

Connectomic Analysis :
Visualization and Analysis of Brain Networks
in Magnetic Resonance Imaging

ICD-10 Coordination and Maintenance Committee Meeting

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THE HIDDEN BURDEN OF CRANIOTOMY SURGERY

2M+

Patients who must undergo brain tumor resection surgery each year¹

37%

Percent of brain tumor surgeries that lead to postoperative brain network deficits²

93%

Percent of brain tumor cases in which non-traditional eloquent networks are affected or at risk³

¹ Dewan MC, Rattani A, Fieggen C, et al. Global neurosurgery: the current capacity and deficit in the provision of essential neurosurgical care. Executive Summary of the Global Neurosurgery Initiative at the Program in Global Surgery and Social Change [published online ahead of print, 2018 Apr 1]. *J Neurosurg*. 2018;1-10. doi:10.3171/2017.11.JNS171500

² Zetterling M, Elf K, Semnic R, Latini F, Engström ER. Time course of neurological deficits after surgery for primary brain tumours. *Acta Neurochir (Wien)*. 2020;162(12):3005-3018. doi:10.1007/s00701-020-04425-3

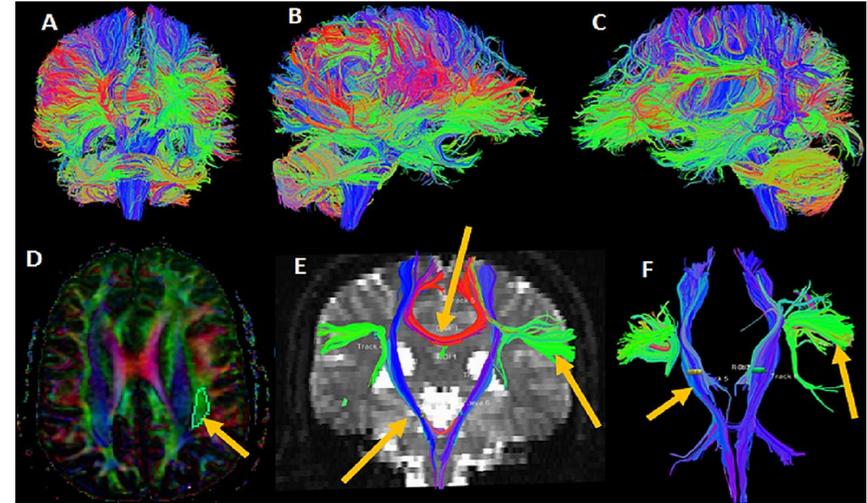
³ Morell AA, Eichberg DG, Shah AH, Luther E, Lu VM, Kader M, Higgins DM, Merenzon M, Patel NV, Komotar RJ, Ivan ME. Using machine learning to evaluate large-scale brain networks in patients with brain tumors: Traditional and non-traditional eloquent areas. *Neuro-Oncology Advances*. 2022 Jan;4(1):vdac142.

⁴ Popp AJ, Scrima T, Cohen BR, et al. Factors affecting profitability for craniotomy. *Neurosurg Focus*. 2002;12(4):1-5. doi:10.3171/foc.2002.12.4.5

⁵ Missios S & Bekelis, K. Drivers of hospitalization cost after craniotomy for tumor resection: creation and validation of a predictive model. *BMC Health Serv Res*. 2015;15(1):1-8. doi:10.1186/s12913-015-0742-2

LIMITATIONS OF CURRENT OPTIONS

Existing techniques do not provide adequately accessible information to preserve function beyond motor, language and vision. But we know that higher cognitive functions are equally important to a patient's QoL.



Soni N, Mehrotra A, Behari S, et al. (October 03, 2017) Diffusion-tensor Imaging and Tractography Application in Pre-operative Planning of Intra-axial Brain Lesions. Cureus 9(10): e1739. doi:10.7759/cureus.1739



Tractography

- Utility largely limited to corticospinal tract, Arcuate Fasciculus (AF), and Frontal Aslant Tract
- Can be confounded by edema



