Novel Ultrasound Application in Regional Anesthesia

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History of Ultrasound

- 1880: Pierre and Jacques Curie discovered the piezoelectric effect in crystals.
- 1915: Ultrasound was used by the navy for detecting submarines.
- 1950s: Ultrasound was used to treat patients with Ménière disease, Parkinson disease, and rheumatic arthritis.
- 1965: The real-time B-scan was developed and was introduced in obstetrics.
- 1978: La Grange published the first case series of ultrasound application for placement of needles for nerve blocks.
- 1994: Steven Kapral and colleagues explored brachial plexus blockade using B-mode ultrasound.

Introduction

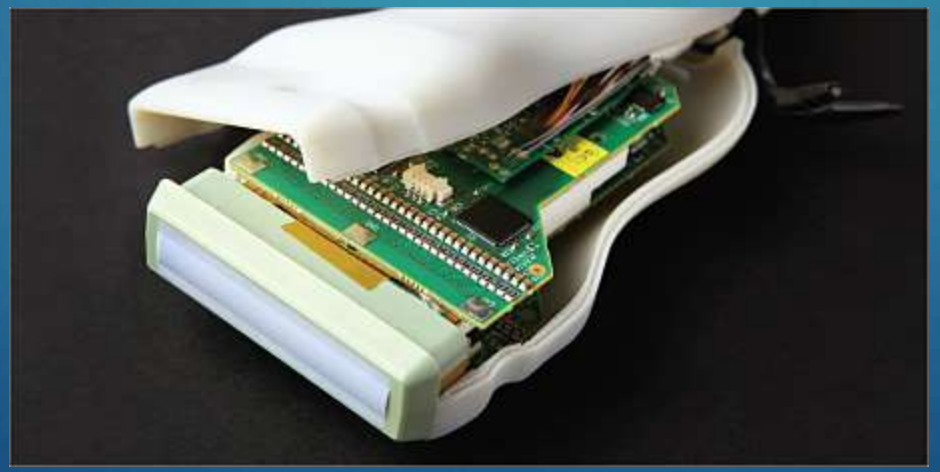
- Use of medical ultrasound can be turned back to as early as the Second World War
- During the following two decades, commercial ultrasound gained more widespread use.
- The introduction of microchip technology and more powerful signal processing by computers has revolutionized various aspects of ultrasound imaging.
- It was not until I994 that the use of ultrasound for regional anesthesia (supraclavicular block) was reported by Kapral et al.

Different Aspects of Image-guided RA that is Considered for improvements

- Ultrasound transducers and image processing
- Different imaging modalities
- Needle guidance

Image Processing and Ultrasound Transducer Technology

In the body, microbubbles in different tissues produce non-linear vibration when exposed to ultrasound waves, resulting in distortion of sound waves ; known as Harmonics
Selectively eliminating the harmonics gives a clearer image with better tissue penetration,



Ultrasound Transducers in RA

- **Linear Transducers:**

For evaluation of the superficial nerves, such as those in the forearm, the brachial plexus, and femoral nerves, a high-frequency (10–15 MHz) linear transducer is required

Ultrasound Transducers in RA

- **curvilinear probe:**

(4–7 MHz), which provides better penetration, is recommended for deeper targets such as the sciatic nerve, or for more obese patients.

Ultrasound Transducers in RA

- **Hockey stick transducer:**

A small footprint "hockey stick" transducer is preferred in pediatric patients where a smaller surface area is being explored.

Image Modes of Ultrasound

- **A-Mode**

A-mode is the oldest ultrasound technique.

The transducer sends a single pulse of ultrasound into the medium. Consequently, a one-dimensional simplest ultrasound image is created on which a series of vertical peaks is generated after ultrasound beams encounter the boundary of the different tissue.

A-mode ultrasound is not applicable to regional anesthesia.

