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Research Article

Transabdominal Imaging of the Lumbar Spine with Portable Ultrasound

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Abstract: Research investigating human transadominal ultrasound imaging of the intervertebral disc which first took place in the mid to late 1980's, was limited by the technology of that time. Later transducer refinements, innovations in harmonic energy control and the digital change-over based on increasingly powerful computer platforms enabled progressive image enhancement with detailed imaging of deeper structures.

With appropriate harmonic settings and probe selection, innovations in diagnostic ultrasound resolution now allow for more detailed anterior lumbar spine image capture even with portable machines.

The images described in this paper may be the first published, high-resolution transabdominal images of the anterior lumbar spine captured with a portable ultrasound machine.

Method: Using a both GE Logiq 9 with a 4C convex probe (1.5-4.5 MHz) and a GE Logiq E portable machine with a GE 4C-RS convex probe (2-5 MHz), transabdominal longitudinal and transverse paraspinal images of the lumbar spine were acquired in an asymptomatic subjects of normal body weight and habitus.

Though the platform model offered somewhat higher resolution, the captured images obtained from the portable machine also demonstrated detailed anatomy of the anterior vertebral body and disc margin architecture. Transverse through images of the lumbar disc, spinal canal were also obtained, and as a side note the caudal nerve roots within the canal were also visualized.

Conclusion: With careful machine settings and probe selection, detailed transabdominal lumbar spine image capture appears to be achievable even with a portable machines.

Key words: Transabdominal, portable ultrasound, lumbar, disc, curvilinear probe, transducer, discogenic.

INTRODUCTION

The last decade has witnessed significant technological advancements in portable diagnostic ultrasound equipment. Machines have become more compact and affordable, with features of improved power efficiency and supportive technologies driving the use of ultrasound into many point-of-care (POC) settings such as emergency rooms, GP surgeries, out patient clinics and the operating theatre.

These upgrades have also been paralleled by vast enhancements in sonographic imaging quality thanks in part to probe technology, making ultrasound a first line imaging choice for many conditions . These qualities bring rapid, imaging services to many remote and underserved areas of the world. 1

Despite these advances in ultrasound imaging, plain film remains an inexpensive first choice imaging for evaluating the lumbar spine. As of 2012 however, the Pan-American Health and World Health organizations have both concluded that nearly 75% of the world's population has no access to diagnostic imaging such as radiography.

These same organizations have also concluded that modern diagnostic ultrasound machines being a more affordable, portable, and flexible imaging choice, could resolve between 70-80% of third world diagnostic imaging access. With low back pain cited as the primary cause of worldwide pain and disability, 1 [Hoy et al 2014] and with the literature reporting that 89% of low back pain may be attributed to lumbar disc pain degeneration 2[Schwarzer et al 1995], the need for more available and

affordable means of imaging is of vital importance to public health. Trans-abdominal ultrasound studies published in the late 1970's primarily focused on demonstrating the ability of ultrasound to measure the spinal canal diameter. The focus on the spinal canal diameter may have been due to visability limitations of many other lumbar spine structures. Interest in pursuing these sort of images apparently diminished however, when later studies failed to quantitatively demonstrate a straightforward association between spinal canal diameter and other clinical findings.3,4

Recent technical advances in portable diagnostic ultrasound capability using curvilinear array probes however, now allow for more detailed visualization of deep spinal structures, which were not possible to see 20-30 years ago. Research in the mid to late 1980's investigating human transadominal imaging of the intervertebral disc , was limited by the technology of the time.5,6,7

These early trials missed out on in later transducer refinements, advancements in harmonic energy control which facilitated imaging on more obese patients and the digital changeover based on the very powerful computer platforms that only became available after the mid 1990's.8

Cadaveric ultrasonography studies have been able to echogenically distinguish the nucleus pulposis from annular tissue using high resolution linear probes and has been proven to yield much greater image quality than conventional sonography.

However the vertebral specimens examined were stripped of paraspinal muscle. 9

These high frequency transducers (vascular probes) are more useful for the image acquisition of surface anatomy. Relative tissue density and typical distances between the skin and the lumbar spine however, currently exceeds the far-field technical capabilities of these probes.

