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Sonography of the Adult Brain through Surgical Defects

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Surgical calvarial defects can serve as small acoustic windows that make the adult brain accessible to evaluation with sonography. Initial experience is reported in eight patients for the postoperative follow-up of brain tumors, extracerebral collections, and intracranial cysts. Sonography proved to be a valuable diagnostic and therapeutic adjunct to computed tomography.

Echoencephalographic examinations of the brain, first reported by Leksell [1] in 1956, were initially limited to A-mode determinations of midline shifts. In 1963, de Vlieger et al. [2] introduced bistable, two-dimensional imaging B-mode. With the advent of modern gray-scale techniques, the quality of sonographic scans improved markedly, and B-scan imaging of the intracranial contents, performed either through the unossified skull or through calvarial defects, now provides informative images in planes similar to computed tomography (CT) scans.

Sonographic evaluation of the newborn infant's head has proved to be a valuable neuroradiologic screening examination in the high-risk infant, in many instances obviating ionizing radiation techniques or expensive CT scans. Real-time sonography can be performed in the newborn nursery without removing the baby from the incubator. It provides accurate neuroanatomic information and is useful in the diagnosis of intraventricular or subependymal hemorrhage, the discrimination between cystic and solid lesions, and the assessment and follow-up of early hydrocephalus [3–9].

As the calvarium ossifies, the attenuating bone creates increasing impedance to the transmission of the sonographic signal. Consequently, the applications of sonography in the management of adult neurosurgical patients have been limited, and the potential of the procedure has been largely overlooked. Attempts to overcome this limitation by using very low-frequency transducers have resulted in images of poor resolution [10]. However, a craniotomy or burr holes provide openings that can function as acoustic windows to the adjacent intracranial contents.

In 1965, Tanaka et al. [11], using A-mode technique, demonstrated the value of sonography in the localization and characterization of brain tumors during craniotomy. In 1975, Hoffman and Landau [12] reported B-scan imaging of an intracranial lesion through a postoperative bone-flap defect. We examined eight adults with postoperative calvarial defects and found clinical applications of greater variety than those reported previously.

Instrumentation

Standard digital sonographic machines with 3.5 and 5 MHz, internally focused transducers generated static images in coronal, axial, and (depending on the site of the burr hole) sagittal planes. Mineral oil served as a coupling agent. Initially, we found that the 5 MHz, internally focused, pencil transducer with a 6 mm face was effective in producing an

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appropriate image of the near side of the brain, but the far side of the brain was not clearly imaged, except for well defined echoes generated from the opposite skull wall. A 3.5 MHz, medium-focus transducer with a 13 mm face provided more detailed anatomic definition across the entire width of the intracranial contents and was used for the definitive studies in all the cases reported here.

Subjects and Methods

Eight patients who had had a craniotomy underwent sonographic examination. In all but one, the cranial defect overlay a neoplastic mass. Sonography identified and characterized the lesion in all cases: four were cystic, one was complex, one was solid with microcysts, and one was partly solid and partly cystic. Three cysts were aspirated under sonographic guidance. The amount of information obtained increased in proportion to the size of the defect, a larger defect providing a larger acoustic window. When the burr hole was laterally placed, the size and extent of shift of the ventricles could be determined. Thin membranes separating the encephalomalacic cavities from the ventricles were readily apparent.

The choroid plexus, falx, tentorium, and septum pellucidum were strongly echogenic. The brain substance itself was of relatively low echogenicity, but was easily differentiated from cerebrospinal fluid or adjacent cystic collections. Steep angulation of the transducer allowed the identification of structures that were not immediately apparent on routine axial or coronal sonograms. In two patients, partial visualization of a cyst was all that could be obtained, in one case because of the small acoustic window and in another because the large lesion extended beyond the cranial defect.

