Intraoperative Ultrasonography during Drainage for Chronic Subdural Hematomas: A Technique to Release Isolated Deep-seated Hematomas—Technical Note

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Abstract

After the drainage of chronic subdural hematomas (CSDHs), residual isolated deep-seated hematomas (IDHs) may recur. We introduce intraoperative ultrasonography to detect and remove such IDHs. Intraoperative ultrasonography is performed with fine transducers introduced via burr holes. Images obtained before dural opening show the CSDHs, hyper- and/or hypoechoic content, and mono- or multilayers. Images are also acquired after irrigation of the hematoma under the dura. Floating hyperechoic spots (cavitations) on the brain cortex created by irrigation confirm the release of all hematoma layers; areas without spots represent IDHs. Their overlying thin membranes are fenestrated with a dural hook for irrigation. Ultrasonographs were evaluated in 43 CSDHs (37 patients); 9 (21%) required IDH fenestration. On computed tomography scans, 17 were homogeneous-, 6 were laminar-, 16 were separated-, and 4 were trabecular type lesions. Of these, 2 (11.8%), 3 (50%), 4 (25%), and 0, respectively, manifested IDHs requiring fenestration. There were no technique-related complications. Patients subjected to IDH fenestration had lower recurrence rates (11.1% vs. 50%, p = 0.095) and required significantly less time for brain re-expansion (mean 3.78 ± 1.62 vs. 18 ± 5.54 weeks, p = 0.0009) than did 6 patients whose IDHs remained after 48 conventional irrigation and drainage procedures. Intraoperative ultrasonography in patients with CSDHs facilitates the safe release of hidden IDHs. It can be expected to reduce the risk of postoperative hematoma recurrence and to shorten the brain re-expansion time.

Key words: chronic subdural hematoma, drainage, recurrence, ultrasonography

Introduction

Although burr hole drainage with or without irrigation has been established as a treatment for chronic subdural hematomas (CSDHs),[1–4] residual isolated deep-seated hematomas (IDHs) overlooked at initial surgery may recur and require prolonged follow-up and additional treatments. We introduce intraoperative ultrasonography to detect and remove such IDHs.

Materials and Methods

Since November 2013, intraoperative ultrasonography for burr hole drainage of CSDHs was performed in all surgically treated patients with CSDHs. The 37 patients, 24 men and 13 women ranging in age from 44 years to 89 years (mean 66.8 years), harbored 43 CSDHs.

Before surgery, a burr hole site was identified based on computed tomography (CT) or magnetic resonance imaging (MRI) scans. Usually the burr hole was placed over the thickest portion of the CSDHs. When they were comprised of superficial and deep layers, i.e., when the lesions were laminar- or separated type lesions,[5] the burr hole was placed over a portion that rendered all layers accessible.

The patient was positioned to place the burr hole in the highest position to minimize postoperative residual air. After drilling an ordinary burr hole, approximately 1 cm in diameter, sterilized fine transducers (Intraoperative Puncture Electronic Sector Probe UST-52114P, Hitachi Aloka Medical Ltd., Tokyo) were introduced via the burr hole and intraoperative ultrasonography was performed using an ultrasound scanner (ProSound α6, Hitachi Aloka Medical, Ltd.) (Fig. 1). The generated frequency, 3–8 MHz, made
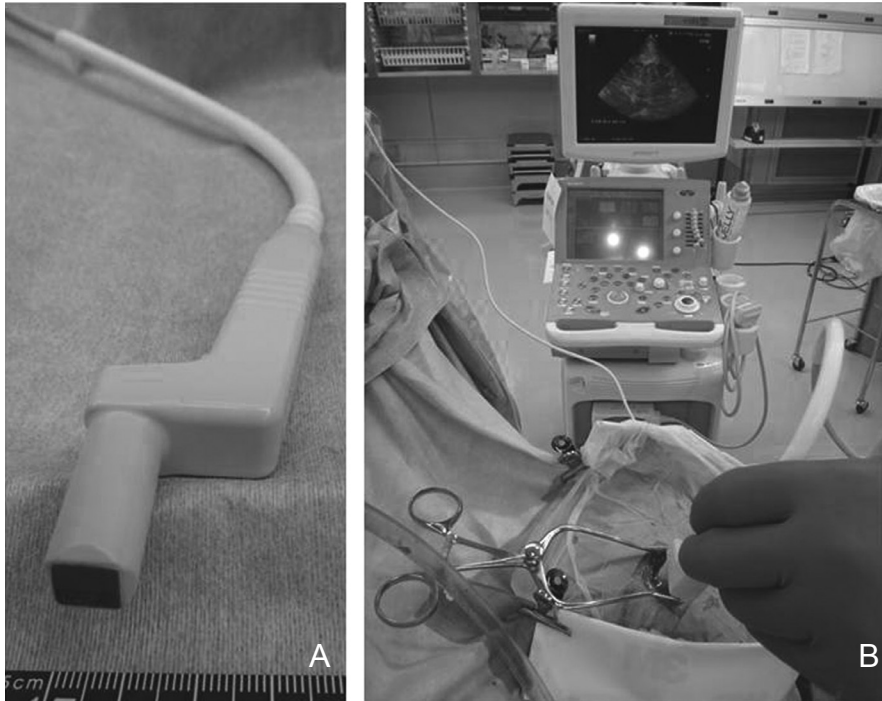
Fig. 1   Photographs showing a fine transducer introduced via burr holes (A) and intraoperative use of the transducer with an ultrasound scanner for drainage of a chronic subdural hematoma (B). The diameter of the tip of the transducer is 1 cm.

