Intraoperative neurosonography: application and technique.

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Intraoperative Neurosonography: Application and Technique

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Intraoperative neurosonography was performed in 44 patients with contact transdural or transgyral scanning technique. Localization of intracranial pathology included primary brain tumors (24), metastatic tumors (11), aneurysms (two), abscesses (two), arteriovenous malformation (one), thrombosed arteriovenous malformations (two), and plasmacytoma (one). Sonographic guidance was used in transdural decompression of three cystic lesions, therapeutic and diagnostic aspiration of two abscesses, and biopsy of three solid lesions. The expertise of the physician-sonographer with sonographic equipment facilitates accurate and expedient intraoperative neurosurgical localization of pathology.

Characterization and localization of focal brain pathology are important during neurosurgical procedures because improved precision may decrease dissection and iatrogenic brain damage. Sonography offers such precision; the advent of the portable real-time scanner with a small transducer has made intraoperative application possible. Several authors have recently reported on the use of intraoperative high-resolution real-time neurosonography as a stereotaxic guide in surgical approach [1–14]. Over the past 2 years we have participated in 44 intracranial operative procedures using real-time sector scanning. We report our technique, observations, and conclusions from the standpoint of the physician-sonographer collaborating with the neurosurgeon in the operating room.

Materials and Methods

Close collaboration between the neurosurgical service and the sonography service is important. When the need for intraoperative sonographic guidance is anticipated, the neurosurgeon ideally should consult with the physician-sonographer 1 day in advance. The sonographer then can review all applicable imaging studies, for example, computed tomographic (CT) scans and arteriograms.

For the operative procedure, the physician-sonographer scrubs and gowns. Sterile technique is maintained at all times [5, 8–10, 12]. We have used a variety of sector scan models (Advanced Technology Laboratories, Bellevue, WA.) including Mark III, 300 I, Mark 600, and NeuroSector, with L-Shaped or In-line 3, 5, and 7.5 MHz transducers. Appropriate transducer selection is based on the predicted depth of the lesion from CT images. A 3 MHz transducer is selected if the depth is greater than 5 cm; otherwise, a 5 or 7.5 MHz transducer is used. A multifrequency transducer head assembly (3, 5, 7.5 MHz) simplifies this task if available. Sterility of the transducer-cable assembly is achieved by placing it in a glove and plastic cover (Shea drill cover drape) (fig. 1A) or specialized latex transducer cable cover. A technologist assists with this procedure, paying special attention to the placement of an adequate amount of sterile coupling gel inside the glove. The physician-sonographer holds the glove inverted (fig. 1B). Next, the transducer and cable are covered with a plastic sheath by passing the glove-encased transducer through the sheath (fig. 1C). By cutting a small hole in the end of the sheath and passing the transducer through this hole, a tight fit is achieved between the sheath and glove. This snug fit may be augmented with a sterile rubber band placed around the transducer head.

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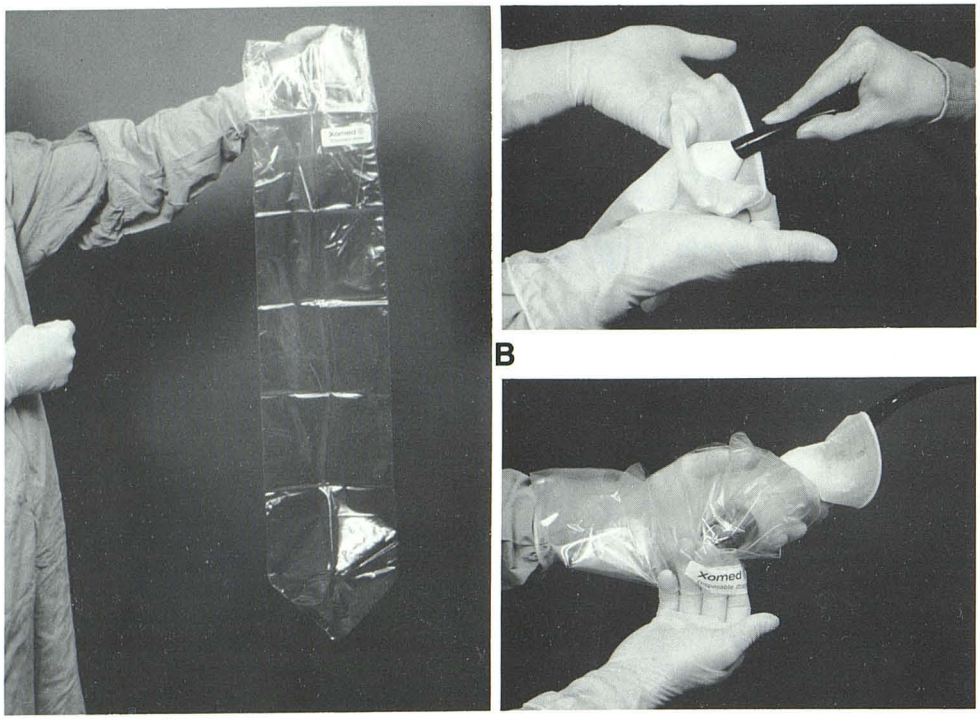