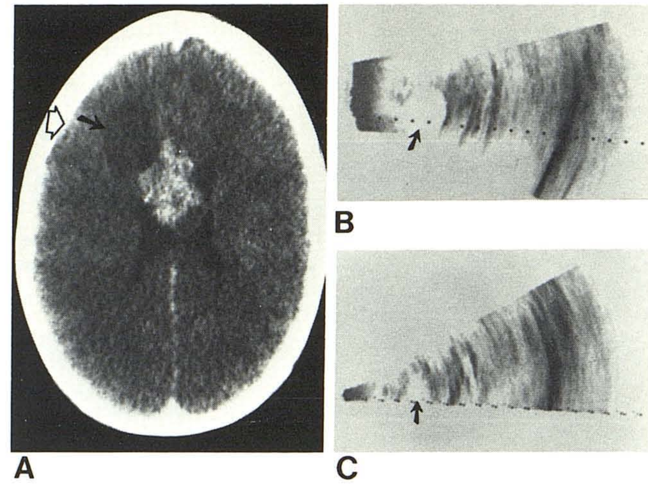


Fig. 1.—Case 1. Recurrent glioma. **A**, Calcified corpus callosa and adjacent low-density area (*closed arrow*). Approximate entry site of sonographic beam (*open arrow*). **B**, Axial plane of low-density area. Cyst (*arrow*). **C**, After aspiration, cyst (*arrow*) is smaller. Distance between dots = 1 cm.

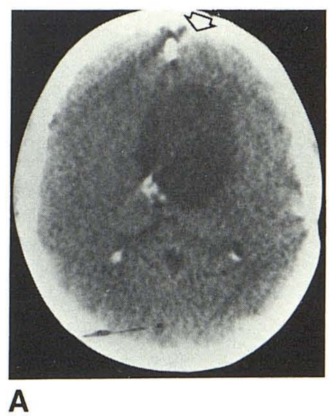
Representative Case Reports

Case 1

This 46-year-old man underwent subtotal resection of a low-grade left frontal glioma; thereafter, he received whole-brain irradiation. By 9 years later, he had developed right-sided focal seizures and mild right hemiparesis; chemotherapy was initiated after CT confirmed recurrent tumor. After 1 more year, the patient had deteriorated further, developing greater expressive aphasia, as well as dementia and increased right hemiparesis. A CT scan revealed enlargement of a corpus callosal lesion and an apparently cystic, low-density, left frontal lesion that could not be clearly distinguished from the ventricle (fig. 1A). Sonography, initially with a 5 and thereafter a 3.5 MHz tranducer, partly visualized and confirmed the presence of a cyst (fig. 1B) and revealed the compressed left frontal horn of the ventricle and the anterior part of the large midline mass. The burr hole, about 1.5 cm diameter, could not be palpated, and was detected only by the through transmission of the signal at the burr hole site. The cyst was aspirated percutaneously under sonographic guidance through the small cranial defect (fig. 1C), resulting in some clinical improvement.

Case 2

This 34-year-old man had a craniopharyngioma that had been biopsied and irradiated. He underwent bilateral ventriculoperitoneal shunting for obstructive hydrocephalus 5 years later. He was readmitted about 1 year after that with headaches and intermittent confusion. A CT scan revealed a large suprasellar cyst that was almost indistinguishable from the frontal horn of the right lateral ventricle (fig. 2A). Sonography using a 3.5 MHz transducer through a 2 cm burr hole partially visualized a separate cystic lesion located inferior to the ventricle (fig. 2B). The lesion was so situated that the axial plane and the sagittal, rather than coronal, plane were used to define the mass. An Ommaya reservoir was placed into the cyst and was used for monthly percutaneous aspiration. Follow-up sonography has documented the decrease in size of this lesion after each drainage (fig. 2C).



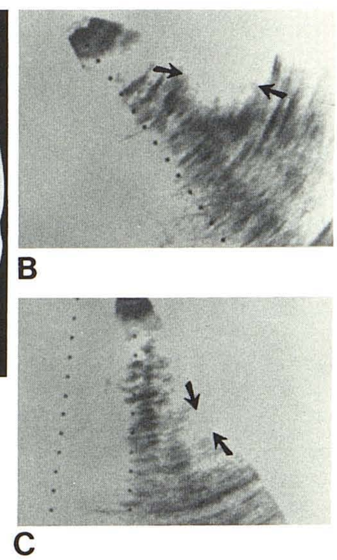
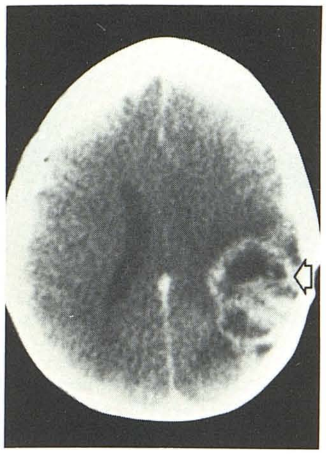


Fig. 2.—Case 2. Craniopharyngioma. **A**, Large suprasellar cyst. Approximate entry site of sonographic beam (*arrow*). **B**, Sagittal plane confirms cyst (*arrows*), delineating it partially. **C**, After aspiration, cyst (*arrows*) is smaller. Distance between dots = 1 cm.