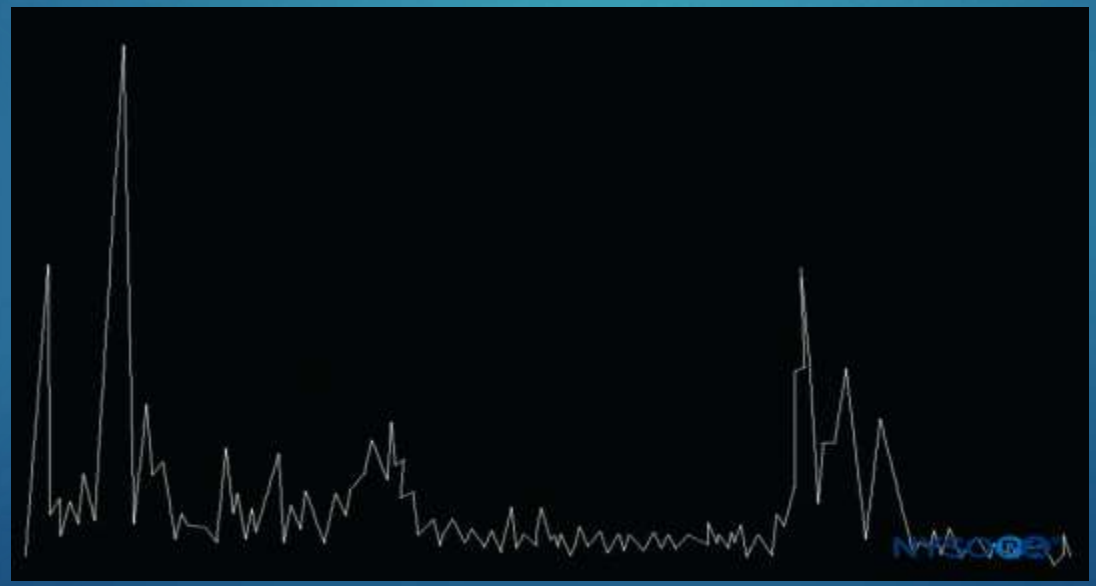


Image Modes of Ultrasound

- **B-mode**

The B-mode is a two-dimensional (2D) image of the area.

The horizontal and vertical directions represent real distances in tissue.

B-mode can provide an image of a cross section through the area of interest, and it is the primary mode currently used in regional anesthesia.

