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Technical Note: Enhanced MR-Guided Stereotaxic Brain Surgery with the Patient Under General Anesthesia

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Stereotaxic surgery guided with CT has long been a valuable tool in neurosurgical practice and has a high degree of accuracy with a low morbidity rate [1]. MR imaging, with its inherently greater soft-tissue contrast resolution and its ability to obtain images directly in any desired plane, is increasingly useful in studying the brain. This latter characteristic is also useful for simulating the probe trajectory toward the target. Recent reports on MR-guided stereotaxic surgery have described its performance under local anesthesia and/or sedation, but not under general anesthesia because significant ferromagnetic artifacts from anesthesia equipment obscure the underlying anatomy [2–5]. We studied the possibility of the use of an anesthesia machine in an MR room. This study was conducted in two parts. First, a phantom study was designed to evaluate the influence of a ferromagnetic anesthesia machine on MR images by placing the machine in the MR room. The influence of the magnetic field on the anesthesia machine was also evaluated. Second, using a Brown-Roberts-Wells (BRW) stereotaxic system, we performed contrast-enhanced MR-guided surgery on six patients who were under general anesthesia. Our results indicate that an anesthesia machine may be used in an MR room if the magnet has a small fringe field.

Materials and Methods

MR images were acquired with a Toshiba MRT-15A system operating at 0.15 T. A 30-cm field of view was used. T1-weighted 500/30,40 (TR/TE) spin-echo images were obtained with a total acquisition time of 4 min. In both the phantom and clinical studies, a 5-mm slice thickness was used. In the clinical study, the examinations were performed within 10–20 min after IV administration of gadopentetate dimeglumine in a dosage of 0.1 mmol/kg body weight. T2-weighted images were not used in this study because they require a longer total acquisition time.

The machine used for general anesthesia was a Boyle International 2 Model B weighing 90 kg with mechanical ventilator, which was pneumatically driven and controlled entirely through the use of fluidics (Fig. 1). An automatic blood pressure monitor and ECG were used for patient monitoring. Ferromagnetic ECG electrodes attached to the patients' chests were replaced with carbon.

A BRW MR-guided stereotaxic system was used in this study. This system consists of four functional components: a head ring, a localizer frame, a programmed computer, and an arc guidance system. The head ring was fixed to a patient's head by four head pins and the localizer frame was attached to the head ring. The head ring, the head pins, and the localizer framer were not made of ferromagnetic materials. For fiducials, the localizer frame had multiplanar tubular channels containing petroleum jelly, which enabled the channels to be seen on MR images. Target and fiducial coordinates were obtained directly from the MR visual display. Calculations were made with this data using BRW software on an Epson HX-20 computer. The patient was then transferred to an operating theater separate from the MR room. After the localizer frame was exchanged for the arc guidance system, brain surgery was carried out through burr holes. During all this procedure, the patient was under general anesthesia and intubated (Fig. 2). The BRW-MR system may also be used for CT-directed surgery, since the tubular rod structures will show up on CT and the Epson software will work for CT data calculations.

Before the anesthesia machine was put to clinical use in the MR room, we determined the effects the machine would have on MR images. Field-strength lines were mapped for the 0.15-T resistive magnet (Fig. 3). We studied transaxial and sagittal MR images of a grid phantom measuring 18.5 cm in diameter placed in the center of the MR field of view. During MR imaging, the ferromagnetic anesthesia machine was placed on lines of varying field strength. The influence of the magnetic field on the anesthesia machine was also evaluated. We compared the accuracy of the BRW-MR system with that of CT, using the latter as the standard. A target phantom (a tubular structure containing petroleum jelly) was attached to the localizer frame with the former parallel to the *z* axis of the latter. The target phantom was placed in the center of the field of view, with the anesthesia machine outside the 10 G line in the MR room. The phantom was then transaxially imaged with MR. The target coordinates were calculated using the fiducial data obtained from the MR images. This target phantom was then scanned with CT and the target coordinates were calculated in the same way.

Six patients, 46 to 66 years old, had MR-guided stereotaxic biopsy and/or implantation of afterloaded catheters for brachytherapy during the period from March 1988 to May 1989. All patients had enhancing masses in the thalamus or the cerebral hemisphere on postcontrast T1-weighted images.

