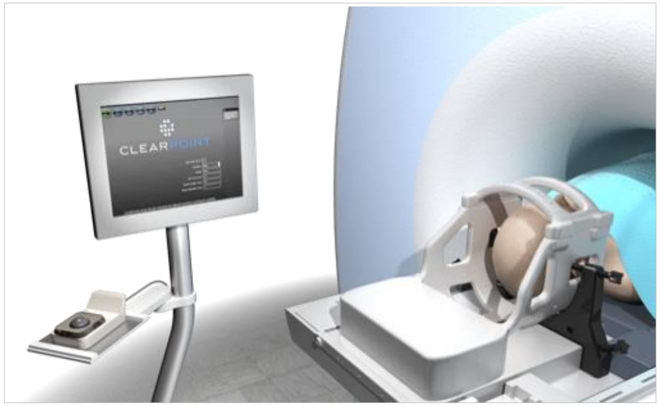
CLEARPOINT®



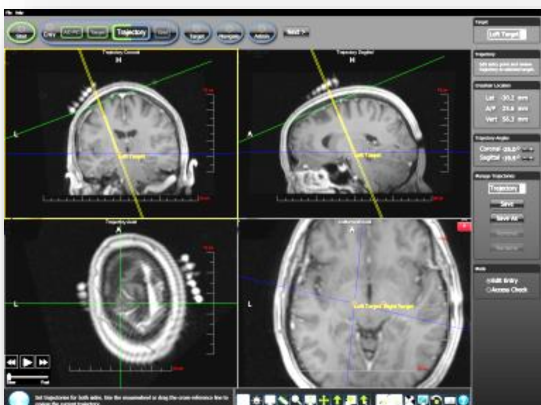
ED-201278 Rev 03 02/2016

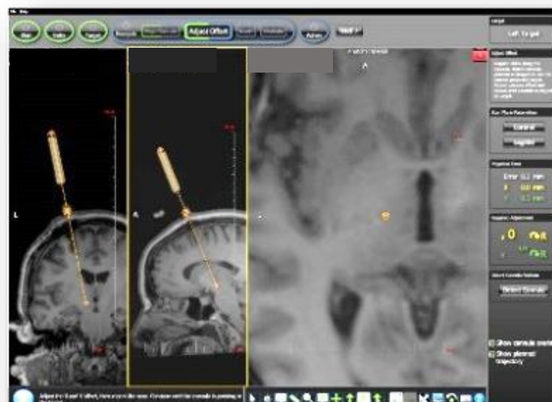
Integrated Software for Real-Time, MRI Guided, Minimally Invasive Neurosurgical Procedures

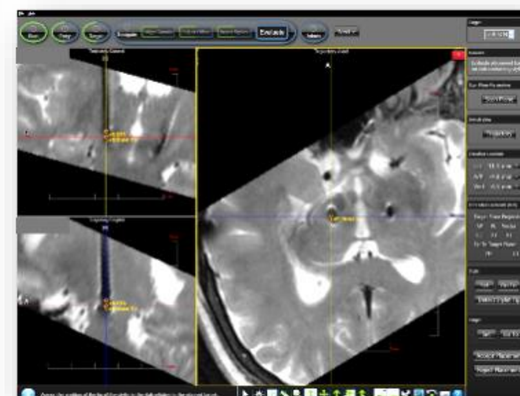
Visualize
- Accurately locate target & define safe trajectories
- Account for shifts in anatomy

Verify
- Observe progression of the device in real time
- Adjust and react to changes as they occur

Confirm
- Confirm precise placement of device and therapy
- Achieve sub-millimetric accuracy







