TECHNICAL NOTE

APPLICATION OF INTRAOPERATIVE ULTRASOUND IN NEURO-SURGERY

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Introduction

Intraoperative ultrasound (IOUS) has become an invaluable tool in neurosurgery, offering real-time imaging that enhances surgical precision and patient outcomes. Its utility spans tumor localization, delineation of lesion boundaries, assessment of residual pathology, and guidance during minimally invasive procedures. This technical note provides an overview of IOUS applications, equipment considerations, procedural techniques, and limitations in the neurosurgical setting.

Applications of IOUS in Neurosurgery

1. Tumor Localization and Characterization
IOUS enables surgeons to identify both superficial and deep-seated brain lesions intraoperatively. It assists in distinguishing tumor tissue from normal parenchyma, thereby facilitating targeted approaches and minimizing damage to healthy tissue. Contrast-enhanced IOUS (iCEUS) further enhances the visualization of tumor vascularity and perfusion patterns, providing functional data in real time.[1]

2. Assessment of Tumor Resection
During resection, IOUS serves as a dynamic tool to evaluate the extent of tumor removal. By providing immediate feedback, it aids in identifying residual tumor tissue, allowing for additional resection if necessary. This real-time assessment is crucial for achieving maximal safe resection, particularly in eloquent brain areas.[2]

3.Guidance in Minimally Invasive Procedures
In minimally invasive neurosurgical procedures, such as those involving tubular retractors, IOUS augments navigation by providing real-time imaging of the surgical corridor and target lesion. This integration enhances the safety and efficacy of the procedure by ensuring accurate instrument placement and minimizing collateral damage.[3]

Equipment and Technical Considerations

Ultrasound Systems and Probes
Modern IOUS systems offer high-resolution imaging with various probe configurations tailored for neurosurgical applications. Linear and convex transducers with frequencies ranging from 3.8 to 10 MHz are commonly used, providing a balance between image resolution and penetration depth. The choice of probe depends on the specific surgical scenario, including lesion location and required imaging depth.[4]

Image Acquisition and Interpretation
IOUS imaging is typically performed in coronal, sagittal, and axial planes to obtain comprehensive views of the lesion and surrounding structures. Surgeons must be adept at interpreting ultrasound images, which can differ significantly from preoperative MRI or CT scans. Familiarity with ultrasound anatomy

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and potential artifacts is essential for accurate assessment.[5]

Integration with Neuronavigation

Combining IOUS with neuronavigation systems enhances surgical accuracy. Real-time ultrasound data can be fused with preoperative imaging, compensating for brain shift and providing updated guidance during the procedure. This integration is particularly beneficial in complex cases where anatomical landmarks may be distorted.[6]

