

Real-time ultrasound-guided paramedian epidural access: evaluation of a novel in-plane technique

M. K. Karmakar*, X. Li, A. M.-H. Ho, W. H. Kwok and P. T. Chui

Department of Anaesthesia and Intensive Care, The Chinese University of Hong Kong, Prince of Wales Hospital, Shatin, NT, Hong Kong, SAR, People's Republic of China

*Corresponding author. E-mail: karmakar@cuhk.edu.hk

Background. Current methods of locating the epidural space rely on surface anatomical landmarks and loss-of-resistance (LOR). We are not aware of any data describing real-time ultrasound (US)-guided epidural access in adults.

Methods. We evaluated the feasibility of performing real-time US-guided paramedian epidural access with the epidural needle inserted in the plane of the US beam in 15 adults who were undergoing groin or lower limb surgery under an epidural or combined spinal–epidural anaesthesia.

Results. The epidural space was successfully identified in 14 of 15 (93.3%) patients in 1 (1–3) attempt using the technique described. There was a failure to locate the epidural space in one elderly man. In 8 of 15 (53.3%) patients, studied neuraxial changes, that is, anterior displacement of the posterior dura and widening of the posterior epidural space, were seen immediately after entry of the Tuohy needle and expulsion of the pressurized saline from the LOR syringe into the epidural space at the level of needle insertion. Compression of the thecal sac was also seen in two of these patients. There were no inadvertent dural punctures or complications directly related to the technique described. Anaesthesia adequate for surgery developed in all patients after the initial spinal or epidural injection and recovery from the epidural or spinal anaesthesia was also uneventful.

Conclusions. We have demonstrated the successful use of real-time US guidance in combination with LOR to saline for paramedian epidural access with the epidural needle inserted in the plane of the US beam.

Br J Anaesth 2009; **102**: 845–54

Keywords: anaesthetic techniques, epidural; analgesic technique, subarachnoid; spinal cord, extradural space; monitoring, ultrasound

Accepted for publication: February 26, 2009

Epidural anaesthesia or analgesia is frequently used during the perioperative period. Success of the technique depends on one's ability to accurately locate the epidural space. Currently, one has to rely on surface anatomical landmarks and 'loss-of-resistance' (LOR). Anatomical landmarks are useful but are surrogate markers, difficult to palpate in the obese and those with oedema in the back, do not take into account anatomical variations or abnormalities, and frequently (70%) lead to incorrect identification of a given lumbar interspace.¹ The LOR technique, which is the gold standard for locating the epidural space, is also a blind technique. Moreover, one cannot predict technical difficulties or the accuracy of needle placement before skin

puncture with any of the landmark-based techniques. This may lead to multiple attempts at epidural needle placement, pain and discomfort to the patient, a failed block, complications, frustration for the anaesthesiologist, and poor patient satisfaction. Therefore, any alternative technique that can circumvent some of these shortcomings and facilitate localization of the epidural space is desirable.

Recently, there has been an increase in interest in the use of ultrasound (US) to guide peripheral nerve blocks.² US imaging has also been used during central neuraxial [epidural or combined spinal–epidural (CSE)] blocks,^{3–5} either to preview the anatomy before needle puncture^{3–5} or to visualize the advancing needle in real time.⁵ A

preview scan performed before needle puncture improves the success rate of epidural access on the first attempt, reduces the number of puncture attempts, or the need to puncture multiple levels.^{3–5} Grau and colleagues⁵ also describe a two-operator technique of real-time US visualization, through a paramedian sagittal scan, of an advancing epidural needle that was inserted through the midline during a CSE procedure. Despite these encouraging results, there are no published data describing real-time US-guided central neuraxial blocks in adults. The aim of this pilot study was to evaluate the feasibility of performing real-time US-guided paramedian epidural access, with the epidural needle inserted in the plane (in-plane) of the US beam, by a single operator.

Methods

After research Ethics Committee (Joint CUHK-NTEC Clinical Research Ethics Committee, Hong Kong, People's Republic of China) approval and written informed consent, either from the subject or from their next of kin (in the elderly who were unable to consent), 15 ASA I–III patients who presented for groin or orthopaedic lower limb surgery, in whom an epidural or a CSE anaesthesia was planned, were enrolled for this study (Table 1). Patients were excluded if they had a BMI >35, clinically obvious or known spinal deformity, infection in the back, allergy to local anaesthetic drugs, previous spine surgery, or coagulopathy.

No premedication was prescribed before surgery to any of the patients. After the patient arrived in the operating theatre, routine monitoring (ECG, heart rate, non-invasive arterial pressure, and arterial oxygen saturation) and i.v. access were established before they were positioned in the lateral position with the side to be operated uppermost, and with the hip and knees slightly flexed. Fentanyl (25–75 µg) was administered i.v., immediately before the positioning, to those in pain or with fractures.

The US scan was performed by a single investigator (M.K.K.), who is experienced in US imaging of the spine and familiar with spinal sonoanatomy. A Micromaxx (Sonosite™ Inc., Bothell, WA, USA) or HD11XE (Philips, Bothell, WA, USA) US system with compound imaging capabilities (MB technology; Sonosite™ Inc. or SonoCT technology; Philips) was used. A curved array transducer (5–2 MHz with the Micromaxx system and 9–4 MHz with the HD11XE system) was used with the US system for the scan. Liberal amounts of US gel were applied to the skin over the lumbar region for acoustic coupling, and a longitudinal (sagittal) paramedian scan of the lumbar spine was performed to locate the L3/L4 or L4/L5 lumbar interspace and to optimize the US image before the intervention as part of the scout scan (pre-intervention scan). The transducer was held in the non-dominant hand of the operator and it was positioned 1–2 cm lateral to the spinous processes,

