Use of the Portable Ultrasound to Determine Favorable Level and Angle for Epidural Puncture

A Proposal for Clinical Use at Providence St. Peter Hospital, Olympia,WA

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SUMMARY:

Periodically, patients present to the anesthesia department for epidural placement with technically difficult anatomy. While the majority of epidural punctures are successfully performed using conventional techniques, occasionally the procedure can become lengthy involving multiple attempts and sometimes it is even abandoned due to time constraints or patient discomfort.

Currently the only technical resource available for completion of the procedure involves consulting the diagnostic imaging department for epidural location with c-arm. This can cause further delays in a scheduled surgery or be impractical if the patient is in labor and has an impending delivery.

This paper offers a technique for a non-invasive, portable, cost-effective, and low-profile method for identifying the presence or absence of optimal approaches to the epidural space using the anesthesia department's portable ultrasound unit.

The work presented in this proposal is largely based on first hand observations and experimentation, and the results and interpretations published by a group in the Department of Anesthesia at the University of Heidelberg, Heidelberg, Germany led by Dr. Thomas Grau.[i]

BACKGROUND:

Ultrasound (US) examination of the back does not lend itself to the easy interpretation associated with areas such as the neck and heart. The spinal structures are largely shielded by bone and the surrounding muscles have homogeneous density so differential rates of propagation and reflection are not distinct and interpretative algorithms within the US machine cannot produce a clear picture of the anatomy. When US waves strike bone surfaces they are almost completely reflected at an angle equal to their incidence and given the curved and angled surfaces involved, few of the reflections reach the transducer. The ultrasound display, then only shows bone surfaces perpendicular to the transducer and any structures behind the reflective surface are acoustically "shadowed out".[ii] In addition there is backscatter of the reflected energy through the surrounding tissues. This gives rise to the somewhat chaotic images seen with vertebral ultrasound.

But even these images give us information about the location of the acoustic barriers and acoustic windows along the back.

Equipment Needs

The Sonosite or Acuson Ultrasound machine with a 5 MHz or lower probe, ultrasonic conductive gel, and sterile condom-like drape (optional).

Transverse Plane Scanning

Determining Vertebral Midline and Levels

The first (most superficial) reflective surface the probe scan will encounter is the spinous process of the vertebrae underlying the probe. The most dorsal surface of the spinous process will reflect the ultrasonic energy and shadow out the rest of the structure. This shadow will appear as a long dark area or darkened ellipse perpendicular to the surface of the US probe.

This is shown in Figures 1 & 2 below in an ultrasound scan of the cervical spine at a scanning depth of 4.6 cm.

Figure 1. Shadow of Spinous Process

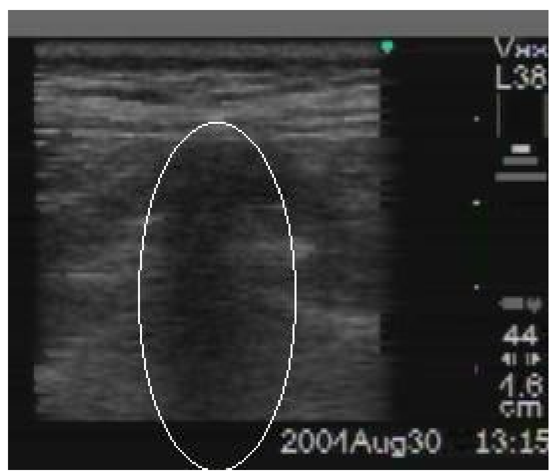


Figure 2. Shadow of Spinous Process, Marked

Hold the probe perpendicular and transverse to the spine and move it up and down along the assumed axis of the vertebral column. The shadow of the spinous processes will appear and disappear as the probe moves over them. When the shadow of the spinous processes disappears the probe has moved over a area which has no superficial reflecting bony surface and so is over an interspace.

Even though the above pictures are not dramatic in their display of anatomy they give us clues to identifying both axes of the vertebral column. By following the line of elliptical shadows up and down (cephalad and caudad), we trace and define the midline. By noting and marking the occurrences of the shadows in the moving survey, we make clear the vertebral levels.

This spinous process shadowing is shown again below in figures 3 & 4, ultrasound images of the lumbar vertebrae (note the scanning depth is 12cm accounting for the narrower image).

