Intraoperative MRI: a moving magnet

Garnette R. Sutherland, MD; Deon F. Louw, MD

Technology: Intraoperative MRI

Use: This mobile, 1.5 Tesla MRI system is placed into a standard neurosurgical operating room. It is used to plan accurate surgical corridors, confirm the accomplishment of operative objectives and detect acute complications such as hemorrhage and ischemia.

History: Lesion localization is paramount for safe neurosurgery. Until the late 19th century phrenologic considerations dictated drill sites for cranial trephinations. In 1861 Paul Broca1 studied stroke patients and nurtured the concept of cortical compartmentation of function. Presumptive clinical localization, however, required imaging confirmation, the first of which was pneumoencephalography. Walter Dandy serendipitously discovered this in the early part of this century. A leak of cerebrospinal fluid (CSF) accompanying a skull fracture allowed entrainment of air into the patient’s ventricular system, which was clearly outlined on the skull radiograph. Egas Moniz perfected cerebral angiography shortly thereafter. However, it was the inventions of CT and MRI scanning that heralded the modern era of neurosurgery.

Promise: MRI scanners generate exquisitely detailed images of brain and spinal cord anatomy and pathology. Moreover, they are multiplanar and radiation free and have a greater sensitivity and specificity than either CT or ultrasonography. Although an engineering challenge, the placement of MRI systems in the operating room will revolutionize neurosurgical care.2,3 This technology enables neurosurgeons to improve the accuracy of craniotomy placement and to reduce the size of bone flaps. The result is minimalist surgery and maximum technical outcome. Surgical navigation can be repeatedly updated by intraoperative images that detect brain shift resulting from CSF leakage. In contrast, navigation systems currently rely on archived images only. Intraoperative MRI has also identified a significant number of patients who harboured unsuspected, residual tumour at the end of surgery, thus sparing them the discomfort and expense of reoperation. It is also reassuring to perform MRI before wound closure to rule out hematoma, especially in patients with arteriovenous malformations.

Problems: Intraoperative MRI technology is expensive. A single system costs $2–3 million. However, using the equipment for conventional diagnostic imaging when it is not required in the operating room can largely offset this cost. The mobile, ceiling-mounted design is ideal for this purpose, because it permits the magnet to move from the operating room to an adjacent radiology suite. Older systems had wide magnetic fields, necessitating the acquisition of MRI-compatible microscopes and drills at a substantial cost. The new mobile magnet, however, is self-shielded. An important concern with an intraoperative magnet is the risk of entraining ferric objects at high speed into its bore, with serious consequences to the patient. Although not necessarily a problem, the use of intraoperative MRI requires a collaboration between physicists, image-processing scientists, MRI technicians, neuroradiologists, neurosurgeons and other OR personnel.

Prospects: The future of intraoperative MRI is exciting. Through pilot studies, functional MRI has been shown to enable the mapping of brain anatomy in the pre-, intra- and postoperative phases. Placement of a radiofrequency coil directly on the brain may generate more accurate images than are available with conventional techniques. Magnetic resonance spectroscopy and angiography will also greatly increase the understanding of neuropathology, while enhancing operative outcomes. We believe that within a decade intraoperative MRI will become the standard of care in neurosurgery.

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References

The authors are with the Department of Clinical Neurosciences, University of Calgary, Calgary, Alta.