on the non-dependent side, with its orientation marker directed cranially (paramedian sagittal scan). The transducer was also tilted slightly medially during the scan, so that the US beam was insonated in a paramedian oblique sagittal plane (Fig. 1). This was done to ensure that the incident US signal entered the spinal canal through the widest part of the interlaminar space. The US image was optimized by making the following adjustments on the US system: (i) an appropriate scanning depth was selected (6–9.2 cm), (ii) the 'General' (mid range) or 'Penetration' (low range) frequency range was selected, since the transducer used was a broadband transducer, and (iii) finally, the gain was manually adjusted to obtain the best possible image (Fig. 1). The sacrum was identified by moving the transducer caudally while still maintaining the same orientation. It was seen as a flat hyperechoic band with an acoustic shadow anterior to it (Fig. 2).⁶ The dip or gap between the sacrum and the lamina of L5 was the L5/S1 intervertebral space. The L3/L4 and L4/L5 intervertebral spaces were identified by counting upwards. The transducer was finally positioned over the L3/L4 and L4/L5 intervertebral spaces, and the position of the transducer was marked on the patient's back using a skin marking pen. This was done to ensure that the transducer was returned to the same position after sterile preparations were made before the intervention. This also circumvented the need to repeat the scout scan routine to identify the L3/4 or L4/5 intervertebral space described above. The US images during the entire procedure were recorded on tape using a digital video camera recorder (DCR-PC9E, Sony® Corporation, Japan) that was connected to the US system via the S-video output port.

After sterile preparations, the epidural or CSE anaesthesia was initiated by the same investigator (M.K.K.) performing the scan (single operator technique) using an 18 G Tuohy needle (Portex® Combined Spinal/Epidural Minipack with Lock, pencil point spinal needle, Smiths Med Int Ltd, Hythe, UK). The US transducer was prepared by applying a thin layer of US gel on its footprint, which was then covered with a sterile-transparent dressing (Tegaderm™, 3M Health Care, MN, USA) ensuring that there was no air trapped between the footprint and the transparent dressing. The transducer with its cable was then covered with a sterile plastic sleeve (Sani Sleeve™, Dasol Int Co. Ltd, Gwangju, Korea). No US gel was applied directly to the skin over the area scanned, and saline, which was applied using a sterile swab, was used as a substitute coupling agent. This was done because there are no data demonstrating the safety of US gel on central neuraxial structures. As expected, there was a slight deterioration in the overall quality of the US image without the US gel on the skin, but it could be optimized by making minor adjustments to the overall gain and compression settings.

With the L3/L4 and L4/L5 lumbar interspaces in view on the US monitor, local anaesthetic (lidocaine 1%, 2–3 ml) was infiltrated to the skin and underlying tissue, 1–2 cm

Table 1 Patient characteristics and CSE anaesthesia details. UVS, ultrasound visibility score

Patient no.	Age (yr)	Gender	Weight (kg)	Height (cm)	BMI	ASA	Diagnosis	Surgery	Technique	Total UVS	Sonographic changes seen at LOR
1	65	Male	73	170	25.2	I	Bilateral lower limb open wound	Debridement of wound and split skin grafting	CSE	22	Anterior displacement of posterior dura and widening of epidural space
2	36	Male	62	168	21.9	I	Left knee anterior cruciate ligament injury	Anterior cruciate ligament repair	Epidural	26	Anterior displacement of posterior dura and widening of epidural space
3	60	Male	64	167	22.9	II	Trochanteric fracture right femur	Gamma nail fixation	CSE	10	None
4	83	Female	62	158	24.8	II	Fracture left neck of femur	Austin more arthrodesis	CSE	8	None
5	78	Male	62	165	22.8	II	Fracture left neck of femur	Screw fixation of hip fracture	CSE (failed to locate the epidural space), so intrathecal injection performed at L45	11	None
6	79	Female	63	162	24	III	Fracture right proximal femur	Gamma nail fixation	CSE (no efflux of CSF, so spinal tap performed at one lower interspace—L45)	9	None
7	36	Female	62	155	25.8	I	Fracture right femoral shaft	GK nail insertion	CSE	14	None
8	27	Male	68	173	22.7	I	Trimalleolar fracture right ankle	Open reduction and internal fixation	CSE (no efflux of CSF, so spinal tap performed at one lower interspace—L45)	24	Anterior displacement of posterior dura, widening of epidural space and compression of thecal sac
9	82	Female	58	162	22.1	III	Fracture left neck of femur	Austin more arthrodesis	CSE	19	Anterior displacement of posterior dura and widening of epidural space
10	67	Female	67	158	26.8	II	Right thigh wound	Debridement and suturing	CSE	17	Anterior displacement of posterior dura and widening of epidural space
11	82	Female	47	160	18.4	II	Fracture right neck of femur	Austin more arthrodesis	CSE	8	None
12	92	Male	72	170	24.9	III	Right irreducible inguinal hernia	Right inguinal herniorrhaphy	CSE	6	Anterior displacement of posterior dura and widening of epidural space
13	89	Female	58	162	22.1	III	Fracture right neck of femur	Screw fixation of hip fracture	CSE	9	None
14	39	Female	67	165	24.6	I	Fracture left neck of femur	Screw fixation of hip fracture	CSE	17	Anterior displacement of posterior dura, widening of epidural space, and compression of the thecal sac
15	80	Male	60	168	21.2	III	Trochanteric fracture right femur	Gamma nail fixation	CSE	15	Anterior displacement of posterior dura and widening of epidural space