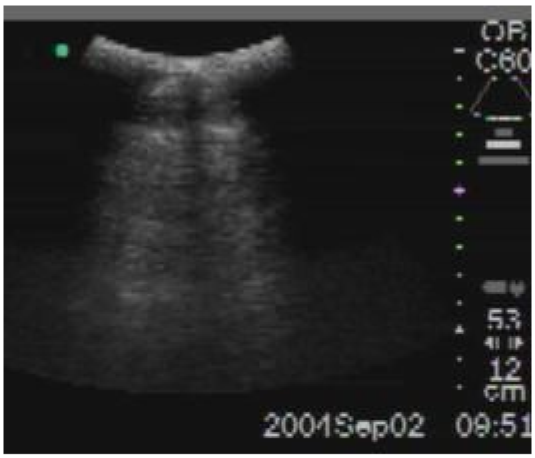


Figure 3. Shadow of Spinous Process Lumbar

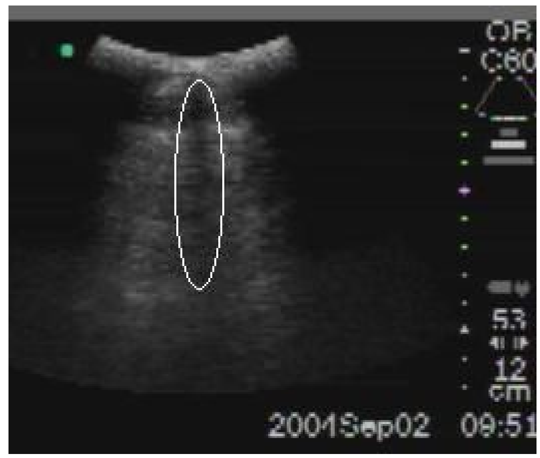


Figure 4. Shadow of Spinous Process Lumbar, Outlined

As we scan the interspace and leave behind the reflective shadow of the spinous process we encounter the next level of structures. If there is no bony over-growth in the interspace the next echo-dense we will see is the ligamentum flavum.[iii] Since normal thickness in the midline for the dense, fibrous ligamentum flavum is 4-6mm[iv] it presents as a good acoustic target. Thus it usually appears as a slightly brighter perpendicular band directly in line with where the shadow of the spinous process was. The reflective density will include the dorsal dura. Small adjustments in angulation and position may now allow us to see the dark gap of the thecal space and bright reflection of the ventral dura

Shown below in figure 5 is a frame demonstrating the appearance of the ligamentum flavum/dorsal dura, theca and ventral dura as seen in a scan of a lumbar intervertebral space.

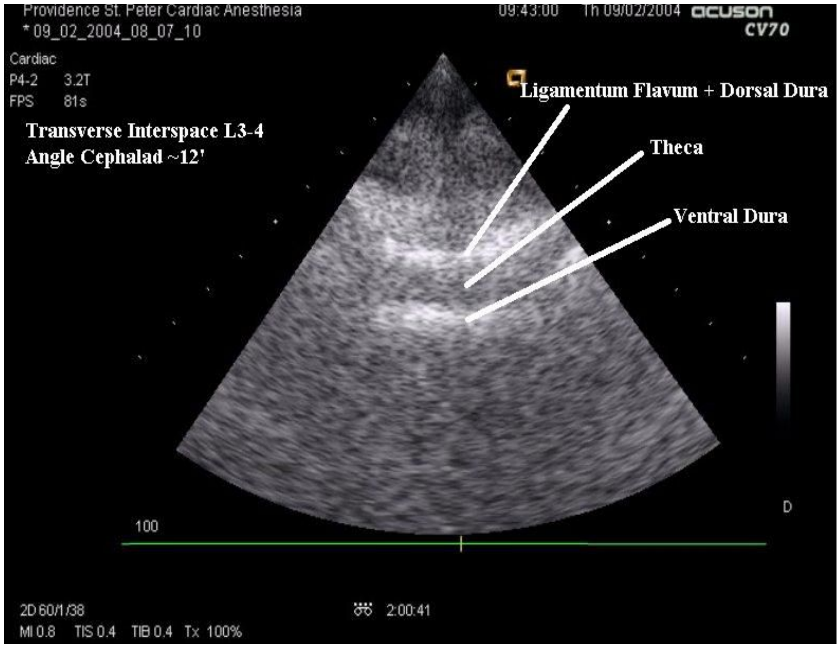


Figure 5. Appearance of Dural Layers and Theca

By making further adjustments in the angulation and position of the probe we can show the reflection of the posterior surfaces of the transverse processes and the facet joints, or more commonly the inferior articular processes (because they are the posterior portion of the joint therefore the most superficial and reflective to the probe, shadowing out the deeper joint components).