it possible to observe the whole brain and focal lesions.[6] Use of our technique in a representative patient with a homogeneous type CSDH[5] is shown in Fig. 2A–C. In this case, axial and coronal images obtained before dural opening revealed the CSDH, its hyper- and hypoechoic content, and multilayers (Fig. 2D). The gyri were depicted as hypoechoic structures with hyperechoic lining. Images were also acquired after irrigation of the hematoma under the dura. Layers with floating hyperechoic spots (cavitations) created by irrigation confirm release of the hematoma layers; areas without spots represented IDHs (Fig. 2E). Under direct vision, the overlying thin membranes, grayish or khaki, were fenestrated for several millimeters with a dural hook (Fig. 2F). Removing the irrigation fluid over the membrane and tensioning the membrane by suction aided the fenestration. After confirming the efflux of the old liquid hematoma (the content of the IDHs) through the fenestration, the area occupied by the released IDHs was irrigated. Floating hyperechoic spots on the brain cortex created by irrigation confirmed the release of all hematoma layers (Fig. 2G). A drain was placed over the fenestrated membrane toward the forehead and the wound was closed in standard fashion. Postoperative imaging findings confirming the release of all hematoma layers (Fig. 2H) were compatible with the final ultrasonography findings.

To evaluate the efficacy of the IDH fenestration ultrasonographically, IDH recurrence rates and the time to postoperative brain re-expansion were compared between the current- and 41 patients (48 CSDHs) treated earlier by conventional irrigation and drainage procedures. The latter were 25 men and 16 women ranging in age from 44 years to 96 years (mean 77.3 years). On follow-up CT studies hematoma recurrence and brain re-expansion were defined as an increase in the hematoma volume and density, and restoration to brain symmetry, respectively.

Results

Each observation was completed within 60 seconds. There were no technique-related complications such as damage to the arachnoid and/or cortical vessels and infection.

