Neurosurgical sonography: intraoperative and postoperative imaging of the brain.

G A Gooding, J E Boggan, S K Powers, N A Martin and P R Weinstein

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Neurosurgical Sonography:
Intraoperative and Postoperative Imaging of the Brain

Gretchen A. W. Gooding[1]
James E. Boggan[2]
Stephen K. Powers[2]
Neil A. Martin[2]
Philip R. Weinstein[2]

Sonography was used to detect and localize intracranial lesions intraoperatively in 16 patients and to examine 31 patients (47 exams) postoperatively for a variety of clinical problems. Current sonographic technology was effective for localizing and differentiating cystic and solid intracranial pathology and for determining the size and boundaries of the intracranial lesions and their distance from the cortical surface. It was used occasionally as an aid for circumventing intracranial vessels during tissue dissection and, when used, determined the completeness of tumor dissection. Sonography also proved to be a reliable postoperative tool when surgically created cranial windows were present, but the location and size of the surgical window were critical to the quality of the images obtained. Both applications of this technique complement computed tomography and therefore can serve as a valuable adjunct in the treatment and follow-up of the neurosurgical patient.

Intraoperative sonography of the brain has been shown to have applications in neurosurgery [1–14]. Previously, we reported the intraoperative scanning of eight patients, in which a bulky linear-array ultrasonic transducer and an ATL (Advanced Technology Labs., Bellevue, WA) Mark III limited to 3 and 5 MHz frequencies were used [11]. We now report intraoperative and postoperative scanning with a later model, the ATL Neuro-SectOR, which can be set to deliver one of three different frequencies, including 7.5 MHz, from the same transducer head (725B).

Subjects, Materials, and Methods

Intraoperative Sonography

Sixteen patients, all men, were scanned intraoperatively during intracranial procedures; 11 patients had primary neoplasms, four had metastatic neoplasms, and one had an abscess. Pathology involved the cerebral hemisphere in 12 patients, the cerebellum in two, the midbrain in one, and the sella turcica in one.

During surgery, the ATL Neuro-SectOR at 3.5, 5, or 7.5 MHz frequency was used. To maintain sterile conditions, the transducer and its cord were encased in a custom-made soft, translucent, disposable, sterile rubber sheath after the tip of the transducer head was covered with sterile gel. This sheath was then stabilized with sterile rubber bands, and a sterile transparent plastic sheet over the face of the ATL machine allowed surgical personnel to manipulate its controls during surgery. Sterile saline solution was the coupling agent at the transducer–cortical surface interface. The scans were obtained after reflection of the dura, although we previously reported no significant difference between sonograms obtained on the dural or cortical surface [11]; real-time sector scans were viewed on a video monitor with a freeze-frame capability and were videotaped. These images were not degraded by the sterile sheath.

Postoperative Sonography

Thirty-one patients, all men, were scanned postoperatively (47 examinations); in seven of

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[1] Department of Radiology, University of California, San Francisco, at Veterans Administration Medical Center, 4150 Clement St., San Francisco, CA 94121. Address reprint requests to G. A. W. Gooding.

[2] Department of Neurosurgery, University of California, San Francisco, at Veterans Administration Medical Center, San Francisco, CA 94121.

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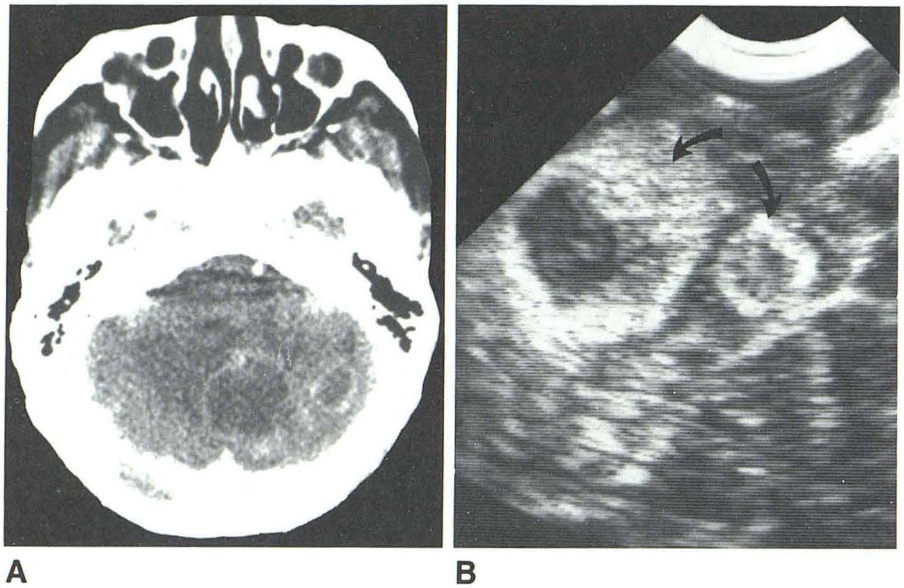


