Advances in Glioma Surgery: Brain Mapping, Individualized Fiber Tracking Signatures

Redefining “Maximal Safe Resection”

Steven Brem, M.D.
Professor and Chief, Neurosurgical Oncology
Department of Neurosurgery
Hospital of the University of Pennsylvania
Steven.brem@uphs.upenn.edu

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Support - Disclosures

- RO1- NS096606 (Verma/Brem)
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- Synaptive
- Tocagen
- Arbor Pharmaceuticals
- Northwest Biotherapeutics
- Novocure
Increase in GBM Survival Since 1999

Patient with a Left Temporal Glioblastoma: Use of Awake Craniotomy, Brain Mapping, and Fiber Tractography (DTI) to Maximize Safe Resection

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**Case Presentation K.D.**  
**MRN: 451722672**

- 48 yo RH male, 7/2016, witnessed, first-onset seizure, fell OOB,
  - Minor TBI, treated for a concussion, MRI shows ill-defined left temporal mass
  - Started on Keppra, treated by neurologist (Dr. H.H.), EEG- epileptiform discharges, reported episodes of déjà vu, transitioned from Keppra to Lamictal
  - Follow-up MRI in 9/2016 showed progression and patient was referred to HUP for awake craniotomy, cortical mapping, DTI, and supratotal resection of Contrast-enhancing tissue
K.D. – Preoperative Tractography/Planning
Surgical Planning - Includes C.E. + FLAIR + DTI

Planning per Dr. P. Koch
Cortical Mapping
Tumor Resection - Microscope-Navigation Merged
Tumor Resection- Entering the Ventricle
Cortical and Subcortical Stimulation Points
POD #1 - MRI
Use of DTI to Maximize Safety and Extent of Resection for Malignant Brain Tumors

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Use of diffusion tensor imaging in glioma resection

KALIL G. ABDULLAH, M.D.,1 DANIEL LUBELSKI, B.A.,2 PAOLO G. P. NUCIFORA, M.D., PH.D.,3 AND STEVEN BREM, M.D.1

1Department of Neurosurgery; 2Department of Radiology, Section of Neuroradiology, Hospital of the University of Pennsylvania, Philadelphia, Pennsylvania; and 3Cleveland Clinic Lerner College of Medicine, Cleveland, Ohio
**Individualized Map of White Matter Pathways: Connectivity-Based Paradigm for Neurosurgical Planning**

**BACKGROUND:** Advances in white matter tractography enhance neurosurgical planning and glioma resection, but white matter tractography is limited by biological variables such as edema, mass effect, and tract infiltration or selection biases related to regions of interest or fractional anisotropy values.

**OBJECTIVE:** To provide an automated tract identification paradigm that corrects for artifacts created by tumor edema and infiltration and provides a consistent, accurate method of fiber bundle identification.

**METHODS:** An automated tract identification paradigm was developed and evaluated for glioma surgery. A fiber bundle atlas was generated from 6 healthy participants. Fibers of a test set (including 3 healthy participants and 10 patients with brain tumors) were clustered adaptively with this atlas. Reliability of the identified tracts in both groups was assessed by comparison with 2 experts with the Cohen κ used to quantify concurrence. We evaluated 6 major fiber bundles: cingulum bundle, fornix, uncinate fasciculus, arcuate fasciculus, inferior fronto-occipital fasciculus, and inferior longitudinal fasciculus, the last 3 tracts mediating language function.

**RESULTS:** The automated paradigm demonstrated a reliable and practical method to identify white matter tracts, despite mass effect, edema, and tract infiltration. When the tumor demonstrated significant mass effect or shift, the automated approach was...
A multi-modal parcellation of human cerebral cortex

Understanding the amazingly complex human cerebral cortex requires a map (or parcellation) of its major subdivisions, known as cortical areas. Making an accurate areal map has been a century-old objective in neuroscience. Using multi-modal magnetic resonance images from the Human Connectome Project (HCP) and an objective semi-automated neuroanatomical approach, we delineated 180 areas per hemisphere bounded by sharp changes in cortical architecture, function, connectivity, and/or topography in a precisely aligned group average of 210 healthy young adults. We characterized 97 new areas and 83 areas previously reported using post-mortem microscopy or other specialized study-specific approaches. To enable automated delineation and identification of these areas in new HCP subjects and in future studies, we trained a machine-learning classifier to recognize the multi-modal ‘fingerprint’ of each cortical area. This classifier detected the presence of 96.6% of the cortical areas in new subjects, replicated the group parcellation, and could correctly locate areas in individuals with atypical parcellations. The freely available parcellation and classifier will enable substantially improved neuroanatomical precision for studies of the structural and functional organization of human cerebral cortex and its variation across individuals and in development, aging, and disease.
Effect of Edema on FA Value

Johansen-Berg H et al., Diffusion MRI, 2009
The influence of maximum safe resection of glioblastoma on survival in 1229 patients: Can we do better than gross-total resection?

*Yan Michael Li, MD, PhD,1,2 Dima Suki, PhD,1 Kenneth Hess, PhD,3 and Raymond Sawaya, MD1
Cytoreductive surgery is a pre-requisite to prolong survival in GBM.

Supratotal resection: survival effects exceed that of age, KPS, or tumor volume.

Sub-Pial Technique

Eskenazi Y, et al. Survival advantage of “supra-total” resection of glioblastoma using selective cortical mapping and the subpial technique, Neurosurgery, 2017
Sub-Pial Technique – H.U.P.

- 69 y.o. male (former Congressman), s/p right frontal craniotomy on 7.1.16, following a MVA and seizure, s/p GTR and Stupp protocol, path: AA (WHO III), IDH1-R132H negative, 1p/19q not deleted, EGFR strong, p53 positive in a subset, MGMT unmethylated, right parietal lesion detected in angular gyrus.

Acknowledgment: Dr. Nik Nayak
Extent of Resection Translates to Survival

3- Zone Tumor Model