One Procedure – One Room

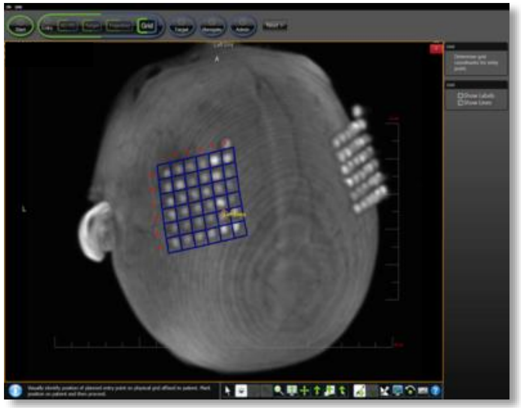
CLEARPOINT

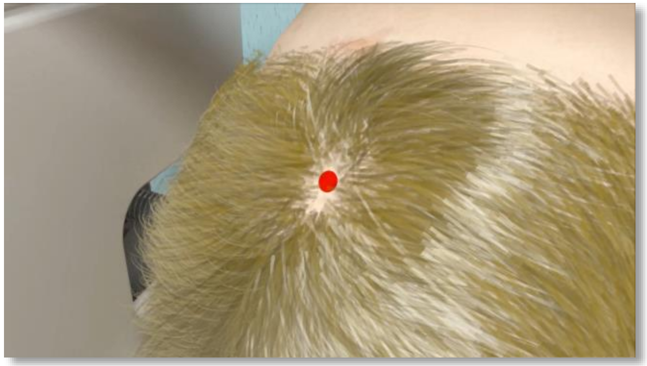
Plus Integrated MRI Safe, Minimally Invasive Neurosurgical Disposable Components

MRI Safe Disposable Components:

SmartGrid® and SmartFrame® – Integrated ClearPoint Targeting and Trajectory Precision with Hand-Controller

ClearPoint® Drape provides sterile procedural field in any diagnostic or intraoperative MRI scanner