Fig. 1.—**A**, Sterile plastic sheath is used to cover transducer cable. **B**, Using sterile technique, technician places transducer assembly into glove held by physician-sonographer. **C**, Glove-encased transducer is passed through plastic sheath.

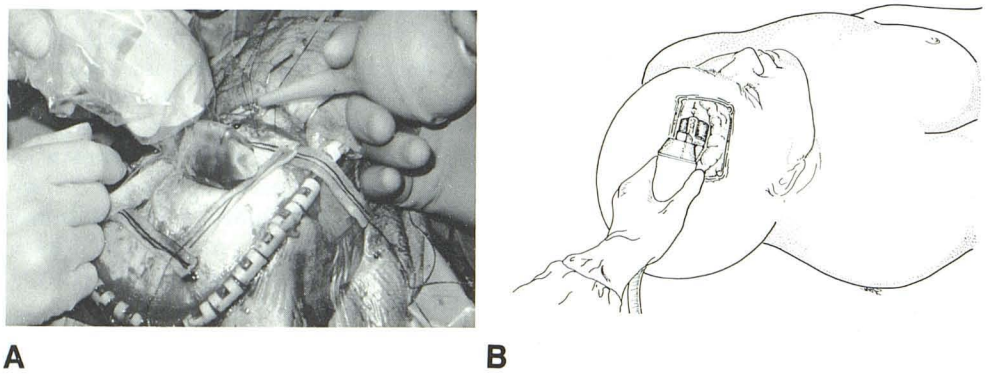


Fig. 2.—**A**, Imaging is performed by touching transducer to dural or gyral surface using continuous saline drip as coupling agent (bulb syringe). **B**, Artist's conception (without patient drapes) shows transducer in relation to craniotomy site and brain surface.

Preoperative selection of the craniotomy site is chosen by the neurosurgeon on the basis of CT and/or angiographic data. After turning the bone flap, sonography can be performed either through the dura or by direct contact on the brain surface. This selection is made by the neurosurgeon depending on whether needle aspiration decompression of cystic areas under pressure or limiting the size of durotomy would aid in preventing herniation of brain substance through the opened dura.

Sonographic localization of lesions involves three steps. First, the sonographer must orient to the patient position and relative location of the craniotomy site. Next, with continuous saline drip irrigation from a bulb syringe for acoustic coupling, the transducer is gently applied to the dura or gyral surface (fig. 2). Third, the sonographer optimizes imaging parameters with the aid of the technologist (gain curve, field size) and orients to normal anatomic structures. Using these as a guide, the pathology is identified and localized in multiple planes by turning and moving the transducer (fig. 3).

Under the direction of the neurosurgeon an appropriate operative approach is selected using the sonographic information. Depth and angle to the pathology in relation to surface anatomy is noted (this is best done perpendicular to the brain surface). This information must be precise and explicitly communicated to the neurosurgeon by the physician-sonographer operating the hand-held transducer. The sonographer's experience and familiarity with sonographic equipment and technique make his role critical.