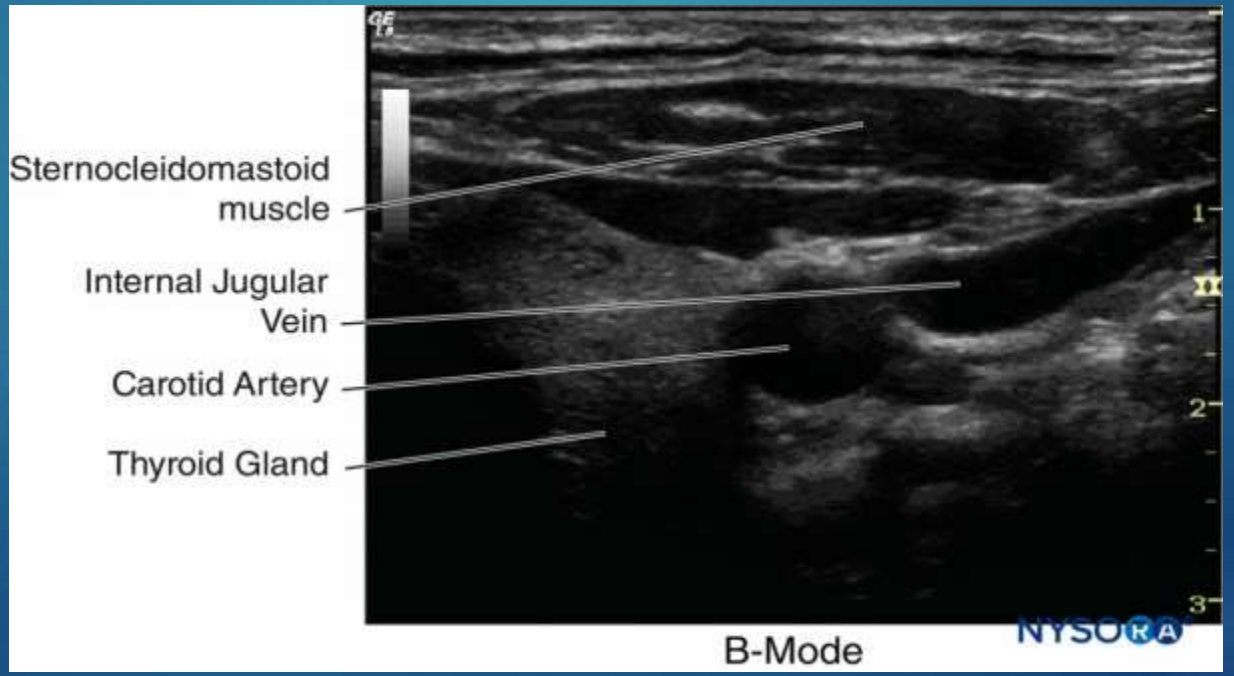


Image Modes of Ultrasound

- **Doppler Mode**

If the sound source moves toward the sound receiver, the sound waves have to be squeezed, and a higher-pitch sound occurs (positive Doppler shift); if the sound source moves away from the receiver, the sound waves have to be stretched, and the received sound has a lower pitch (negative Doppler shift)

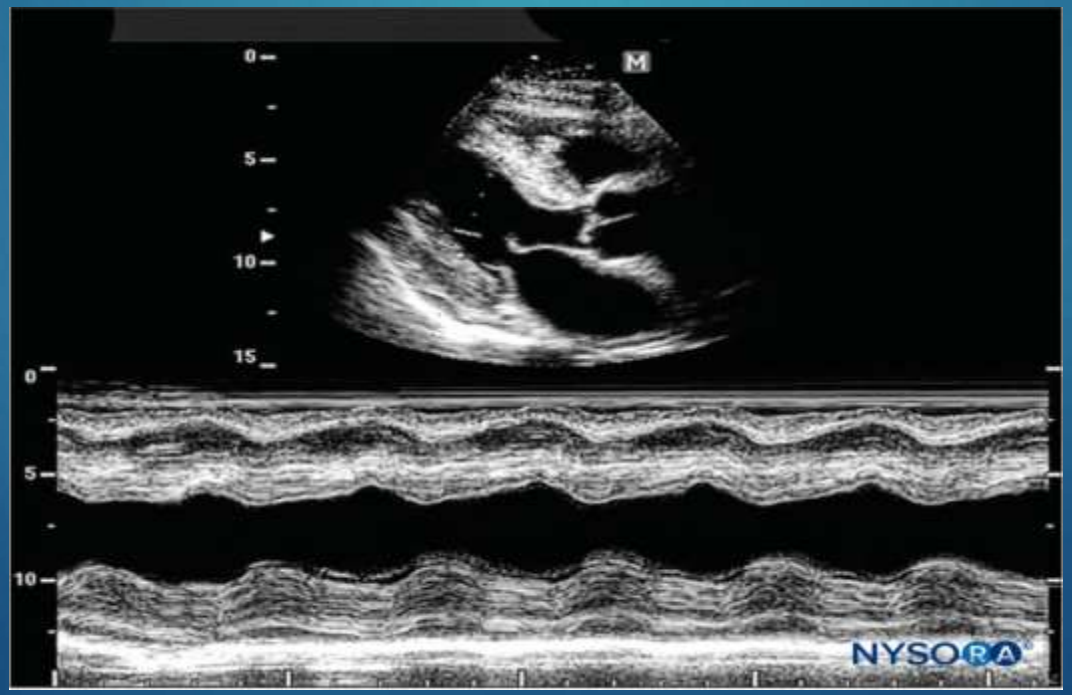
In medical settings, the Doppler shifts usually fall in the audible range.

Color Doppler produces a color-coded map of Doppler shifts superimposed onto a B-mode ultrasound image.

