A Shift in Concepts: Approach

External
- Outside-in
- Convergent

Endonasal (endoscopic)
- Inside-out
- Divergent

- Remove or displace structures (remove tumor last)
- Brain retraction

- Minimal displacement (remove tumor first)
- No brain retraction

A Shift in Concepts: Resection

External
- 3D

Endonasal (endoscopic)
- “2D”

- En bloc possible
- Standard instrumentation
- Blind spots
- Vascular control
- Sequential teams

- Piecemeal resection
- Special instrumentation
- Look around corners
- Vascular control?
- Simultaneous teams

A Shift in Concepts: Reconstruction

External
- Dura: direct repair (“watertight”)
- Obliteration of sinuses
- Bone: titanium/ HAC

Endonasal (endoscopic)
- Dura: inlay/onlay grafts, mucosal flaps
- Drainage of sinuses
- Bone: no reconstruction

Evolution of Endoscopic Skull Base Surgery
Controversy

Open vs Endoscopic:
Access
Visualization
Complications
Morbidity
Oncological Control

Advantages of Endoscopic Techniques
- Improved visualization
  - Increased access
  - Complete tumor removal
  - Avoid complications?
- No external incision
- Decreased morbidity?
  - Brain, soft tissue, bone, nerves, vasculature
- Duration of surgery?

Sagittal Plane
- Transfrontal
- Transcribriform
- Transplanum
- Transsellar
- Transclival
- Transodontoid

Transfrontal Approach: Osteoma

Transcribriform Approach: Olfactory Schwannoma

Transfrontal Approach: Nasal Dermoid

PreOp
PostOp
Transplanum Approach:
Nasal Dermoid

PreOp

PostOp

Transfrontal + Transcribriform + Transplanum = “Craniofacial Resection”

Transplanum Approach:
Craniopharyngioma

Transsellar Approach:
Pituitary Tumor

PreOp

PostOp

Transsellar Approach:
Extrasellar Pituitary Tumor

Transclival Approach

• Superior: pituitary transposition
• Middle: mid-clivus
• Inferior: foramen magnum
Transclival Approach: clival chordoma

Pituitary Transposition

PreOp  
PostOp

TransOdontoid Approach
(Craniovertebral Junction)
- Basilar invagination with brainstem compression: rheumatoid pannus
- Access to tumors at the foramen magnum
- Trauma?

Limit of TransOdontoid Approach

- Inferior limit: body of C2 (nasionate line)

Coronal Plane

- Anterior (superior)
  - Supraorbital
  - Transorbital
- Middle
  - Medial cavernous sinus
  - Transpterygoid approach
  - Medial petrous apex
  - Contralateral transmaxillary
  - Lateral cavernous sinus
  - Meckel’s cave
  - Infra temporal fossa
- Posterior (inferior)
  - Transcondylar
  - Infratemporal
  - Parapharyngeal space

Anterior Coronal Plane: Supraorbital Approach

- PreOp

- PostOp
**Problem Areas**

- Petrous apex
- Middle fossa
- Parapharyngeal space

**Petrosus Apex:**

Infracochlear vs Endonasal

<table>
<thead>
<tr>
<th>EEA (n = 10)</th>
<th>TICA (n = 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superior PA</td>
<td>100%</td>
</tr>
<tr>
<td>Ant. Inferior</td>
<td>100%</td>
</tr>
<tr>
<td>Post. Inferior</td>
<td>90%</td>
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</table>

<table>
<thead>
<tr>
<th>Min</th>
<th>Max</th>
<th>Mean ± SD</th>
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<tbody>
<tr>
<td>EEA</td>
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<td>1.77</td>
</tr>
<tr>
<td>TICA</td>
<td>0.1</td>
<td>0.64</td>
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</table>

**Endoscopic Endonasal Approach to Petrous Apex**

- Lateral access limited by ICA
  - Skeletonization and lateralization of paraclival ICA
    - Risk of injury to ICA
  - Transpterygoid infrapetrous approach
    - Risk of injury to Eustachian tube; sacrifice of vidian nerve