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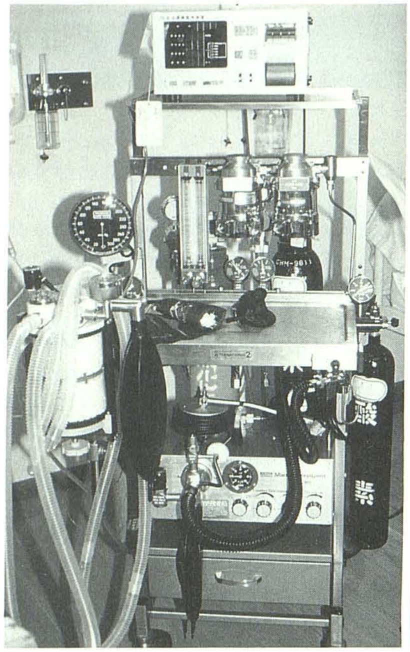

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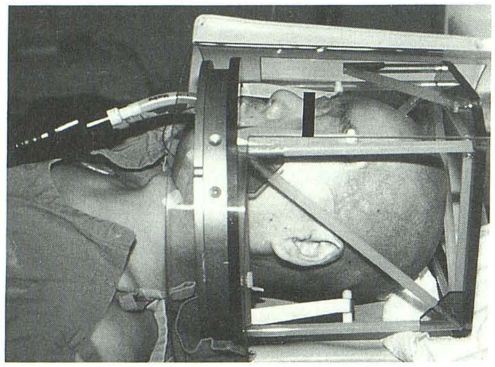

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Fig. 1.—Photograph of machine used for administering general anesthesia. Automatic blood pressure monitor is placed on it.

Fig. 2.—Photograph of patient intubated and under general anesthesia. Head ring is fixed to patient's head. Localizer frame is attached to head ring during scanning.

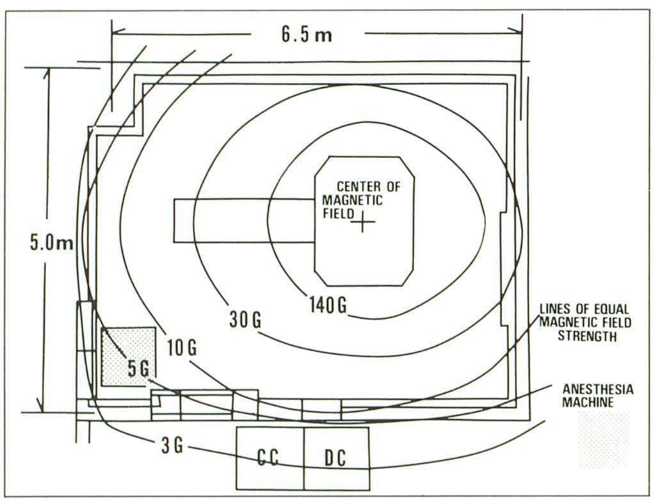

Fig. 3.—Schematic of MR room. Field-strength lines are presented for 0.15-T resistive magnet. Anesthesia machine is placed outside 10 G line.

Results

Image distortion and image shift in position of the grid phantom were seen on transaxial sections when the anesthesia machine was placed on the 120 G line and on sagittal sections when the machine was on the 60 G line. The machine did not cause significant image distortion or image shift in position when it was placed outside the 10 G line (Fig. 4). The anesthesia machine was attracted to the magnet when it was placed on the 60 G line, but not when it was placed on the 50 G line. The machine functioned properly when placed outside the 10 G line. The mean differences between MR- and CT-calculated target coordinates were 0.03 ± 0.4 mm (SD) in the x axis, 1.7 ± 0.4 mm in the y axis, and 3.7 ± 1.6 mm in the z axis on transaxial sections.

All patients were submitted to MR-guided surgery under general anesthesia, with the anesthesia machine placed outside the 10 G line. Patient monitoring did not produce radiofrequency interference. Pathologic material was obtained from all patients (glioma in four cases, malignant lymphoma in one case, and metastasis in one case). In five cases implantation of afterloaded catheters for brachytherapy was successfully performed (Fig. 5).

Discussion

CT-guided stereotaxic surgery is a well-established technique and has proved to be a valuable aid in tissue diagnosis [1]. Since the application of MR imaging to stereotaxy by Leksell et al. in 1985 [6], it has become apparent that MR may offer a new and more sensitive alternative to CT for lesion localization. Earlier reports [2–5] have focused on the use of MR under local anesthesia. Currently available anesthesia machines have been thought to be unsuitable for use in the MR room because of their high ferromagnetic properties.

