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Acquisition of navigated biopsy samples of cerebral gliomas using navigated ultrasound

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We use this protocol and it's working.

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Keywords: biopsy, neurosurgery, brain shift, ultrasound, tumour boundary delineation for surgical planning, tumour boundaries on preoperative mri, navigated biopsy sample, individualised contouring for adjuvant radiotherapy, biopsy samples of cerebral glioma, defined tumour boundary, tumour boundary delineation, validated imaging, tumour recurrence at the resection margin, preoperative mri, using navigated 3d ultrasound, infiltrative brain tumour, multiparametric imaging, navigated 3d ultrasound, individualised contouring, brain mri, intraoperative brain, intraoperative brain shift, imaging data, including intraoperative brain, cerebral glioma, surgical planning, navigated data point acquisition, based supramarginal resection planning, navigated sampling, supramarginal resection planning, imaging, navigated ultrasound problem, intraoperative ultrasound, performing intraoperative ultrasound, grade glioma, tumour recurrence, margin recognition, complete surgical resection, resection margin, digital integration of histopa

Abstract

Problem: High-grade gliomas are highly aggressive and infiltrative brain tumours, for which complete surgical resection remains impossible. Current surgical strategies are limited by (1) ill-defined tumour boundaries on preoperative MRI, particularly in the presence of oedema or other pathological changes, and (2) intraoperative brain shift, which complicates reliable navigation and margin recognition. Consequently, incomplete resections and tumour recurrence at the resection margins remain common.

Aim: This protocol describes a standardised method for obtaining tissue samples that are spatially matched to preoperative brain MRI, including intraoperative brain-shift correction using navigated 3D ultrasound. The resulting dataset allows the development of machine-learning models that integrate multiparametric imaging and histopathological features to infer tissue characteristics non-invasively. These models aim to improve tumour boundary delineation for surgical planning and navigation, and to support individualised contouring for adjuvant radiotherapy.

Innovation: The protocol provides a reproducible, time-efficient workflow for spatially precise, navigated sampling and digital integration of histopathology with imaging data. This framework enables large-scale generation of spatially validated imaging–pathology pairs for machine-learning–based supramarginal resection planning.

Prerequisites: The user must be familiar with performing intraoperative ultrasound and navigated data point acquisition.



Guidelines

Limitations: This protocol is designed for acquiring samples of brain tissue that are spacially registered to a brain shift-corrected preoperative anatomical image. It is not intended as a surgical training tool but as an aid for obtaining spacially-corrected biopsy samples.

Assumptions: This protocol assumes the user is familiar with neurosurgical procedures and all required material are available. Disruption of the standard care of the patient must be minimised by testing the protocol before implementation and training all staff involved. To ease the implementation of the protocol, it should be performed by at least two people who (1) perform the navigated biopsy and (2) navigate the neuronavigation interface, respectively.

Required expertise: The user must be familiar with performing intraoperative ultrasound and navigating the neuronavigation interface to acquire navigated points. Moreover, the user must be familiar with the safety precautions attached to handling cancerous tissue samples.

Materials

Software

- Neuronavigation: Brainlab AG; Image Fusion - 4.0.2.8 release; SmartBrush - 2.6.0.121 release; Viewer - 5.1.1.98 release; Backbone - 1.6.2.54 release; Backbone Viewer - 1.6.2.578 release; Brainlab NodeMaster - 1.6.0.48 release; Brainlab TrackingService - 4.1.0.9 release; BrainwashExportPerformer - 2.0.0.24 release

Hardware

- Sterile, navigated pointer
- BK Medical: bk5000 ultrasound system
- BK Medical: BK Medical N13C5 9062 Curved Array transducer

Neuronavigation system

- Navigation software: Elements, Brainlab, Munich, Germany
- Navigational camera : Brainlab, Munich, Germany
- Double monitor mounted on the ceiling: Curve, Brainlab, Munich, Germany
- Two screens fixed to the wall: Buzz, Brainlab, Munich, Germany

Safety warnings

 This protocol involves handling of cancerous tissue samples. User discretion is advised.

Ethics statement

Ethical clearance for the use of this protocol must be obtained by the local ethics committee. Each patient must provide written informed consent for the participation in any study using this protocol.

Before start

Before implementing this protocol, ethical clearance and patient consent must be obtained. All materials (see the "Materials" section) should be readily available.

Before surgery

- 1 Define regions, ideally 3-5, from which tissue samples are to be taken.
- 2 Reference the patient's head position with the Brainlab navigation system. Check the accuracy of the navigation before proceeding.
- 3 Attach fiducial points to the ultrasound transducer for navigation and the surgical head clamp. All equipment must be sterile.
- 4 Connect the navigated ultrasound to the Brainlab navigation system.

Ultrasound-based brain shift correction

- 5 When acquisition of tissue samples is deemed sensible, perform a subdural navigated ultrasound scan.
- 6 In Brainlab, open the ultrasound application.
- 7 If the ultrasound is performed after resection of tissue, fill the resection cavity with water to avoid air-induced artefacts.
- 8 Adjust the frequency settings to obtain optimal tissue contrast with the ultrasound.
- 9 Tilt the transducer under the craniotomy edge. Slowly bring it in vertical position and move it slowly across the brain surface in-line with one image plane, e.g., rostral to caudal. Finally, tilt the transducer under the opposite craniotomy edge.
- 10 Co-register the ultrasound image with the preoperative anatomical image using Brainlab's automatic co-registration software (Digital Ultrasound Integration, Brainlab, Munich, Germany). Thereby, the preoperative anatomical image is spatially corrected and the subsequent acquisition of biopsies will be performed on the spatially corrected image.

Biopsy



- 11 Take a tissue sample with sterile tumour grasping forceps in one location.
- 12 Immediately after tissue acquisition, take a sterile navigated pointer and hold it in the exact location of the biopsy.
- 13 In Brainlab's navigation window, select "acquire point".
- 14 Number the sample (ascending order) and store it in a sterile container with 5% formaldehyde at room temperature.
- 15 Repeat this process for each sample you take.
- 16 Transfer the samples to your lab for histological analysis as soon as possible (within 72h latest).