The transverse processes may appear as lateral elongations of the ligamentum flavum/dura reflections. More acute angulation of the probe may show the articular surfaces of the facet joints.

Depending on the depth of the scan, we may perceive a shadow deep to the line of the ventral dura, this is the vertebral body shadowed by its posterior surface (seen in figures 6 & 7). The figures below show a scanned view of the structures seen in the interspace and the same view with markers shown on the second figure.

For our purposes any angle and position which shows the ligamentum flavum represents an acceptable angle for epidural puncture.

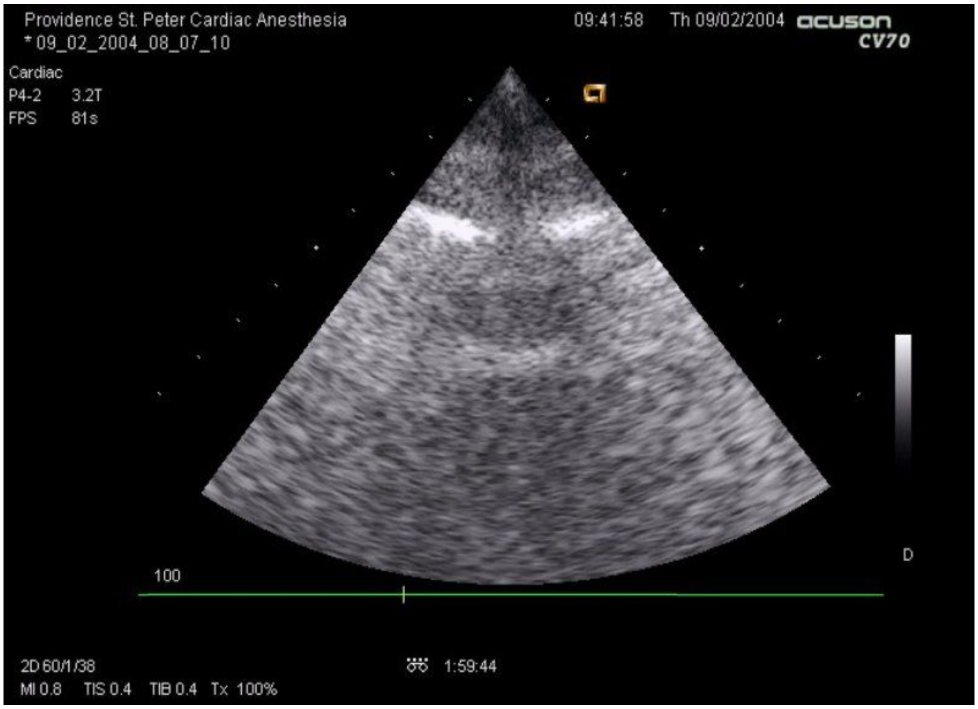


Figure 6. View of Interspace

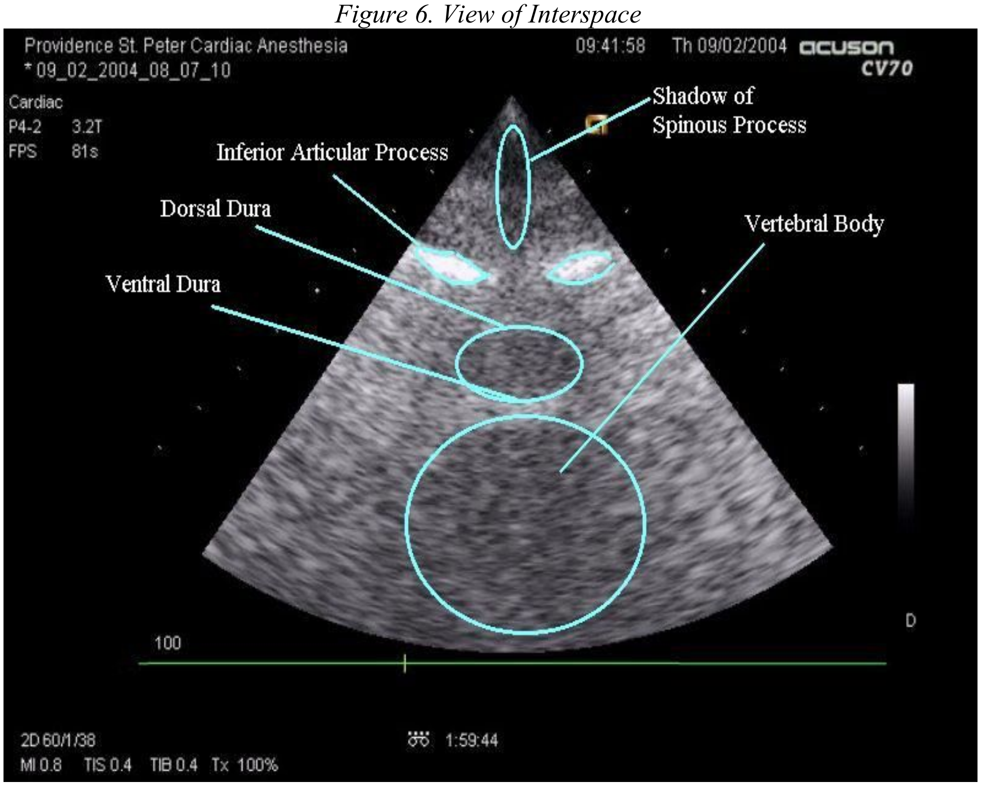
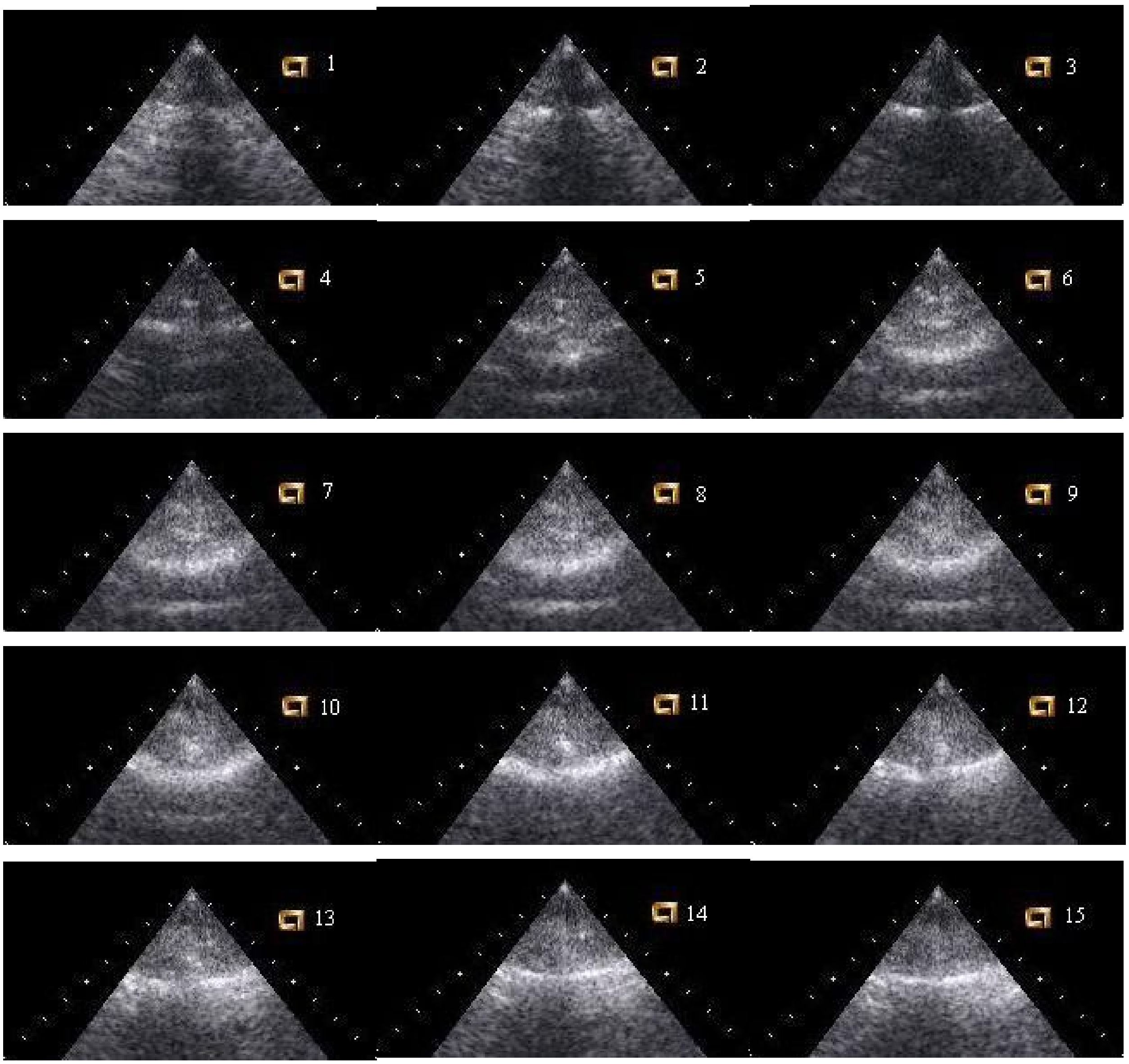


