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Imaging

Image fusion of fluid-attenuated inversion recovery magnetic resonance imaging sequences for surgical image guidance

Christopher R. Mascott, MD, FRCS(C)[a,*], Lori E. Summers, MD[b]

[a]Beacon Department of Neurosciences, Beacon Hospital, Dublin 18, Ireland
[b]Department of Neurological Surgery, Tulane University Hospital and Clinic, New Orleans, LA 70112, USA

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Abstract

Background: Nonenhancing brain lesions can be relatively poorly defined on volumetric data sets routinely used for surgical guidance. Fluid-attenuated inversion recovery MRI sequences can provide better margin visualization of nonenhancing or poorly enhancing lesions.

Methods: Using image fusion programs, we combined data sets of SPGR imaging pulse sequence or volumetric CT with volumetrically acquired FLAIR sequences and subsequently used the fused data set for image-guided surgery. This technique was used in 50 surgical cases. Of these, 9 were nonenhancing intrinsic brain tumors, 13 were partially enhancing tumors, and 11 were enhancing tumors. In addition, FLAIR fusion was selectively used for 6 nontumoral lesions and in 11 nonlesional epilepsy surgery cases.

Results: Image guidance using the fused data set was accurate in all 50 cases. Despite the lack of enhancement, 3 of the 9 nonenhancing tumors were found to be high grade. One of the low-grade tumors was associated with considerable areas of gliotic change not considered to represent tumor on permanent histology. In all other cases, the FLAIR-bright resected margins were consistent with tumor, not gliosis. Radical resection (>95% volume) was achieved in 21 of 23 tumor cases in which this had been the preoperative intent.

Conclusions: Nonenhancing lesions are often poorly demarcated not only on imaging studies, but also during surgery. Fluid-attenuated inversion recovery fusion allows resection of such lesions using intraoperative computer image guidance. Complementary FLAIR information can also occasionally be useful during surgical approaches to enhancing lesions or in nontumor cases. It must be kept in mind that FLAIR has high sensitivity but low specificity. Fluid-attenuated inversion recovery abnormalities do not obviate the need for mapping in potentially functional areas.

Keywords: Brain tumor; Epilepsy; FLAIR; Image fusion; Image guidance

1. Introduction

Widespread availability of frameless stereotactic systems has brought image-guided surgery into the operating theaters of many neurosurgeons. With regard to brain tumors, for those of us who were biased toward radical resection before volumetric image guidance, this technology has provided an intraoperative second anatomical opinion. It must be stressed that, at the present time, the bias for radical resection in this and many other studies is empirical and retrospective because there is no class I evidence yet to support this approach [3,18,23,35]. Most

Abbreviations: AVM, arterio-venous malformation; CA, carcinoma; CSF, cerebrospinal fluid; CT, computed tomography; DNET, dysembryoplastic neuroepithelial tumor; ECoG, electrocorticography; EEG, electroencephalography; FLAIR, fluid-attenuated inversion recovery; GBM, glioblastoma multiforme; GFAP, glial fibrillary acidic protein immunocytochemistry; IV, intravenous; MCA, middle cerebral artery; MR, magnetic resonance; MRI, magnetic resonance imaging; NeuN, neuron-specific nuclear protein immunocytochemistry; PE, pulmonary embolus; PET, positron emission tomography; SE, spin-echo; SPECT, single-photon emission computed tomography; SPGR, radiofrequency-spoiled gradient-recalled.

* Corresponding author. Tel.: +353 8769 05632; fax: +353 1293 6601.
E-mail address: MascottDonnelly@gmail.com (C.R. Mascott).

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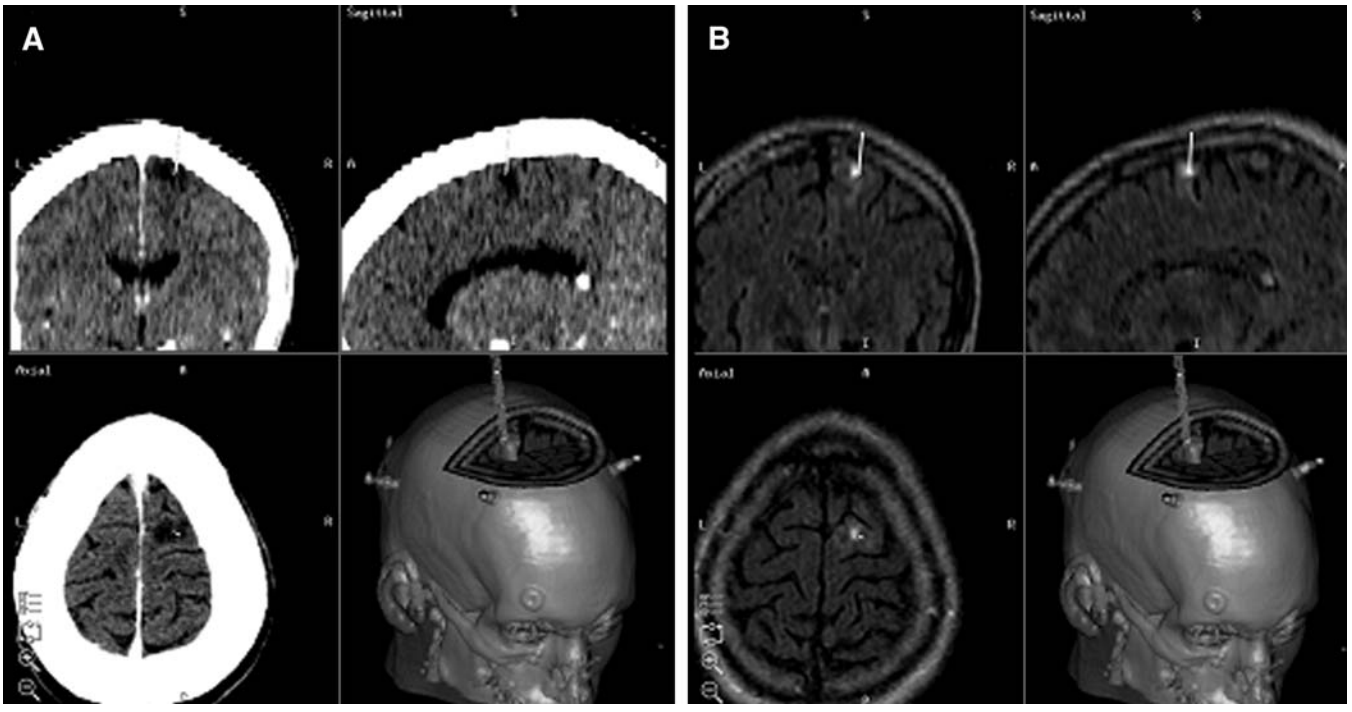