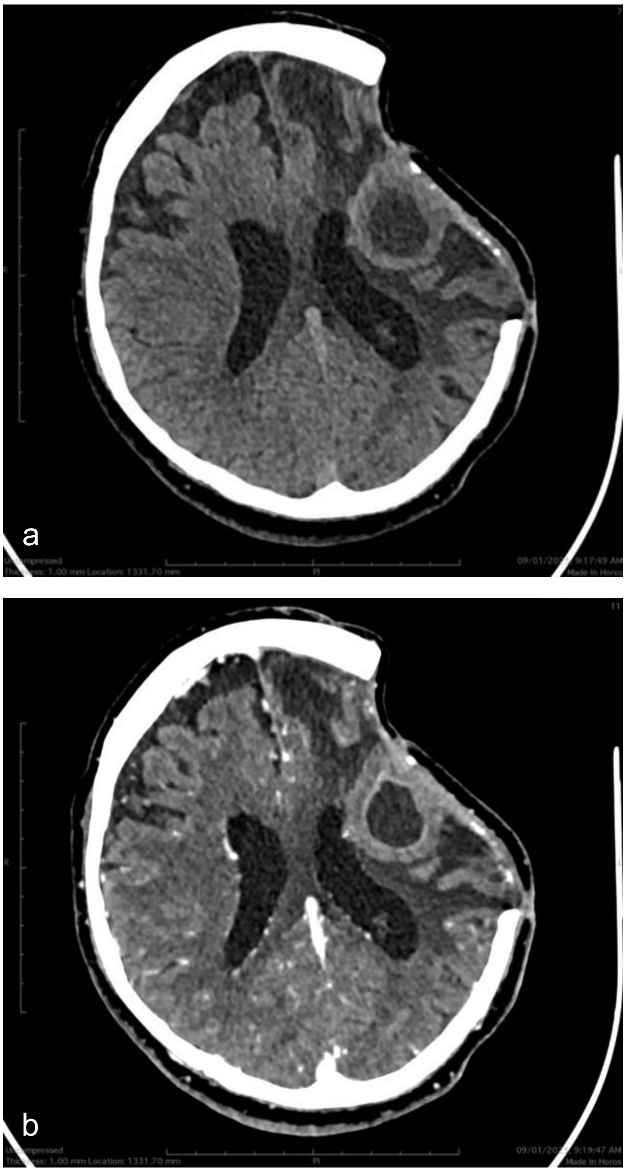

Figure 1: CT scan Brain axial images pre-contrast (a) and postcontrast (b), showing a thick walled cavitating lesion, with rim enhancement and surrounding gyri form edema. No midline shift is noted. Craniectomy defect is seen on lest side.

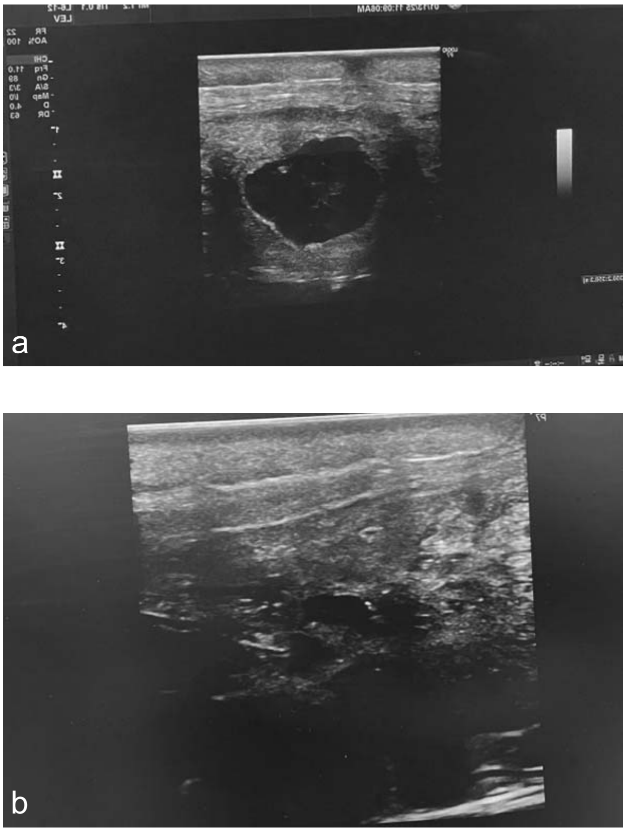

Figure 2: Pre-procedure ultrasound Image (a) of the brain showing brain abscess. Post-procedure ultrasound (b) with same magnification showing decompressed abscess cavity. Tip of the needle is seen within the residual cavity.

Limitations and Challenges

1. Learning Curve

Effective utilization of IOUS requires specific training and experience. Surgeons must develop proficiency in image acquisition, interpretation, and integration into the surgical workflow. Continuous education and hands-on practice are vital to overcome the initial learning curve.[2]

Image Quality Factors

Factors such as acoustic impedance mismatches, presence of air bubbles, and patient positioning can affect image quality. Meticulous technique in probe handling, coupling agent application, and avoidance of air introduction are necessary to optimize imaging.[7]

Technological Limitations

Despite advancements, IOUS may have limitations in imaging certain pathologies or deep-seated lesions due to attenuation and limited penetration depth. Ongoing research into advanced modalities, such as elastosonography and 3D ultrasound, aims to address these challenges.[6]

Conclusion

Intraoperative ultrasound is a versatile and powerful tool in neurosurgery, offering real-time imaging that enhances surgical precision and patient safety. Its applications in tumor localization, resection assessment, and minimally invasive procedure guidance are well-established. However, successful implementation requires appropriate equipment selection, technical expertise, and awareness of its limitations. Continued advancements and training in IOUS technology hold promise for further improving neurosurgical outcomes.

CONFLICT OF INTEREST: None.

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