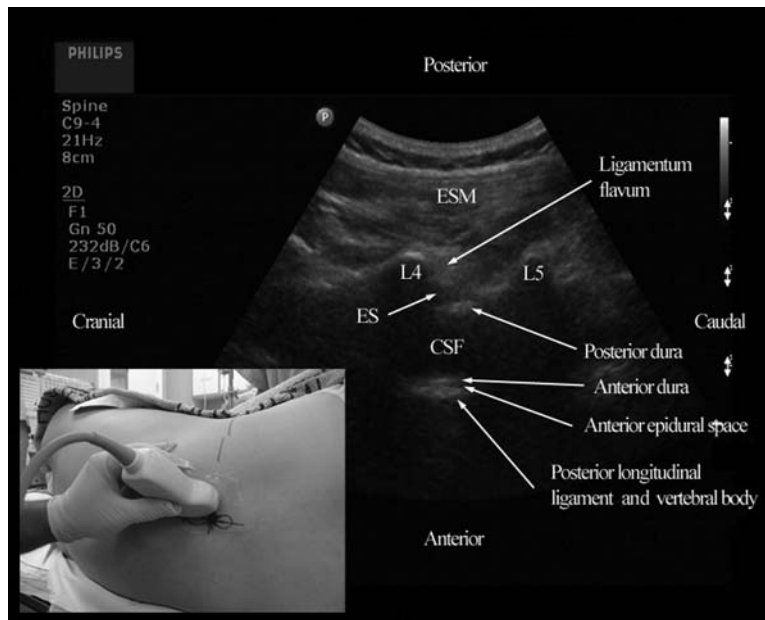


Fig 1 Paramedian oblique sagittal sonogram of the lumbar spine. Note the posterior epidural space is a hypoechoic area between the hyperechoic ligamentum flavum and the posterior dura. The intrathecal space is the anechoic space between the anterior and the posterior dura. The anterior epidural space, although not visible in most patients, is seen here as a hypoechoic space between the anterior dura and the posterior longitudinal ligament. Picture in the inset shows the position and orientation of the transducer with a slight medial tilt during the scan. ESM, erector spinae muscle; CSF, cerebrospinal fluid; ES, epidural space; L4, lamina of L4 vertebra; L5, lamina of L5 vertebra. (Reproduced with permission from www.aic.cuhk.edu.hk/usgraweb.)

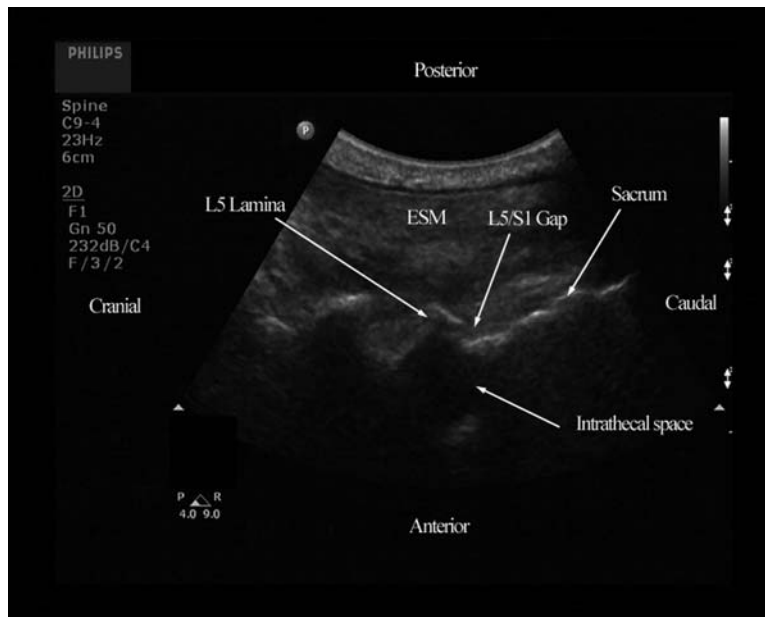


Fig 2 Paramedian sagittal sonogram of the lumbosacral junction. The posterior surface of the sacrum is identified as a flat hyperechoic band with an acoustic shadow anterior to it. The dip or gap between the sacrum and the lamina of L5 is the L5/S1 intervertebral space. The L4/L5 and L3/L4 intervertebral spaces are identified by counting upwards. ESM, erector spinae muscle. (Reproduced with permission from www.aic.cuhk.edu.hk/usgraweb.)

lateral to the spinous process. The Tuohy needle was then inserted in the long axis (in-plane) of the US transducer from the caudal end (Fig. 3) with its tip directed towards the interlaminar space (L3/L4 or L4/L5) that had the best

visibility of the neuraxial structures on the US image. This target interlaminar space was always maintained in the centre of the US image. The angle of needle insertion, that is, the trajectory for needle insertion, was optimized while

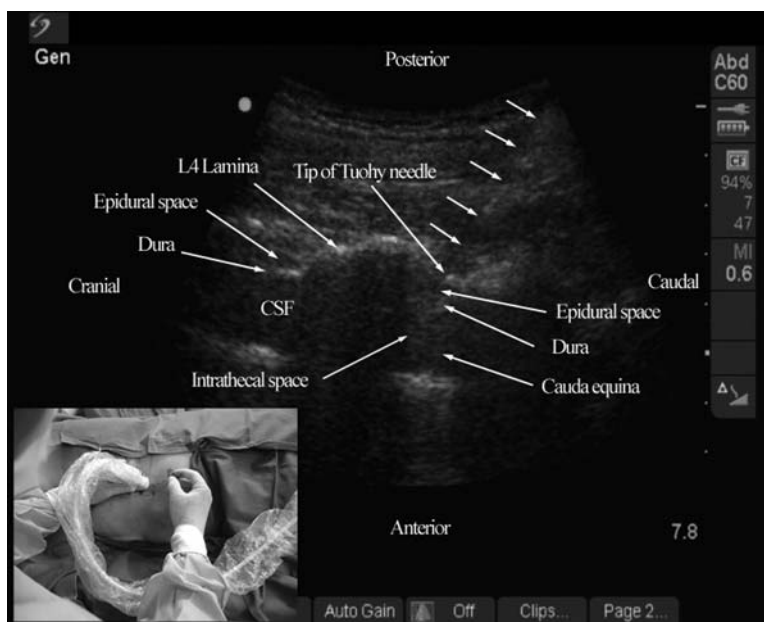


Fig 3 Paramedian oblique sagittal sonogram of the lumbar spine during real-time US-guided paramedian epidural access. Picture in the inset shows the orientation of the transducer and the direction in which the Tuohy needle is introduced (in-plane) during the epidural access. The tip of the Tuohy needle (short white arrows) is seen embedded in the ligamentum flavum. CSF, cerebrospinal fluid. (Reproduced with permission from www.aic.cuhk.edu.hk/usgraweb.)