Image Modes of Ultrasound

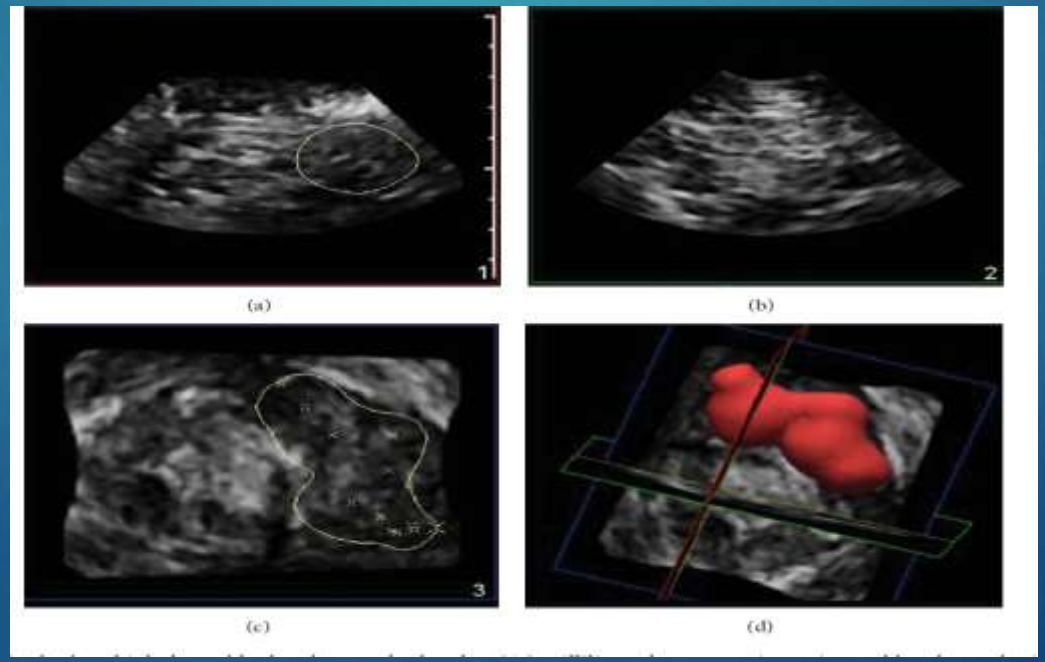
- **M-Mode**

A single beam in an ultrasound scan can be used to produce a picture with a motion signal, where movement of a structure such as a heart valve can be depicted in a wave-like manner. M-mode is used extensively in cardiac and fetal cardiac imaging; however, its present use in regional anesthesia is negligible.



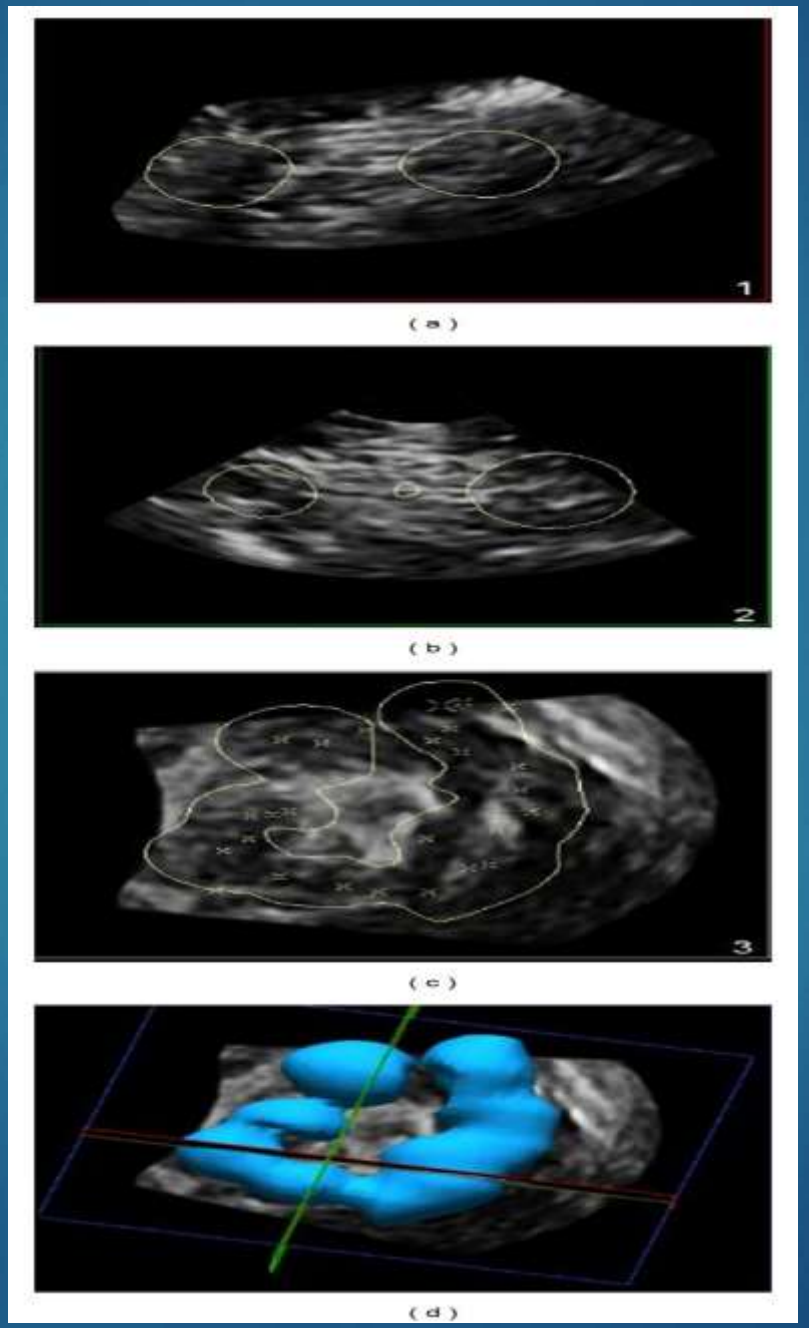
Multidimensional Imaging: 3D and 4D Ultrasound