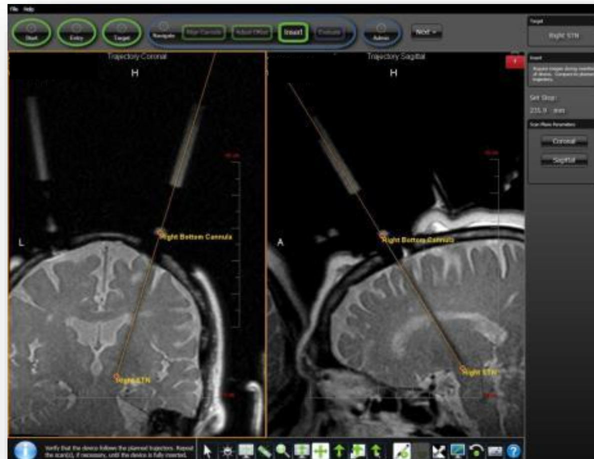


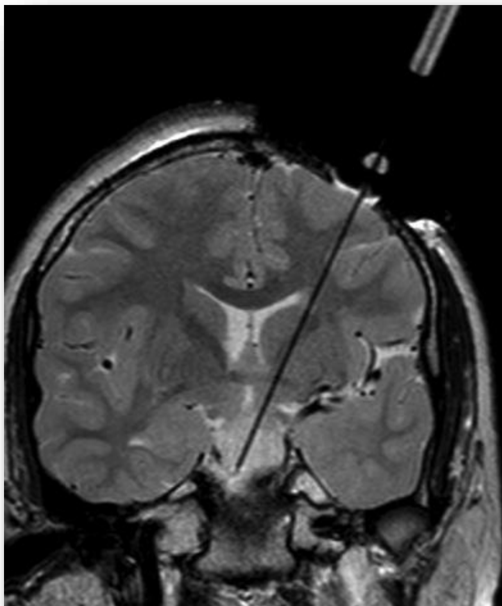
ClearPoint® Neuro Navigation

Expanding Variety of Neurosurgical Procedures

Placement of Electrodes

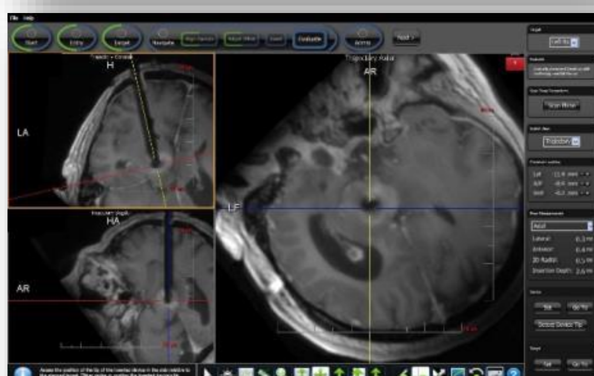
Depth and location…





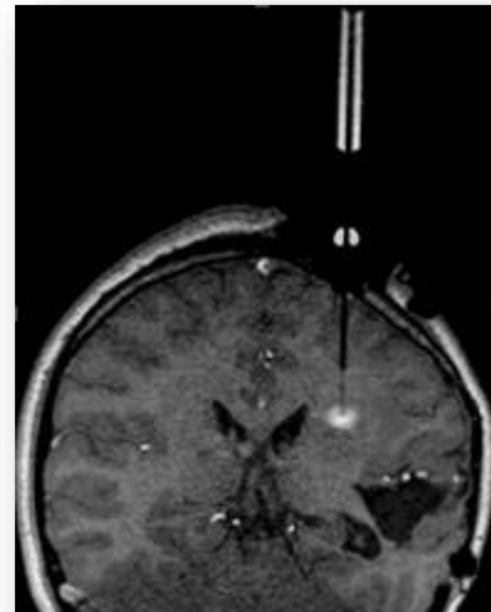
Placement of Laser Ablation Catheters

For hippocampal ablation, ablation of tumor, ablation of radiation necrosis…



Placement of Biopsy Needles

Small, deep tumors, brain stem gliomas…



Placement of Drug Delivery Catheters

Clinical trials, research…

Expanding Your Neurosurgical Practice

CLEARPOINT

US Patient Populations

Neuro Disorder	Patient Population	Treatment Resistant Patient Population
Epilepsy	2,300,000	250,000
Brain Tumor	200,000	30,000
Parkinson's Disease	1,500,000	150,000
Dystonia	250,000	25,000
OCD	3,300,000	100,000
Alzheimer's	5,400,000	500,000
Huntington's	30,000	30,000

= Massive unmet patient need

Therapeutic Approaches

Electrode Placement	Focal Ablation	Biopsy	Direct Drug Delivery

CLEARPOINT

ClearPoint Platform Supports All of These Current and Emerging Therapeutic Approaches

ClearPoint® Neuro Navigation System

1.5T or 3T MR Scanners, also works in intraop MRI Suites

University of Pittsburgh Medical Center

Emory University Hospital

UCSF Medical Center

Brigham and Women's Hospital*

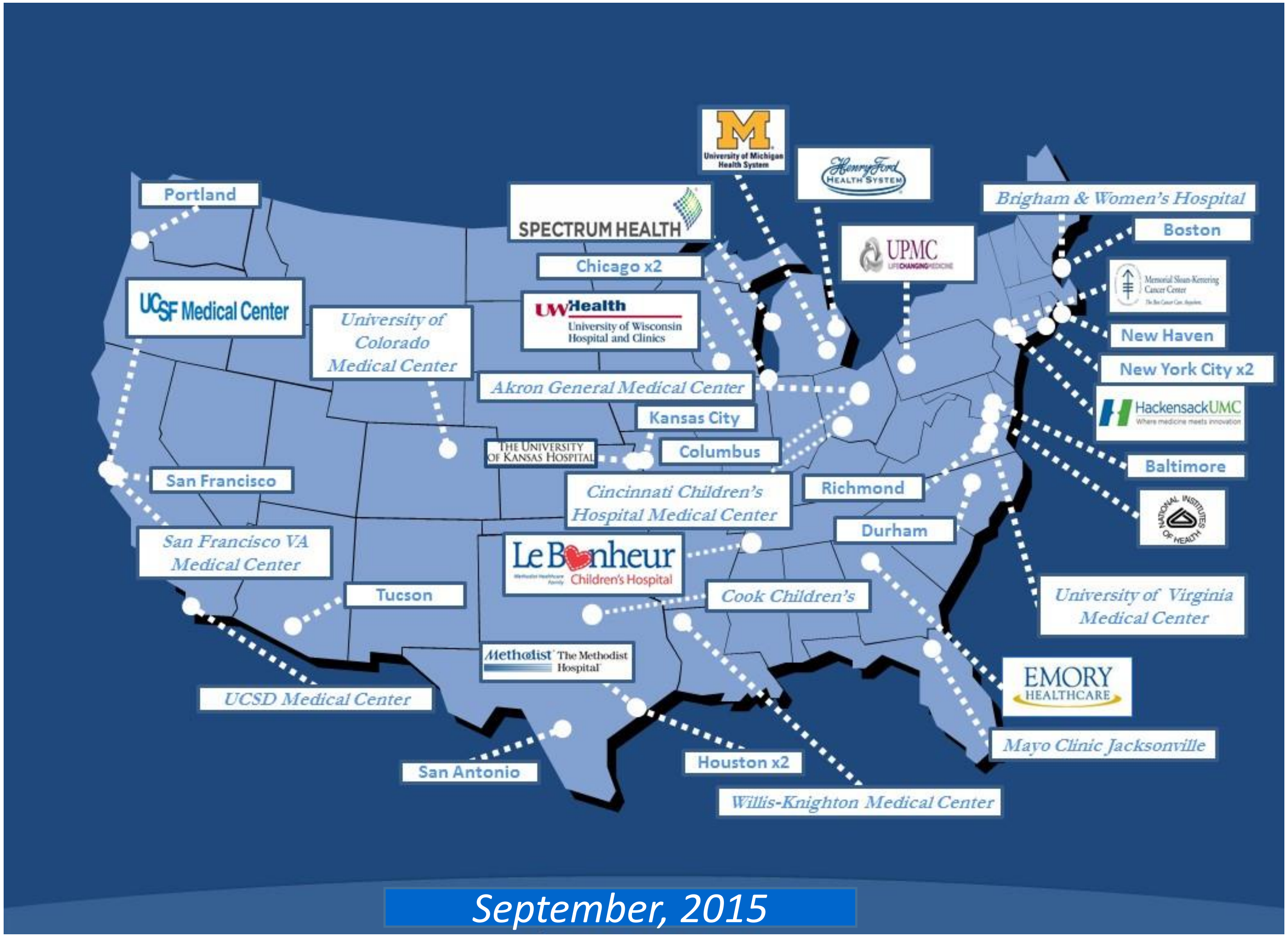
*Image courtesy of IMRIS, Inc.