Figure 7. View of Interspace - Marked

Reviewing a Sequence of Frames from a Transverse Scan

Below is a series of clips of the transducer probe in a transverse orientation moving from a spinous process to the interspace below it.



In the series above, frames 1-3 shows the shadow of the spinous process, frames 2-4 shows the reflection of the inferior articular process of the facet joints at approximately 3cm depth as 2 white bands on either side of the spinous process shadow.

The ligamentum flavum/dorsal dura reflective band just begins to come into view in frame 5 at a little over the 4cm mark and becomes much brighter over the next few frames.

Also note starting in frame 5 the appearance of a dark band approximately 1cm thick distal to the band of the ligamentum flavum/dorsal dura, this is the thecal space and it is bordered distally by the slightly fainter band of the ventral dura at about 6 cm in depth.

Starting in frame 8, slightly superficial of the ligamentum flavum/dorsal dural band at 4cm and extending laterally on both sides we can see the transverse processes of the vertebrae. The transverse process reflections continue after we lose sight of the ventral dura across the dark band of the spinal canal.

Of the frames shown here, frames 6 thru 9 probably represent the best angle for approach to the epidural space for puncture.

Sagittal/Longitudinal Scanning

Sagittal ultrasound scanning involves holding the ultrasound probe "sideways" so the long axis of the probe is parallel to the long axis of the vertebral column. The most informative view is paramedian, 2-4 mm off of the midline and angled toward the midline sufficiently to show the characteristic picket-fence pattern of the spinous processes. The resulting images will show the spine from the side and so the simplest anatomical reference points will once again be the spinous processes which will appear as a series of rounded hyper-echoic knobs like rounded-over tops of a picket fence when the probe is held at an accommodating angle to them. This is shown in the figures 8 & 9 below.

