Comparative Effectiveness of Frame-Based, Frameless, and Intraoperative Magnetic Resonance Imaging–Guided Brain Biopsy Techniques

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■ OBJECTIVE: **To compare the diagnostic yield and safety profiles of intraoperative magnetic resonance imaging (MRI)–guided needle brain biopsy with 2 traditional brain biopsy methods: frame-based and frameless stereotactic brain biopsy.**

■ METHODS: **A retrospective analysis was performed of 288 consecutive needle brain biopsies in 277 patients undergoing stereotactic brain biopsy with any of the 3 biopsy methods at Brigham and Women's Hospital from 2000–2008. Variables including age, sex, history of radiation and previous surgery, pathology results, complications, and postoperative length of hospital stay were analyzed.**

■ RESULTS: **Over the course of 8 years, 288 brain biopsies were performed. Of these, 253 (87.8%) biopsies yielded positive diagnostic tissue. Young age (<40 years old) and history of brain radiation or surgery were significant negative predictors for a positive biopsy diagnostic yield. Excluding patients with prior radiation or surgeries, no significant difference in diagnostic yield was detected among the 3 groups, with frame-based biopsies yielding 96.9%, frameless biopsies yielding 91.8%, and intraoperative MRI–guided needle biopsies yielding 89.9% positive diagnostic yield. Serious adverse events occurred 19 biopsies (6.6%). Intraoperative MRI–guided brain biopsies were associated with less serious adverse events and the shortest postoperative hospital stay.**

■ CONCLUSIONS: **Frame-based, frameless stereotactic, and intraoperative MRI–guided brain needle biopsy techniques have comparable diagnostic yield for patients with no prior treatments (either radiation or surgery). Intraoperative MRI–guided brain biopsy is associated with fewer serious adverse events and shorter hospital stay.**

INTRODUCTION

The continued evolution of image-guided surgical techniques over the past 20 years has led to tremendous advances in neurosurgery. Frame-based techniques have long been considered the "gold standard" for sampling intracranial lesions, with the rigid frame providing excellent targeting precision (2, 3, 6, 12, 13, 18, 20). However, use of a frame-based technique is limited by the frame's bulkiness, the patient's discomfort, the calculations involved in defining stereotactic entry points, the possible prolonged surgical time, and the risk of postoperative infection at the frame's fixture points (17). Frameless stereotactic techniques have become a popular choice among neurosurgeons because they are easy to use and provide comparable diagnostic yield (1, 6).

Because both frame-based and frameless stereotactic biopsy techniques use preoperative images with a registered probe to access target tissue, they both have a similar drawback: there is no real-time radiographic feedback confirming that the biopsy needle is in the target tissue. Intraoperative brain shifting and cerebrospinal fluid loss or technical issues can lead to a potential misalignment between the image guide and the actual brain configuration during the operation (5, 7, 11, 14-16, 20). The development of intraoperative magnetic resonance imaging (MRI) systems has made real-time radiographic feedback a possibility for brain biopsy. In the intraoperative MRI system used, a frameless three-dimensional optical stereotactic system is combined with intraoperative acquisition of MRI images to provide surgeons with near real-time navigation (15). Using a combination of light-emitting diode–based optical tracking of biopsy probes with intraoperative manipulation of MRI planes, surgeons are able to modify the preplanned trajectory based on the real-time intraoperative MRI image (4). Intralesional biopsy could be confirmed with the real-time MRI image.

Several reports have been published comparing the effectiveness of the frame-based and frameless stereotactic brain biopsy methods (6, 8, 19, 21). These reports found similar diagnostic

Key words
- Brain biopsy
- Frame-based
- Frameless stereotactic
- Intraoperative MRI

Abbreviations and Acronyms
CI: Confidence interval
MRI: Magnetic resonance imaging
OR: Odds ratio

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yield between the 2 methods (6, 8, 19, 21). However, results comparing the complications and length of hospitalization vary among different studies (8, 19). We previously demonstrated the feasibility and accuracy of an intraoperative MRI brain biopsy technique in a case series of an earlier cohort of 68 patients (15). A separate group from the University of Minnesota also demonstrated in a case series that interventional MRI—guided biopsy is a safe and effective method (9). However, there have not been any studies comparing the safety and effectiveness of intraoperative MRI brain biopsy with the traditional stereotactic biopsy methods. In the present study, we evaluate a series of 288 consecutive brain biopsies performed over 8 years at the Brigham and Women's Hospital in Boston, Massachusetts. We report our analysis of diagnostic yield, complications, and length of postoperative hospital stay between frame-based, frameless, and intraoperative MRI—guided brain biopsy procedures.