If needle biopsy or aspiration is performed, needle placement is usually performed by the neurosurgeon with continuous monitoring of needle position and guidance by the sonographer. Since the depth of the lesion is not great in most intracranial lesions, sonographically guided biopsy may be performed freehand without an attached mechanical needle guide by holding the plane of the needle parallel to the plane of scanning. After initial tumor localization, intermittent scanning during the operative procedure may be helpful. This can be done to assess progress of resection, iatrogenic brain parenchymal hemorrhage, or changing relations between resection site and surrounding normal anatomy. Repeat scanning is facilitated by filling the surgical defect with saline and touching the transducer to the surface of the saline pool (fig. 4). The sonographic procedure may be documented on film (freeze-frame images) or on video tape for real-time review later.

Patient selection in our series was arbitrary based on possible need for sonographic guidance as perceived by the neurosurgeon after review of CT and angiographic studies. Studies were performed at three University of Washington Hospitals (University, Harborview,

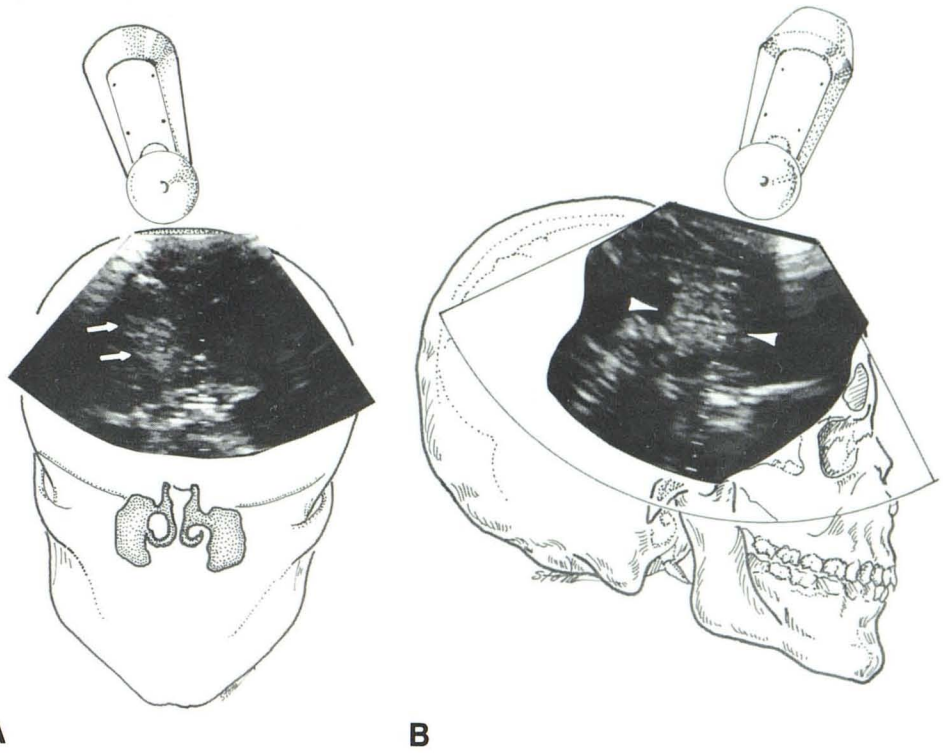


Fig. 3.—**A**, After orienting to normal anatomy, pathology is identified in multiple planes. Ependymoma (*arrows*) is seen in anterior horn of right lateral ventricle in coronal plane. **B**, Sagittal plane through right lateral ventricle. Crisply circumscribed ependymoma (*arrowheads*).