Fig. 1.—**A**, Contrast-enhanced CT scan. Two cerebellar metastases. **B**, Intraoperative sonogram delineates two solid lesions (*arrows*) with hypoechoic centers. Pathologic examination revealed adenocarcinoma.

these, an intraoperative sonogram was available for comparison. Most of the patients had primary intracranial neoplasms, but there was one case each of metastatic disease of the brain, infratentorial extraaxial fluid collection, abscesses of the cerebellum and the occipital cortex, porencephalic cyst, and arachnoid cyst. Six other patients had had prior intracranial vascular procedures.

Reasons for postoperative sonography included evaluation of the size of the ventricles and/or midline shift (26 examinations); intraaxial (eight) or extraaxial (one) fluid localization; evaluation of response to chemotherapy or radiation (eight); baseline postoperative study (three); and evaluation of an ophthalmic aneurysm (one).

Patients were scanned postoperatively with either the portable real-time ATL Neuro-SectOR or a static digital unit which had a 13-mm face and produced 3.5 or 5 MHz. If the patient had a healing craniotomy wound, sterile acoustic gel was used as the coupling agent. All patients were scanned in at least two planes at right angles to each other. Computed tomographic (CT) scans of each patient were used as standards for evaluating the sonographic findings.

Results

Intraoperative Sonography

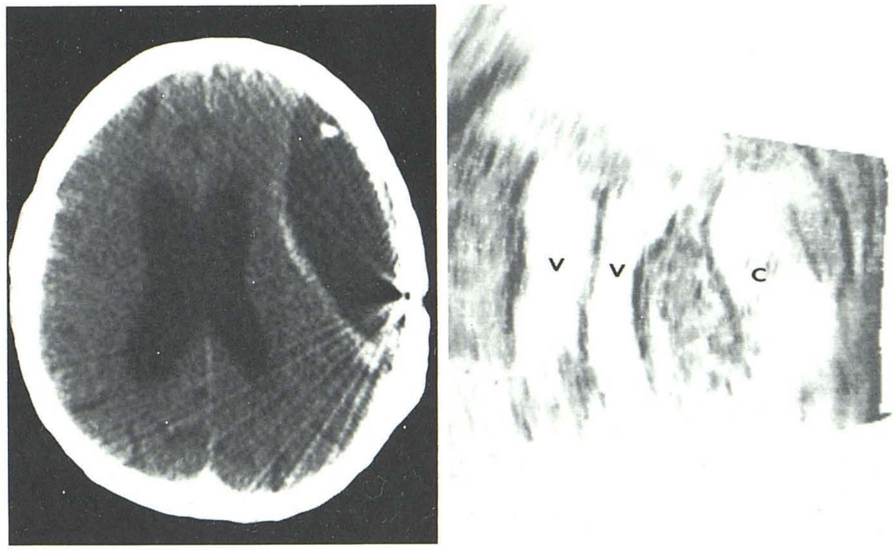
In all 16 cases, sonography located the pathologic process and correctly characterized the lesions as cystic (two), solid (eight) (fig. 1), or containing both cystic and solid components (six cases). The electronic measurements of these lesions by the sector scanner were correlated precisely with manual measurements obtained where feasible. Sonography was unable to predict the pathology of the lesions by appearance alone. Cystic components appeared in both primary and secondary neoplasms, and primary neoplasms could not be distinguished from metastases by the sonographic appearance.