Fig. 1. A tiny frontal ganglioglioma illustrating fusion of CT (A) and MR FLAIR (B) data sets (ImMerge, StealthStation; Medtronics).

intrinsic malignant brain tumors have somewhat defined delineations at the time of surgery. As a result, immediate postoperative imaging studies often confirm a gross total resection of the enhancing component of these tumors even without the benefit of volumetric image guidance. The situation can be somewhat different for nonenhancing intrinsic lesions, however. The transition between brain, gliotic brain, and nonenhancing glial tumor may be difficult

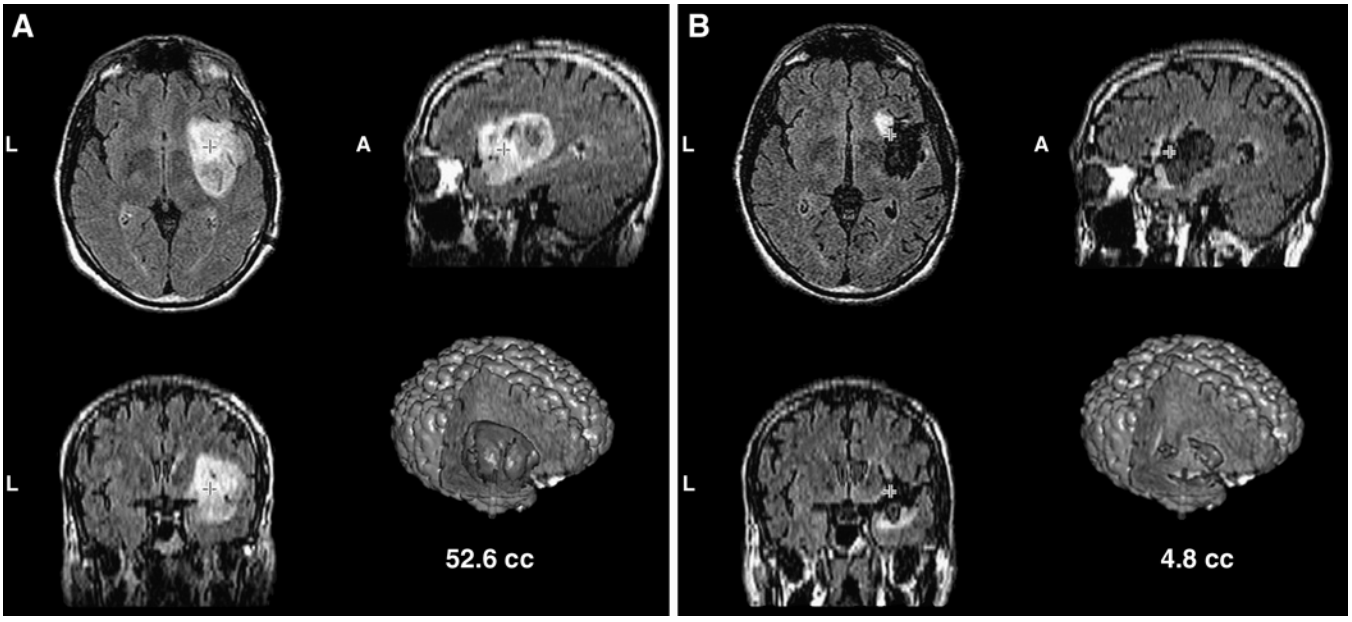

Fig. 2. FLAIR sequences of a nonenhancing grade A oligodendroglioma of the insula. As part of functional risk assessment, this left-handed patient underwent preoperative sodium amobarbital testing, which demonstrated left-sided speech. Panel A shows the FLAIR sequences used at surgery, which were correlated to an SPGR sequence (not shown). Panel B shows FLAIR sequences at 6-month follow-up, which have been fused to the preoperative volume (A) for this illustration (Compass Image-correlation, 3-dimensional model done on StealthStation). The immediate postoperative FLAIR-bright edema changes have disappeared. The residual FLAIR-bright areas most likely represent residual tumor. The patient who had very poorly controlled seizures preoperatively has been seizure-free and deficit-free postoperatively. He refused additional surgery for residual tumor. Residual tumor has been stable on sequential volumetric imaging studies over 2 years without adjuvant therapy.