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Intraoperative Sonography through a Burr Hole: Guide for Brain Biopsy

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Sonographic imaging of the brain was accomplished through a burr hole using a small, real-time, 5 MHz transducer in five patients. Brain tumors were accurately imaged, corresponding closely in morphology to the computed tomographic scan. Intraoperative sonography through a burr hole allows flexibility in technique and greatly facilitates brain biopsy procedures.

Not only is neuroradiologic imaging undergoing a technologic revolution, but it is also undergoing a change of venue. The portability of sonography has brought about noncentralized imaging similar to radiography. Intraoperative sonography during neurosurgical procedures is an example of this and is being rapidly accepted because of its obvious benefits [1–12]. Neurosonographic applications are only beginning to be explored. The ability to obtain high-quality images through a burr hole as demonstrated in this report will accelerate this trend.

Subjects and Methods

Five patients were studied intraoperatively through an acoustic window provided by a burr hole. Four of these patients had gliomas and one had intracranial lymphoma. All patients underwent a biopsy procedure. Sonography was performed with a 5 MHz transducer (Diasonics) and a 60° field of view. The transducer was of small size, the end of the transducer being only 15 mm in diameter, small enough to fit within a burr hole.

Before the biosy procedure, each patient had a pre- and postcontrast computed tomographic (CT) scan; two patients had coronal and sagittal reformatted images. Placement of the burr hole was decided from the position of the lesion on the CT scan by consultation between the neurosurgeon and neuroradiologist. Both a single-hole and two-hoie burr-hole technique were used. With the single hole, imaging and the biopsy procedure were performed in an alternating fashion with the imaging performed first to obtain a depth measurement to the point of interest. The biopsy was then performed, and a subsequent postbiopsy image was obtained to check for possible hemorrhage. With the two-burr-hole technique, imaging and the biopsy procedure were performed simultaneously. Imaging was first performed through the burr hole through which the biopsy needle would subsequently pass. The direction and depth of the area of interest were determined. The transducer was then moved over to the second burr hole, which was about 3 or 4 cm away from the first. Imaging was performed in a real-time mode while a 13 gauge Cone biopsy needle was passed into the area of interest. The needle and needle tip could be visualized easily, as could the exact site of biopsy. The neurosurgeon passed the biopsy needle, while the neuroradiologist handled the transducer for imaging. A follow-up scan was obtained after the biopsy procedure to determine the presence of hemorrhage.

The transducer itself was not sterile, but sterile conditions were maintained by enclosing it in a sterile condom using gel as an acoustic coupling medium. Care was taken to remove any bubbles from this gel. The entire transducer and cable were enclosed in a sterile drape designed for arthroscopy. Irrigation with saline improved the acoustic coupling at the burr hole and dura interface.

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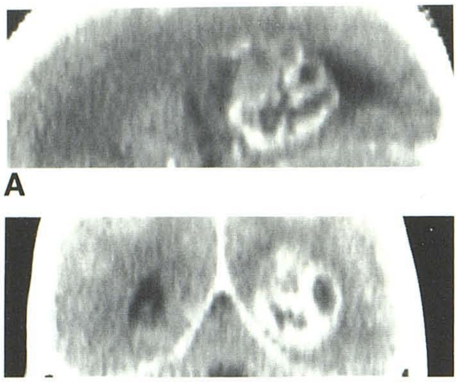

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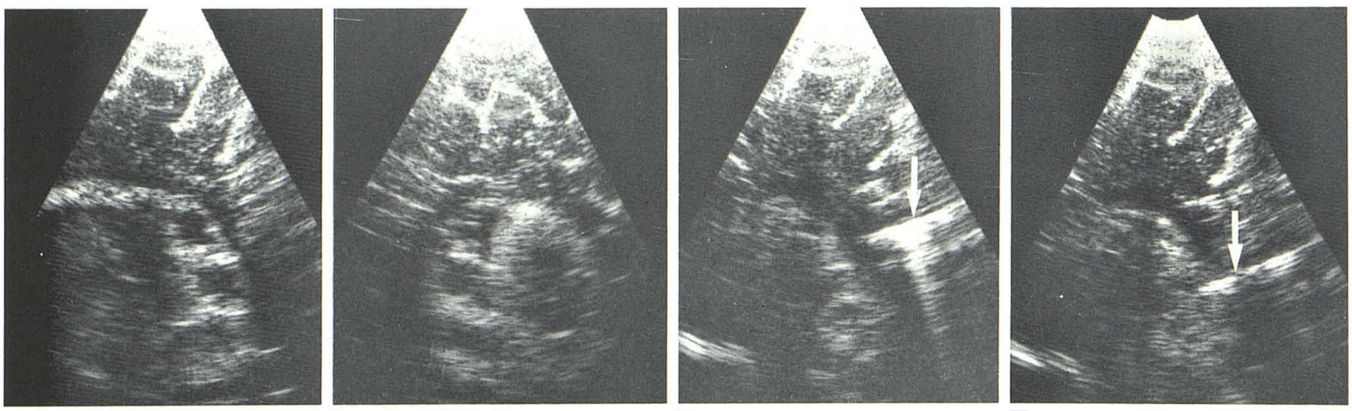