Postoperative Sonography

The size of the ventricles and/or the presence of midline shift was evaluated in 26 patients; sonography defined the ventricles in 22 of these, and results were correlated with CT in all instances (fig. 2). The first 15 consecutive cases in this series of ventricular evaluation have been reported elsewhere [15]. In two cases in which only small, suboccipital craniectomy defects were present and in two cases with frontal cranial defects, sonography failed to provide an adequate image of the lateral ventricles. In one case in which dilated ventricles and a ventriculoperitoneal shunt tip could be seen, the neoplasm adjacent to the ventricles could not be clearly defined through the frontal surgical defect.

In eight examinations for evaluation of presumed intraparenchymal fluid collection, the collections of fluid were visualized; each was aspirated successfully under sonographic guidance except for one that failed to yield fluid despite appropriate needle location. Sonography and CT readily located subdural fluid in a patient who also had large lateral ventricles. These ventricles and a small cerebellar infarct noted on CT were not visualized sonographically, presumably because of the location of the suboccipital craniectomy defects in relation to these entities. In six cases where tumor enlargement was in question, the interpretations of postoperative sonography and CT were in agreement. A decrease in tumor size after radiation therapy was documented in two other patients by both imaging methods. Another patient with recurrent cystic glioblastoma multiforme had phosphorus-32 injected into the cyst; sonography several days after the procedure demonstrated that the uncomplicated cyst had converted to a complicated one. Multiple echoes developed during the interval, indicating either reaction within the cyst to the medication or further progression of the tumor (fig. 3). In another patient previously operated for a cystic glioblastoma multiforme, who developed an infection of a cystic component of the residual tumor, sonography showed (1) the simple cystic character before the infection, confirmed by CT; (2) the development of multiloculation, verified at the time of intraoperative evacuation and not detected by CT (fig. 4A); and (3) residual solid tumor postoperatively with a few residual

Fig. 2.—Postoperative CT scan (**A**) and sonogram (**B**) both demonstrate large arachnoid cyst (c) with enlarged ventricles (v) shifted away from the lesion.



A B

Fig. 3.—**A**, Axial postoperative sonogram through 1.5-cm surgical defect demonstrates cystic glioblastoma multiforme (*arrow*). **B**, After phosphorus-32 therapy, cystic mass (*arrow*) has changed in character and developed internal echoes.

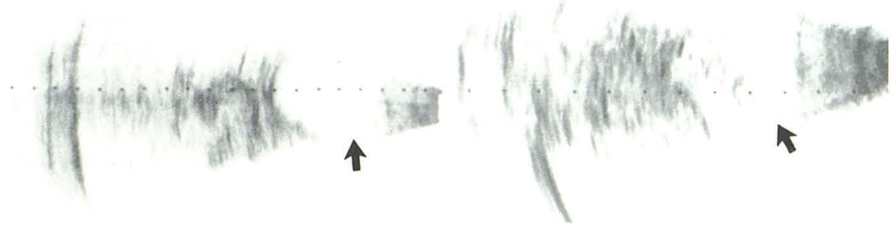


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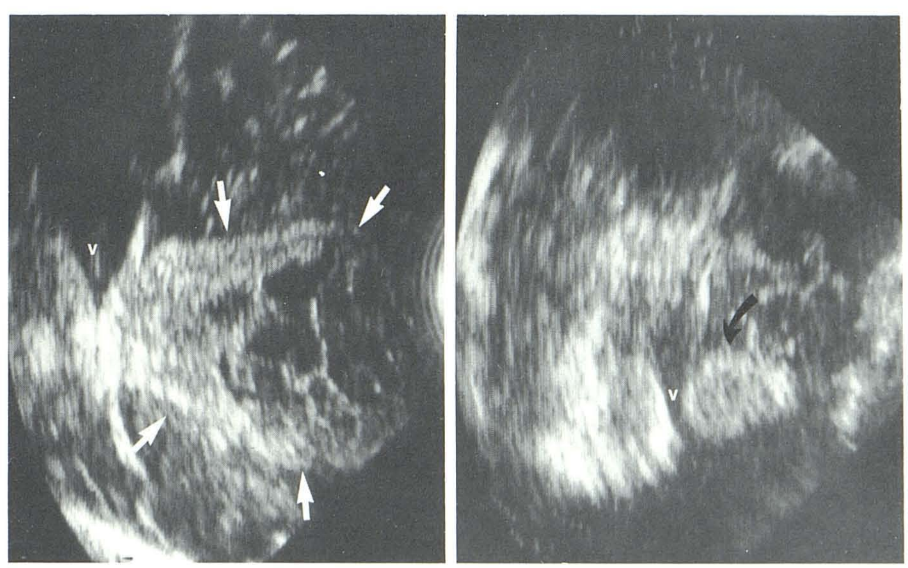
Fig. 4.—**A**, Intraoperative sonogram demonstrates glioblastoma multiforme with large multiseptated fluid collection as well as large solid tumor component (*arrows*). v = ventricle. **B**, Postoperative sonogram shows residual solid tumor (*arrow*). Small residual cystic areas are seen to right of arrow.