MATERIALS AND METHODS

We reviewed a consecutive series of patients who underwent needle-based brain biopsy at Brigham & Women's Hospital from 2000—2008. Open biopsy cases were excluded from the study. The attending neurosurgeons had a choice of 1 of 3 biopsy methods (frame-based, frameless, and intraoperative MRI—guided stereotactic). There were 288 biopsies performed in 277 patients. Age, gender, image characteristics, history of prior treatments, duration of hospital stay, and postoperative complications were retrospectively collected from electronic medical records. The diagnosis was obtained from the final pathologic report.

Frame-Based Image-Guided Stereotactic Biopsy

For frame-based stereotactic brain biopsy procedures, the surgeon placed a CRW stereotactic frame (Integra Burlington MA, Inc., formerly Integra Radionics, Inc., Burlington, Massachusetts, USA) preoperatively. A computed tomography scan was performed with the frame and birdcage fiducial in place, and the images were fused with a preoperative MRI scan (T1 postcontrast or T2-weighted images) to establish the target. Radionics (Integra Burlington MA, Inc., Burlington, Massachusetts, USA) software was used for image registration, targeting, and calculation of offsets and ring and arc settings. The arc system was set up attached to the head ring. A burr hole or twist drill hole was made at the defined stereotactic site, and tissue specimens were obtained using a biopsy needle and standard suction-aspiration technique.

Frameless Image-Guided Stereotactic Biopsy

For frameless stereotactic brain biopsy, MRI (T1 postcontrast or T2-weighted image) or computed tomography scans were used. One of the 2 imaging methods was used for surface registration. Either fiducials or surface matching was used for operating room neuronavigation registration. Patients' heads were fixed in a 3-point Mayfield clamp. The surgical plan (entry point, biopsy target, and needle trajectory) was determined using GE (GE Healthcare, Milwaukee, Wisconsin, USA) navigation system software. After accuracy of the neuronavigation system was confirmed using anatomic landmarks, a burr hole was placed, and biopsy samples were obtained using standard biopsy needles attached to the burr hole fixation needle trajectory guide.

Intraoperative MRI—Guided Biopsy

All procedures were performed in the intraoperative MRI suite at Brigham and Women's Hospital. A Signa SP open configuration intraoperative MRI scanner (GE Healthcare, Milwaukee, Wisconsin, USA) was used for the intraoperative MRI—guided biopsy. The intraoperative MRI suite was a fully functional operating room equipped with MRI-compatible anesthesia machine and patient monitoring devices. The scanner is based on a 0.5-T open configuration superconducting magnet. The MRI-compatible Mayfield head holder was used. After positioning, a series of multislice (usually T1-weighted) preoperative images was acquired to assess the adequacy of imaging and to plan the biopsy. Intravenous gadolinium was administered if it was indicated. To determine the site of the burr hole, the surgeon placed a marker on the patient's scalp and acquired a sequence of images. The biopsy needle cannula with its optical tracking sensors was affixed on a BOOKWALTER arm (Codman, Inc., Raynham, Massachusetts, USA) and placed at a proposed angle of entry. Single-slice image acquisition was performed in 3 separate oblique planes to define clearly the vector to the target and the proposed biopsy site. A Sedan Side-Cutting Biopsy Needle (Elekta AB, Stockholm, Sweden) was inserted through the cannula and into the brain under image guidance. The biopsy needle used was composed of a titanium alloy. Several further single-slice images were obtained as the needle was passed into the lesion. Biopsy specimens were obtained using standard technique. When an adequate tissue sample was obtained with the needle in place, a set of volumetric images of the entire brain was obtained. The needle was withdrawn, and a final set of images of the entire brain was obtained as the incision was closed.

Histopathologic Analysis

Needle biopsy samples were sent for pathologic evaluation soon after they were obtained. Definitive diagnoses included pathology of gliomas (e.g., glioblastoma multiforme, anaplastic astrocytoma, oligodendroglioma), diffuse large B-cell lymphoma, multiple sclerosis or other demyelinating lesion, abscess, metastatic tumors, central neurocytoma, and infarction. Nondefinitive diagnoses included pathology of hypercellular tissue, reactive change, gliosis, and inflammation (**Table 1**).

Statistical Analysis

Statistical analysis was performed using GraphPad Prism 5.01 (GraphPad Software, La Jolla, California, USA). Statistical analyses for biopsy diagnostic yield and complications were performed with 2-tailed Fisher exact test (for 2-group comparison) or χ^2 test (for 3-group comparison). Age and postoperative hospital length of stay univariate analysis was performed with 2-tailed unpaired t test. P values <0.05 were considered statistically significant.

RESULTS

Factors Affecting Needle Biopsy Yields

The overall diagnostic yield was 87.8%, with a definitive histologic diagnosis in 253 of 288 cases. In 35 cases (12.2%), the biopsy yielded nondefinitive diagnoses, such as atypical cells, inflammation cells, or gliosis. We first analyzed possible factors that might affect needle biopsy yields, including age, gender, image characteristics, and history of previous treatments. **Table 1** shows