Abstract

Most clinical neurosurgeries today are performed without intraoperative tomographic imaging, instead relying on preoperative images which may be hours or days old. An optical tracking system, used in the operating room while aiming interventional devices, renders updates of the predicted trajectory on the preoperative image by repeatedly measuring fiducials on the device and patient's head. This technique rests on the assumption that the brain does not shift inside the skull, but brain shift is observed. For procedures like biopsy of large tumors, this is acceptable because the shift is much smaller than the target size.

When targets are small and interventional devices must be placed very accurately, as in the studies we undertake in this work, the standard method is inadequate. The surgeries we focus on are: implantation of deep brain stimulation (DBS) electrodes, infusion of viral vectors carrying gene-therapy payloads, injection of neural progenitor cells, and intracerebral hemorrhage (ICH) evacuation by administration of thrombolytic drugs directly into clot.

The main findings of this work are: Perforating vessels of the basal ganglia are depicted well by bSSFP imaging (compared to TOF), have an enlarged appearance in 12% of the subpopulation near the age of typical Parkinson's disease onset (50–70 years), and influence the choice of trajectories when planning functional neurosurgeries such as DBS lead placement.

Complex and previously unachievable surgical goals are enabled by the development of a physically accurate method for preoperative planning of IMRI-guided surgeries. A computational approach to neurosurgical trajectory guide tracking (rather than an approach based on human interpretation of images) enables rapid interactive feedback, decreased subjectivity, and accurate aiming of the trajectory guide. The usefulness of the preoperative planning and IMRI device tracking methods are borne out by several preclinical studies (totaling over 80 IMRI neurosurgeries to date) in gene delivery, cell delivery, infusion monitoring, and causal fMRI.

In clotting blood, MRI is capable of sensing different contrast mechanisms than CT (the standard modality used during intracerebral hemorrhage monitoring) and in vitro models of IMRI-guided clot lysing suggest there is value in applying IMRI to preclinical in vivo ICH evacuation studies.