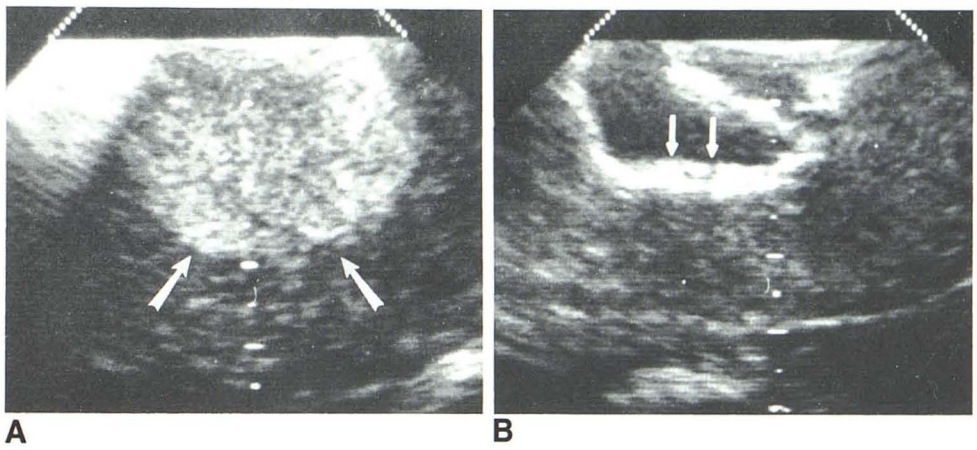


Fig. 4.—**A**, Well marginated metastatic adenocarcinoma (*arrows*). Tumor was palpable from brain surface. **B**, After resection. Saline in defect enables reexamination. Layered blood (*arrows*).

Seattle Veterans) and at Swedish Hospital, Seattle; only a few of the neurosurgeons on each staff requested intraoperative sonography. Studies were performed by three physician-sonographers experience in neonatal neurosonography (J. V. R., J. H. H., and W. P. S.). All intraoperative sonographic images and available video tapes were reviewed in conjunction with CT images in each case by two of the authors.

Results

All 44 patients in this series were adults, three women and 41 men. Pathology included vascular lesions (five patients), abscess (two), and tumor (36) (table 1). One normal patient was imaged as a guide to a trigeminal nerve radiofrequency lysis. Pathology was located in the frontal lobe (14), parietal lobe (15), temporal lobe (five), occipital lobe (two), cerebellum (three), anterior communicating artery (two), lateral ventricles (two), basal ganglia (one), thalamus (one), and corpus callosum (one). Lesions were 1.2–10 cm in size.

Sonographic findings included moderately to markedly increased echogenicity relative to brain parenchyma for all lesions. Two abscesses, eight primary brain tumors, and four metastatic tumors had cystic components. Twenty-seven lesions were well marginated and crisply circumscribed: ependymoma (one), grade II astrocytoma (two), glioblastoma multiforme (one), oligodendroglioma-astrocytoma (two), aneurysm (one), arteriovenous malformation (AVM) (one), thrombosed AVM (one), abscess (two), meningioma (five), and metastatic tumor (eleven). Sixteen lesions were poorly marginated: glioblastoma multiforme tumors (nine), plasmacytoma (one), grade II astrocytoma (one), grade III astrocytoma (two), oligodendroglia (one), aneurysm with hemorrhage (one),

TABLE 1: **Findings in Patients Studied with Intraoperative Neurosonography**

Pathology	No. of Patients	Sonographic Findings (No.)		
		Echogenicity Increased	Cystic Areas	Well Marginated
Vascular:				
Aneurysm	2	2*	0	1
Arteriovenous malformation	1	1	0	1
Cryptic arteriovenous malformation	2	2	0	1
Abscess	2	2†	2	2
Tumor:				
Ependymoma	1	1	0	1
Meningioma	5	5	0	5
Grade II astrocytoma	3	3	2	2
Grade III–IV astrocytoma	2	2	1	0
Oligodendroglioma-astrocytoma	3	3	0	2
Glioblastoma multiforme	10	10	5	1
Plasmacytoma (β-hemolytic streptococcus infection)	1	1	0	0
Metastatic	11	11	4	10
Normal	1	0	0	0
Total	44			

* Hemorrhage.
† Rim.

and thrombosed AVM with old hemorrhage (one). The low-density edema seen on CT was identified by sonography in 16 cases. In all of these the edema was slightly more echogenic than was normal brain substance (fig. 5). Identification of edema required careful attention to proper time-gain compensation curve adjustment. It was important during biopsy procedures that the CT size and appearance of a lesion be correlated directly with the sonographic size and appearance so that an area of slightly increased echogenicity in an area of edema would not be confused with the lesion intended for biopsy. One case (oligodendroglioma) exhibited echogenic foci with distal acoustic shadowing characteristic of punctate calcification. The sonographic location and size (within 10%) agreed with CT findings in all cases.

Transdural needle aspiration decompression of cystic areas in sonographically evident malignant primary brain tumors was accomplished in three cases (fig. 6). This was performed to prevent herniation of brain substance under pressure after durotomy. Following durotomy, sonographic monitoring of needle placement was performed in four tumor biopsies and in aspiration of two abscesses. A needle guide attached to the transducer was not used, although such an apparatus was available; no difficulty was encountered in keeping the needle and sonographic imaging plane aligned by freehand technique, since the depth of brain lesions usually was not great. In addition the needle guides were believed to be too bulky for use in the small operative field.

