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Current applications of Point-of-care ultrasound (POCUS) in neurosurgery

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Abstract
Point-of-care ultrasound has become increasingly popular as a new term covering a wide range of diagnostic and therapeutic activities. The role of POCUS has been proven in many diagnostic and interventional pre-, intra-, and post-operative procedures in neurosurgery. We collected some common procedures that use POCUS at low cost and with no risk of neurosurgery.
Keywords: Point-of-care ultrasound (POCUS); Neurosurgery; Intraoperative ultrasound; Transcranial Doppler; Optic nerve sheath diameter; Traumatic brain injury; Brain tumor resection; Neurocritical care

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Introduction

"Point-of-Care Ultrasound" (POCUS) is a broad term that refers to the use of portable ultrasound outside the radiology department. For instance, a patient may be scanned with a portable ultrasound in an emergency room, operating room, or intensive care unit. As such, "point-of-care ultrasound" refers to practices in which portable ultrasound equipment can be transported to the patient's location. There has been a significant rise in the notion of POCUS in the world over the last decade. The development of smaller, higher-quality instruments enables ultrasound to be used beyond the radiology department. Ultrasound was used for tumor resection in neurosurgery many years ago and is now used for many indications in diagnosis, treatment assistance, and post-operative care. Advancements in ultrasound techniques and the introduction of portable ultrasound scanners have expanded its use across all areas of neurosurgery. Here, we briefly review different POCUS uses in neurosurgery for researchers.

Anesthesiologists can use POCUS preoperatively to assess cardiac, lung, abdominal, and airway status, especially in emergent neurosurgical operations.[1]

Intraoperative Applications of POCUS in Cranial and Spinal Surgery

Ultrasound usage as a diagnostic tool for traumatic abdominal/thoracic injuries emerged at least three decades ago. Ultrasound in trauma is used for the detection of intraperitoneal hemorrhage, pericardial tamponade, and hemothorax/pneumothorax. This application is commonly named the "extended focused assessment with sonography for trauma" (FAST). [1] Ultrasound can detect skull fractures in pediatrics. New literature suggests that POCUS is a valid option for diagnosing skull fractures in children in the emergency wards after blunt head injury.[2]

Intracranial hypertension (ICP) can be monitored with a non-invasive method, optic nerve sheath diameter (ONSD) assessment. The optic nerve sheath diameter changes with CSF pressure, expanding with raised intracranial pressure. These changes are appreciated more along the anterior aspect of the nerve. ONSD inner-edge above 5mmHg (bilaterally) is equivalent to an elevation of ICP above 20mmHg. A decrease in ONSD can indicate a decrease in ICP.[3]

Cerebral perfusion can be affected by ICP and vasospasm in traumatic brain injury. Traumatic vasospasm is a negative prognostic risk factor in head injury. Detection of vasospasm by transcranial Doppler ultrasound (TCD) is described in patients with subarachnoid hemorrhage. TCD can detect autoregulation, perfusion, and intracranial hypertension.[4] A cranial bone defect can be used as a window to image microvascular blood flow by the POCUS in the trauma and non-trauma setting.

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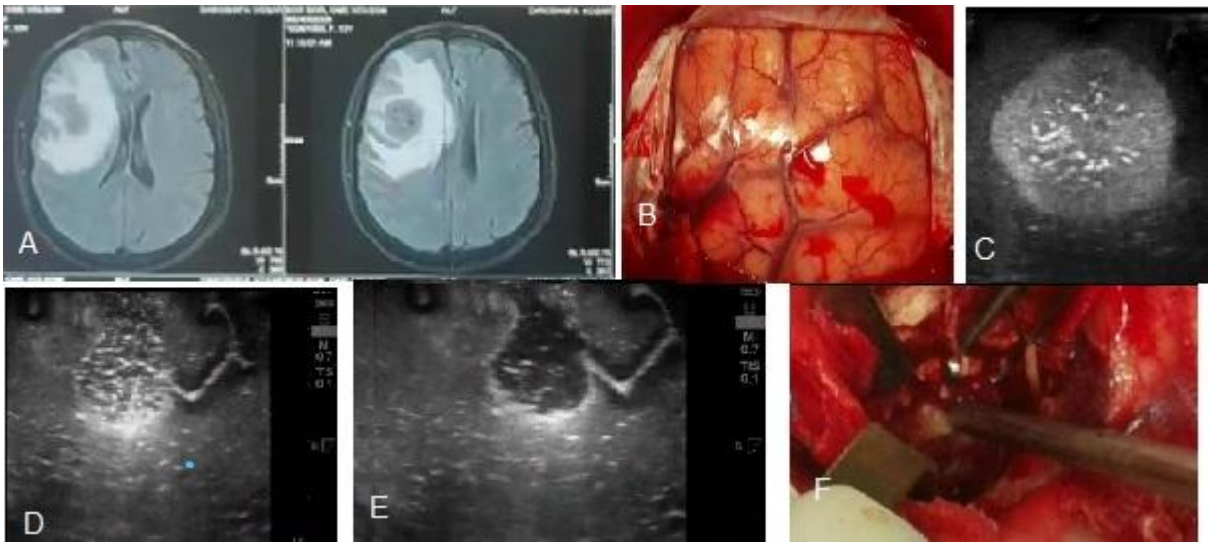