the needle was still in the erector spinae muscle. No attempt was made to deliberately contact the lamina with the Tuohy needle during the procedure. The Tuohy needle was gradually advanced to the interlaminar space, under real-time US guidance, until the tip was judged to have engaged in the ligamentum flavum (Fig. 3). This was also confirmed by testing for ‘resistance to injection of air’ through the Tuohy needle using the standard LOR syringe included in the epidural kit. Since the Tuohy needle was inserted in the plane of the US beam, it was possible to follow the advancing needle in real time. However, as the angle of insertion was relatively steep, it was not possible to visualize the entire needle at all times, and the position of the needle tip could only be inferred by gently jiggling the needle and observing tissue movement or at times as a bright spot on the US scan (Fig. 3). Once the Tuohy needle was confirmed to have engaged in the ligamentum flavum, an Episure™ AutoDetect™ syringe (Indigo Orb, Inc., Irvine, CA, USA),⁷ which is a new LOR syringe with an internal compression spring that applies constant pressure on the plunger,⁷ filled with 3–4 ml of normal saline was carefully attached to the Tuohy needle ensuring that the syringe tip was secure and there was no leakage of saline (Fig. 4). The needle-syringe assembly was then stabilized by gently supporting the middle, ring, and little finger of the hand holding it on the patient’s back. The needle-syringe assembly was then gradually advanced, while observing the plunger of the syringe, until forward movement of the plunger and expulsion of the saline indicating entry of the needle tip into the epidural space was visually detected.

In patients who were due to receive an epidural anaesthetic for surgery, 3–4 cm of an epidural catheter was inserted into the epidural space through the Tuohy needle and secured to the back using a LOCKiT™ (Portex®, Smiths Medical Int Ltd, UK) epidural catheter clamp. Patients were then returned to the supine position, and bupivacaine 0.5%, 15 ml was injected in 3–5 ml aliquots over 5–10 min. When a CSE was planned for anaesthesia, a 27 G pencil point spinal needle was inserted through the Tuohy needle (needle-through-needle technique) to perform the dural puncture. Once a free flow of cerebrospinal fluid (CSF) was ascertained, the spinal needle was locked into place and plain bupivacaine 0.5%, 2–2.5 ml (10–12.5 mg) was injected over 15–20 s. The spinal needle was removed and 3–4 cm of an epidural catheter was immediately inserted into the epidural space through the Tuohy needle and secured to the back as described above. The patients were then returned to the supine position and no local anaesthetic was injected through the epidural catheter unless the level of sensory block after the spinal injection was deemed to have been inadequate for surgery.

Heart rate and arterial pressure were recorded at 3 min intervals for the first 15–20 min and then at 5 min intervals for the duration of surgery. Hypotension (defined as >20% decrease in systolic arterial pressure from the baseline) was treated using i.v phenylephrine (100 µg bolus). No formal sensory-motor assessment, other than assessing for a lack of response to pinprick at the level of the umbilicus (T10), was performed 15–20 min after the initial epidural or intrathecal injection, since the majority of our

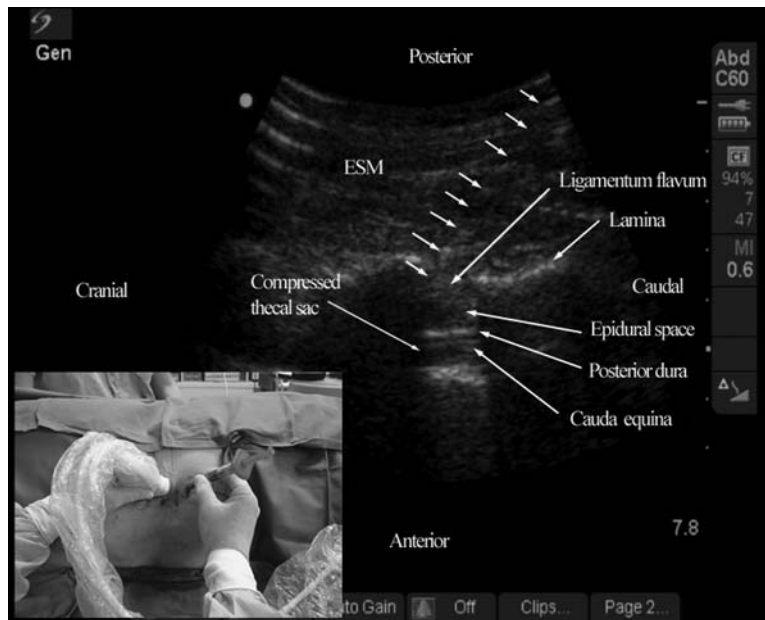


Fig 4 Paramedian oblique sagittal sonogram of the lumbar spine showing the sonographic changes within the spinal canal after the LOR to saline. Note the anterior displacement of the posterior dura and widening of the posterior epidural space. There is also compression of the thecal sac, and the cauda equina nerve roots are now visible within the thecal sac in this patient. ESM, erector spinae muscle. (Reproduced with permission from www.aic.cuhk.edu.hk/usgraweb.)

patients were elderly (>60 yr) or undergoing emergency surgery for trauma. A lack of response to pin-prick stimulation at the level of the umbilicus 20 min after the intrathecal injection was defined as being adequate for surgery. Midazolam (0.5–2 mg i.v. bolus) or propofol (1–2 mg kg⁻¹ h⁻¹) was used for intraoperative sedation, and oxygen (4 litre min⁻¹) was administered via a facemask to the elderly patients. On conclusion of surgery, sedation was discontinued and the patients were transferred to the recovery room. An infusion of bupivacaine (0.125%) and fentanyl (2.5 µg ml⁻¹) was commenced via the epidural catheter at a rate of 0.1 ml kg⁻¹ h⁻¹ for postoperative analgesia, once the patients were deemed to be haemodynamically stable and there was evidence of recovery from the epidural or spinal anaesthesia (ability to move the toes). Postoperative care in the ward was entirely at the discretion of the orthopaedic surgeons except for the epidural analgesia that was managed by our acute pain team. The epidural catheters were removed 48–72 h after surgery.

