Bedside Ultrasound After Decompressive Craniectomy: A New Standard?

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Evaluation of brain structures represents a vital element of the practice in a neurointensive care unit. Several monitoring techniques may be used to guide crucial therapeutic decisions. Currently, repeated computed tomography (CT) is used to monitor progression (or improvement) in patients with intracerebral hemorrhage (ICH) or cerebral ischemia. CT allows rapid assessment of brain pathology, especially to evaluate hematoma and ventricular size, edema progression, ischemic infarcts, and midline shift. However, transferring an instable or intubated patient to the CT-scanner may be a time- and resource-consuming task. Portable CT scanning in the intensive care unit (ICU) is equally costly and not universally available. Because of its bedside application, ultrasound has become increasingly popular in the neuro-ICU [1, 2]. Advantages of sonography are its noninvasive technique, portability, and possibility of fast interpretation. Several studies indicated that it is possible to evaluate cerebral anatomy as well as hematomas and ventricular enlargements [3, 4]. However, the ultrasound technique is dependent upon the examiner's experience [1]. Moreover, skull thickness and bone density often limit the image quality achievable by ultrasonography. Patients after decompressive craniectomy may present an ideal candidate to visualize intracerebral anatomy with a high resolution. A few studies suggested that the sonographic technique might be considered an alternative to CT in monitoring these patients [5].

In this issue of *Neurocritical Care*, Bendella et al. [6] evaluated in their prospective study the ventricular diameters of all ventricles in patients after decompressive craniectomy by sonographic duplex technique versus CT. A total of 102 consecutive patients underwent decompressive craniectomy because of increased intracranial pressure after cerebral ischemia, ICH or traumatic brain injury. Ultrasound was performed no later than 24 h after cranial imaging, and equally important the examiner was blinded to the results of the CT. Authors revealed a remarkably high and statistically relevant correlation between CT and sonography in measuring the four ventricles as well as deviation of the midline.

How important are these results and can they change practice? Despite some technical shortcomings, sonography presents an excellent and reliable method to examine ventricle size and midline shift in craniectomized patients. As sonography depends on the experience of the examiner, comprehensive training is needed to transform the results of this trial into clinical practice. In general practice, sonography is also of benefit to other patients in the ICU (Please see table for benefits and limitations of ultrasound at the bedside).

The acute treatment of patients with severe ICH and intraventricular hemorrhage (IVH) is often hampered by obstructive hydrocephalus leading to the placement of an external ventricular drainage (EVD). However, fibrosis of the arachnoidea and inflammation often results in delayed communicating hydrocephalus and shunt-dependency [7]. Recent studies provide evidence that the combination of intraventricular fibrinolysis and lumbar drainage is safe and able to reduce mortality and shunt-dependency [8, 9]. During drainage weaning and clamping attempts, monitoring of ventricular size is essential. As shown recently,

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transcranial duplex sonography (TCD) is a reliable and fast method to monitor ventricular width and can be used to avoid repeated transports [10]. Moreover, sonography is also capable of detecting vasospasm in large ICH with IVH [11]. As patients with rapid edema growth tend to have more midline shift, regular ultrasound-based screening of midline shift represents another helpful tool in clinical practice for monitoring the course of edema in ICH patients [12].

Patients with poor-grade SAH often present with hydrocephalus in need for placement of an EVD. In clinical practice, a lumbar drainage is often used to replace EVD [13]. In this case, sonography is useful to monitor ventricle size during clamping attempts. If a detailed neurological examination for vasospasm or delayed cerebral infarction is not possible, e.g., in an intubated patient, close bedside TCD examinations are a reasonable approach. While digital subtraction angiography (DSA) represents the gold standard in detection of vasospasm—including eventual vasospasmolysis—DSA it is not feasible for daily routine diagnostics. In a recent study, TCD showed a high sensitivity compared with Perfusion-CT why TCD is a useful tool in daily follow-up [14, 15].

Taken together, ultrasound in neurocritical care offers various advantages, especially in craniectomized patients. Monitoring of vasospasms and hydrocephalus facilitate management of patients with intracranial bleedings. Therefore, it represents a reliable and fast diagnostic method to address relevant problems in routine management of neurocritical care patients. However, it is limited due to examiners experience and its technique. Given the lack of patient harm, bedside ultrasound should be incorporated in daily routine of neurocritical care.

PRO	CON
Availability at every neuro-ICU, applicability in several settings (heart/vascular/lung/trauma/brain/central venous catheterization)	Ultrasound findings depend on experience of investigator
Fast investigation and interpretation at the bedside without transport of the patient	Limited information on standards and reference values for measurements
Valid monitoring of midline shift	No detection of new ischemia or ICH possible
Monitoring of vasospasms in SAH or IVH	Visualization limited due to inadequate acoustic window (for TCCS)
Monitoring of hydrocephalus in the process of EVD weaning	
No radiation dosage	
TCCS transcranial color-coded duplex ultrasonography	

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

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