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COMMENTARY

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Potential benefits of intraoperative ultrasound in neurosurgery

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Abstract

Computed tomography and magnetic resonance imaging are the most popular diagnostic tools to visualize intracranial pathology and help surgical planning in the neurosurgical practice. However, these preoperative techniques need to be supplemented with intraoperative methods, if the lesion size may increase or preoperative anatomy may change after the primary imaging due to rapid progression of the underlying intracranial disease. In such situations intraoperative ultrasound could be a valuable technique in real-time imaging of intracranial pathologic processes, real-time control of surgical procedure, assistance in drain or catheter placement, and real-time assessment of residual tumor or hematoma volume during neurosurgical interventions.

KEYWORDS

neurosurgery, transcranial sonography, ultrasound

Computed tomography (CT) and magnetic resonance imaging (MRI) are the most popular diagnostic tools to visualize intracranial pathology and help surgical planning in the neurosurgical practice. However, these preoperative techniques need to be supplemented with intraoperative methods, if the lesion size may increase or new lesions may develop after the primary imaging due to rapid progression of the underlying intracranial disease. As Sam et al. highlighted, the intraoperative ultrasound was a useful diagnostic tool in patients with traumatic brain injury during ultrasound-guided haematoma evacuation and ventricular drain insertion.[1] They used the craniectomy hole as an excellent acoustic window for imaging the intracranial structures. When intraoperative ultrasound was used, delayed intracerebral hemorrhage with mass effect was found during the surgery in 85% of patients, while this rate was only 25% in the control group without use of intraoperative imaging. Intraoperative detection and removal of delayed hemorrhage allowed immediate and almost complete hematoma removal. Moreover, ultrasound was used for assisting ventricular drain insertion. The mortality rate was significantly smaller in the ultrasound group than in the controls (0% vs. 25%), which benefit was attributed to the more effective hematoma removal and better postoperative intracranial pressure control. They concluded that intraoperative ultrasound was a useful tool for diagnosing new lesions developed after the primary imaging (CT or MRI) and assisting with treatment in patients with traumatic brain injury.

Not only delayed intracerebral hemorrhage, but also other rapidly ongoing pathologic processes, such as perihematomal edema, midline shift, hydrocephalus, or ventricular compression may change the anatomical conditions compared to the preoperative CT or MRI image. Furthermore, itself the craniectomy, cerebrospinal fluid drainage, haematoma removal may also modify the preoperative anatomy. In such situations intraoperative ultrasound could be a valuable technique to accurately update and reflect the actual intraoperative conditions.[2]

Brain sonography has been used not only in patients with traumatic brain injury, but also in patients with intracranial tumors. Intraoperative ultrasound-guided surgical resection of gliomas was published as a useful tool for guiding the resection and for improving the extent of resection.[3] Furthermore, a new ultrasound technique, called ultrasound elastography was reported to help differentiate between tissues by their elasticity. This method helps detect residual tumors, distinguish between tumor and healthy brain tissue, and detect epileptogenic foci.[4]

Transcranial B-mode sonography (TCS) is a neuroimaging method that enables visualization of the brain parenchyma and the intracranial ventricles through the intact skull. The poor acoustic window in patients not undergoing craniectomy is often cited as a limitation of TCS. However, TCS has been known to be suitable for intracranial examination in about 80% of adult patients, and intracerebral structures and pathologies such as intracerebral hemorrhages (ICH) can be displayed sufficiently through the temporal bone.[5,6] Therefore, use of TCS should not be restricted for patients with previous craniectomy or for newborns and infants with opened fontanelle, but maybe applied for follow-up examinations and assistance in less invasive surgical procedures not requiring craniectomy also in adults. It was already published in 1993 that most intracerebral hematomas in adults could be imaged by B-mode transcranial ultrasound imaging.[6] Sonographic characteristics of the intracerebral hemorrhage was described in different stages of the disease, and its suitability was highlighted for follow-up examinations. Others reported good correlation between the hematoma volume measured by TCS and CT.[7] Moreover, TCS was found to be reliable in detection of early haematoma expansion that occurred in 40% of patients with ICH, mainly in the first 8 h after symptom onset.[7]