The following parameters were recorded during the study. The visibility of the nine neuraxial structures (lamina, ligamentum flavum, interlaminar space, epidural space, posterior dura, intrathecal space, cauda equina, pulsations of the cauda equina, and anterior dura–posterior longitudinal ligament complex) at the L3/L4 or L4/L5 lumbar interspace were scored in real time during the scout scan, by the same investigator who performed the US scan (M.K.K.), using a four-point numerical scale⁵ (0, not visible; 1, hardly visible; 2, well visible; 3, very well visible, maximum score possible=27), and the total US visibility score (UVS) was

determined for every patient. The scan was considered a success, if the lamina and at least one deep soft tissue structure were seen. The US visibility of the neuraxial structures was judged to have been good, if the mean total UVS was >18, average if the score was 9–18, and poor if the score was <9. The number of attempts it took to access the epidural space was also recorded. Any change in the neuraxial anatomy that was seen on the US image after the entry of the Tuohy needle and expulsion of saline from the EpisurTM AutoDetectTM syringe into the epidural space was noted. Complications directly related to the technique (vascular or dural puncture) or inadequacies of the block that required rescue epidural injection of local anaesthetic during surgery was also recorded. Vertical and oblique (to closely represent the midline and paramedian approach) distances from the skin to the lamina, anterior aspect of the ligamentum flavum, and the posterior dura were also measured using an off-cart method (Table 2). Still images (TIFF format, 720×576 pixels, and 8-bit gray levels) were captured from the video recordings made during the scout scan using Adobe Premier Pro 2.0 (Adobe Systems Inc., San Jose, CA, USA) and Image-Pro[®] Plus (version 6.2, Media Cybernetics, Silver Spring, MD, USA) was used to measure the distances in these images. A spatial scale specific for the transducer used (Sonosite C60e or Philips C9-4) was calibrated in Image-Pro Plus (IPP) before the measurements were made. In the spatial calibration dialogue box of IPP, the ‘centimetre’ unit was selected as the unit for measurement. Thereafter, the number of pixels cm⁻¹ in the horizontal (*X*) and vertical (*Y*) axes of the US image (Sonosite C60e: 46.3 pixels cm⁻¹ and Philips C9-4: 42.5 pixels cm⁻¹) was determined by setting

Table 2 Mean (SD) vertical and oblique distances from the skin to the lamina, ligamentum flavum, and posterior dura

	Vertical	Oblique	P-value
Distance from skin to lamina (cm)	3.08 (0.54)	5.34 (0.82)	0.000
Distance from skin to anterior aspect of ligament flavum (cm)	3.92 (0.49)	5.71 (0.71)	0.000
Distance from skin to posterior dura (cm)	4.24 (0.48)	5.94 (0.71)	0.000

the calibration scale to match the depth scale (object of known size) marked on the US image. To measure the distance, the appropriate spatial scale, depending on the US system and transducer used, was selected and a straight line was stretched between two anatomical landmarks. The distance between these two points was expressed in centimetres.

The data were analysed using SPSS for windows (version 14, SPSS, Inc., Chicago, IL, USA). The Kolmogorov–Smirnov test was used to test the normality of the data recorded. The data are presented as mean (SD) when normally distributed and as median (range) when not normally distributed. Since data that were analysed were normally distributed, the paired sample *t*-test was used for the statistical comparison and a *P*-value of <0.05 was considered statistically significant.

Results

Real-time US-guided paramedian epidural access, in which the epidural needle was inserted in the plane of the US beam, was successfully performed in 15 adults, ASA I–II, by a single experienced operator. There were seven men and eight women with a mean age of 66.3 (21.7) yr, weight 63 (6.3) kg, height 164 (5.2) cm, and BMI 23.3 (2.1). The US scan was successful in all patients, and the US visibility of neuraxial structures was judged as good in four (26.6%), average in seven (46.7%), and poor in four (26.6%) patients. The mean total UVS of the neuraxial structures in this cohort of patients was 14.3 (6.3). When viewed from the posterior aspect, the lamina was the first osseous structure seen and it appeared hyperechoic. Since bone impedes the transmission of the US signal, there was an ‘acoustic shadow’ anterior to each lamina. In-between the dark acoustic shadows of adjacent lamina, there was a rectangular area in the sonogram where the neuraxial structures were seen. This was the ‘acoustic window’ and resulted from reflections of the US signal from neuraxial structures within the spinal canal. The ligamentum flavum was also hyperechoic, but less so than the lamina, and often appeared as a thick band across adjacent lamina (Fig. 1). The posterior dura was the next hyperechoic structure anterior to the ligamentum flavum and the epidural space was the hypoechoic area between the ligamentum flavum and the posterior dura (Fig. 1). The thecal sac with the CSF was the anechoic space anterior to the posterior dura. The

cauda equina appeared as multiple horizontal hyperechoic shadows within the anechoic thecal sac. Pulsations of the cauda equina were also identified in some patients (26.6%). The anterior dura was also hyperechoic, but it was often difficult to differentiate it from the posterior longitudinal ligament of the vertebra as they were closely apposed to each other and often of the same echogenicity (isoechoic), although in some cases the anterior epidural space could be identified as a hypoechoic area between the two (Fig. 1).