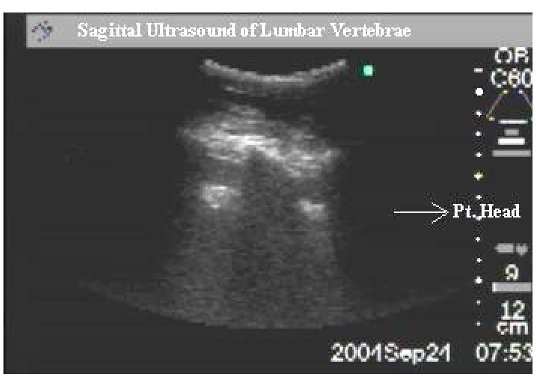


Figure 8. Sagittal Lumbar Scan

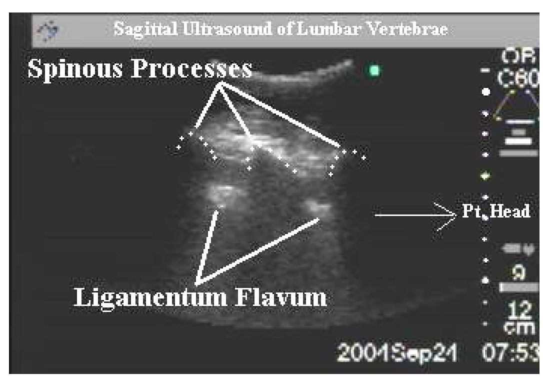


Figure 9. Sagittal Lumbar Scan Labeled

As we move up and down the spine longitudinally we see the same "shadowing-out" of structures lying beneath the spinous processes with periodic windows between the processes where the acoustic "light" of the ultrasound illuminates structures previously hidden. Note the appearance, in figure 9 above, of the bright band in the acoustic window at approximately 4.5–5 cm., this is, once again, the ligamentum flavum and dorsal dura.

In figure 10 below we view the interspace of L2-3 and are able to see both the ligamentum flavum/dorsal dura reflection and the ventral dura bracketing the theca.

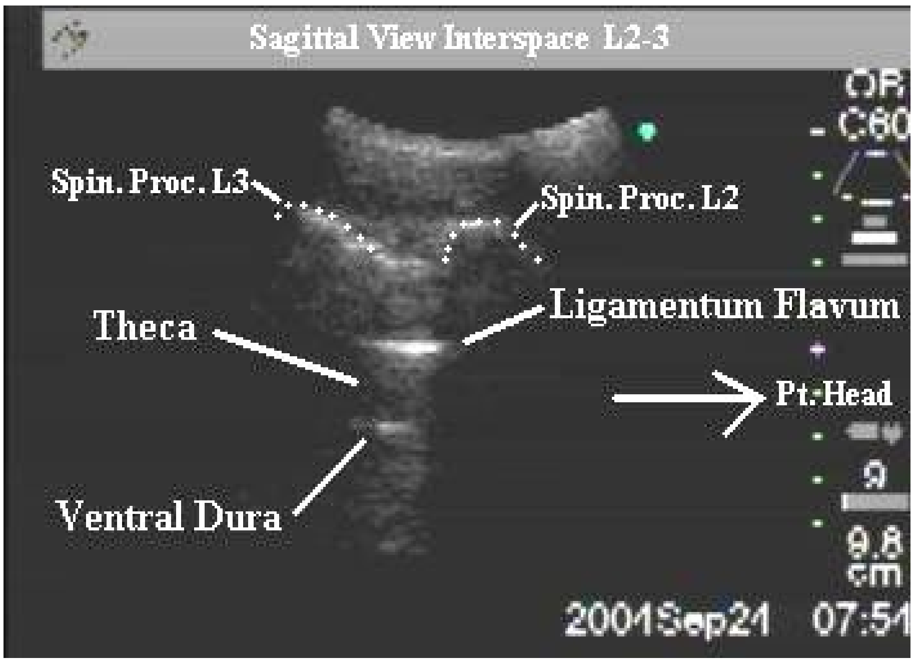


Figure 10. Sagittal Scan Structures Visible

Depth to the epidural space

Measurement of the depth of the epidural space ultrasound correlates reasonably well with measurements by Magnetic Resonance Imaging (MRI)[v]. Because of variations in patient anatomy the lumbar epidural space may vary in depth from 20-90mm[vi,vii]. Angle of approach for the puncture can add further variables to the predicting at what depth the epidural space will be encountered.

In using ultrasound to estimate expected depth to the epidural space of an epidural needle it is important to remember that the ultrasound beam must follow the same path intended for the needle and any tissue deformation caused by either the probe or the needle must be taken into account.[viii]

The scans shown in this paper were all from normal sized young males and the band of ligamentum flavum and dorsal dura occurs at between 4.5-6 cms as seen by the 1 cm depth marks along the side of the images.