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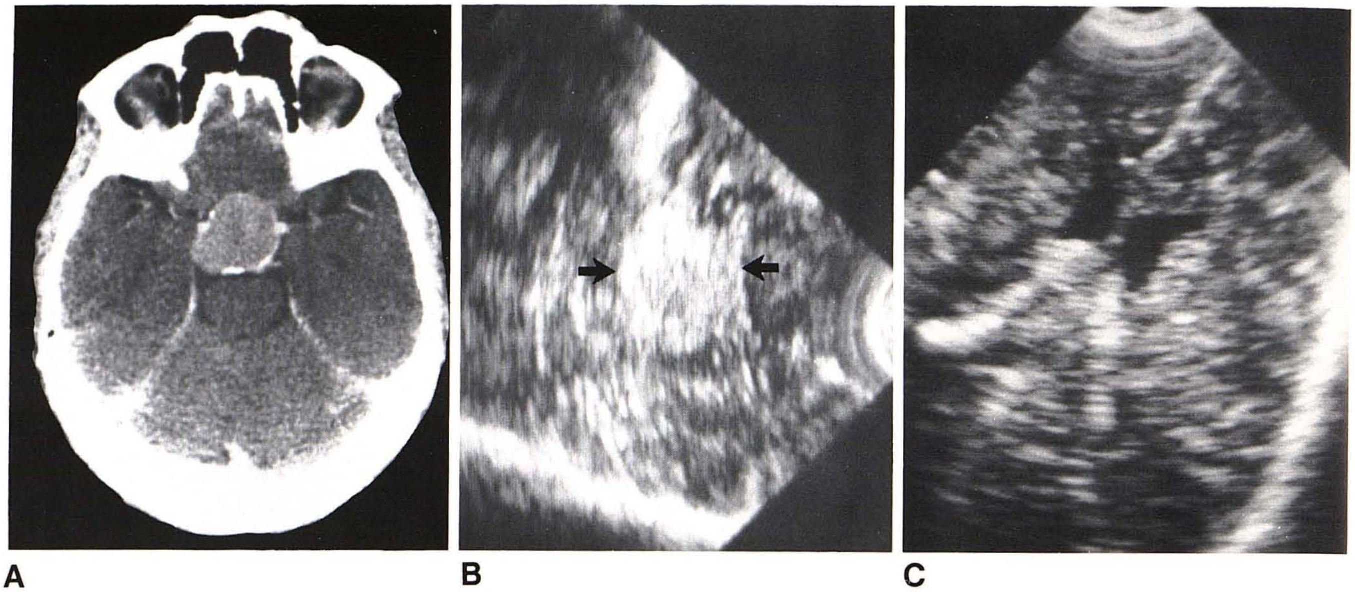

Fig. 5.—**A**, Contrast-enhanced CT scan shows suprasellar extension of pituitary adenoma. Intraoperative sonograms confirm solid nature of adenoma (**B**, *arrows*) and define normal ventricles (**C**). Postoperative sonography showed no change in ventricles.

cystic areas (fig. 4B). In this instance, sonography indicated the character of the tumor more clearly than did CT.

Suprasellar extension of a pituitary adenoma that indented the third ventricle was defined readily by sonography at surgery, and postoperative sonography demonstrated that the lateral ventricles were unchanged with no midline shift (fig. 5). Immediately after another operation for repair of a frontal sinus leak, sonography again revealed no change in ventricular size and the absence of midline shift. This sonogram was obtained because of neurologic deterioration and was clinically advantageous because the patient, who eventually recovered, was able to remain in the surgical intensive-care unit for the diagnostic test. Sonography offered a quick and accurate assessment within 10 min, whereas CT to evaluate the intracranial space would have required transfer of the critically ill patient to the radiology department for examination.