B D E F

Fig. 1.—Posterior parietal lobe glioma. **A,** Sagittal reformatted CT scan of glioma with "multicystic" appearance caused by multiple low-density regions scattered thorughout large contrast-enhancing tumor. Posterior border shows lobulated pattern of multiple adjacent "rings." **B,** Sagittal sonogram through burr hole shows close correlation of tumor appearance on CT vs. sonography. Hyperechoic regions of tumor correspond closely to areas of enhancement, whereas hypoechoic regions correspond to areas of low density within tumor, presumably necrosis. **C,** Coronal reformatted CT scan of same glioma. **D,** Coronal sonogram through burr hole again shows close correlation between appearance of glioma on sonography and CT. **E,** Sagittal sonogram through burr hole in posterior parietal region shows biopsy needle as it approaches peripheral part of tumor. Needle tip (*arrow*) has reverberation artifact distal to it. **F,** Another burr-hole sagittal sonogram showing needle (*arrow*) entering superficial, peripheral aspect of tumor from which biopsy was taken.

Results

In each of the five patients, the sonogram provided a limited but accurate view of the lesion to be biopsied. All the gliomas and the lymphoma were hyperechoic in comparison with normal brain. Necrotic parts of the tumor, as determined by CT, were hypoechoic by sonography (figs. 1 and 2). The hyperechoic regions correlated closely to the areas of contrast enhancement seen on the CT scan. Tumors well delineated from surrounding edema on CT were also sharply circumscribed by sonography. In those patients in whom coronal and sagittal reformatted images were available, a close correlation existed between the configuration of the lesion by CT and sonography (fig. 1).

Using the two-burr-hole technique, the biopsy needle tip could be visualized consistently in real time (figs. 1–3). It was hyperechoic, and the metal tip caused a characteristic distal reverberation artifact. This permitted guidance of the needle tip to an echogenic part of the tumor. This helped avoid necrotic areas and increased the likelihood of obtaining diagnostic tumor tissue.

In all patients adequate biopsy material was obtained for neuropathologic diagnosis. There were no complications. Only one patient, the lymphoma patient, showed any evidence of hemorrhage, and in this patient it was very small and focal. After removal of the needle, the needle track could often be visualized by sonography as a straight line of increased echogenicity (fig. 3). This was seen immediately after removal of the needle and presumably represented small local hemorrhage along the needle path.

Discussion

Intraoperative sonography during neurosurgical procedures has already been described and is rapidly acquiring new adherents. The development of a transducer that allows imaging through a burr hole will accelerate this already rapid acceptance.

The intraoperative imaging-biopsy technique using burr holes is facile when compared with a craniotomy. When combined with real-time imaging, the brain biopsy procedure is convenient, fast, and highly accurate. The exact location of the lesion can be determined despite the limited field of view. Measurements can be made to determine the depth of the biopsy. Specific parts of the lesion, most likely to provide diagnostic tissue, can be selected and needle position within them can be confirmed with simultaneous real-time imaging. Burr-hole techniques allow a great deal of flexibility in that one may choose to use one or two burr holes. The second, slightly removed burr hole allows simultaneous visualization of the biopsy needle, something more difficult to attain when