According to the CT classification,[5] 17 of the 43 CSDHs were homogeneous-, 6 were laminar-, 16 were separated-, and 4 were trabecular type lesions; 9 (21%) required IDH fenestration. Of the 17 homogeneous lesions 2 (11.8%) manifested IDHs requiring fenestration, as did 3 (50%) of the laminar-, and 4 (25%) of the separated type lesions. Findings on the different types of CSDH are shown in Fig. 3. Among the 48 CSDHs that were addressed by conventional procedures 20 were homogeneous-, 4 were laminar-, and 24 were separated type lesions. In 6 lesions (12.5%) IDHs remained after surgery; they were 2 homogeneous- (10%), 2 laminar- (50%), and 2 separated type lesions (8.3%).
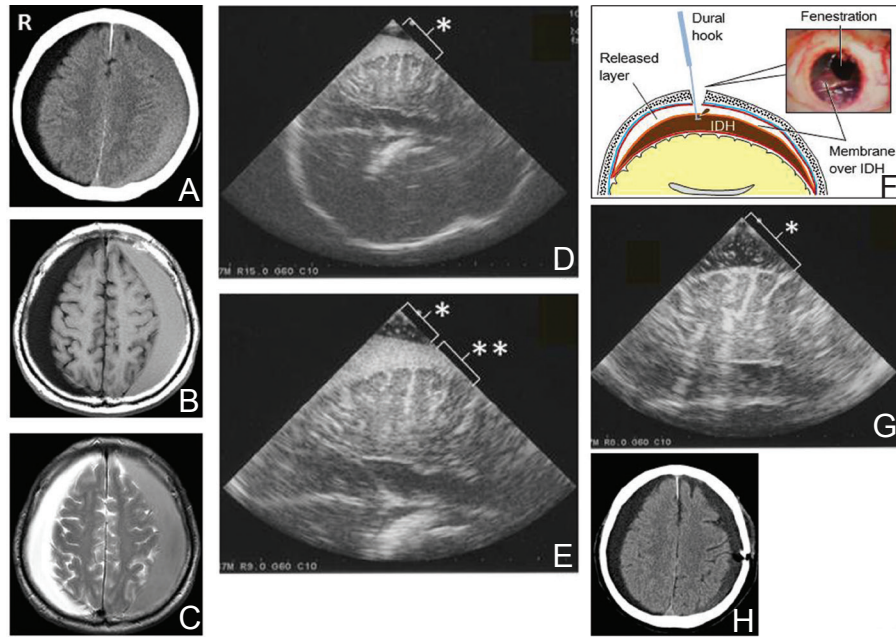
Fig. 2 Demonstration of the use of intraoperative ultrasonography in a representative patient with a chronic homogeneous type subdural hematoma. A preoperative computed tomography (CT) scan (A) and magnetic resonance imaging scans, T$_1$- (B) and T$_2$-weighted images (C), demonstrate a homogeneous hematoma on the left. No isolation is seen in the hematoma. On the intraoperative ultrasonogram obtained before dural opening, the hematoma (*asterisk*) is depicted as a double-layered lesion composed of hypoechoic superficial- and hyperechoic deep layers (D). After irrigation of the hematoma under the dura, floating hyperechoic spots (cavitations) created by irrigation are observed in the superficial layer (*asterisk*). However, the hyperechoic deep layer remains, reflecting the presence of an isolated deep-seated hematoma (IDH) (*double asterisks*) (E). After fenestrating the membrane over the IDH and irrigating the released IDH (F), floating hyperechoic spots are observed in all hematoma layers (*asterisk*) (G). Postoperative CT (H) demonstrates replacement of the hematoma by the irrigation medium.
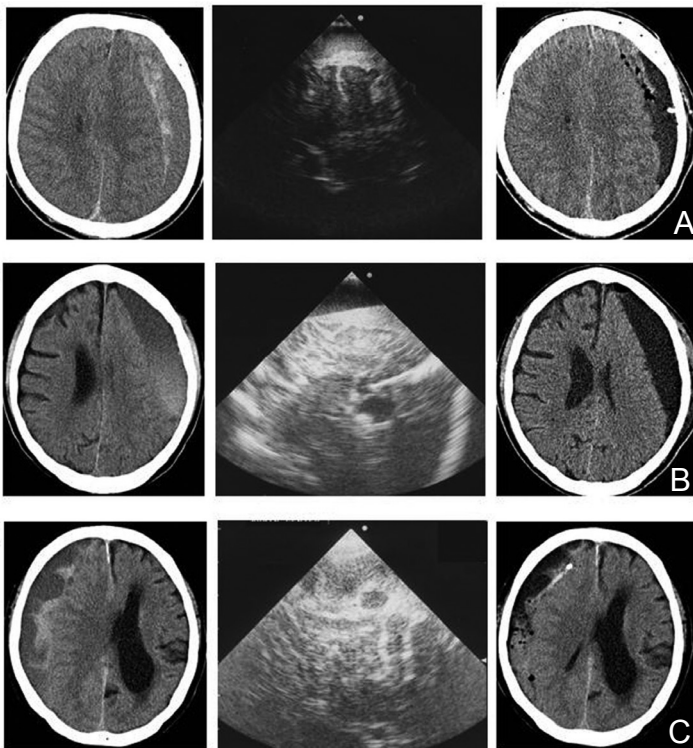