Task-based fMRI

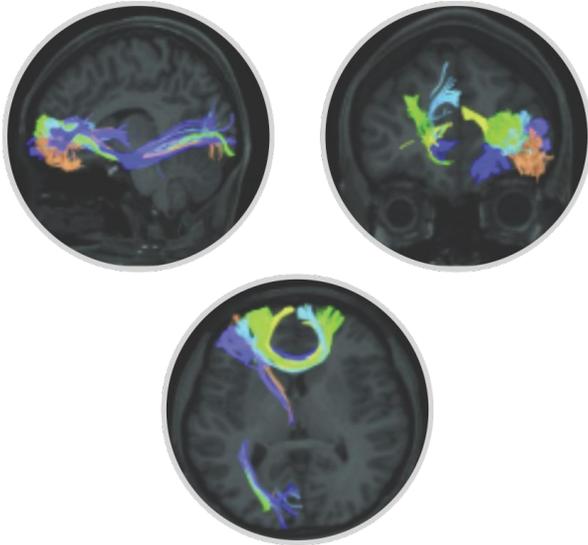
- Utility limited to functions that can be assessed by a technician, including vision and motor
- Requires patient compliance
- Displays only the part of the brain activated by the task (e.g., tongue movement is only one part of the motor cortex)



Intraoperative Cortical Mapping

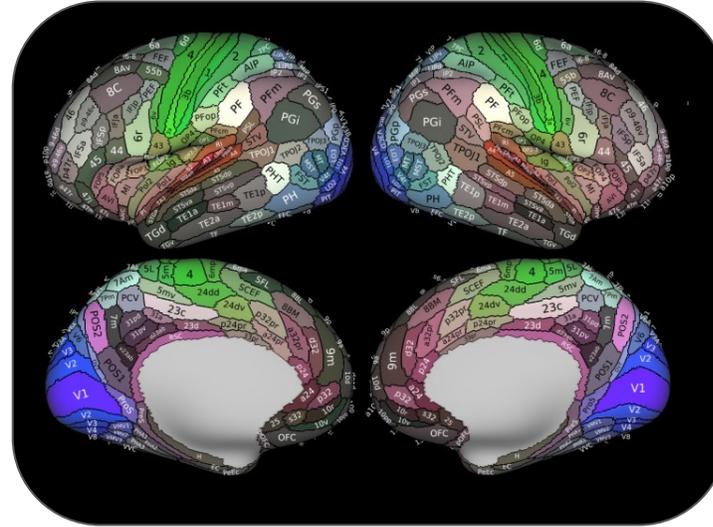
- Utility limited to functions that can be assessed intraoperatively, including language and motor
- Requires patient compliance

THE ROLE OF CONNECTOMICS



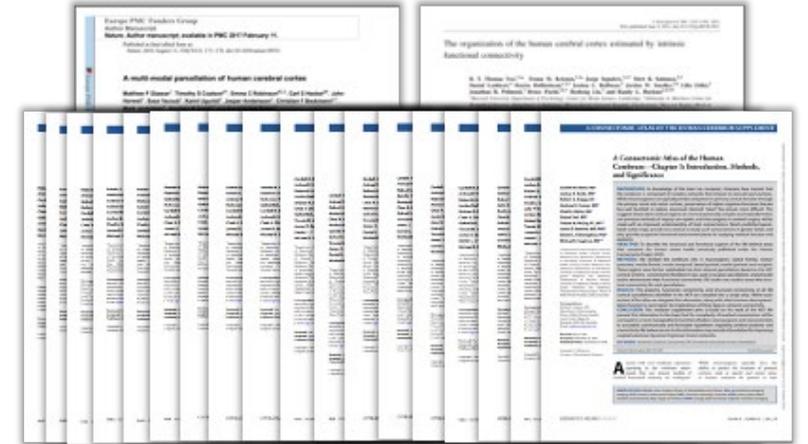
2009

The Human Connectome Project (HCP) commences history's most ambitious work on the brain yet