Integrates with All Major Scanner Platforms

SIEMENS | PHILIPS | GE Healthcare | IMRIS | BrainSUITE

Growing the ClearPoint Footprint

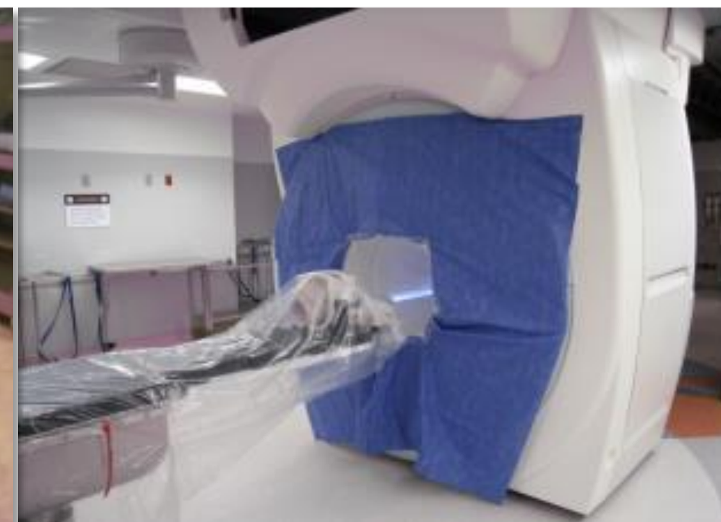
Installed Base of 39 sites in the US



ClearPoint® Neuro Navigation Draping System

CLEARPOINT

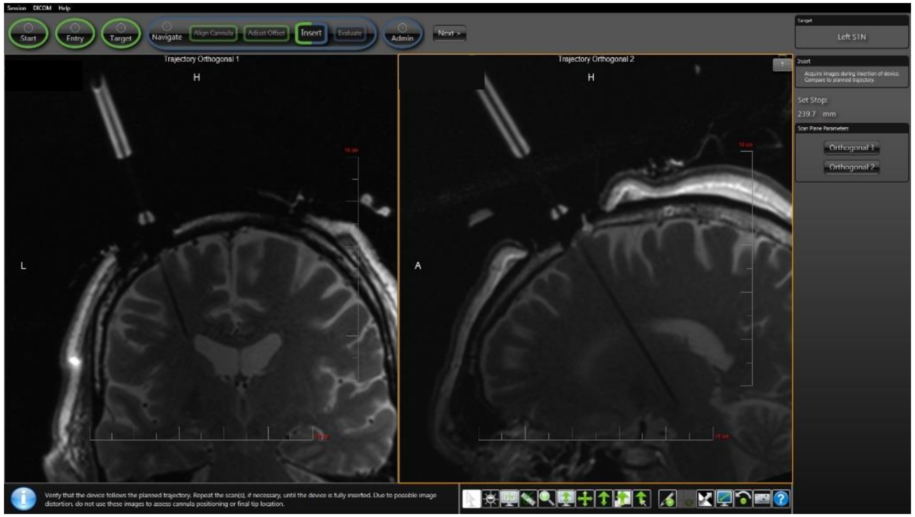
- The ClearPoint system has a variety of sterile drape configurations designed to be compatible with the most widely used MRI scanners.
- The ClearPoint sterile drape system received 510(k) clearance for use during surgical procedures conducted under MRI imaging.
- The ClearPoint drape provides a sterile covering between incision and MRI scanner.