Surgical impact of intraoperative sonography included rapid and accurate localization of pathology not visible or palpable from the gyral or dural surface of the brain in 22 cases (fig. 7). In 21 cases the pathology was palpable from the brain surface, but sonography provided an estimate of lateral and deep margins. In two cases, at the presumed conclusion of a tumor resection, repeat sonographic examination demonstrated residual tumor, which was confirmed by further dissection.

Discussion

The active participation of the physician-sonographer in intraoperative imaging is crucial to the overall success of the technique. The sonographer optimizes the real-time image through appropriate transducer selection and gain-curve manipulation. Quick and accurate identification of pathology requires a sonographer familiar with sonographic intracranial anatomy and skilled real-time hand-eye coordination. Equally important is easy communication between the sonographer and the neurosurgery team.

We believe that any real-time equipment with a small contact surface (less than 2 cm^2) will suffice for this technique as long as it can be covered with a sterile barrier. While the sector scanners are optimal because of the large field of view provided, a small linear-array transducer could be used. In our experience, equipment with a fixed or automated gain curve was less sensitive to subtle differences in brain echo texture when it was compared with the usual equipment having operator-adjusted gain-curve.

We agree that all focal pathology encountered thus far increased in echogenicity relative to normal brain substance, except for focal cystic areas within areas of larger pathology [5–14]. We disagree with the contention that brain edema is isoechoic with normal brain substance [2] and agree with Knake et al. [8] that edema is slightly more echogenic than normal brain substance. In our experience, brain edema seen on CT is more echogenic than brain substance but less echogenic than tumor. Edema was also noted around two abscesses.

Aspiration proved useful to decompress cystic parts of tumor in swollen brain. This may have decreased brain herniation through the durotomy site. Aspiration was also used successfully for histologic evaluation (two cases) and for culture in two abscesses. An important technical point we encountered in one instance involved a small glioblastoma multiforme that was predominantly cystic. After decompressing the cystic component of the lesion it was difficult to identify the lesion for a tissue biopsy. In retrospect, it would have been much easier to biopsy the periphery of the cystic area before collapsing the cyst.

Poorly marginated lesions correlated best with both high-grade primary brain malignancies and hemorrhage around benign lesions. Sonography was unable to differentiate between these two causes of poor margination. Low-grade primary brain tumors, metastatic lesions, and abscesses all exhibited good margination. Sonography worked well regardless of the location of the craniotomy site. Pathology was successfully localized in frontal and parietal lobes, cerebellum, basal ganglia, thalamus, and within the ventricles.

We believe the greatest impact of intraoperative sonography is in shortening the intraoperative localization time and dissection. While this impact is difficult to quantitate, it has resulted in enthusiastic acceptance of the technique by neu-