Hypertensive intracerebral hemorrhage is a devastating disease with high rate of mortality and disability. Although surgical hematoma evacuation failed to show superiority compared to best medical management in large clinical trials,[8,9] surgery may be required in intracerebral hemorrhage to reduce the intracranial pressure, prevent cerebral herniation, and decrease the neurotoxic blood products. As hypertensive intracerebral hemorrhage usually develops in the deep brain region, brain tissue must be crossed during surgery with open craniectomy or decompressive craniectomy. In order to prevent iatrogenic damage of healthy brain tissue when targeting hematoma, minimally invasive techniques were introduced, in which blood is aspirated by an endoscope or a catheter, combined with intra-hemorrhage thrombolysis.[9] The goal in the Minimally Invasive Surgery Plus Alteplase for Intracerebral Hemorrhage Evacuation III (MISTIE III) trial was to achieve a significant decrease in clot size to less than 15 ml. Although this trial showed that the minimally invasive technique is safe, it did not show long-term functional benefit compared to the conservative treatment group.[9] However, a subgroup analysis revealed that when the predefined target end-of-treatment intracerebral hemorrhage volume of ≤15 ml or evacuation of ≥70% of the initial blood volume was achieved, the surgery was associated with favorable functional outcome at 1 year.[10] As intracerebral hemorrhage is a dynamic process, TCS imaging maybe useful in real-time localization of hematoma. Moreover, during the neurosurgical intervention, ultrasound may assist for catheter placement, and may assess the volume of residual hematoma. It is critical according to the results of the MISTIE III trial that proved that early and more complete evacuation of intracerebral hemorrhage was associated with better outcome, and also defined a threshold value for the size of the residual hemtoma.[10]

In line with the findings of Sam et al., when ultrasound was used during open craniectomy in patients with hypertensive intracerebral hemorrhage, there was a better rate of hematoma clearance, and better therapeutic efficacy and clinical outcome than in the control group without ultrasound assistance.[1,11] Using the minimal-invasive evacuation technique, TCS imaging of intracerebral haematoma and catheter positioning was found to be optimal in 10 of 11 consecutive patients with intracerebral hemorrhage, indicating that TCS through the temporal bone was also useful for intraoperative navigation and evacuation assessment.[5] Endoscopic surgery also plays a significant role in the treatment of intracerebral hemorrhage. However, the residual hematoma volume cannot be measured intraoperatively from the endoscopic view, and it is difficult to determine the precise location of the endoscope within the hematoma cavity. Sadahiro et al. attempted to develop a real-time ultrasound-guided endoscopic surgery using a burr-hole-type probe that is a special, commercially available transducer, ideal for scanning during burr-hole guidance procedures.[12] The mean evacuation rate of hematoma was 96% ±3% in their study, demonstrating the effectiveness of this navigation method. In conclusion, ultrasound may be effective for intraoperative navigation and evacuation assessment during surgical treatment of intracerebral hemorrhage.

TCS has many advantages compared to CT or MRI, including repeatability, portability, low costs, safety, short investigation time and lack of radiation hazard.[3] Continuous evolution of ultrasound methods since its introduction has resulted in faster image processing, better image resolution, smaller transducers, new ultrasound modalities, allowing its extensive application in medicine.[2] However, TCS is still an underestimated and underutilized imaging technique that could be used in many fields of neurology and neurosurgery.[13] Although ultrasound does not serve as a primary diagnostic tool in intracranial diseases, it may help follow-up intracranial pathology and show real-time intraoperative conditions. Repeated measurement of the optic nerve sheet diameter and the size of the ventricles, as well as the detection of the midline shift without ionizing radiation exposure has made the application of TCS useful in the neurointensive care.[14] In addition, real-time imaging of intracranial pathologic processes, real-time control of surgical procedure, navigation during drain or catheter placement, and real-time assessment of residual tumor or hematoma volume either through the craniectomy hole or through the intact skull provide significant assistance to the neurosurgeon. Use of intraoperative ultrasound may improve the surgeon's confidence and the patient's safety during the operation, and may contribute to the better clinical outcome.[15] Qualified training courses could enhance the wider application of TCS making the intraoperative ultrasound a cost-effective method that may supplement other imaging modalities and update surgical plans without significant workflow interruption.[13]

CONFLICT OF INTEREST

None.

DATA AVAILABILITY STATEMENT

No data are in the manuscript.

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