The distances from the skin to the lamina, anterior aspect of the ligamentum flavum, and the posterior dura on the US images were significantly greater in the oblique axis compared with the vertical axis ($P=0.000$, Table 2). The epidural space was successfully identified in 14 of 15 (93.3%) patients in 1 (1–3) attempt using the technique described. There was a failure to locate the epidural space in one elderly man (Patient 5, 78 yr old) in whom, although the US visibility was average (UVS=11), there were multiple bony contacts and we were unable to insert the Tuohy needle through the interlaminar space due to bony resistance. The procedure was successfully converted to a spinal anaesthesia through the midline at the lower interspace (L4/L5). In 8 of 15 (53.3%) patients, studied neuraxial changes, that is, anterior displacement of the posterior dura and widening of the epidural space, were seen on the US image after entry of the Tuohy needle and expulsion of saline from the Episure™ AutoDetect™ syringe into the epidural space (Fig. 4). Compression of the thecal sac was also seen in two (13.3%) of these patients (Fig. 4). The mean UVS [18.4 (6.7)] in patients in whom neuraxial changes were seen ($n=8$) was significantly higher ($P<0.02$) than those in whom neuraxial changes were not seen [10.8 (3.2), $n=7$]. In two patients (Patients 6 and 8), there was no efflux of CSF through the spinal needle that was considered to have been successfully placed in the intrathecal space using the technique described above. In both these patients, the epidural catheter was placed through the Tuohy needle at the original level of epidural access (L3/L4) and the spinal puncture was successfully performed through the lower lumbar interspace (L4/L5). There were no inadvertent dural punctures during the epidural access or complications directly related to the technique described. Anaesthesia adequate for surgery developed in all patients after the initial spinal or epidural injection, and there was no need for any intraoperative supplementation. Recovery from the epidural or spinal anaesthesia was also uneventful.

Discussion

In this pilot study, we have demonstrated the successful use of real-time US guidance for paramedian epidural access, performed by a single experienced operator, with the epidural needle inserted in the plane of the US beam. We also provide objective (sonographic) evidence of

changes that occur within the spinal canal, at the level of needle insertion, after the entry of the Tuohy needle and expulsion of saline from the LOR syringe into the epidural space.

During lumbar spinal sonography, the neuraxial structures are better seen through a longitudinal paramedian plane than through the median transverse or median longitudinal plane.⁸ We also performed US imaging through the longitudinal paramedian plane in our patients, but the mean total UVS of the neuraxial structures in this cohort of patients was 14.3 (6.33) and was judged as average in the majority of our patients (46.7%). These data have to be interpreted after considering the fact that the neuraxial structures that were identified and scored for their visibility were not verified, for logistical reasons, using an alternative imaging modality such as magnetic resonance imaging but were based on our experience and understanding of spinal sonography from previously published data in adults^{8,9} and children.^{10,11} Factors that affect the quality of US images of the spine during spinal sonography are poorly understood. Excessive fat in obesity, by (i) attenuating the transmission of the US signal, (ii) causing scattering of the US in the tissues, and (iii) increasing the overall depth to the neuraxial structures seen, may decrease image quality during spinal sonography.¹² However, obesity was not a problem in our patients as they were excluded from this pilot study. Future studies should evaluate the utility of US guidance in the obese since epidural access in these patients can be challenging. Despite the small sample size in this case series, we believe age-related changes in echogenicity of musculoskeletal structures may explain why the quality of the US images of the spine was less than optimal because the majority of our patients were elderly [66.3 (21.7) yr]. The echo-intensity of muscles is significantly increased in the elderly,¹³ and it is our observation that US images are generally whiter and also much brighter in the elderly. The resultant loss in image resolution can compromise the quality of musculoskeletal US imaging in the elderly. Currently, there are no objective data on age-related differences in the visibility of neuraxial structures during spinal sonography and a study to address these differences is currently underway at our institution.

We measured vertical (to closely represent the midline approach) and oblique (to closely represent the paramedian approach) distances from the skin to the lamina, anterior aspect of the ligamentum flavum, and the posterior dura using an off-cart method. As expected, the oblique distances were greater than the vertical distances. These data are useful in estimating the length of the epidural needle required during a US-guided paramedian epidural access and in our case if the oblique distance to the posterior dura was >80 mm, then we would have had to choose a longer epidural needle, which fortunately was not required.

Grau and colleagues⁵ describe a technique of real-time US visualization, through a paramedian sagittal scan, of an

advancing epidural needle that was inserted through the midline during a CSE procedure. We are not aware of any published data describing real-time, in-plane, US guidance during epidural access in adults, although US-guided epidural catheterization has been reported in children.¹¹ In the latter, the technique is performed by two operators,¹¹ one performs the US scan through the paramedian window and the second operator performs the epidural catheterization through the midline using the traditional LOR technique.¹¹ Although effective in children, the need for a second operator proficient in spinal sonography to perform the US scan and the limited space available for the three or four hands that are required to perform the US-guided intervention may be considered a disadvantage in clinical practice. The problem is compounded in infants and young children where space is even more limited and may partly explain why real-time US guidance for epidural access is not as popular as US-guided peripheral nerve blocks today.

In this study, we describe a novel technique of performing US-guided paramedian epidural access in the lumbar region. Since the epidural needle was inserted in the plane of the US beam, it was possible to visualize the advancing needle in real time. We were also able to circumvent the need for a second operator (additional hands), to perform the LOR, by using the Episure™ AutoDetect™ syringe, which is a new LOR syringe with an internal compression spring that applies constant pressure on the plunger.⁷ Preliminary data suggest that the use of the spring-loaded LOR syringe during the initiation of epidural analgesia in parturients reduces the number of attempts and the time required to identify the epidural space.⁷ It also reduces the incidence of failed epidural analgesia and there is a trend towards fewer dural punctures.⁷ We also found it easy to use the Episure™ AutoDetect™ syringe. However, one must be aware that a false LOR may occur if the syringe is attached when the tip of the Tuohy needle is in the s.c. tissue or erector spinae muscle. Therefore, it is important to ensure that the tip of the Tuohy needle is engaged in the ligamentum flavum before the spring-loaded syringe is attached. Being able to sonographically confirm that the tip of the Tuohy needle was engaged in the ligamentum flavum in real time during the procedure was an advantage. We were also able to visually observe the LOR, that is, the forward movement of the plunger and expulsion of the saline from the syringe, on entry of the needle tip into the epidural space. Habib and colleagues⁷ believe that this visual confirmation offers a more precise endpoint for epidural access than the standard LOR technique by removing operator subjectivity and variability. Larger trials will be required to confirm this in clinical practice. We failed to locate the epidural space in one elderly man (78 yr old) in whom the US visibility was average (UVS=11), but we were unable to insert the needle through the interlaminar space due to bony resistance which we believe may be due to age-related ossification of the ligamentum flavum.¹⁴

Larger randomized trials are required to quantify the success and failure rates of the technique described.