Identifying Vertebral Levels using Ultrasound

Ultrasound study is, on average, probably more accurate than physical examination at determining vertebral level. A paper published in in the journal Anaesthesia in March 2002 compared identification of lumbar intervertebral spaces using physical examination by anesthesiologists with ultrasound examination by radiologists against x-ray of the lumbar spine in 50 patients.[ix] Ultrasound imaging was correct 71% of the time, palpation was correct in 30% of cases. 27% of palpated marks were more then one level off up or down. None of the ultrasound marks were more than 1 level off up or down.

A reasonable method for using ultrasound to identify intervertebral levels is to start by identifying the sacrum and then the L5-S1 level. Starting a sagittal (longitudinal) scan at or below the crease between the buttocks, the sacrum usually shows no identifiable spinous processes and no interspaces. The sacrum presents on ultrasound as a rather flat table-like hyperechoic area, this is shown in figures 11 & 12 below. Moving the probe cephalad we suddenly see a drop-off and then a typical sagittal view of a spinous process, this is L5. If the L5-S1 interspace is narrowed or absent due to disease or injury, our first sign of transition to lumbar vertebrae will be a step up to the spinous process of L5.

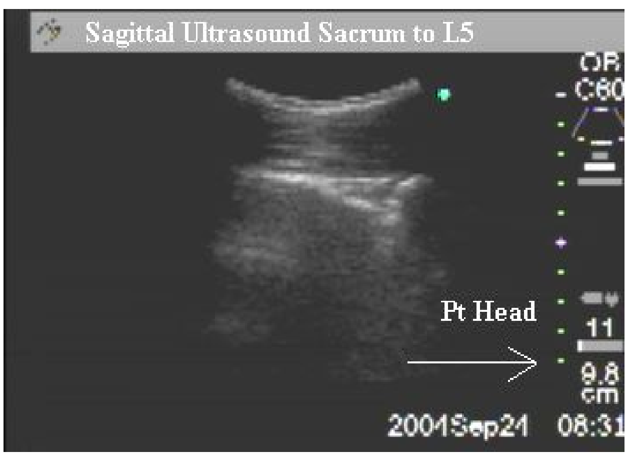


Figure 11. Sagittal view showing sacrum

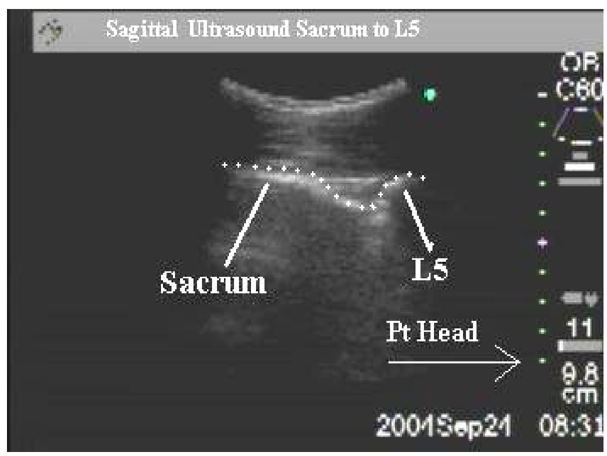


Figure 12. Sagittal view of sacrum-labeled

After identifying L5-S1 then mark off spinous process shadows as you scan cephalad.

Advantages to Ultrasound Assisted Epidurals

The Heidelberg group published a study[x] involving a series of 300 patients undergoing epidural placement for childbirth. The patients were randomly assigned to 2 groups of 150 women each. One group would act as control and the other would have pre-epidural puncture ultrasound imaging to determine the ideal approach to the epidural space. In each group 85 women had epidural for labor and vaginal delivery and 65 women had epidural for C-section. The groups were similar in age, weight, height, gestational age, ASA physical status and other relevant demography. All epidurals were performed by the same anesthesiologist.

Preparation time for epidural puncture was increased an average of 75 seconds in the ultrasound group.

In the ultrasound group, the average distance from the skin to the ligamentum flavum measured by ultrasound was 53.1 mm, while the mean puncture depth in the group was 51.2 mm. The mean puncture depth in the control group was 56.3 mm.

The number of puncture attempts (defined as ventral advancement of the needle with redirection) in the control group had an average of 2.2 ± 1.1, in the ultrasound group the number of attempts was 1.3 ± 0.6 before success.