The essential criteria for deciding whether to use the anesthesia machine in the MR room are as follows: (1) there is no danger to the patient; (2) the machine functions properly within the magnetic field; and (3) the machine has no effect on MR imaging [7]. In our study, the anesthesia machine functioned properly and had no significant magnetic attraction when it was placed outside the 10 G line. Also, image distortion proved to be insignificant for our clinical purposes when the

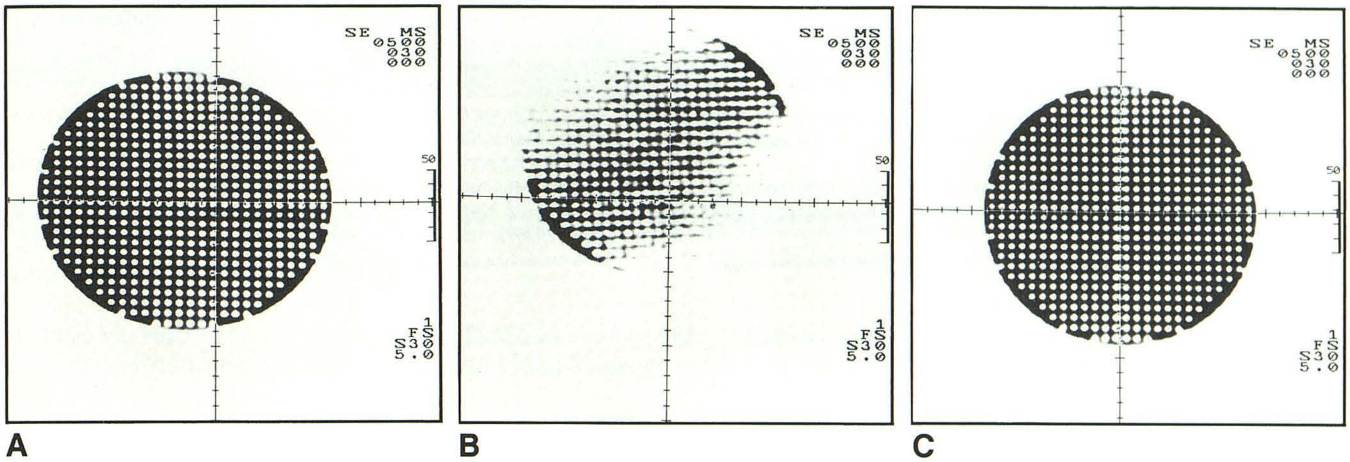

Fig. 4.—Image distortion and image shift in position of grid phantom caused by placing anesthesia machine on lines of varying field strength.
***A*, Transaxial section; anesthesia machine is on 120 G line.**
***B*, Sagittal section; anesthesia machine is on 60 G line.**
***C*, Transaxial section; anesthesia machine is outside 10 G line.**