ClearPoint® Neuro Navigation System

For Electrode Placement

CLEARPOINT



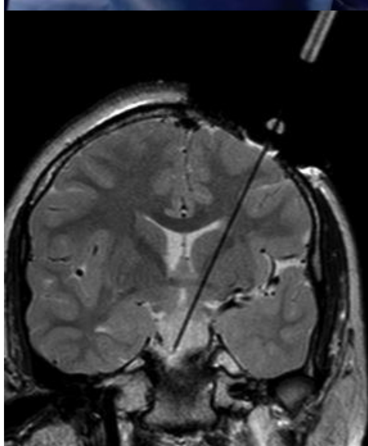
"Real-Time" Image Control

Frame-less anatomic targeting under real-time MRI Visualization enables:

- Patient to be under general anesthesia
- Corrections of intra-procedural Brain-Shift*
- Often single pass electrode placement
- Monitoring of hemorrhage
- Adjustments without the need re-register to historic images

**Pre-Op images cannot account for intra-procedural anatomic changes due to air or CSF leakage*

ClearPoint® Neuro Navigation System
For Laser Ablation

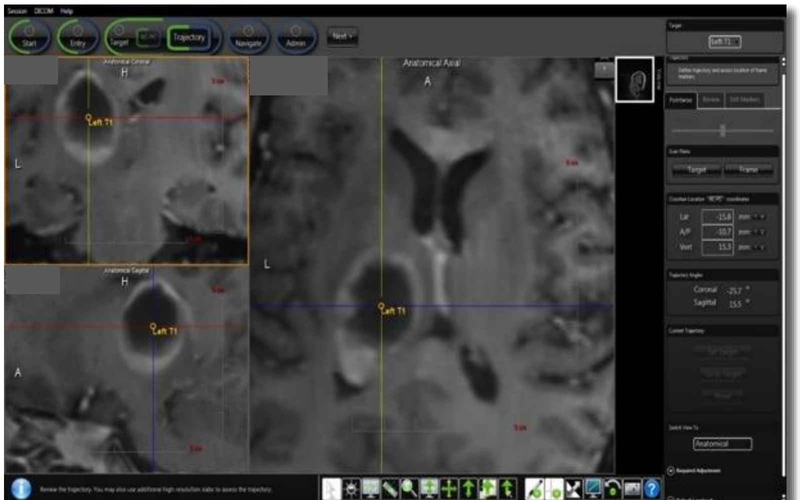


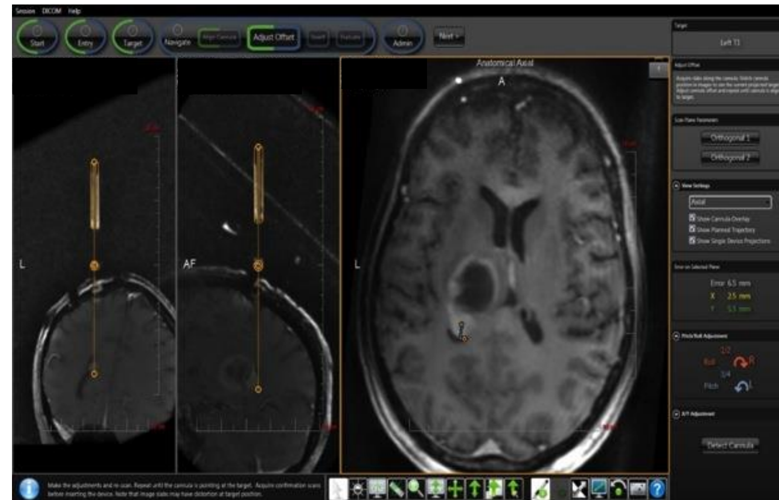
One procedure, One Room:

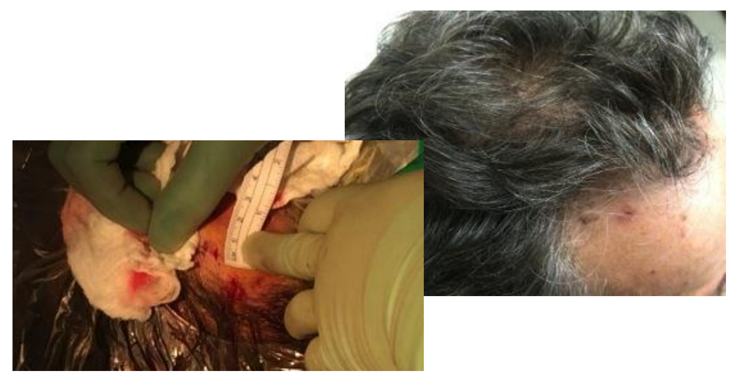
- Eliminate patient transport from the OR to the MR
- Reduce the risk of movement of the catheter in situ
- Reduce the risk of infection during transportation
- Reduce the risk of hemorrhage with real-time imaging control
- Reduce procedure time and laser catheter usage when multiple trajectories are required
- Combine biopsy and laser tumor ablation in the same setting
- Minimally Invasive