We observed sonographic changes within the spinal canal, at the level of needle insertion, immediately after the LOR in the majority (53.3%) of our patients. This was encouraging because the acoustic window was relatively narrow and the US visibility was average in our cohort of patients. Recent advances in US technology, improved image processing capabilities of US machines, and the use of compound imaging, which improves image quality, may have contributed to this success. Also not surprising was the finding that the UVS was higher in patients in whom the sonographic changes were seen at LOR. Anterior displacement of the posterior dura and widening of the posterior epidural space were the most common changes seen within the spinal canal, but compression of the thecal sac was also seen in a few patients. Such changes have previously been described in children and are objective signs of a correct epidural injection.¹¹ We believe this is the first report to demonstrate sonographic changes within the spinal canal after LOR in adults. The sonographic changes that we observed within the spinal canal may have clinical implications. The anterior displacement of the posterior dura and widening of the posterior epidural space by the pressurized saline, at the moment of LOR, support suggestions that the incidence of dural puncture may be lower when one uses a continuous LOR to saline compared with an intermittent LOR with air,¹⁵ and may also explain why the incidence of dural puncture is lower when saline is used for the LOR compared with air.¹⁶ Compression of the thecal sac by an epidural injection is also the proposed mechanism for the technique of 'epidural volume extension' that involves injecting saline into the epidural space immediately after an intrathecal injection, as part of a CSE, to extend the cephalad spread of the spinal block.¹⁷

The efflux of CSF from the spinal needle (27 G) after a successful spinal puncture during the CSE was noted to be very slow. In a few cases, we had to wait for as long as 3 min before the CSF emerged from the spinal needle. This is a well-known problem of needle-through-needle CSE¹⁸ and related to the use of long and fine gauge spinal needles that have high internal resistance to flow of fluid.¹⁹ The lumbar CSF pressure is also believed to be lower when patients lie on their side²⁰ and the technique of paramedian needle insertion that we have described in this study may also contribute to the slow efflux of CSF. The needle was inserted in the plane of the US beam from the non-dependent side, with the patient in the lateral position, and thus from a slightly higher level than the thecal sac. Therefore, a certain hydrostatic pressure had to be overcome before the CSF could emerge from the spinal needle. Although our hypothesis may suggest that a paramedian spinal puncture from the dependent side is preferable to the non-dependent side, there are no data to support our belief and further research in this area is warranted.

There was no efflux of CSF through the spinal needle in two patients. The spinal needle could not be directly seen in the intrathecal space using US in these two patients, but we can only speculate that it was in the intrathecal space because the LOR was visually confirmed on the Episure™ AutoDetect™ syringe in both these cases and dural displacement was also seen on the US image in one patient during the epidural access. Moreover, the distinct click of dural puncture was also perceived in both these patients. Inability to obtain CSF through a spinal needle during a needle-through-needle CSE may occur in 3–5% of cases,²⁰ and various mechanisms have been proposed to explain this phenomenon,¹⁸ including the use of too short a spinal needle, lack of rigidity, and sharpness of the fine spinal needle to puncture the dura, pencil point spinal needles may not always pierce the dura even when properly inserted, lateral deviation of the spinal needle from the midline during insertion, a long fine-gauge spinal needle may enter the dura, and then be advanced to the anterior epidural space due to the delay in efflux of CSF, and blockage of the spinal needle. Although the above may be true during a paramedian CSE, we believe the anterior displacement of the posterior dura, widening of the posterior epidural space, and compression of the thecal sac that we have demonstrated after the LOR to saline in this study may be yet another mechanism that has previously not been considered as a cause of failure to obtain CSF during CSE anaesthesia.

A limitation of our study is that it is descriptive and not a randomized trial. However, the objective of this study was to evaluate the feasibility of performing real-time US guidance for epidural access, which we have successfully demonstrated. Compared with the traditional 'blind' methods of locating the epidural space, US guidance during epidural access may offer several advantages. US is non-invasive, safe, and simple-to-use technology, provides real-time images, and no radiation is involved. A scout scan allows the operator to preview the spinal anatomy,^{3,4} identify the midline, and determine the interspace for needle insertion.⁶ US is more accurate than palpation in identifying a given lumbar interspace.⁶ However, since US localization relies on one's ability to identify the L5–S1 gap on the sonogram,⁶ there may be limitations in the presence of a sacralized L5 vertebra or lumbarized S1 vertebra when the L4–L5 interspace may be misinterpreted as the L5–S1 gap. US also allows one to predict the depth to the epidural space^{3,21} and determine the optimal site and angle for needle insertion.^{3,5} When a US examination is performed before the epidural puncture, it improves the success rate of epidural access on the first attempt,^{3–5} reduces the number of puncture attempts,^{3–5} and the need to puncture multiple levels.^{3–5} When used for obstetric epidural analgesia, it also improves the quality of analgesia,⁴ reduces side-effects,⁴ and improves patient satisfaction.⁴ The same may also be true when real-time US guidance is used to locate the epidural space and may

outweigh the delay that occurs during US-guided interventions due to the additional time that is required for the scout scan and the sterile preparation of the US transducer. In our experience, this rarely adds more than 5–10 min to the whole procedure time which is in agreement with previous reports.²² Moreover, the improved precision with real-time US guidance may translate into higher success rates and reduced needle-related complications during epidural access, similar to that seen with real-time US-guided peripheral nerve blocks.²³ A randomized study comparing the safety and efficacy of real-time US guidance with the traditional LOR method to locate the epidural space is being planned as a follow on study.