The number of intervertebral spaces tried before success was 1.3 ± 0.6 in the control group and 1.1 ± 0.4 in the ultrasound group.

Attempts to successfully advance the catheter were an average of 2.1 ± 1.1 in the control group while the ultrasound had an average of 1.3 ± 0.6 attempts to be successful.

Maximum Visual Analog Scale (VAS) of pain during labor and surgery was 1.3 ± 2.2 in the control group and 0.8 ± 1.5 in the ultrasound group.

Wet taps in the control group occurred twice and once in the ultrasound group. Blood aspiration through the catheter indicating epidural vessel cannulation happened 3 times in the ultrasound group and 11 times in the control group.

Failed epidurals were 0 in the ultrasound group and 2 in the controls, while those rated as incomplete analgesia were 3 for the ultrasounders and 12 for the controls.

Other study results such as pain scores before and after epidural placement during labor and C-section, adverse effects and additional medications needed, all favored the ultrasound group in this study.

The above study's authors postulate that since the ultrasound shows a clear path to the epidural space, needle placement following ultrasound survey has a greater chance of success than blind attempts. Distance from skin to epidural space measurements made during ultrasound visualization allow the anesthesiologist to have more confidence in Loss of Resistance events and fewer inadvertent sub-arachnoid punctures.

Presumably, since you can survey a more desirable path to the epidural space using ultrasound and make the puncture successful the first time, more catheter placements will result in the catheter perforations that distribute the medications lying in the midline of the epidural space and medication will therefore be infused more evenly resulting in fewer patchy blocks, requiring less additional medication and greater satisfaction with the technique and experience.

Conclusion

Using ultrasound survey of patient's backs (especially those with difficult anatomy) prior to or during attempted epidural placement may present a method to; remove guesswork as to the optimum approach to the epidural space, increase accuracy in identifying the vertebral interspace level, provide a comparatively accurate estimate of the depth at which the anesthesiologist can expect a loss-of-resistance, shorten the overall procedure, and increase the chance of a more midline placement of the catheter.

Ultrasound is a non-invasive, inexpensive, non-threatening, and accurate method that can used to complement and enhance the anesthesiologist's epidural technique. Because of the possible benefits of this adjunctive technique, we recommend that it's use be explored at the Providence St. Peter Hospital Anesthesia Department.

i Grau T, Leipold RW, Horter J, Conradi R, Martin E, Motsch J. **The lumbar epidural space in pregnancy: visualization by ultrasonography**. *British Journal of Anaesthesia* 2001 **86(6)**:798-804

ii Brendel B, Winter S, Rick A, Stockheim M, Ermert H. *Computer Aided Surgery 7:146–155 (2002),* **Registration of 3D CT and Ultrasound Datasets of the Spine using Bone Structures**

iii Grau T, Leipold RW, Fatehi S, Martin E, Motsch J. European Journal of Anaesthesiology 2004;21:25-31, **Real-time ultrasonic observation of combined spinal-epidural anesthesia**

iv http://www.yna.org/NewPages/NLSp03.html, **Lumbar Spinal Stenosis**, Robert J. Schlegel, M.D.

v Grau T, Leipold RW, Delorme S, Martin E, Motsch J. **Ultrasound Imaging of the Thoracic Epidural Space**, Regional Anesthesia and Pain Medicine, Vol 27, No2 (Mar-Apr), 2002:pp 200-206

vi Blomberg RG, Olsson SS. **The lumbar epidural space in patients examined with epiduroscopy**. Anesth Analg 1989; **68**:157-160

vii Harrison GR. **The epidural space** (Letter). Anaesthesia 1989; **44**:361-362

viii Grau T, Leipold RW, Conradi, R, Martin E. Acta Anaethesiologica Scandinavica, **Ultrasound control for presumed difficult epidural puncture**. 2001;45:766-771,

ix Fumess G, Reily MP, Kuchi S. Anaesthesia Vol 57 Issue 3 Pg 277,March 2002. **An evaluation of ultrasound imaging for identification of lumbar intervertebral level**

x Grau T, Leipold RW, Conradi R, Martin E, Motsch J. **Efficacy of Ultrasound Imaging in Obstetric Epidural Anesthesia**, *Journal of Clinical Anesthesia* , 2002 Vol 14:169-175