Three patients had normal postoperative sonograms, in accord with the CT scans. In another patient, sonography failed to detect an ophthalmic artery aneurysm noted on CT.

Postoperatively, static scans provided images of slightly greater resolution, but had less flexibility with respect to angulation of the transducer than did real-time scans and required that the patient be moved to the sonography suite. Real-time images were generated quickly, enabled the sonographer to distinguish the pathologic entity from surrounding anatomy with ease, and could be performed at bedside if necessary. Steep angulation of the transducer when appropriate expanded the area that could be examined through the acoustic window.

Discussion

Intraoperative sonography has the ability to locate intracranial pathology within seconds and to delineate the character of the lesion as to its boundary, size, acoustic qualities, distance from the surface, and, in some cases, its relation to adjacent major vessels, which can be seen to pulsate on real-time studies. This asset can be particularly important in evaluating meningiomas that involve the important vessels at the base of the brain.

Sonography can provide immediate information about the character and location of a cystic, solid, or more complex pathologic lesion both during and after operative procedures. A needle used for aspiration or biopsy is easily recognized in the tissues; thus, its sonographic guidance is relatively simple. A special biopsy attachment for the transducer is available for increased precision of needle aspiration. Lesions can be precisely localized sonographically, thus minimizing the trauma associated with surgical localization, exposure, and excision. With sonography, the operator can evaluate instantly the size of the ventricles and their relation to the lesion. Calcifications and areas of fluid, both intraaxial and extraaxial, are easily recognized.

In comparison with CT, intraoperative sonography is a better indicator of the fluid components of a lesion, but does not demonstrate the contrast enhancement or, as a rule, the low-density areas of surrounding edema that are typical of many lesions on contrast-enhanced CT. On the other hand, the sonographic demonstration of multiple septa in a cystic mass, not defined by CT, was of clinical importance in that a multiloculated compartment is not amenable to a single-needle aspiration.

Various physical factors contribute to a successful intraoperative examination. Because the standard electrocautery equipment can cause a significant artifact, this device should be disconnected from its power outlet during sonographic examinations with such a unit. Real-time images generated during these examinations are more easily observed when the room lights are dimmed. Although the ATL unit is so designed that the surgeon may adjust the machine, in practice these adjustments are better made by a sonographic technologist who understands the surgeon's needs. Examinations are taped, and significant images can be "frozen" for subsequent photographs with Polaroid or on multiformat film displays.

Another source of significant artifacts is acoustic-gel bubbles, which may form in the transducer head-sheath interface. In one instance, bubbles developed within the transducer itself, causing significant image degradation. The transducer should be checked before every procedure to avert this potential problem.

Taking measurements on the ATL unit can be tedious and time-consuming because it requires manipulation of a complex series of directional buttons. Incorporation of a joystick would expedite this task. Although the transducer is bulky, it is easily manipulated for accurate planar orientation. The frequency can be changed among three available settings when necessary; we used 3.5 MHz for identification of overall anatomic landmarks and switched to 5 or 7.5 MHz for the delineation of pathology, depending on the distance of the lesion from the surface. The apparatus could be technically improved by incorporating the multifrequency head within a smaller transducer. Saline is an excellent coupling agent and when the wound is filled with isotonic salt solution, physical contact with the brain can sometimes be avoided.

The relation between the size of the cranial window and the information generated by postoperative sonography deserves particular emphasis: *The larger the cranial defect, the more detailed the anatomic information*. Small suboccipital craniectomy defects or extreme frontal burr holes did not allow delineation of the lateral ventricles. The soft-tissue edema that occasionally occurs in the postoperative period may be severe enough to impair access to the cranial defect; this, in effect, narrows the acoustic window, resulting in reverberations and consequent degradation of images. Metallic clips at the operative site cast tiny acoustic shadows. While intraoperative sonography can yield comprehensive information about a localized intracranial mass, postoperative sonography, because of its limited field of view, commonly reveals only partly or incompletely the type and extent of the pathologic process [16]. In specific instances, however, postoperative sonography may obviate CT.

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