Selection of a scanner with harmonic features and a curvilinear convex array probe with lower frequencies between 1-8 MHz, offers deeper sonic wave penetration, optimizing the transabdominal resolution of pelvic-abdominal structures[Bakhru et al 2013], which would include far-field acquisition of anterior lumbar spinal structures in live subjects.10

In 1976, Porter and colleagues were the first describe on how US might be used to measure the spinal canal diameter and attempted to correlate smaller canal diameters or trefoil shaped canals with low back pain, with this and other studies reporting statistically significant differences in comparing the diameters of trefoil shaped vertebral canals in comparison to other vertebra. This spinal canal diameter research was carried on throughout the 1970's and 80's by Porter and others.11,12,13

Ultimately however, prospective studies carried out in 1990's and more recent literature reviews concluded that though spinal canal size was only one consideration in a potential number of risk factors for low back pain, and that ultrasound measurement of spinal canal size has no practical role in the actual in prediction or prognosis. 14,15. Studies attempting to correlate canal diameter to sciatic symptoms around that time also failed, probably due to the limitations of ultrasound imaging capability at that time.

Whatever the goal in those days, accurate sonographic measurements of the lumbar spinal canal diameter was highly operator dependent and so this imaging approach did not become well known. However, as ultrasound imaging resolution capability has evolved with machines become cheaper, more powerful and plentiful, it is likely that the applications of ultrasound to lumbar spine imaging will be revisited.

METHOD

A GE Logiq 9 with a 4C convex probe (1.5-4.5 Mhz), and GE Logiq E portable machine with a GE 4C-RS convex probe (2-5 MHz), was used to obtain comparative trans-abdominal longitudinal and midline transverse paraspinal images of the lumbar in asymptomatic patients of normal body weight and postural habitus.

The subjects were supine, resting with a relaxed abdomen. A curvilinear probe was applied paraspinally with coupling gel, around 5 cm. From the midline in the right para-sagittal plane. (Figure 1)

Figure 1: Longitudinal paraspinal (parasaggital)

Figure 2: Transverse Centerline for transabdominal starting position. disc and spinal canal image capture.

Figure 1: Longitudinal paraspinal transabdominal starting position.

The probe was then moved back and forth in a coronal plane. Gentle and progressive probe pressure was then applied while monitoring the patient's tolerance, in order to bring the transducer footprint as close as possible to the anterior margin of the lumbar spine. Due to continued probe pressure, patient comfort was verbally monitored throughout. Harmonics and focal depth adjustments were then made until the anterior margins of the lumbar vertebral spine were brought to optimal resolution and the images were captured.

Next, while centered over the anterior lumbar disc margin, the probe was rotated orthogonally and moved to the abdominal midline. Further fine tuning of harmonic and focal depth adjustments were made, while maintaining anterior to posterior probe pressure and orientation in a transverse plane. The probe was then incrementally directed cephalad and caudad until the outline of the disc came into view. The probe was then tilted in keeping with a slight lordosis, squaring off the vertebral end -plates and bringing the entire disc and posterior margin into view for further transverse image capture. (Figure 2)

Figure 2: Transverse Centerline for disc and spinal canal image capture

In subjects with large omentums, longitudinal para spinal views image capture may best be obtained with the patient positioned in a lateral decubitus position. Thus gravity shifts the omental tissues away from the tranducer. A pillow between the subject's knees aids in comfort. (Figure 3)

Figure 3: Side lying probe position to move omentum.

Determining Lumbar Disc Level: Due to the typically narrow ultrasound window (field of view), determination of disc level is aided through identifying of both surface anatomy and visualization of the abdominal aorta bifurcation. For example, the L3-4 vertebra are located at the level of the umbilicus and the aortic bifurcation is usually seen at the level of L4.

