Surgery Within and Around Critical White Matter Tracts

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Subcortical Space

- Area of the brain below the cortical surface
- Critical white matter tracts
- Critical gray matter regions
- Traditional techniques to access these regions can be associated with significant morbidity
Critical White Matter Tracts

- 3 different types of tracts
  - Commissural
  - Projection
  - Association

<table>
<thead>
<tr>
<th>WHITE MATTER TRACT</th>
<th>FIBER CATEGORY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corona Radiata/Internal Capsule (CR/IC)</td>
<td>Projection</td>
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<tr>
<td>Optic Radiations (OR)</td>
<td>Projection</td>
</tr>
<tr>
<td>Superior Longitudinal Fasciculus (SLF)</td>
<td>Association</td>
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<tr>
<td>Inferior Longitudinal Fasciculus (ILF)</td>
<td>Association</td>
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<tr>
<td>Uncinate Fasciculus (UNC)</td>
<td>Association</td>
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<tr>
<td>Inferior Fronto-Occipital Fasciculus (IFO)</td>
<td>Association</td>
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<tr>
<td>Cingulate Fasciculus (CNG)</td>
<td>Association</td>
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<tr>
<td>Corpus Callosum (CC)</td>
<td>Commissural</td>
</tr>
<tr>
<td>Anterior Commissure (AComm)</td>
<td>Commissural</td>
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</tbody>
</table>
Corticospinal Tract

- Principle projection fibers of the cerebral hemisphere
- Largest projection fiber tract
- Consists of:
  - Corona radiata superiorly
  - Classic V-shaped capsule at level of basal ganglia
  - Crus cerebri in cerebral peduncle
Superior Longitudinal Fasciculus/Arcuate Fasciculus

- Lateral to ventricles and centrum ovale
- Indirect: SLF I-III, SLF-tp; Direct: AF
- Dorsal Stream
- Connects portions of frontal lobe with occipital and temporal areas
- Disruption can cause deficits in:
  - Language (phonetics/articulation/repetition)
  - Motor coordination
  - Visual spatial perception
Inferior Frontal-Occipital Fasciculus

- Connects orbital and frontopolar regions with ventromedial occipital cortex
- Ventral Stream
- Under insular region, deep to SLF, at level of external capsule
- Disruption can cause deficits in:
  - Language (semantics)
Inferior Longitudinal Fasciculus

- Connects temporal and occipital lobes
- Runs at level of optic radiation
- Fibers blend with the IFOF
- Involved in:
  - Object Recognition
  - Visual Agnosia
  - Prospagnosia
Other Tracts

- Left Frontal Aslant Tract
- Subcallosal Fasciculus
- Uncinate Fasciculus
- Superior Frontal-Occipital Fasciculus
- Middle Longitudinal Fasciculus
Why Does It Matter?

- Neurological exam not sensitive for detecting deficits
- Functional status is critical
- Every patient prior to surgery
  - Neuropsych testing
  - Goals of care discussion
  - DTI +/- fMRI
  - High resolution T2 MRI (axial/coronal)
General Approaches to Subcortical Brain Tumors

- Goal is to preserve eloquent cortical areas and white matter tracts
- Two methods:
  - 1) Identify and avoid these areas (i.e. awake mapping)
  - 2) Displace these tracts (i.e. parafascicular approach)

Chaichana et al, Neuro Oncol, 16 (1), 1113, 2014
Jackson et al. J Neurosurg, 78 (6), 588, 2017
Iyer et al. J Neurosurg, in press
Awake Brain Mapping

• Critical elements
  • Resection based on onco-functional boundaries
  • Real time evaluation of neurological function
  • Need to know what tracts/functions you are looking for

• fMRI
  • Coupling between neurological activity and blood flow
  • Cannot determine critical functions
  • Sensitivity (37.1%), Specificity (83.4%) (Kuchsinski et al, 2015)

• DTI
  • Diffusion of water along tracts
  • Diffusion properties altered with tumors
  • No agreement in construction (Pujol et al, 2015)
Awake Brain Mapping Protocols

