Obese control (group 4)	*P*
Paresthesia					
Yes	4 (16)	1 (4)	2 (8)	6 (24)	0.144
Backache					
Yes	0	0	1 (4)	3 (12)	0.077
CSF					
Bloody	6 (24)	8 (32)	9 (36)	7 (28)	0.813
Headache					
Yes	2 (8)	0	0	1 (4)	0.202

Data are given as number (%)[†]

CSF cerebrospinal fluid

[†] Chi square test was used

Discussion

Preinsertion ultrasound imaging to identify the L4–L5 level reduced the number of required insertion attempts for both obese and nonobese parturients. The first attempt success rates under US guidance were 92 % in comparison to 44 % using a conventional technique in obese parturients. Every attempt carries the risk of infection, hematoma, and neurological damage. Some patients complained of paresthesia during the needle insertion, but none of the patients complained of pain during administration of the anesthetic.

Palpation using anatomical landmarks has repeatedly been shown to be inaccurate at identifying lumbar vertebrae and their corresponding interspaces [10, 11]. In a recent study [2] the authors demonstrated that the intercristal line determined by palpation intersects the lumbar spine in term pregnant women at a more cephalad level than the L4–L5 interspace. In our study, the rate of the correct identification of the L4–L5 space or level of L4 by clinical evaluation was low, especially in obese parturients. The intercristal line was at the L2–L3 interspace in 54.2 % of obese patients. Locks et al. [12] also compared obese patients with nonobese patients in their study. In contrast to our study, they marked the L3–L4 interspace with palpation and confirmed with US. In the Locks study, it was found that in 33–47 % of the patients the exact level was actually the L2–L3 interspace instead of the L3–L4 interspace.

Ultrasonography may be more accurate than palpation in correctly identifying lumbar interspaces. A preview scan allows the anesthesiologist to identify the midline and determine the interspace for needle insertion [10, 13]. In our study, the subarachnoid space was successfully identified at a premarked insertion point by observation of the free flow of cerebrospinal fluid in both US groups.

Factors that affect the quality of US images of the neuraxial structures are not well understood. Excessive fat in obesity, by attenuating the transmission of the US signal, causing scattering of the US in the tissues and increasing the overall depth to the neuraxial structures seen, may decrease image quality during spinal ultrasonography [14].

Grau et al. [15] compared the quality of images obtained with transverse, median longitudinal, and paramedian longitudinal approaches and suggested that the paramedian longitudinal approach was optimal. We performed US imaging through the longitudinal paramedian and transverse planes in our patients and found a high correlation between these approaches.

These data are also useful in estimating the length of the spinal needle required during a subarachnoid access. We found a high correlation between the ultrasound depth and the needle depth ($r = 0.709$, $p < 0.001$) in obese and nonobese patients. However, the mean depth determined by US was much shallower than the actual needle depth, especially in obese patients (the mean difference is about 0.9 cm in obese patients and 0.7 cm in nonobese patients). This difference may be attributed to the greater subcutaneous tissue compression by the ultrasound probe with increasing BMI and edema.

Limitations of our study were that neither preprocedural ultrasound imaging time nor patient acceptance of the technique was evaluated.

In conclusion, prepuncture ultrasound examination improves the success rate of subarachnoid access on the first attempt, and reduces the number of puncture attempts and the need to puncture different levels, especially in obese parturients.

Conflict of interest None declared.

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