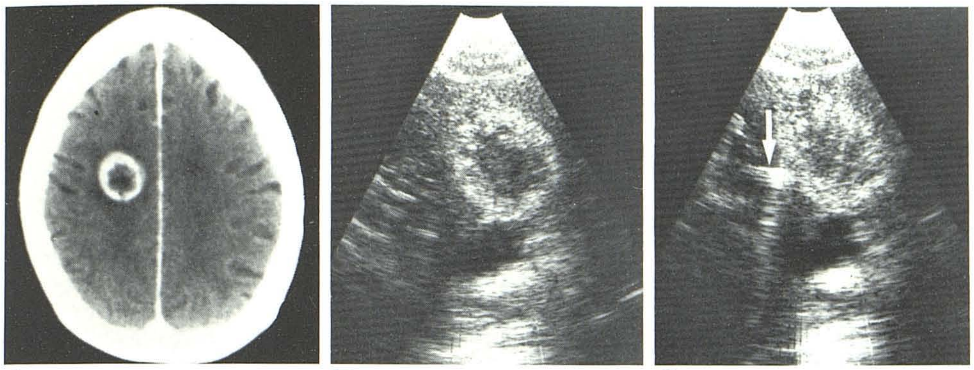

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Fig. 2.—Parietal lobe glioma. **A,** Axial CT scan of single ring glioma situated just superior to right lateral ventricle (courtesy of Richard Kramer). **B,** Coronal burr-hole sonogram shows thick ring of echogenicity around hypoechoic center. Anechoic region below this lesion is lateral ventricle. Close correlation between morphology of tumor on sonography and CT. **C,** Similar coronal sonogram shows needle tip (*arrow*) at peripheral aspect of tumor.

Fig. 3.—Needle entering glioma. Sagittal sonogram of large glioma shows needle tip (*closed arrow*), which is unmistakable by virtue of its echogenicity and reverberation artifact. Oval area of increased echogenicity (*open arrow*) in middle of tumor represents residual needle tract of previous needle pass for biopsy.

the needle passes in a more parallel fashion to the sound beam, a situation common with a craniotomy. Methods for making the biopsy needle more echogenic are available, but with the two-burr-hole technique, this is unnecessary. Although there were no significant complications in our series, these would be immediately visualized by sonography since hemorrhage has very characteristic sonographic features. Sonography would, therefore, also be useful in the treatment of hemorrhagic complications.

Intraoperative neurosonography does have some limitations; one of them is the limited field of view. This potential obstacle can be circumvented with adequate presurgical planning. A useful aid is the use of sagittal and coronal reformatted CT images, which aid in proper placement of burr holes. They also provide an image of the tumor morphology that can be expected on the sonogram. Because of the close correlation between contrast-enhanced CT scans and the sonograms, the limited field of view is not a problem since the sonogram can be incorporated into a larger field of view provided by reformatted iamges. Rapid sonographic scanning of the lesion allows quick orientation. Depending on tumor location, burr holes may be placed in a variety of locations, and thus the anatomy one sees through the burr hole can appear quite distorted. Landmarks for deep lesions may be difficult to visualize because of the limited field of view and loss of resolution in the far field. Again, presurgical reformatted CT images alleviate this problem to a large extent. It is quite useful to be precise in one's technique of sonographic scanning and to use primarily coronal, sagittal, and axial planes in intraoperative imaging. These are familiar to the radiologist and allow comparison and verification with CT scans. The burr-hole technique requires the use of a sector scanner to obtain a reasonable field of view. The near-field is a well known difficulty of mechanical sector scanners. Except for very superficial lesions, this should not be a significant obstacle.

Many types of parenchymal or brain lesions are hyperechoic compared with normal surrounding brain [1–11, 13, 14]. The sonographic findings, therefore, are somewhat nonspecific for a variety of lesions, but this does not detract from the limited role that intraoperative sonography plays, which is that of lesion localization and characterization. The tumors in our series and in previously reported patients have all been echogenic [1–12]. These echogenic abnormalities correlate closely to the areas of contrast enhancement seen on the CT scan. Necrotic areas are hypoechoic compared with viable tumor. These hypoechoic regions correlated closely to low-density areas seen on CT. Cysts are anechoic and sharply circumscribed. Whether echogenicity can be related to the grade or type of tumor remains to be determined, but it is unlikely. Evidence from an experimental model and from other patients suggests that echogenicity is present even when contrast enhancement is not detectable on the CT scan.

The role of intraoperative sonography for biopsy procedures is becoming established. However, sonography may be of use in numerous other intracranial procedures for lesion localization and for allowing parsimonious dissections. The ability to visualize intracranial lesions through a small acoustic window allows use of this imaging technique in the follow-up of lesions. Therefore, the regression of tumors after radiation therapy or a diminution in size of abscesses after aspiration and antibiotic treatment could be followed by sonography and serve as a useful and less expensive adjunct to CT. The advent of high-quality sonograms through a small acoustic window will most certainly expand the use of sonography to other neurosurgical areas such as the spinal canal and spinal cord [12]. This distributed approach to imaging promises to be an interesting challenge for radiologists.

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