RESULTS

Figure 4

Figure 4: Centerline transabdominal lumbar disc and spinal canal image obtained with a GE Logiq 9

Figure 5

Figure 5: Side by side comparision of centerline transabdominal lumbar disc and spinal canal image obtained with a GE Logiq E portable machine

Figure 6

Figure 6: Longitudinal paraspinal transabdominal image obtained with a GE Logiq 9

Figure 7

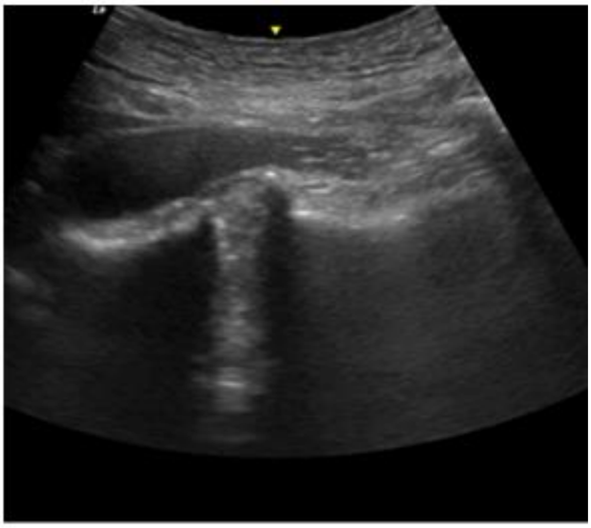

Figure 7: Comparative longitudinal paraspinal transabdominal transabdominal
image obtained with a GE Logiq E portable machine

Figure 4-7: Side by side comparison of trans-abdominal transverse and longitudinal imaging of the anterior lumbar vertebral margins intervertebral disc spaces. Images on the left were obtained with a GE Logiq 9 with a 4C 1.5-4.5 Mhz curved tranducer.

Images on the right were obtained with a GE Logiq E portable machine with a GE Logiq E portable machine with a GE 4C-RS convex probe (2-5 Mhz).

Figure 8

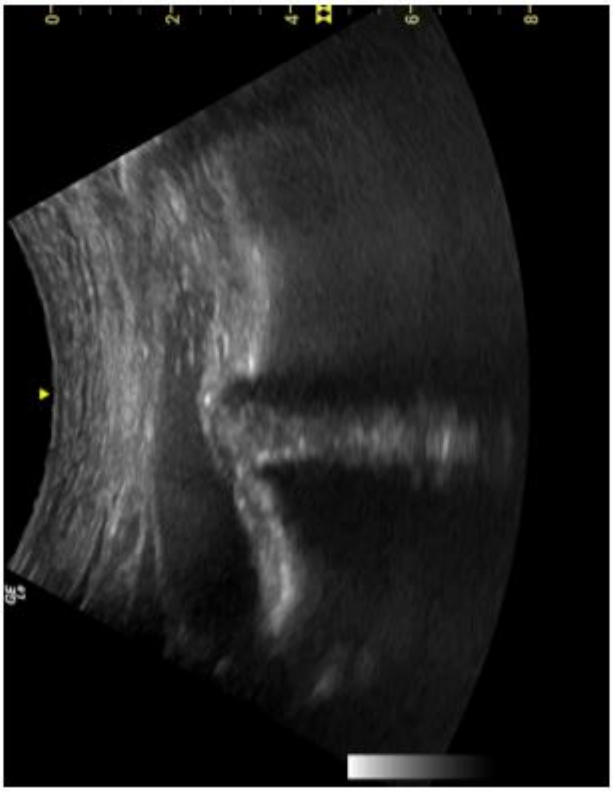

Figure 8: Portable ultrasound image in Figure 5 rotated 90 degrees left to ease side by side comparison with the lateral lumbar x-ray

Figure 9

Figure 9: Lateral lumbar x-ray

Figures 8 & 9: Side by side comparative images of portable US and a lateral lumbar radiograph (magnified). Both demonstrate osteophytic lipping of the anterior margins of the L2/3 vertebral bodies in keeping with lumbar spondylosis.

DISCUSSION

The pioneers of transabdominal lumbar spine imaging described differences in anatomical tissue and the oblique direction of lordotic vertebral discs as obstacles to sonographic visualization. The above images clearly demonstrate improved image quality of the anterior lumbar structures (intervertebral disc & vertebral body) since this imaging technique was first attempted over 40 years ago.