Figure 1. Patient's imaging at initial presentation demonstrating 35 years old man presented with new-onset seizure. A: MRI FLAIR axial image demonstrating the lesion with vasogenic edema. B: Intraoperiave image of brain. C: Intraoperative ultrasonography demonstrated the lesion with a different echo from the adjacent brain. D: Intraoperative ultrasound demonstrated total excision of the lesion and refill with serum bubbles. E: Intraoperative ultrasound shows total resection lesion. F: The intraoperative image that shows total excision.

POCUS helps to assess the target of the solid mass lesion after craniotomy (Figure 1). In cystic lesions, POCUS can guide cyst puncture or even ventricular puncture before resection.[2] The POCUS can discriminate between tumors, brain edema, and normal brain tissues. POCUS can help in the planning of surgery, navigation for biopsies, or operation guiding and resection control.[1] The POCUS can also be used for detecting tumor residue after intra or extra-axial brain tumor resection to achieve safe maximum surgical resection. POCUS can be performed with a conventional ultrasound scanner. POCUS can be used for navigation by merging preoperative MRI or CT images with intraoperative ultrasound images. Contrast-enhanced ultrasound (CEUS) scans blood flow through arteries, veins, and capillaries via intravascular microbubbles as contrast agents with maximum sensitivity and specificity.[5] Using the intraoperative US with shear-wave elastography technique verified the assessment of not only brain tumors but also epileptic lesions like focal cortical dysplasia of the brain.[6] The intraoperative ultrasound in patients undergoing transsphenoidal surgery for pituitary adenoma has been applied as a safe and effective technology.

The POCUS is the method of choice for the diagnosis of hydrocephaly and intraparenchymal hemorrhage in infants. The POCUS can detect flow conditions and may be helpful as an additional method in determining shunt malfunction and the need for surgical shunt exploration.[7]

In spine surgeries, POCUS can be used to localize tumors and thoracic discs, evaluate adequate decompression, and assess resection control. POCUS has been used for Chiari malformation, diastematomyelia (split cord), tethered cord, lipomyelomeningoceles and lipomas, syringomyelia, and cystic surgeries.[8]

POCUS in Peripheral Nerve Surgery and Regional Anesthesia

Real-time intraoperative ultrasound can be used in peripheral nerve surgeries, including nerve localization, peripheral nerve tumor resection, and lead implantation for peripheral nerve stimulation. [10] The POCUS can also be used for nerve block and regional anesthesia.

High-resolution ultrasound can be used for any peripheral nerve procedure in pain management. Spinal pain procedures include facet injections, costotransverse joint injections, medial branch blocks, sacroiliac joint injections, and epidural injections. The US can prove the severity of carpal tunnel syndrome. The US is particularly sensitive in the diagnosis of patients with carpal tunnel syndrome. [9] Some authors describe minimal invasive carpal tunnel surgery with a smaller incision and shorter return to work time.

Conclusion

POCUS should be considered for use in neurosurgery. Ultrasound can be helpful at all peri-, intra-, and post-operative stages, with low cost and fewer side effects.

Ethical consideration

None.

Competing Interests

The authors declare no conflict of interest.

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