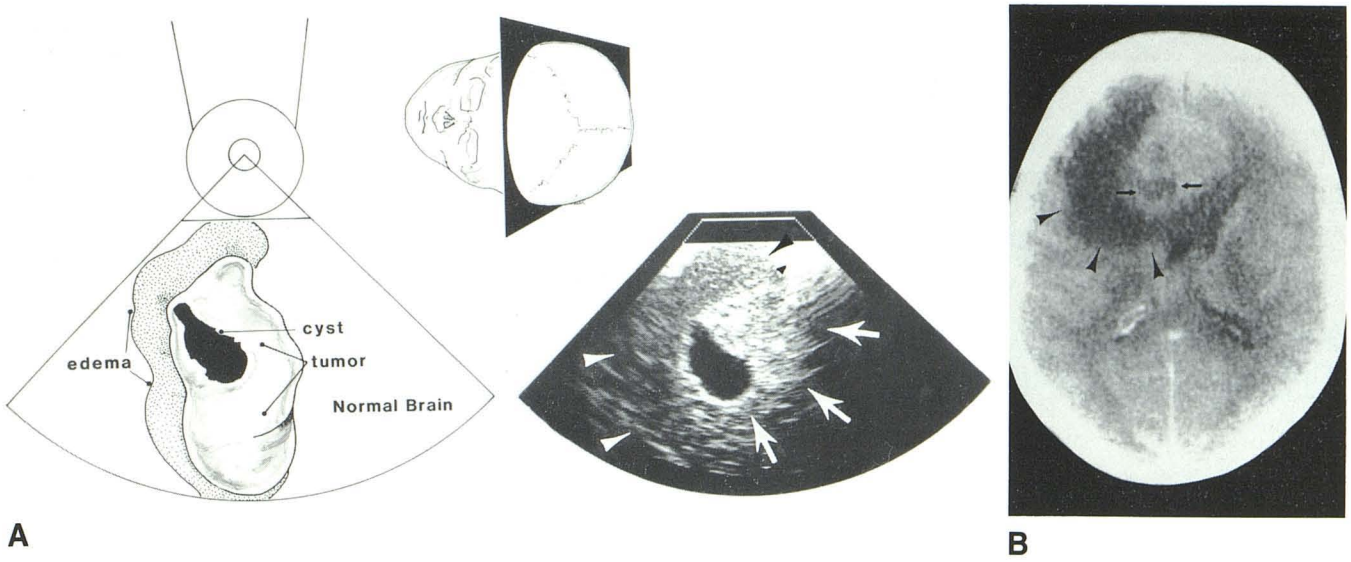


Fig. 5.—**A**, Poorly defined glioblastoma multiforme (*arrows*) with central cystic area. Surrounding edema with echogenicity slightly greater than brain (*arrowheads*). **B**, CT scan. Central cystic area (*arrows*) and surrounding edema (*arrowheads*).

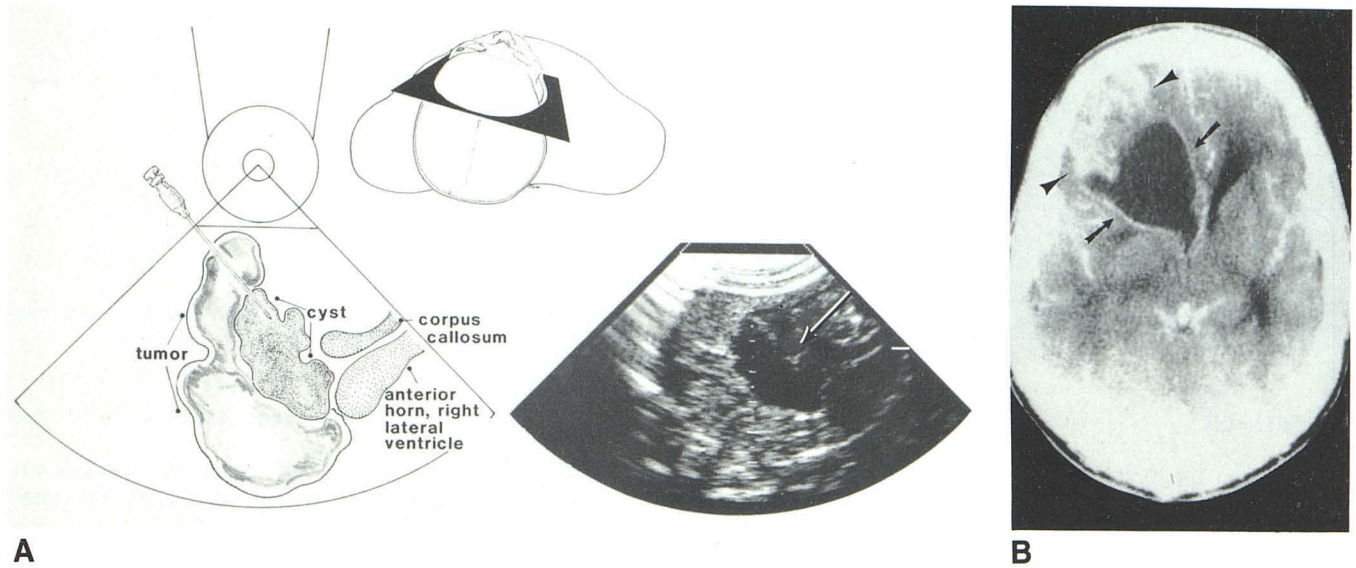
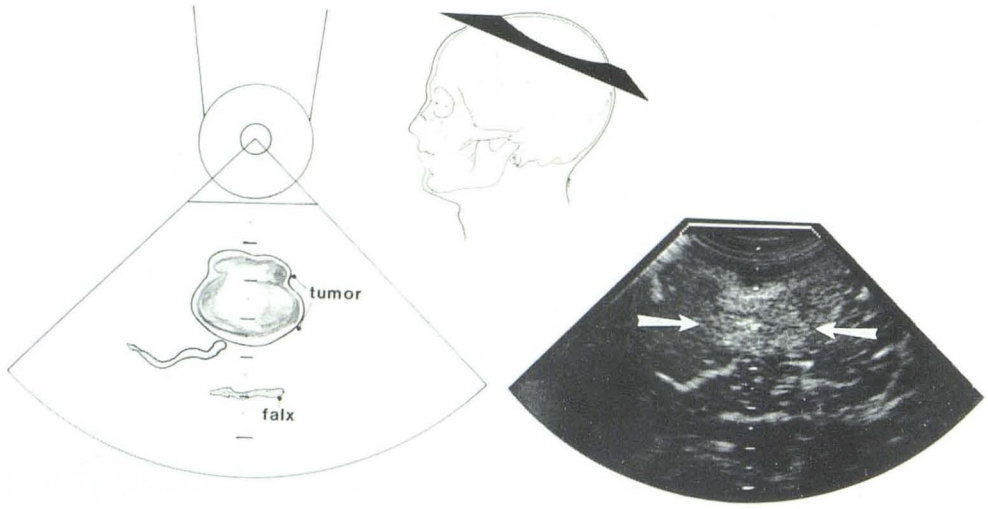