Fig. 3 Intraoperative ultrasonographs of several types of chronic subdural hematomas. Preoperative computed tomography (CT) scan (*left*), intraoperative ultrasonograph obtained before dural opening (*middle*), and postoperative CT scan (*right*). In cases with the laminar type lesion (A), the isolated deep-seated hematoma was released. Postoperative images show air and fluid density in the deep hematoma, findings suggesting sufficient irrigation. On ultrasonographs, separated- (B) and trabecular type lesions (C) are identified as a hyperechoic neveau and as hyperechoic irregular trabeculae, respectively. Those lesions featured no isolated part and postoperative images showed sufficient irrigation.

Patients subjected to IDH fenestration had lower recurrence rates and required significantly less time for brain re-expansion than did patients whose IDHs remained after conventional irrigation and drainage procedures (recurrence rate 11.1 vs. 50%, p = 0.095, Chi-square test; brain re-expansion mean 3.78 ± 1.62 vs. 18 ± 5.54 weeks, p = 0.0009, Mann-Whitney U test). No patient with hematoma recurrence in either treatment group suffered neurological deterioration or required re-operation. Only one patient who manifested coagulopathy suffered hematoma recurrence after IDH fenestration; none of the patients with residual IDHs after conventional surgery presented with coagulopathy.

Discussion

CSDHs grow in the dural border cell layer located on the inner dural surface; they are encapsulated by outer and inner membranes.[7] The outer membrane has many fragile sinusoidal channels (macrocapillaries) fed by the dural vasculature; it is thought to be the main source of recurrent hemorrhage.[7–9] The inner membrane is less likely to be involved in hemorrhage because of its poor vascularity as a result of the low reaction potential of the adjacent avascular arachnoid.[8,10,11] However, a black band on the inner membrane on T_2*-weighted MRI scans[12] and enhancement of the inner membrane on CT images[13] suggest that the inner membrane contributes to hemorrhage. These findings may reflect the storage of hemosiderin or ferritin in macrophages, an inflammatory process in the CSDHs, and the development of a feeding system from the pia mater beneath the inner membrane. Therefore, if the inner membrane is left at the base of IDHs after surgery, an inflammatory process may persist and vessels in the inner membrane may be injured by continuous brain pulsation as may be the case with respect to the outer membrane.[14] Consequently, the IDHs may rebleed and the hematomas may recur. In fact, the positive correlation between postoperative recurrence rates[5] and the incidence of IDHs on ultrasonographs of CSDH, 36% and 25% for separated type CSDHs, 19% and 50% for laminar type CSDHs, 15% and 11.8% for homogeneous type CSDHs, and 0% and 0% for trabecular type CSDHs, suggests that IDHs contribute to hematoma recurrence.

After irrigation of the hematoma under the dura, the membrane over the IDH is exposed. When conventional irrigation and drainage are performed it is difficult to distinguish the overlying- from the inner membrane just over the arachnoid through the burr hole. Therefore, surgeons hesitate to tear the unidentified membrane because there is the risk of iatrogenic damage to the arachnoid and/or cortical vessels when the membrane is just over the arachnoid, i.e., in the case of CSDHs without IDHs.

Intraoperative ultrasonography via burr holes, developed to facilitate the accurate puncture of the lateral ventricle,[15] was useful for the detection and safe evacuation of IDHs, especially when IDHs not depicted on preoperative neuroimaging studies are found unexpectedly as was the case in our patients with homogeneous type lesions (Fig. 2). On the other hand, our study revealed that laminar and separated type lesions that are expected to have IDHs on preoperative neuroimaging studies did not always feature IDHs requiring fenestration. This suggests the fragility of the membrane covering the IDHs that could be fenestrated by the first irrigation procedure.

With our method, the membrane cannot be addressed under real-time ultrasonographic observation because the burr holes of ordinary size are too small for insertion of a dural hook beside the transducer. However, enlargement of the burr hole makes it possible to carry out the maneuver.

In conclusion, intraoperative ultrasonography in patients with CSDHs facilitates the safe release of hidden IDHs. It can be expected to reduce the risk of postoperative hematoma recurrence and to shorten the brain re-expansion time.

Acknowledgments

Conflicts of Interest Disclosure

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