ClearPoint® Neuro Navigation System
For Biopsy

CLEARPOINT







Images courtesy of Dr. Clark Chen, UCSD

For Research including Drug Delivery

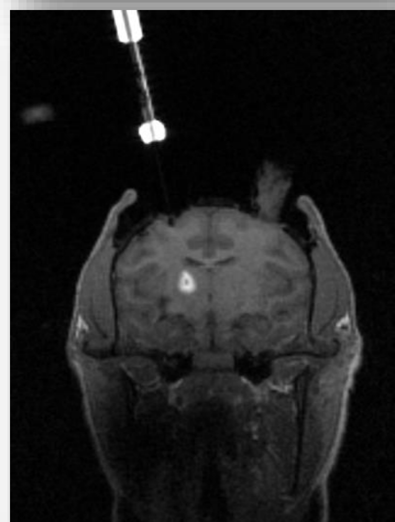
Clinical Research

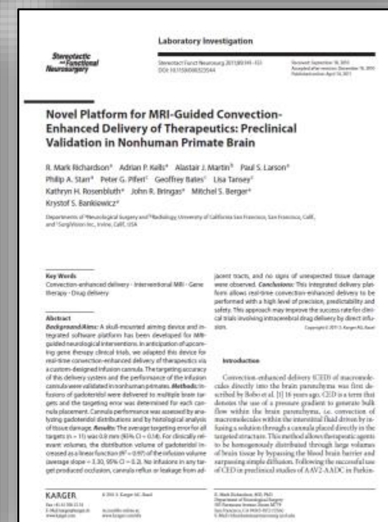
ClearPoint is being used in Six Phase I Investigational Drug Clinical Trials*

Preclinical Research

Preclinical research at UCSF, Emory, Colorado State, Oregon, UPMC and Northern Biomed

Fixation frames available for multiple large animal models (non-human primates, pigs, dogs, sheep)





Laboratory Investigation

Stereotactic and Functional Neurosurgery

Novel Platform for MRI-Guided Convection-Enhanced Delivery of Therapeutics: Preclinical Validation in Nonhuman Primate Brain

R. Mark Richardson, Adrian P. Kells, Alastair J. Martin, Paul S. Larson, Philip A. Starr, Peter G. Piferi, Geoffrey Bates, Lisa Tansey, Kathryn H. Rosenbluth, John R. Bringas, Mitchel S. Berger, Krystof S. Bankiewicz

Key Words

Abstract

Introduction

KARGER

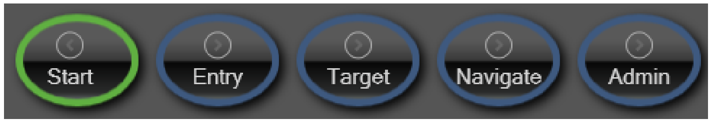
Seeing is Believing

*SmartFlow Cannula is approved for injection of Cyterabine or removal of CSF from the ventricles during intracranial procedures. Uses other than the approved indication are limited by Federal law to investigational use.