2016

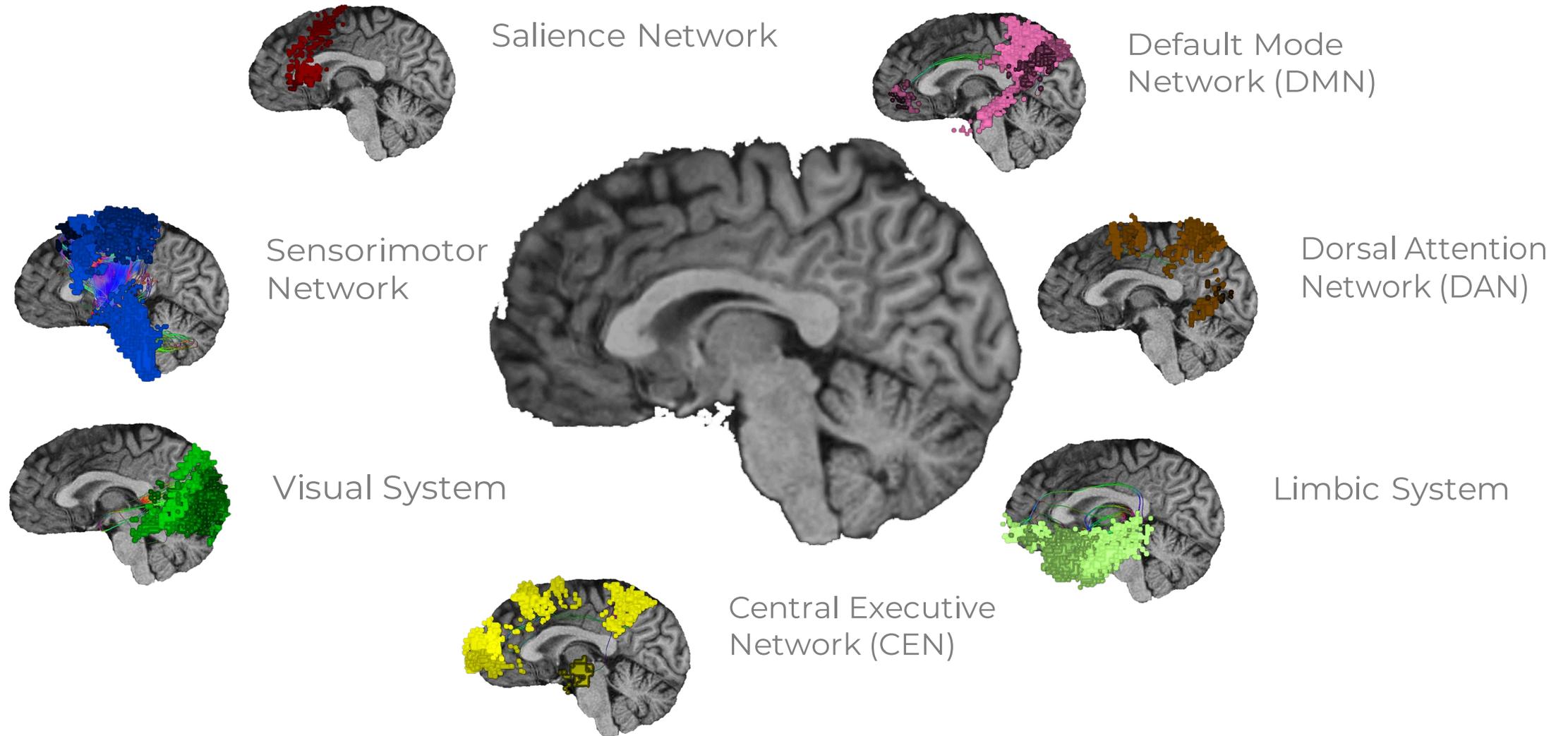
The HCP identifies 379 functional areas of the brain, opening the doors to further discussion and research on brain connectivity and function



2010s - 2020s

Extensive academic research gains further insight into the connections between these areas and how they relate to neurological deficit

BRAIN NETWORKS AS VISUALIZED IN QUICKTOME

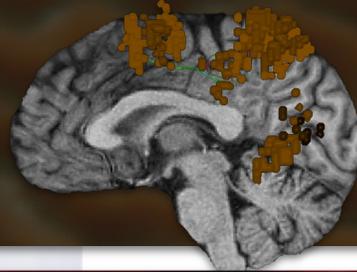


IMPACT TO THE **PATIENT**

Beyond “**eloquent**” regions, damaging brain networks reduces **functional independence**...