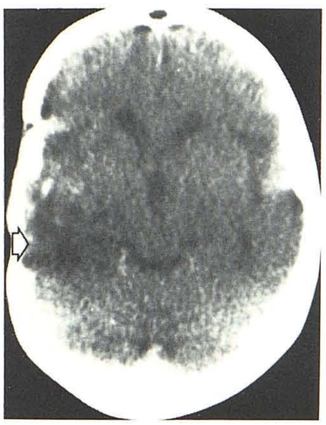
Case 3

A 58-year-old woman was seen with a sudden onset of headaches and a left homonymous hemianopsia with macular sparing. She underwent a subtotal resection of a right parietooccipital glioblastoma and received irradiation of the whole brain postoperatively. After the completion of radiation therapy and her first course of chemotherapy, she was readmitted 2 months later complaining of severe headache. The CT scan revealed decreased total mass


A


B

Fig. 3.—Case 3. Glioblastoma. **A**, Parietal lesion with rim enhancement with both high- and low-density components suggests partly cystic neoplasm. Approximate entry site of sonographic beam (*arrow*). **B**, Axial plane reveals solid irreguular mass (*long arrows*) with tiny cyst in periphery (*short arrow*). Distance between dots = 1 cm.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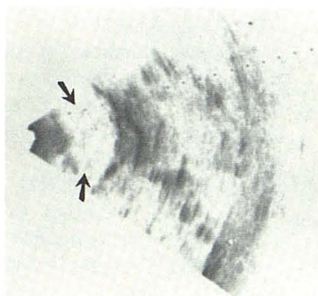
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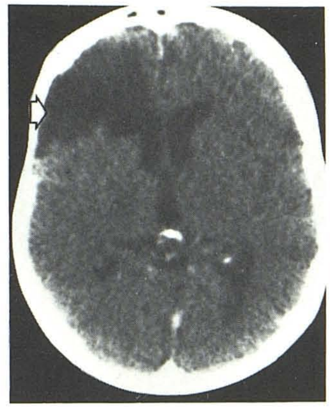
Fig. 4.—Subdural hematoma complicating oligodendroglioma. **A**, Low-density area in right parietal area. Approximate entry site of sonographic beam (*arrow*). **B**, Axial plane confirms well circumscribed, complex mass adjacent to inner table of skull (*arrows*), which proved to be chronic subdural hematoma in patient with right parietal occipital oligodendroglioma. Distance between dots = 1 cm.

effect, but demonstrated the persistence of an enhancing right parietal lesion with an apparently cystic, low-density periphery (fig. 3A). Sonography confirmed the presence of this lesion, but revealed coarse, inhomogeneous echoes throughout the tuor with poor enhancement of the posterior wall and tiny areas of fluid accumulation. This finding suggested a predominantly solid tumor with microcystic components (fig. 3B). Needle aspiration under sonographic guidance did not yield fluid, confirming the basically solid nature of this necrotic tumor.

Discussion

Sonography through a surgical defect cannot substitute for more comprehensive CT scanning, yet it can be a valuable adjunct in the follow-up management of selected patients. Once a patient has been assessed postoperatively with a baseline CT scan, sonography provides an inexpensive, accurate means to differentiate between solid and cystic lesions, to follow changes in ventricular size, and to detect changes in the size and configuration of porencephalic or neoplastic cysts before and after therapy. Theoretically, in light of the experience with infants [9] recognition of intraventricular hemorrhage is also a possibility.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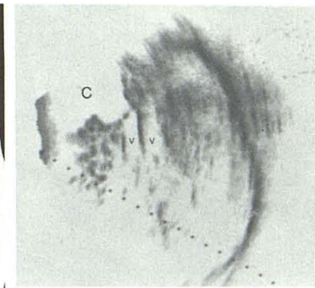

