

Introduction

The relevance of cerebral venous system is often underestimated during neurosurgical procedures. Damage to this draining system could lead to catastrophic implications for the patient. Surgical decision making and planning must consider each components of the venous compartment, from the medullary draining vein to the dural sinuses and extra-cranial veins. Intra-operative ultrasound (ioUS) permits the real-time study of venous compartments, with different modalities, thus obtaining a complete characterization of its anatomical and functional features. B-mode offers a high-resolution anatomical representation of veins and their relationships with lesions. Doppler modalities (color-, power-, spectral-) allow the study of blood flow and to identify vessels characterizing their functional characteristics. Contrast-enhanced ultrasound allows to perform a real-time angiosonography showing both functional and anatomical aspects of vessels.

Methods

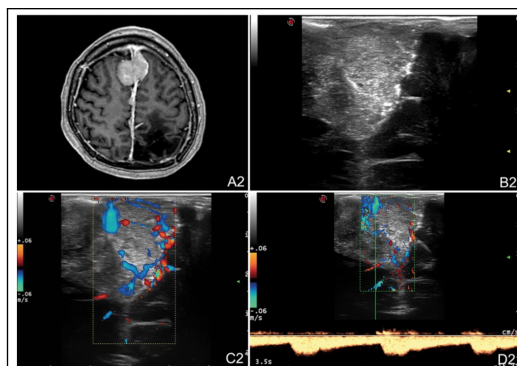
we review different clinical scenarios, demonstrating how the combination of different US modalities has the potential to detect all those dynamic changes that take place within the venous system

Results

ioUS permits a real-time, dynamic intra-operative characterization of the venous compartment, not limited to the anatomical representation with B-mode, but through multiple modalities allows to evaluate blood flow, tissue and tumor perfusion, changes in venous districts and extra-cranial outflow.

Conclusions

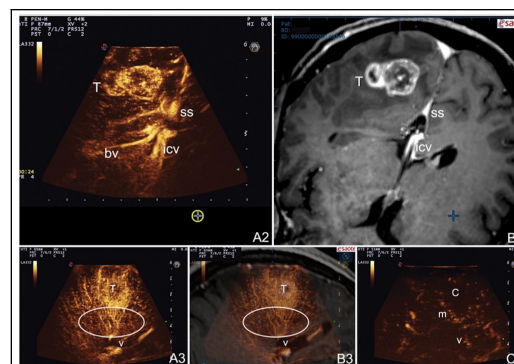
Multi-modal ioUS is a great adjunct, alone or used in a synergistic manner with other imaging modalities, to the surgical armamentarium.



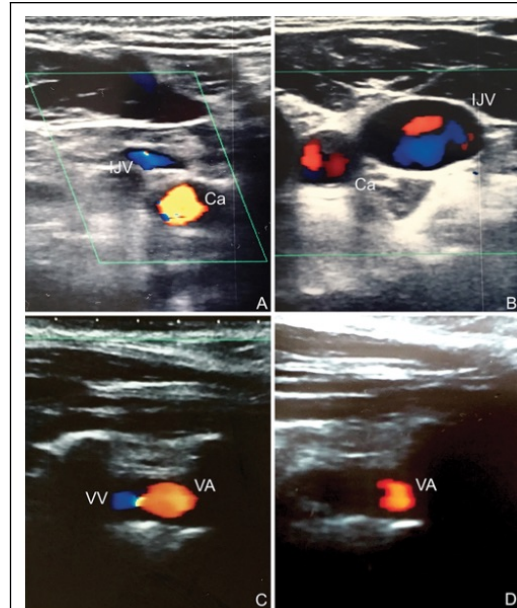
Transdural multimodal US - Bilateral frontal sagittal meningioma (A2–D2): on preoperative MRI (A2) and B-mode (B2) the superior sagittal sinus appears closed. Color and Spectral Doppler imaging (C2–D2) demonstrates relevant flow in the sinus, bridging veins, and collateral venous drainage. F = falx; S = sinus; T = tumor.

Learning Objectives

The purpose of this work is to further familiarize readers with US application other than B-mode, such as Doppler modalities, CEUS and fusion imaging, particularly their specific strength for vessels visualization, in neurosurgical procedures.



Intraoperative CEUS permits to visualize and characterize the entire vascular venous tree and its changes during surgery. Right parietooccipital GBM: a CEUS scan (A2) and the corresponding coplanar preoperative gadolinium-enhanced MR image (B2) are displayed, showing the deep venous system. A case of left parietooccipital GBM (A3–C3): CEUS highlights tumor together with venous, capillary, and arterial vessels. Pre-resection CEUS examinations highlight venous drainage through small vessels directed toward the ventricle (ellipses, A3 and B3). After complete resection, venous drainage disappeared (C3). bv = basal vein; C = cavity; CS = cavernous sinus; icv = internal cerebral veins; m = margins; ss = straight sinus; T = tumor; v = ventricle.



Cerebral venous outflow. Area and flux direction in the IJV and vertebral venous plexus (VV) in a patient sitting (A-C) or supine (B-D).