DORSAL ATTENTION NETWORK



Concentration, working memory, emotional expression and motivation.³

“I can’t... multi-task”

“I can’t... focus”

SALIENCE NETWORK



Pain and moral reasoning and is critical to **cognitive function.**²

“I can’t... stop overthinking”

“I can’t... control myself”

DEFAULT MODE NETWORK

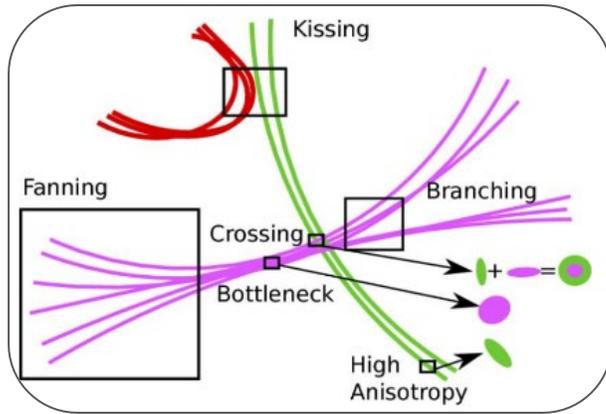


Memory, emotion, behavior, and control of the senses. Implicated in **dementia.**¹

“I can’t... remember”

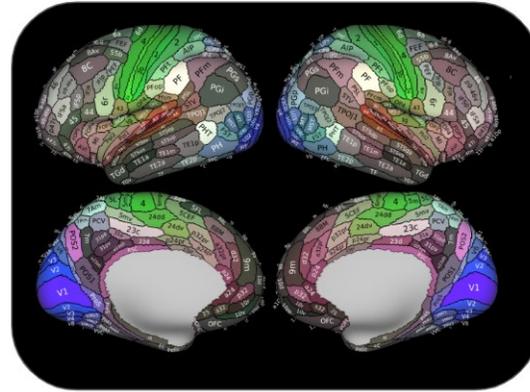
“I can’t... empathize”

HOW QUICKTOME WORKS



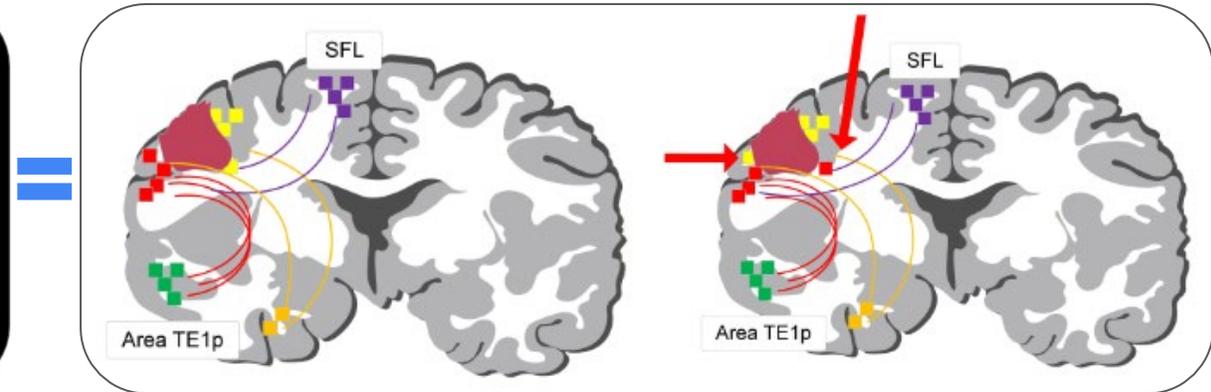
Constrained Spherical Deconvolution (CSD) Tractography

how areas of the brain are connected



Human Connectome Project (HCP)

definition of areas of the brain



Structural Connectivity Atlas

provides a refined location of areas (within a bounding box) in the face of anatomical changes in the brain - driven by patient-specific connectivity

THE EVIDENCE



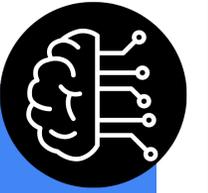
Useful in identifying functional regions at risk of damage during resection, and correlates to intraoperative language mapping findings.¹



Large scale brain network involvement has been found in a majority of brain tumor patients.^{2,3}



Cognitive deficits (n = 226, 41%), such as in attentional processing, memory, and executive functioning, are the most commonly identified outcomes of network disturbances⁴



Study of 364 Patients with Cavernous Malformations undergoing surgery found a decline in mRS (functional status) linked to cutting through networks as visualized in Quicktome (p=0.0025)⁵

¹ Shah HA, Ablyazova F, Alrez A, Wernicke AG, Vojnic M, Silverstein JW, Yaffe B, D'Amico RS. Intraoperative awake language mapping correlates to preoperative connectomics imaging: An instructive case. *Clin Neurol Neurosurg.* 2023 Jun;229:107751.