- Prior to surgery
  - Neuropsych testing
  - Goals of care discussion
  - DTI +/- fMRI
  - High resolution T2 MRI (axial/coronal)
- During surgery
  - Asleep-Awake-Asleep Anesthesia
  - Ultrasound, Navigation
  - Mapping
  - +/- iMRI
- After surgery
  - SLP/PT
  - Neuropsych testing (3-6 months)
Awake Brain Mapping – Case 1

- CC: seizures
- HPI: 45 yo RH female college professor who presented with partial seizures
- PE: intact, neuropsych normal
- Concerning areas
  - Cortical: Broca’s, premotor, motor
  - Subcortical: SLF/AF, IFOF (anterior limb), FAT, caudate

Chaichana et al, Approaches to Brain Tumors, Elsevier, 2018, in press
Letters – ultrasound projection of tumor
1, 5, 8 – motor cortex/Broca’s (anarthria, facial twitching)
6, 7 – ventral premotor (articulation disturbances)
2, 3 – motor cortex (RH movement arrest)
4 – somatosensory (RH and face paresthesias)
47 – head of the caudate (perseveration)
48 – IFOF (semantic paraphasia)
49 – FAT (speech initiation problems)
50 – SLF (articulation)
Awake Brain Mapping – Case 1

- Pathology – IDH1+, 1p19q-
- Immediate postop – hesitancy with speech, dysarthria
- 2 weeks postop – intact exam
- 1 mo back to teaching
- 3 mo neuropsych – normal

Chaichana et al, Approaches to Brain Tumors, Elsevier, 2018, in press
Awake Brain Mapping – Case 2

- CC: seizures
- HPI: 49 yo RH male business owner who presented with partial seizures
- PE: intact, neuropsych normal
- Concerning areas
  - Cortical: Wernicke’s, motor
  - Subcortical: SLF (III, tp)/AF, IFOF
Letters – ultrasound projection of tumor
1, 2 – ventral premotor (articulation disturbances)
3 - complete anomia
48 – SLF (articulation difficulty)
49 – AF (phonological paraphasias, repetition)
50 – IFOF (semantic paraphasia)
Awake Brain Mapping – Case 2

• Pathology - IDH1-, 1p19q-
• Immediate postop – some comprehension difficulty
• 2 weeks postop – intact exam
• 1 mo – returned to work
• 3 mo neuropsych - normal

Chaichana et al, Approaches to Brain Tumors, Elsevier, 2018, in press
General Approaches to Subcortical Brain Tumors

- Goal is to preserve eloquent cortical areas and white matter tracts
- Two methods:
  1) Identify and avoid these areas (i.e. awake mapping)
  2) Displace these tracts (i.e. parafascicular approach)

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Jackson et al. J Neurosurg, 78 (6), 588, 2017
Iyer et al. J Neurosurg, in press
Traditional Approaches to Subcortical Brain Tumors

- Large craniotomy
- Extensive white matter dissection
- Use of fixed retractor systems
- Potential sources of injury
  - White matter dissection
  - Tissue creep
  - Repetitive entry into resection site
  - Ischemia induced by retraction

Concept of Minimally Disruptive Approaches

- Trans-sulcal vs. Trans-gyral
- Displacement of white matter tracts (<15 mm)
- Tubular retractors
  - Circumferential retraction
  - Protected corridor for dissection and resection

Use of Tubular Retractors is an Old Concept


The stereotaxic retractor in computer-assisted stereotaxic microsurgery

Technical note

Patrick J. Kelly, M.D., Stephan J. Goerss, B.S., and Bruce A. Kall, M.S.

