Using AR for Ultrasound-guided Needle Procedures

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What is ultrasound-guided needle placement?

Several common procedures such as biopsies, central venous access, chest tube insertion, epidural injections, lumbar/chronic pain blocks, catheter placement, and laparoscopic ablation require identifying a particular anatomical structure or mass, then inserting a needle to reach the desired target. For many of these procedures, clinicians use ultrasound imaging, which displays internal structures and organs on a monitor. This helps the clinician better visualize the target and trajectory of the needle as it moves through tissue.

What are the challenges with ultrasound guidance in needle-based procedures?

While ultrasound guidance has been associated with better outcomes compared with free-hand techniques,[1] there are significant limitations with ultrasound image guidance related to: (i) visualization and (ii) ergonomics.

- Visualization: Clinicians may not be able to determine, in real time, the spatial relationship between the target (e.g., anatomy such as lumbar spine, lesion, mass) and the needle.[2] This can make it difficult to accurately guide the needle, requiring the clinician to make multiple attempts to reach the target, which can cause pain and discomfort to the patient.[3] It can also result in undesirable outcomes such as misclassification of a tumor or mistargeting and puncturing a vessel or nerve.[4] [5]
- Ergonomics: While clinicians perform the procedure, they must look away from the surgical site to view ultrasound images.[6] This necessitates “alternate attention,” which can pose hand-eye coordination challenges, reduce operational efficiency, and increase the risk of error.[7] [8] [9] These types of movements can also increase the risk of workplace injury such as shoulder, neck, and back pain.[10] [11]

How can AR address limitations with ultrasound image guidance?

Augmented reality (AR) -- a set of technologies that integrates digital 3D content into our visual field and allows us to interact with the content -- offers real potential to improve current ultrasound guidance technology for needle-based procedures. AR-enabled headsets can be used to overlay computer-generated 3D ultrasound images directly into the procedural field when registering the ultrasound transducer to the patient’s anatomy. By overlaying images directly onto a patient’s anatomy, along with the assistance of optical device tracking, clinicians may be better able to track and precisely locate the target. In addition, with AR-enabled headsets, clinicians are not required to turn their heads towards a monitor during the procedure, which can help reduce clinicians’ cognitive load, improve ergonomics, and achieve better accuracy.[12] [13]

Current applications of AR systems that enhance ultrasound guidance for needle procedures are already demonstrating promising results, though these outcomes are largely limited to preclinical (i.e., usability and pilot testing) evaluations. Evaluations that compare AR systems used in conjunction with ultrasound guidance to ultrasound guidance (alone) have demonstrated improvements in needle accuracy and success rates across a range of procedures, from needle biopsies to epidural injections for spinal anesthesia to laparoscopic liver ablation.[14] [15] [16] [17]

What’s next for AR integration with ultrasound?

It is possible that a greater level of integration between AR-enabled headsets and ultrasound technology -- specifically integrating optical tracking with an ultrasound transducer compatible with the headset -- could prove beneficial in both needle tracking and digital information fusion. Digital information fusion, wherein high-resolution augmented reality images (e.g., a patient’s previous CT scans) could be combined with lower resolution ultrasound images. This could be especially beneficial for precision-based use cases, such as drug delivery to tumor sites. As technology evolves, AR -- in combination with in-situ modeled plans and artificial intelligence -- could not only guide clinicians in real time, but also correct their needle trajectory during procedures.

References

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