Stereotactic Biopsy Platforms with Intraoperative Imaging Guidance

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KEYWORDS

• Biopsy • Brain • Technique • Intraoperative magnetic resonance imaging
• Real time image guided biopsy

KEY POINTS

- Resolution and real-time navigation of intraoperative MRI (iMRI) has been leveraged by different fields in neurosurgery.
- Frameless stereotactic systems that rely on preoperative imaging have become the most common brain biopsy systems being used with relatively good success but have serious drawbacks.
- Brain biopsy with iMRI is an accurate way to sample tissue and correct the trajectory of biopsy cannula during surgery, eliminating misdiagnosis secondary to faulty targeting.
- The ClearPoint Smartframe biopsy platform uses a minimally invasive approach for frameless stereotactic brain biopsy using a percutaneous neuronavigation platform compatible with iMRI.

INTRODUCTION

Advancements in medical imaging with the introduction of computed tomography scans and MRI have dramatically influenced diagnostic capabilities in human health. The usefulness of this technology has led to earlier detection and management of patients with neurologic disease. Consequently, it has resulted in the early detection of ambiguous lesions in eloquent brain areas, surrounded by critical vascular structures raising radiographic suspicion for underlying disease.[1,2] The dilemma to treat or not treat suspicious lesions in asymptotic patients relies often on accurate tissue acquisition and diagnosis. As a result, brain biopsy techniques continue to evolve in providing the safest and most precise methods for obtaining a diagnosis.

The development of image-guided brain biopsy methods began with techniques such as open free-hand methods using data from computed tomography scans for surgical planning to stereotactic frame-based approaches. More recently, frameless stereotactic systems incorporating preoperative imaging have become the most common biopsy systems in use today.[3,4] This evolution underscores the dynamic development of technology and methods that continue to push stereotactic brain surgery in becoming safer and more effective. Careful examination between frame-based and frameless stereotaxy has compelled most neurosurgeons to conveniently adopt a frameless brain biopsy technique based on comparable diagnostic yield between both approaches, decreased operating room time and reduced the risk of postoperative infection

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secondary to frame fixture points.[5–7] A metaanalysis 15 years ago of 7471 frameless biopsies demonstrated a diagnostic yield of 91%, morbidity of 3.5%, and mortality of 0.7%.[8] More contemporary data suggest that modest gains have been made, pushing the diagnostic yield to 93.8% according to a recent metaanalysis, but with a comparable safety profile.[9]

Despite such advances and widespread popularity, both frame-based and frameless stereotactic biopsy rely on preoperative images with intraoperative anatomic or fiducial registration to reach target tissue based on calculated measurements in 3-dimensional space. The primary limitation of this approach is the inability to account for dynamic changes, such as shift of intracranial structures, potentially interfering with the diagnostic accuracy in cases with small lesions.[10–12] A critical review of the literature has raised concerns that, although reported diagnostic yields remain high, the diagnostic accuracy of stereotaxy with preoperative neuronavigation may be lower than previously reported.[9] In addition, miscalculations or faulty technical misalignment of hardware during surgery can potentially contribute to fatal intraoperative events.[8,13] These potential pitfalls leave very little room for error when surrounding neurovascular structures are at stake.

The integration of intraoperative MRI (iMRI) with stereotactic frameless biopsy has been the logical next step in the evolutionary refinement of brain biopsy techniques.[14–19] The resolution and real-time radiographic feedback of iMRI is remarkably accurate in phantom experiments[15,20] and in a recent case series demonstrated a diagnostic yield in 78 patients of 97.4%.[17] This technology eliminates the possibility of misdiagnosis secondary to faulty targeting by confirmation of accurate positioning of the biopsy cannula. Although a few groups have reported on this technique, low-resolution intraoperative scanners and the lack of a standardized protocol continue to delay its potential for broad clinical application. Here we review various biopsy platforms that rely on preoperative image guidance and focus particularly on the integration of intraoperative imaging and newly developed MRI-compatible biopsy platform with a case illustration. This platform uses a minimally invasive approach for frameless stereotactic brain biopsy using a percutaneous neuronavigation platform, ClearPoint System neuronavigation platform (MRI Interventions, Memphis, TN), compatible with standard 1.5 and 3.0 T scanners, resulting in safe and successful diagnostic yield in 5 patients.[21] The advantages and limitations of this approach are discussed. Although current frameless, stereotactic techniques are capable of providing satisfactory accuracy and safety in a majority of cases, there are specific diagnostic scenarios for which the MRI-guided biopsy technique described here is more ideally suited.

FRAMELESS STEREOTACTIC BIOPSY PLATFORMS WITH PREOPERATIVE IMAGE GUIDANCE

There are several frameless stereotactic biopsy platforms that are currently available for neurosurgeons. The 2 most commonly used and that recently have been compared head to head are the Medtronic Stealth Treon Vertek (Medtronic Inc., Minneapolis, MN) and BrainLAB Varioguide (BrainLAB, Feldkirchen, Germany). Technical notes and large case series published with these stereotactic biopsy platforms have been described in the literature with relatively good reproducibility and expeditious integration into clinical practice. Both systems rely on a software computer module that allows for preoperative image registration and guidance for preoperative trajectory planning.

Use of the Medtronic Stealth Treon Vertek was described initially in a large case series of 164 consecutive intracranial biopsies.[6] This system relies on a skull-mounted trajectory guide that is affixed over the planned burr hole for the biopsy trajectory. The platform also includes a flexible arm with a navigated aiming device that provides limited degrees of rotation in positioning and targeting with the biopsy needle. The surgeon's incision and burr hole are planned based on preoperative image guidance and the length of the incision needs to account for the burr hole and the size of the skull mount, which is about to 1 to 2 cm larger than a 14-mm burr hole. The system relies on a biopsy needle with an outer diameter of 2.2 mm and a cutting window of 7 mm that is then inserted through the needle guide through preoperative planned trajectory toward the lesion.

The BrainLAB Varioguide biopsy platform was introduced in 2009 after the Medtronic system, and was used in an initial cohort of 27 patients in a preliminary technical report[22] and then in a larger case series of 102 patients.[23] Unlike the Medtronic biopsy platform, the BrainLAB Varioguide does not rely on a skull-mounted trajectory guide, but rather uses a stereotactic arm with a biopsy needle adaptor that is capable of holding 3 different biopsy needle sizes (**Fig. 1**). The system is precalibrated for a 1.8-mm biopsy needle with a 1.8-mm diameter and 10-mm cutting window. The surgeon plans an incision for the size of a 14-mm burr hole because no skull mount is required. The stereotactic arm is guided into the surgical field based on a