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Variety of Tubular Retractors

- Peel-away catheters (12F, 14F, 17F)
- Viewsite™
- BrainPath™
Peel-Away Catheters

• Advantages
  No brain retraction
  Minimal collateral damage

• Disadvantages
  Requires endoscope
  Limited degree of freedom
  Limited number of instruments
  Hemostasis
  Cavity-based surgeries
Colloid Cyst with Peel-Away Catheters

- 22 year-old female with history of colloid cyst that increased in size on serial imaging from 3 mm to 8mm, with increase in headaches.
- Right frontal, trans-cortical approach
Colloid Cyst with Peel-Away Catheters
Colloid Cyst with Peel-Away Catheters

- Final pathology: colloid cyst
- Discharged to home on POD 1
BrainPath™ Tubular Retractor

- **Advantages**
  - Circumferential retraction
  - Trans-sulcal or gyral
  - Minimal collateral damage
  - Microscope or exoscope

- **Disadvantages**
  - Limited to 13.5 mm aperture
  - Limited instruments
  - Limited degree of freedom
Exoscopic Visualization
Surgical Adjuncts

- High resolution T2 axial and coronal MRI images
- Intraop navigation
- DTI/tractography
- Intra-operative monitoring
- Ultrasound
Tubular-Based Tumor Resection – Case 1

- CC: right UE/LE weakness
- HPI: 22 yo RH female presented with progressive right sided weakness
- PE: RUE/RLE 4-/5
- Concerning areas
  - Cortical: Broca’s, motor
  - Subcortical: SLF/AF, IFOF (anterior limb), FAT, internal capsule

Iyer et al, J Neurosurg, 2018, in press
Tubular-Based Tumor Resection – Case 1

Chaichana et al, JNS-A, 178, 2017
Iyer et al, J Neurosurg, 2018, in press
Pathology: Glioblastoma (MGMT+/IDH-)
Disposition: Home on POD 3 (18 months out without recurrence), neuro intact
6 mo – competing in archery competitions

Tubular-Based Tumor Resection – Case 1

Chaichana et al, JNS-A, 178, 2017
Iyer et al, J Neurosurg, 2018, in press
CC: right weakness
HPI: This is a 53 year-old RH male presented with progressive right upper and lower extremity weakness.
PE: 1/5 RUE/RLE
Concerning areas:
  - Cortical: motor cortex, sensory cortex
  - Subcortical: SLF/AF, IFOF, thalamus, basal ganglia, internal capsule

Chaichana et al, JNS-A, 178, 2017
Iyer et al, J Neurosurg, 2018, in press
Tubular-Based Tumor Resection – Case 2

- Pathology: glioblastoma (MGMT-/IDH-)
- Post-op 4/5 strength, discharged to home on POD 3
- No recurrence at 7 months, slight left drift

Chaichana et al, JNS-A, 178, 2017
Iyer et al, J Neurosurg, 2018, in press
Tubular-Based Tumor Resection – Case 3

- **CC:** left sided weakness
- **HPI:** This is a 32 yo RH male presented left hemiparesis
- **PE:** LUE/LLE 1-2/5
- Concerning areas:
  - Cortical: motor cortex, sensory cortex
  - Subcortical: CST

Tubular-Based Tumor Resection – Case 3

- Pathology: GBM
- Disposition: Neuro intact, Discharged to home on POD3
- No recurrence at 8 months
CC: persistent emesis

HPI: This is a 49 yo female who presented with persistent nausea and vomiting on two previous occasions from two hemorrhages of a right middle cerebellar peduncle cavernoma

PE: neuro intact except right facial (HB1-2/6) and CNVI weakness
Tubular-Based Tumor Resection – Case 4
Tubular-Based Tumor Resection – Case 4

- Pathology: cavernoma
- Disposition: Neuro intact, discharged to home on POD2
BrainPath Brain Tumor Case Totals - 53

- Surgery
  36 resections
  17 excisional biopsies

- Locations
  Thalamus/basal ganglia - 24
  Centrum semiovale/white matter tracts - 16
  Optic pathways 4
  Deep cerebellar nuclei – 8

- Pathology
  GBM/AA - 30
  Metastatic - 10
  Low grade glioma - 2
  Cavernoma - 8
  Other - 2

- Outcomes
  Improved - 39
  Stable – 10
  Worsened – 3 (2 transient)
Conclusions

• Neurological function beyond the standard neurological exam is important to preserve
• Need to understand where the white matter tracts are and what they do
• You can either identify and avoid, or work around or displace these tracts
• Critical to be able to do both, which require a different set of tools