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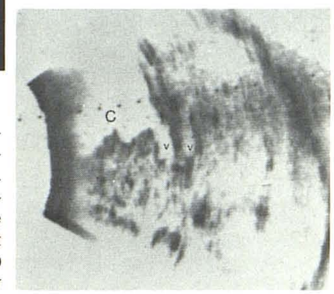


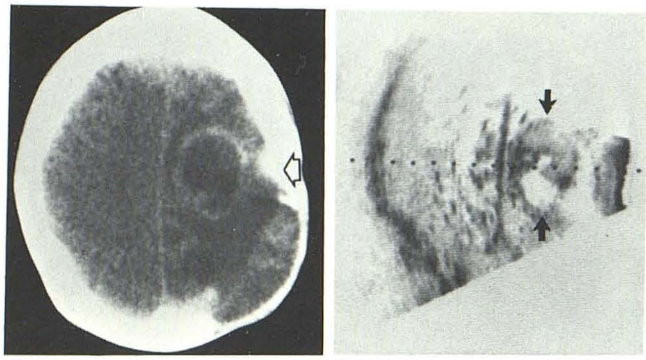
C

Fig. 5.—Postsurgical fluid collection. **A**, Right frontal atrophy secondary to surgical resection of glioma. Approximate entry site of sonographic beam (*arrow*). **B**, Axial plane superiorly demonstrates distinct separation between right ventricle (v) and fluid collection (C). **C**, Lower level. Clear communication between ventricle and fluid collection. Distance between dots = 1 cm.

Sonography affords several advantages. As a screening procedure, it rapidly provides accurate postoperative information. It is valuable for monitoring ventricular size, and is useful in detecting complications such as subdural collections (fig. 4). In addition, any obliquity or plane can be used. The study does not involve the hazards of contrast injection. Its relatively low cost, ease, rapidity, and lack of discomfort make it a preferable alternative to CT scanning and angiography in certain cases.

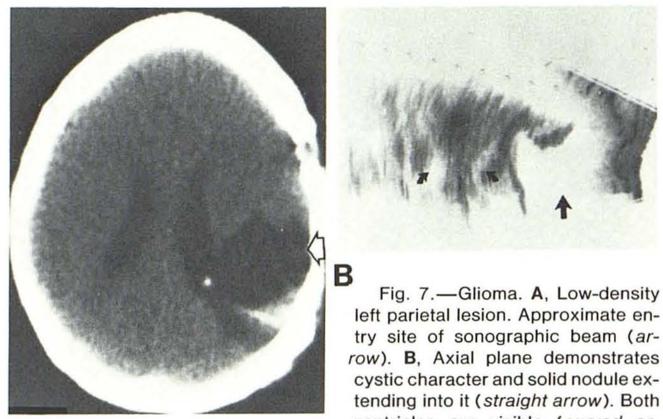
In patients whose postoperative CT scan shows a low-density lesion, sonography accurately differentiates between a solid and a cystic mass, a distinction that cannot always be made by CT (figs. 5–7). In figure 6, for example, the lesion, seen as low-density area on the CT scan, was thought to be cystic, but sonography showed that it was actually solid anteriorly and cystic posteriorly. In case 3, the mass as it appeared on CT was considered to have a large cystic component, but sonography indicated that it was solid with microcystic areas. When a collection of cystic fluid is demonstrated, sonography completely guides and monitors percutaneous aspiration. In our experience, several aspirations under sonographic guidance verified the suspected cystic nature of the underlying lesion in all cases.

Among these are preliminary findings, they suggest that



A B

Fig. 6.—Glioblastoma. **A**, Enhancing, left parietal, low-density lesion with surrounding edema. Approximate entry site of sonographic beam (*arrow*). **B**, Axial plane defines more precisely character of lesion: solid anteriorly, cystic posteriorly. Edema (*arrows*). Distance between dots = 1 cm.



A B

Fig. 7.—Glioma. **A**, Low-density left parietal lesion. Approximate entry site of sonographic beam (*arrow*). **B**, Axial plane demonstrates cystic character and solid nodule extending into it (*straight arrow*). Both ventricles are visible (*curved arrows*). Distance between dots = 1 cm.

sonography can be useful in the postoperative management of patients with brain tumors, cystic lesions, extraaxial collections, and ventricular abnormalities.

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