Fig. 6.—**A**, Poorly defined glioblastoma multiforme with cystic component. Needle (*arrow*) for transdural decompression. **B**, CT scan. Large cystic area (*arrows*) and adjacent solid tumor (*arrowheads*).

rosurgeons. Their eventual insistence on sonographic guidance in a substantial number of cases is evidence of this acceptance. Quick and accurate localization of unpalpable pathology in critical anatomic areas may decrease anxiety over iatrogenic damage and increase confidence in craniotomy and durotomy placement. Additional impact of the technique was found in its ability to assess for residual tumor at the presumed conclusion of dissection. Echogenic blood in the region of the dissection may make this task difficult, but by comparing pre- and postresection appearance, we were able to find echogenic material consistent with residual tumor. Further dissection confirmed this finding in two cases. Hemorrhage seen on the brain surface by the neurosurgeon during a resection or biopsy may be from a superficial bleeding vessel or a deep substance bleed. The use of sonographic monitoring at this stage may help clarify a deep-substance hemorrhage by demonstrating new echogenic material deep to the brain surface.

We have found this procedure requires planning, a preconception of the location and appearance of a lesion based on CT scans, and good cooperation between the physician-sonographer and the neurosurgeon. Real-time equipment now available in many institutions is adequate for intraoperative application. The role of the physician-sonographer in performing the study is the key to the speed and success of the technique.



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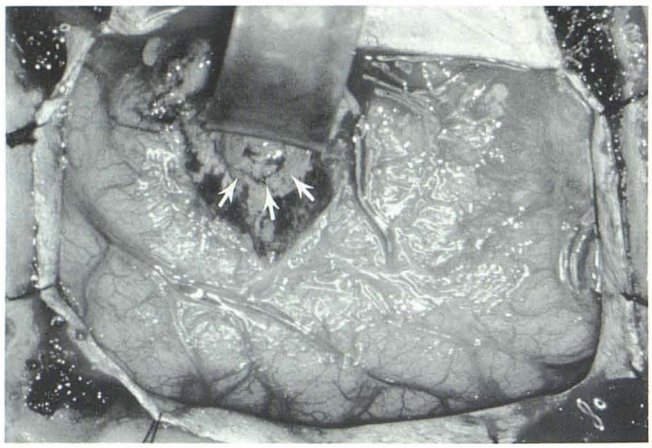

B

Fig. 7.—**A**, Nonpalpable metastatic melanoma (*arrows*). **B**, Metastatic melanoma nodule (*arrows*) after sonographically guided dissection.

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