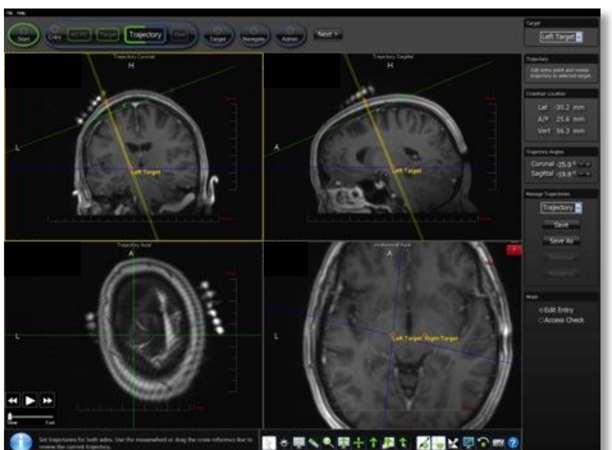
CLEARPOINT

Appendix

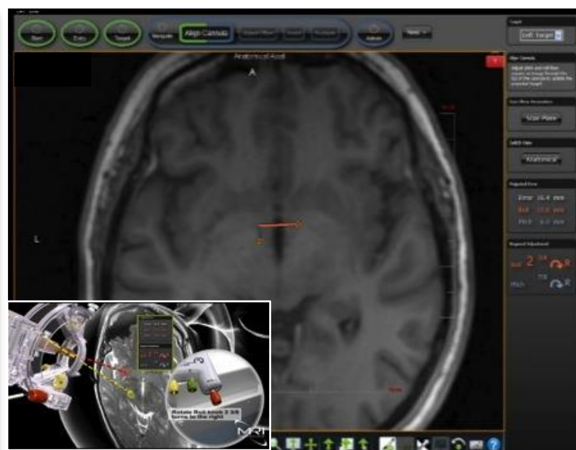
ClearPoint® Neuro Navigation Software



- Intuitive, menu-driven software for surgical planning, navigation to target and device delivery.
- Streamlined workflows and user flexibility simplify frameless stereotactic procedure.
- Using intraprocedure MR images and coordinates, the software provides navigational instruction to reach the target with a high degree of precision.



PLAN



NAVIGATE

DELIVER

Interventional MRI-Guided DBS
A Practical Atlas
Paul Larson and Others

This book is available for download with iBooks on your Mac or iOS device.

Description

This is a micro-textbook geared toward functional neurosurgeons, imaging scientists and others interested in MRI-guided DBS implantation using the ClearPoint system. Full of figures, animations and intraoperative videos, this hands-on surgical atlas is designed to teach both new and experienced teams who are looking to expand their expertise with ClearPoint. Detailed step-by-step descriptions of the procedure, MRI imaging protocols and numerous tips and pearls are provided by the group at the University of California, San Francisco, the originators of this technique.

What's New in Version 2.1
Version 2.1 has updated figures and a new MR Safety Checklist included in the supplemental materials.

Brain Shift During Neurosurgical Procedures

DOI: 10.3171/2014.3.JNS121312

Brain shift during bur hole–based procedures using interventional MRI

Clinical article

Michael E. Ivan, M.D.,[1] Jay Yarlagadda, M.D.,[2] Akriti P. Saxena, M.D.,[3] Alastair J. Martin, Ph.D.,[4] Philip A. Starr, M.D., Ph.D.,[1] W. Keith Sootsman, R.T., and Paul S. Larson, M.D.[1]

Departments of [1]Neurological Surgery and [4]Radiology, University of California, San Francisco, California; [2]Jefferson Medical College, Philadelphia, Pennsylvania; and [3]Internal Medicine Department, Tufts Medical Center, Boston, Massachusetts

Object. Brain shift during minimally invasive, bur hole–based procedures such as deep brain stimulation (DBS) electrode implantation and stereotactic brain biopsy is not well characterized or understood. We examine shift in various regions of the brain during a novel paradigm of DBS electrode implantation using interventional imaging throughout the procedure with high-field interventional MRI.

Methods. Serial MR images were obtained and analyzed using a 1.5-T magnet prior to, during, and after the placement of DBS electrodes via frontal bur holes in 44 procedures. Three-dimensional coordinates in MR space of unique superficial and deep brain structures were recorded, and the magnitude, direction, and rate of shift were calculated. Measurements were recorded to the nearest 0.1 mm.

Results. Shift ranged from 0.0 to 10.1 mm throughout all structures in the brain. The greatest shift was seen in the frontal lobe, followed by the temporal and occipital lobes. Shift was also observed in deep structures such as the anterior and posterior commissures and basal ganglia; shift in the pallidum and subthalamic region ipsilateral to the bur hole averaged 0.6 mm, with 9% of patients having over 2 mm of shift in deep brain structures. Small amounts of shift were observed during all procedures; however, the initial degree of shift and its direction were unpredictable.

Conclusions. Brain shift is continual and unpredictable and can render traditional stereotactic targeting based on preoperative imaging inaccurate even in deep brain structures such as those used for DBS.
(http://thejns.org/doi/abs/10.3171/2014.3.JNS121312)

Key Words • **brain shift** • **interventional MRI** • **deep brain stimulation** • **functional neurosurgery**

Frame-based and frameless stereotaxis are methods that can be used to access small targets in the brain through minimally invasive entry sites. These targets are then biopsied, ablated, injected, or electrically stimulated. Although the target size and location in each case is slightly different, accuracy is of the utmost importance. Error at any point during navigation, setup, registration, and surgery can produce less than accurate results.