Some initial imaging attempts concluded that with ‘present technique’, ultrasound did not seem to be of diagnostic value for patients with herniated disk.16

Though later application of high resolution linear probes readily demonstrated disc infrastructural anatomy in prepared cadaveric studies[Kakitsubata et al 2005], a lower frequency probe is probably required to visualize spinal anatomy in live patients.8

Urology ultrasound studies have concluded that ultrasound is superior to CT for detection of mild to moderate nephrocalcinosis, using a 2-4 MHz probe for abdominal imaging. 17 A conventional GE 4C-RS convex probe (2-5 MHz), with an optimized special resolution and slice thickness was therefore chosen for this portable ultrasound study.

Other studies 18[Ponomarenko 2015], described imaging the intervertebral disc, spinal canal, radicular channels, ligaments, and measured intervertebral blood flow in the veins of the epidural lumbar spine, but the focus of that study was of a methodological perspective and for standardizing research. Other studies have also concluded that some aspects of lumbar degenerative disc disease may be identified via diagnostic ultrasound. 19

Prior to their main sudy of canine specimens, [Naish et al 2003], a novel strategy for sonographically appreciating lumbar intervertebral disc degeneration had been described [McNally et al 2000] in one female subject, but this particular method relied on a posterolateral imaging approach. 20,21 .This comparison was made because of the marked similarity of degeneration changes between human and canine intervertebral disc material.

These methods were certainly worth following-up, as loss of the intervertebral disc height is a known marker of degenerative disc disease which may be associated with low back pain [Dabbs et al 1990, Urban et al 2003, Adams et al 2006, Cheung et al 2012], and is also a hallmark of disc herniation, [Tibrewall et al 1985] 22.23.24.25,26

Studies conducted over 25 years ago have reported on the diagnostic utility of ultrasound for identifying the level of lumbar disc herniation. 27

Although trans-abdominal ultrasound visualization of the lumbar spine disc for the purpose of attempting to identify degeneration changes and other spinal pathologies may press the current limits of portable machine capability, there is a potential here for convenient and economical screening for certain back pain patients that may also have merit. There is also potential for bringing at least

some form of spinal diagnostic imaging to the world's underserved areas. 1

There are some disadvantages to the presented technique. Large-bodied or obese patients with increased tissue density and excessive omental body fat are probably not ideal candidates. Also, in order to generate optimal images even on normal body weight patients, a degree of transducer pressure is required to compress abdominal soft tissue and bring the transducer footprint into close proximity to the anterior margin of the spine. Most patients seem to tolerate this well, but others may find the applied probe pressure uncomfortable. Unfortunately, maintaining probe pressure appears to be necessary in order to achieve optimal resolution, even in those of normal body weight. A full bladder may also facilitate improved imaging of the L5-S1 vertebral disc. However, transducer compression over the bladder may also be uncomfortable for similar reasons.

Ultrasound with a more limited field of view than other imaging modalities, presents certain challenges in readily recognizing the exact level of lumbar vertebral body and disc being imaged. Expanded field of view ultrasound is subject to further development. Till then, this limitation may be partially overcome by correlating spinal level to surface and visceral anatomical landmarks as in this present study.

CONCLUSIONS

Technical advances in diagnostic ultrasound offer the potential for enhanced detailed acquisition of the anterior lumbar vertebral body margins, spinal ligaments, and intervertebral disc even with portable machines. Transverse imaging through the acoustic window of the intervertebral disc to image the spinal canal and potentially, the caudal nerve roots within the canal is also possible.

Although there are practical limits to using portable transabdominal ultrasound for the in-vivo delineation of intradiscal architecture, ligamentous structure, and its potential for quantifying osteodiscal degenerative change, these issues will be topics for future studies with correlative imaging.

This ultrasound spinal imaging technique seems fairly simple to learn and teach. Given the resolution detail of some aspects of anterior spinal architecture demonstrated here with a portable machine, further advancement in the identification of lumbar spine anatomy via ultrasound is already underway and may have particular diagnostic utility and interest in areas of the world underserved by imaging.

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