We believe at present there are very few practitioners of real-time US-guided central neuraxial blocks. This may reflect the greater degree of difficulty and skill required to perform such an intervention. Therefore, real-time US-guided epidural access should be considered a procedure that requires advanced interventional skills and we believe should only be performed by practitioners who have a sound knowledge of spinal sonoanatomy and are proficient in US-guided peripheral nerve blocks. A preview US scan before epidural access has been shown to improve the learning curves of residents performing obstetric epidurals,²⁴ and there is a need to evaluate the learning curve of the described technique. Another limitation of US-guided epidural access is that success may depend on the quality of US images. Since the US visibility of neuraxial structures is compromised in the elderly (unpublished data), they tend to pose the greatest challenge.

In conclusion, we have demonstrated the successful use of real-time US guidance in combination with LOR to saline for paramedian epidural access, performed by a single experienced operator, with the epidural needle inserted in the plane of the US beam. Further randomized trials are required to establish the role of real-time US guidance for epidural access in clinical practice.

Funding

This work was locally funded by the Department of Anaesthesia and Intensive Care, The Chinese University of Hong Kong, Shatin, Hong Kong, People's Republic of China.

References

- Broadbent CR, Maxwell WB, Ferrie R, Wilson DJ, Gawne-Cain M, Russell R. Ability of anaesthetists to identify a marked lumbar interspace. *Anaesthesia* 2000; **55**: 1122–6
- Marhofer P, Greher M, Kapral S. Ultrasound guidance in regional anaesthesia. *Br J Anaesth* 2005; **94**: 7–17
- Grau T, Leipold RW, Conradi R, Martin E, Motsch J. Ultrasound imaging facilitates localization of the epidural space during combined spinal and epidural anesthesia. *Reg Anesth Pain Med* 2001; **26**: 64–7
- Grau T, Leipold RW, Conradi R, Martin E, Motsch J. Efficacy of ultrasound imaging in obstetric epidural anesthesia. *J Clin Anesth* 2002; **14**: 169–75
- Grau T, Leipold RW, Fatehi S, Martin E, Motsch J. Real-time ultrasonic observation of combined spinal–epidural anaesthesia. *Eur J Anaesthesiol* 2004; **21**: 25–31
- Furness G, Reilly MP, Kuchi S. An evaluation of ultrasound imaging for identification of lumbar intervertebral level. *Anaesthesia* 2002; **57**: 277–80
- Habib AS, George RB, Allen TK, Olufolabi AJ. A pilot study to compare the Episure Autodetect syringe with the glass syringe for identification of the epidural space in parturients. *Anesth Analg* 2008; **106**: 541–3
- Grau T, Leipold RW, Horter J, Conradi R, Martin EO, Motsch J. Paramedian access to the epidural space: the optimum window for ultrasound imaging. *J Clin Anesth* 2001; **13**: 213–7
- Grau T, Leipold RW, Delorme S, Martin E, Motsch J. Ultrasound imaging of the thoracic epidural space. *Reg Anesth Pain Med* 2002; **27**: 200–6
- Marhofer P, Bosenberg A, Sitzwohl C, Willschke H, Wanzel O, Kapral S. Pilot study of neuraxial imaging by ultrasound in infants and children. *Paediatr Anaesth* 2005; **15**: 671–6
- Rapp HJ, Folger A, Grau T. Ultrasound-guided epidural catheter insertion in children. *Anesth Analg* 2005; **101**: 333–9
- Carvalho JC. Ultrasound-facilitated epidurals and spinals in obstetrics. *Anesthesiol Clin* 2008; **26**: 145–58
- Maurits NM, Bollen AE, Windhausen A, De Jager AE, Van Der Hoeven JH. Muscle ultrasound analysis: normal values and differentiation between myopathies and neuropathies. *Ultrasound Med Biol* 2003; **29**: 215–25
- Okada A, Harata S, Takeda Y, Nakamura T, Takagaki K, Endo M. Age-related changes in proteoglycans of human ligamentum flavum. *Spine* 1993; **18**: 2261–6
- Scrutton MJ, Kinsella SM. Continuous or intermittent loss of resistance for identifying the epidural space. *Anaesthesia* 2000; **55**: 497–8
- Gleeson CM, Reynolds F. Accidental dural puncture rates in UK obstetric practice. *Int J Obstet Anesth* 2008; **7**: 242–6
- Blumgart CH, Ryall D, Dennison B, Thompson-Hill LM. Mechanism of extension of spinal anaesthesia by extradural injection of local anaesthetic. *Br J Anaesth* 1992; **69**: 457–60
- Cook TM. Combined spinal–epidural techniques. *Anaesthesia* 2000; **55**: 42–64
- Waldman SA, Liguori GA. Comparison of the flow rates of 27-gauge Whitacre and Sprotte needles for combined spinal and epidural anesthesia. *Reg Anesth* 1996; **21**: 378–9
- Norris MC, Grieco WM, Borkowski M, *et al.* Complications of labor analgesia: epidural versus combined spinal epidural techniques. *Anesth Analg* 1994; **79**: 529–37
- Currie JM. Measurement of the depth to the extradural space using ultrasound. *Br J Anaesth* 1984; **56**: 345–7
- Grau T. The evaluation of ultrasound imaging for neuraxial anesthesia. *Can J Anaesth* 2003; **50**: R1–8
- Sites BD, Beach ML, Spence BC, *et al.* Ultrasound guidance improves the success rate of a perivascular axillary plexus block. *Acta Anaesthesiol Scand* 2006; **50**: 678–84
- Grau T, Bartussek E, Conradi R, Martin E, Motsch J. Ultrasound imaging improves learning curves in obstetric epidural anesthesia: a preliminary study. *Can J Anaesth* 2003; **50**: 1047–50