- A 3D image containing information about the whole volume of tissue can be obtained. Consecutive images thus acquired when displayed in real time will result in a dynamic (also known as 4D or live video) ultrasound image. Just as the 2D units are called pixels, the units of the 3D ultrasound unit are called Voxel.



Multidimensional Imaging: 3D and 4D Ultrasound

- 4D US allows for needle tracking in multiple planes simultaneously and accurate measurement of the local anesthetic volume surrounding the nerve following injection.
- Additionally, the morphology and proximity of local anesthetic spread around the target nerve is clearly seen with the described technique. This method provides additional spatial information in real time compared to standard two-dimensional ultrasound.


1
(a)
2
(b)
3
(c)
(d)

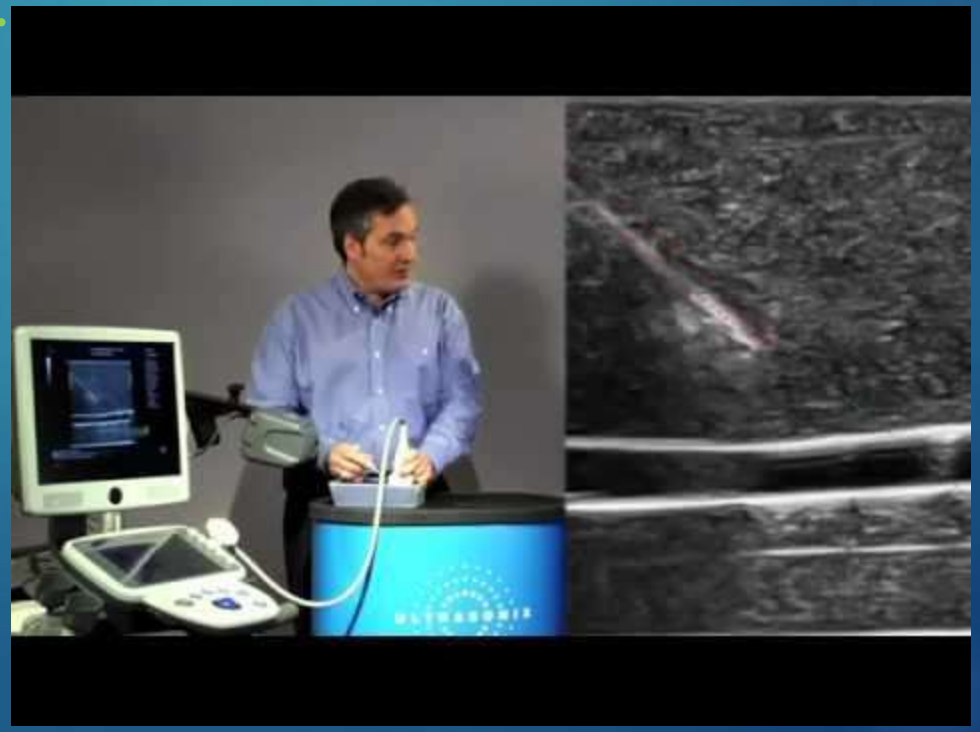
Needle Guidance

- Needles are best seen when directed precisely along the beam of the ultrasound probe, at a small angle relative to the skin.
- Preserve the orientation of the needle exactly in line with the beam is difficult, and minor misalignments may be associated with profound loss of needle visibility.
- "Echogenic" needles have recently introduced into clinical practice and are characterized by a textured surface with circumferential reflectors separated by a non-echogenic gap.