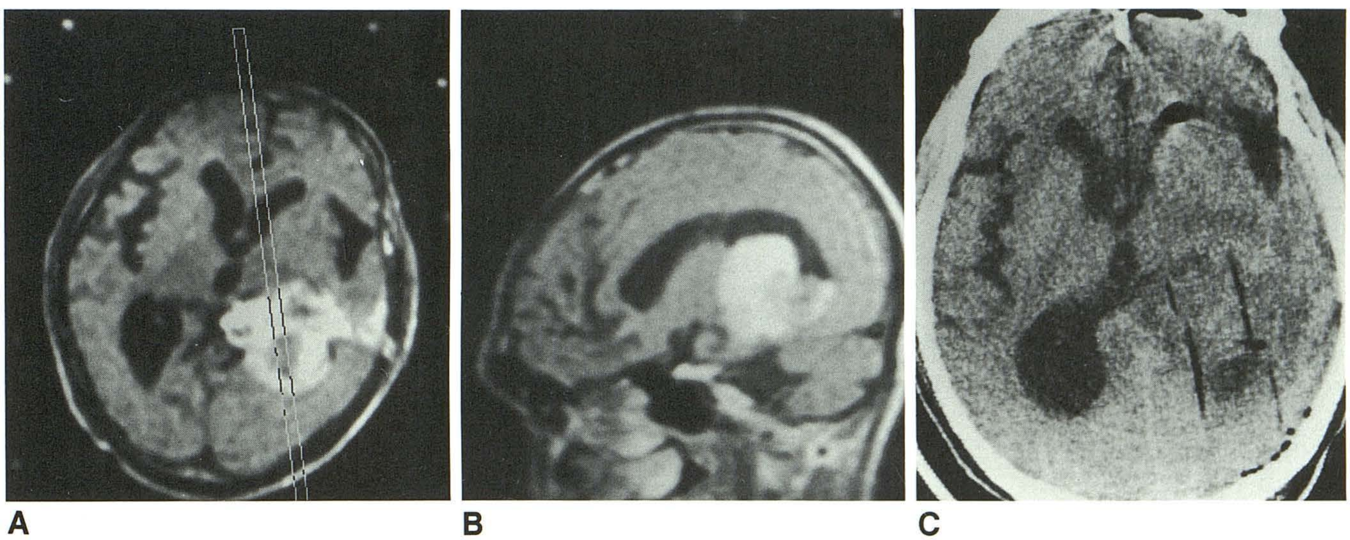

Fig. 5.—66-year-old man with glioblastoma multiforme in left thalamus.
***A*, Catheter implantation for brachytherapy is planned on axial postcontrast T1-weighted MR image (500/40).**
***B*, Obliqued sagittal postcontrast T1-weighted MR image (500/40) to simulate probe trajectory toward tumor.**
***C*, Axial postoperative CT scan demonstrates afterloaded catheters at tumor.**

machine was outside the 10 G line. Bradford et al. [5], using a BRW system without any ferromagnetic materials in the MR room, reported mean differences between MR- and CT-calculated coordinates as 1.0 ± 0.9 mm (SD) in the *x* axis, 3.75 ± 1.2 mm in the *y* axis, and 5 ± 2.2 mm in the *z* axis. Our data compare favorably with their report. Compared with CT localization, MR may be less accurate in determining the target points, but this is clinically acceptable as long as larger lesions are being addressed.

By using MR for target localization, any angled section to simulate the probe trajectory toward the target can be imaged and the deep side of the target can be easily recognized. This provides useful information to neurosurgeons, especially in planning implantation of afterloaded catheters for brachytherapy. The MR images are virtually free of artifacts from head pins or head rings, which are often the causes of artifacts on CT images [2, 8]. For these reasons, we prefer MR-directed surgery. Artifacts from motion became less evident on MR images as a shorter acquisition time and general anesthesia were used. Shorter acquisition time and greater lesion contrast have been achieved by using spin-echo short TR/short TE sequences after IV contrast administration.

It remains to be determined how an anesthesia machine should be applied clinically with stronger magnets. Our preliminary study suggests that it may be feasible if magnets with a small fringe field, such as those with a self-shield, are used.

REFERENCES

1. Lunsford LD, Martinez AJ. Stereotactic exploration of the brain in the era of computed tomography. *Surg Neurol* **1984**;22:222–230
2. Lunsford LD, Martinez AJ, Latchaw RE. Stereotaxic surgery with a magnetic resonance- and computerized tomography-compatible system. *J Neurosurg* **1986**;64:872–878
3. Thomas DGT, Davis CH, Ingram S, Olney JS, Bydder GM, Young IR. Stereotaxic biopsy of the brain under MR imaging control. *AJNR* **1986**; 7:161–163
4. Kelly PJ, Daumas-Duport C, Kispert DB, Kall BA, Scheithauer BW, Illig JJ. Imaging-based stereotaxic serial biopsies in untreated intracranial glial neoplasms. *J Neurosurg* **1987**;66:865–867
5. Bradford R, Thomas DGT, Bydder GM. MRI-directed stereotactic biopsy of cerebral lesions. *Acta Neurochir Suppl* (Wien) **1987**;39:25–27
6. Leksell L, Leksell D, Schwebel J. Stereotaxis and nuclear magnetic resonance. *J Neurol Neurosurg Psychiatry* **1985**;48:14–18
7. Karlik SJ, Heatherley T, Pavan F, et al. Patient anesthesia and monitoring at a 1.5-T MRI installation. *Magn Reson Med* **1988**;7:210–221
8. Earnest F IV, Kelly PJ, Scheithauer BW, et al. Cerebral astrocytomas: histopathologic correlation of MR and CT contrast enhancement with stereotactic biopsy. *Radiology* **1988**;166:823–827