Advances in image quality and registration techniques continue to improve accuracy and speed. Procedures that use preoperative images for targeting, however, are based on the assumption that the brain does not move with respect to external coordinate systems. This assumption is violated if shift or deformation of brain structures occurs after images are obtained.[19]

To date, brain shift during minimally invasive, bur hole–based procedures such as implantation of deep brain stimulation (DBS) electrodes and stereotactic brain biopsy is not well characterized or understood. Many studies of brain shift are difficult to generalize due to inconsistencies in craniotomy size, amount of lesion removed, patient position, and dosage of osmotic therapy. These variations make the already complex phenomena of brain shift even more difficult to analyze. In this study we use a novel method of comparing serial high-field interventional MR images in a group of patients undergoing DBS electrode placement to evaluate and understand brain shift in small bur hole–based procedures. Serial MR images were obtained before and at multiple time points after creation of a bur hole during MRI-guided electrode implantation with the patient's head rigidly fixed and immobile at the isocenter of a 1.5-T MRI scanner. This technique for analysis of brain shift minimizes many of the variables that exist in other studies. There is no brain retraction, osmotic therapy, lesion resection, or variation of patient positioning. Causes of brain shift in this study are limited to those associated with intracranial air entry (due to CSF loss or to equalization of intracranial and atmospheric

Abbreviations used in this paper: AC = anterior commissure; DBS = deep brain stimulation; GPi = globus pallidus internus; PC = posterior commissure; PD = Parkinson's disease; ROI = region of interest; STN = subthalamic nucleus; VR = Virchow-Robin.

This article contains some figures that are displayed in color online but in black-and-white in the print edition.

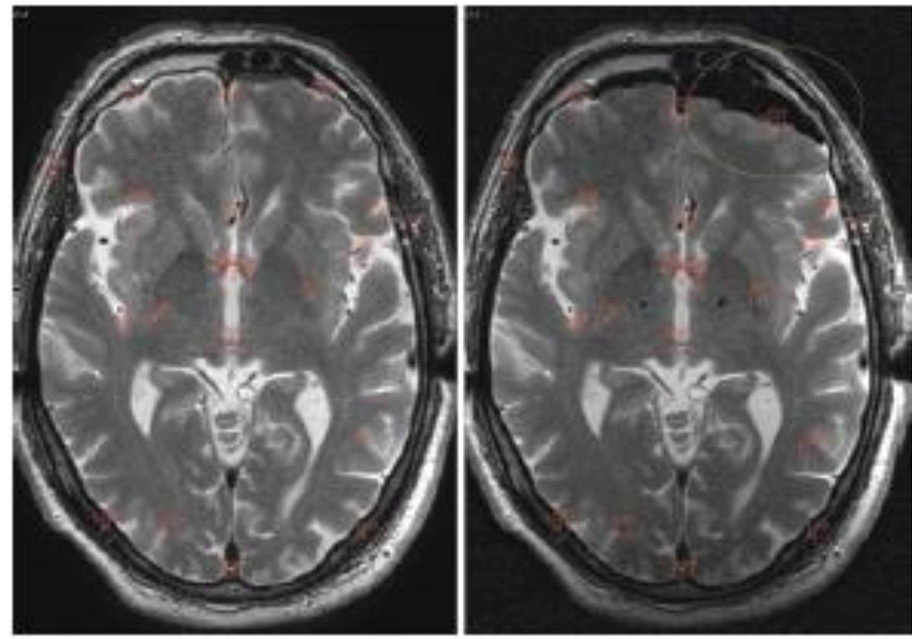


Fig. 1. Comparison of unique structures using ROIs. A T2-weighted axial MR image is obtained at 2 separate time points during surgery. On the **left** is the pre–electrode placement image used for targeting. On the **right** is the post–bilateral electrode placement image. Each *red outline* is a specific ROI identifying a structure used to calculated shift. Obvious shift can be noted in the left frontal lobe surface *(circled)*.

Michael E. Ivan, M.D., Jay Yarlagadda, M.D., Akriti P. Saxena, M.D., Alastair J. Martin, Ph.D., Philip A. Starr, M.D., Ph.D., W. Keith Sootsman, R.T., and Paul S. Larson, M.D.. Brain shift during bur hole–based procedures using interventional MRI. J. Neurosurg. 2014

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MRI Interventions ClearPoint Indications for Use (K142505):

The ClearPoint® System is intended to provide stereotactic guidance for the placement and operation of instruments or devices during planning and operation of neurological procedures within the MRI environment and in conjunction with MR imaging. The ClearPoint® System is intended as an integral part of procedures that have traditionally used stereotactic methodology. These procedures include biopsies, catheter and electrode insertion. The System is intended for use only with 1.5 and 3.0 Tesla MRI scanners.

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CLEARPOINT

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