Needle Guidance

- **GPS Needle Guidance System**

The Sonix GPS needle guidance system consists of a transmitter and sensors at the needle tip and in the transducer allowing real-time tracking in three dimensions.

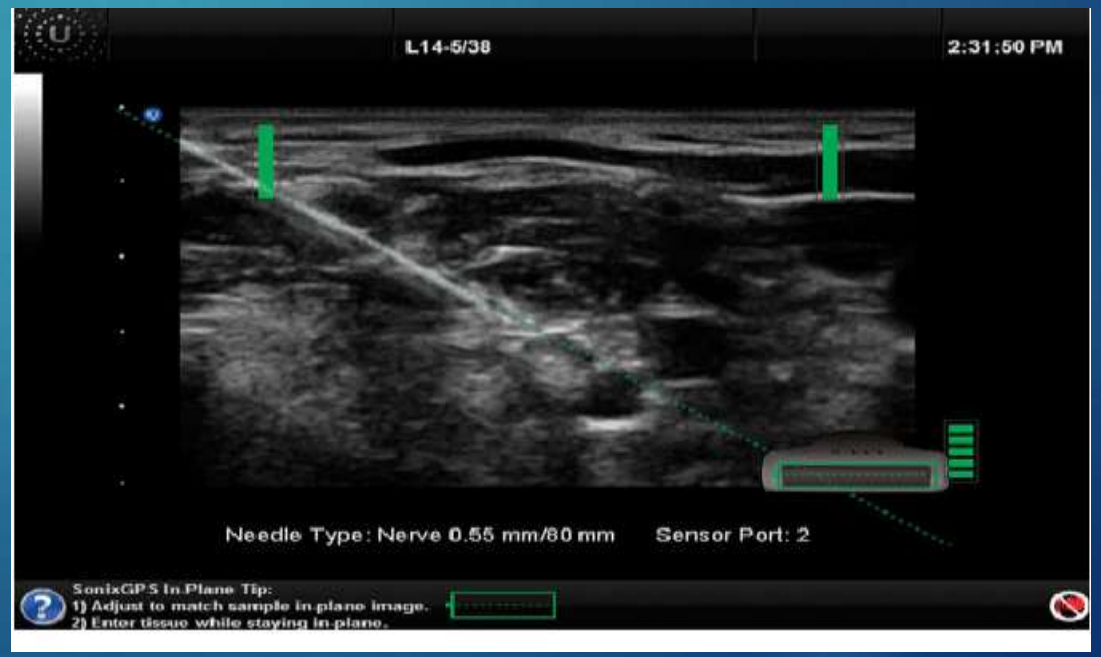


GPS Needle Guidance System

- The potential advantages of SonixGPS are that the optimal needle angle is decided before insertion, potentially reducing the number of needle passes and tissue damage, the needle tip is seen irrespective of plane or angle, and that it is applicable to linear and curvilinear transducers.

Electromagnetic Needle Tracking

- An alternative electromagnetic needle tracking system consists of a sterile, reusable coaxial needle with a sensor at the tip fitted onto the mount area of a custom-made ultrasound bracket.
- The manufacturers claim real-time visibility of needle trajectory before and during needle placement.



Summary

- The future of ultrasound holds great promise.
- For patients undergoing ultrasound guided regional anesthesia, benefits will be derived from design and production of anesthesia-specific ultrasound probes and software modifications enabling clear visibility of non-echogenic needles in color.
- Miniature ultrasound probes integrated within needles will enable clinicians to image regions such as the epidural space or perineural spaces and identify tissue morphology from within the tissue region of interest.

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Thank You!