83 Ultrasound Guidance in Interventional Pain Medicine

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Key Concepts

- Ultrasound has experienced explosive growth in popularity for advanced imaging in interventional pain management.
- Real-time needle visualization may improve success rate of interventions and avoid trespassing vital structures.
- Ultrasound is a reliable alternative to fluoroscopy in terms of reproducibility, accuracy, and safety for optimal image-guided pain procedures.
- Lack of ionizing radiation exposure makes the use of ultrasound appealing in both diagnostic and therapeutic image-guided injections.
- Knowledge of basic anatomy, ultrasound machine, and having a systematic approach are essential in the success of ultrasound imaging.

Introduction

Ultrasound is a growing technology in the field of interventional pain management and the treatment of musculoskeletal injuries. It has been adopted for both diagnostic and image-guided blocks. Table 83.1 summarizes the advantages and disadvantages of ultrasound.

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Basic Concepts of Ultrasound Imaging

- The brightness-mode (B-mode) display with a pulse-echo approach involves transmission of small pulses of ultrasound echo from a transducer into the body.
- The image is generated by the returned echo signals from many sequential coplanar processed pulses.
- The ultrasound transducer contains piezoelectric crystals that vibrate after application of electrical current. The machine in turn decodes the reflected waves to make the picture.
- Medical ultrasound utilizes sound waves and can be described in terms of frequency, wavelength, and amplitude.
- The frequency and wavelength are inversely related and help determine resolution and tissue penetration.
  - High frequency/high resolution/low penetration
    - Better for superficial structures
  - Low frequency/low resolution/more penetration
    - Better for deeper structures
- Image artifact as seen with ultrasound occurs most frequently in the fat-soft tissue interface and is caused by refraction. This is due to the difference in the speed of sound transmission as it travels through the interface of two tissues. The speed of sound is low in fat and high in soft tissues.
- The intensity of ultrasound pulses is reduced and attenuated as it traverses through tissue as a result of scattering and reflection of waves.

Knobology: Understanding Your Machine

- Understanding the operative functions of the ultrasound machine will help optimize imaging. Although ultrasound machines look different, basic functions are the same.

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Table 83.1 Pros and cons of ultrasound

Pros	Cons
More accurate than landmark techniques	2D representation of 3D structure (1 mm wide slice)
Precise needle placement leads to less risk of inadvertent trauma	Poor penetration for visualization of deep structures
Affordable	Prone to artifacts
Portable	User-dependent, advanced skills needed
No radiation	Contrast-guided injection not appreciated
Dynamic – scanning while moving the relevant anatomy	Anatomical variation (e.g., obesity) may cause technical difficulty
Sonoauscultation – place ultrasound probe directly onto the point of pain	

- Selection and adjustment of the appropriate frequency helps optimize image and albeit most crucial in ultrasound technique.
  - Usual frequency used is in the range of 8–12 MHz and 10–15 MHz.
  - Higher-frequency waves are *attenuated*, have a gradual loss in intensity, are more in comparison to lower frequency waves as they penetrate through the tissue.
- Probe selection
  - Ultrasound probes come in a variety of shapes and sizes. The primary distinction between ultrasound probes is based on classifications on frequency, shape, and size.
  - Lower-frequency probes (2–5 MHz) are used to visualize deeper structures.
  - Higher-frequency probes (>5 MHz up to 18 MHz) are most often used for superficial structures.
- *Depth* adjustment is necessary to enable the structure of interest to fall within the field of view.
  - Set the depth of the survey a little deep to begin. Be mindful that excessive depth will degrade the picture unnecessarily.
  - Minimizing the depth will lead to better temporal resolution.
  - The trick is "get target in view and then adjust image."
  - Machines will try to improve lag by reducing the width of image.
- *Gain* dictates the brightness and darkness as the image appears on the screen. The image that is bright is termed *hyperechoic* and dark is *hypoechoico*
  - Increasing the gain amplifies electrical signal that thereby increases the brightness of the image, which also includes the background noise and vice versa.
  - Louder is *not* always better as this may distort the subtle differences between adjacent tissues.
- *Time gain compensation* (TGC) allows the operator to control brightness at specific depth independently. This property basically allows the machine to create a uniform image to compensate for attenuation.
- The *focus* dial helps to optimize lateral resolution. This may not be always present in all ultrasound machines.
  - Lateral resolution is the ability of the ultrasound machine to discern two objects lying next to each other at the same depth.
  - Always adjust focus to the depth of target.
- *Color Doppler* technology allows identification and quantification (velocity, direction) of blood flow.
- *Power Doppler* is a newer ultrasound technology that is more sensitive, almost angle-independent, and detects blood flow that is harder to detect with standard color Doppler. However, it does not demonstrate direction of flow and is highly vulnerable to motion artifact.
- The *freeze* button allows the machine to display the current image on the screen.

Needle Visualization and Managing Ultrasound

- The use of echogenic needle technology helps in the direct visualization of the needle as it traverses the tissues to hit the target.
- The image quality in itself is also dependent on the appropriate-sized probe and properties of the ultrasound machine to obtain an optimal image resolution.
  - Sonographic artifacts impede visualization of targeted structure and real-time needle visualization, caused by acoustic beam misalignment, termed as *anisotropy*.
  - The ultrasound beam that is emitted from the probe is very narrow, about 1 mm, and misalignment during the procedure may cause difficulty in needle visualization.
    - *Anisotropy* – "directionally dependent" produces focal areas of hypo-echogenicity when the probe is not at 90 to the linear structure being imaged.
- There are two ways by which optimal needle visualization can be achieved:
  - "In-plane" approach: The needle is inserted midline, parallel, and under the long axis of the probe. Visualization of the entire needle and the tip can be achieved.
  - "Out-of-plane" approach: The needle is inserted under, midline, and perpendicular to the probe in the short axis view. The needle tip/shaft appears as a hyperechoic dot.

Ultrasound Guidance for Musculoskeletal and Interventional Pain

- Ultrasound has been used to perform nerve blocks involving the brachial and lumbar plexus, including their distal branches.
- It has been a useful tool in blockade of sensory and mixed nerves that include ilioinguinal, lateral femoral cutaneous, pudendal, and intercostal nerves.
- Intraarticular injections of medications (e.g., corticosteroids) may increase the rate of responders and even decrease discomfort in patients compared to surface landmark techniques. However, benefits in long-term outcomes are controversial with mixed results.
- The use of ultrasound may decrease complication rate associated with trigger point injections and deep muscular injections (e.g., pneumothorax).
- Blockade of medial branch blocks and zygapophyseal joints has been done using ultrasound. The third occipital nerve block is one of the few that has been studied and demonstrated accurate localization in comparison to fluoroscopy. However, its superiority over the standard fluoroscopy on this particular block remains to be elucidated.
- Epidural blocks have been performed under ultrasound guidance but only caudal has been the most promising to date. The inherent issue with ultrasound like lack of contrast dye and failure to visualize the needle as it traverses bony structures limit its use.
- Direct visualization of neurovascular structures with ultrasound such as stellate ganglion block makes this modality particularly appealing.

Conclusion

The use of ultrasound in today's practice of pain management has many benefits including lack of radiation and improved visualization of soft tissue structures. However, clinicians should be mindful of the inherent risk, requiring proper training, and disadvantages associated with its use. Knowledge of basic anatomy, ultrasound machine, and having a systematic approach are essential in the success of ultrasound imaging.

Suggested Reading

1. Narouze SN. Atlas of ultrasound guided procedures in interventional pain management. New York: Springer; 2010.