² Wu Z, Hu G, Cao B, Liu X, Zhang Z, Dadario NB, Shi Q, Fan X, Tang Y, Cheng Z, Wang X, Zhang X, Hu X, Zhang J, You Y. Non-traditional cognitive brain network involvement in insulo-Sylvian gliomas: a case series study and clinical experience using Quicktome. *Chin Neurosurg J.* 2023 May 26;9(1):16. doi: 10.1186/s41016-023-00325-4.

Dadario NB, Sughrue ME. Should Neurosurgeons Try to Preserve Non-Traditional Brain Networks? A Systematic Review of the Neuroscientific Evidence. *Journal of Personalized Medicine.* 2022; 12(4):587.

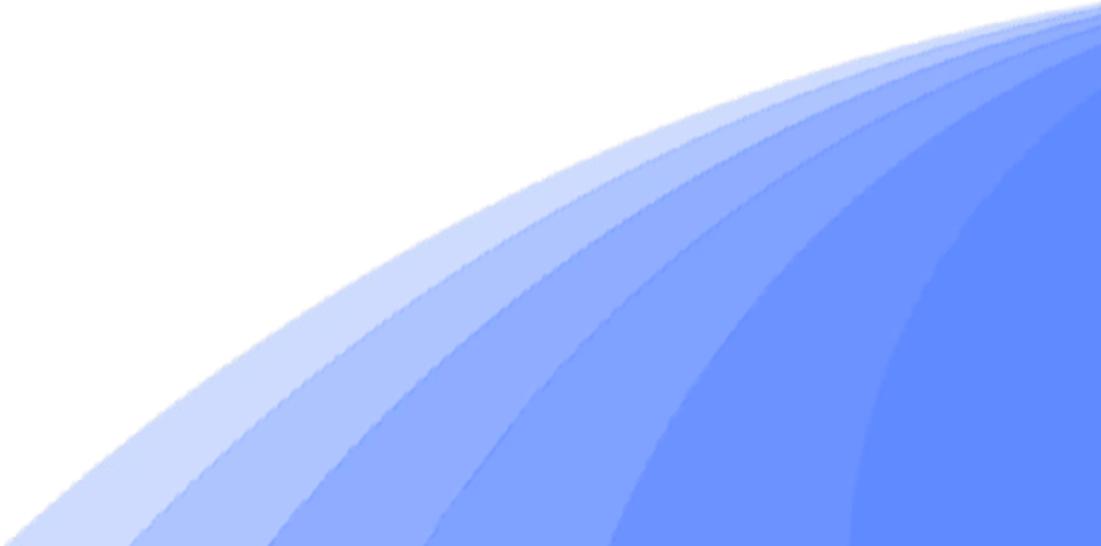
³ Morell AA, Eichberg DG, Shah AH, Luther E, Lu VM, Kader M, Higgins DMO, Merenzon M, Patel NV, Komotar RJ, Ivan ME. Using machine learning to evaluate large-scale brain networks in patients with brain tumors: Traditional and non-traditional eloquent areas. *Neurooncol Adv.* 2022 Sep 19;4(1):vdac142. doi: 10.1093/noajnl/vdac142.

⁴ Dadario NB, Sughrue ME. Should Neurosurgeons Try to Preserve Non-Traditional Brain Networks? A Systematic Review of the Neuroscientific Evidence. *Journal of Personalized Medicine.* 2022; 12(4):587.

⁵ SUBMITTED MANUSCRIPT: Hendricks B, Scherschinski L, Jubran J, Karahalios K, Benner D, Lawtown MT. Supratentorial Cavernous Malformation Surgery: The Seven Hotspots of Novel Cerebral Risk

SUMMARY

- Documentation of system use
 - Use is expected to be documented by the end user in either progress notes or an operative report
 - The end user is the clinician reviewing the connectomic information and performing the analysis and/or planning, and may include neurosurgeons, neurologists, oncologists, advanced practice nurses and others
 - The procedure may be performed in an inpatient or outpatient setting

 - There have been no adverse events reported with the use of Quicktome
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THANK YOU