**Augmented Endoscopic Approach to Petrous Apex:**

Contralateral Transmaxillary Corridor

Carl Snyderman, MD, MBA
Chirag Patel, MD
Paul Gardner, MD
Juan Fernandez-Miranda, MD
Eric Wang, MD

**Contralateral Transmaxillary Approach**

**New Approach: CTM Approach**

<table>
<thead>
<tr>
<th>Patient</th>
<th>EEA</th>
<th>CTM</th>
<th>Difference</th>
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<tbody>
<tr>
<td>1</td>
<td>42</td>
<td>30</td>
<td>12</td>
</tr>
<tr>
<td>2</td>
<td>40</td>
<td>32</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
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<td>4</td>
<td>43</td>
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<td>36</td>
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<td>42</td>
<td>5</td>
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<tr>
<td>9</td>
<td>48</td>
<td>43</td>
<td>5</td>
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</tbody>
</table>

**Contralateral Transmaxillary Corridor:**

An Extended Endoscopic Endonasal Approach to the Petrous Apex

Chirag R. Patel, MD; Eric W. Wang, MD; Juan C. Fernandez-Miranda, MD; Paul Gardner, MD; Carl H. Snyderman, MD, MBA

Center for Cranial Base Surgery, University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania, USA
CTM Approach

Limits of CTM Approach
- Superolateral
- Inferolateral

What are the Limits of Endoscopic Surgery?
- Age
- Pathology
- Blood loss
- Access (anatomy)
- Reconstruction
- Duration of surgery
- Complications
- Morbidity
- Training
- Resources

Anatomical limits of Endonasal Skull Base Surgery are vessels and nerves

Anatomical Limits: “Inoperable” Chordoma

<table>
<thead>
<tr>
<th>#</th>
<th>Age</th>
<th>Sex</th>
<th>Dx</th>
<th>Reconstruction</th>
<th>CTM</th>
<th>Flap</th>
<th>CSF leak</th>
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<tr>
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<td>F</td>
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<td>ITF</td>
<td>L</td>
<td>R</td>
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</tr>
<tr>
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<td>R</td>
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<tr>
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<td>L</td>
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</tr>
<tr>
<td>4</td>
<td>58</td>
<td>M</td>
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<td>L</td>
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<tr>
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<tr>
<td>11</td>
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<td>L</td>
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</tr>
<tr>
<td>12</td>
<td>43</td>
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<td>L</td>
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<td>NSF</td>
<td>R</td>
<td>R</td>
<td>no</td>
</tr>
</tbody>
</table>
Contraindications to Endoscopic Cranial Base Surgery

- Neural and vascular structures are superficial (have to be mobilized).
- Sacrifice or reconstruction of a major vessel
- Malignant tumors?
  - Invasion of orbit, superficial tissues.

Stage V Angiofibroma: combined transmaxillary and lateral orbitotomy approaches

Controversy

Are outcomes improved with endoscopic endonasal surgery?

Pituitary Adenomas

Transplanum Approach: Craniopharyngioma
Visual deterioration is 2x–5x more frequent in Transcranial than Endonasal approaches *

* Size comparison bias / Goal of surgery

### Recurrence of Chordoma after EEA

<table>
<thead>
<tr>
<th></th>
<th>Free of disease</th>
<th>Stable or decreased residual</th>
<th>Tumor progression</th>
<th>Deaths (due to disease progression)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary chordomas</td>
<td>21 (61%)</td>
<td>9 (29%)</td>
<td>1 (2%)</td>
<td></td>
</tr>
<tr>
<td>Recurrent chordomas</td>
<td>10 (40%)</td>
<td>4 (16%)</td>
<td>1 (20%)</td>
<td></td>
</tr>
<tr>
<td>Total (n=30)</td>
<td>31 (51.7%)</td>
<td>9 (15%)</td>
<td>1 (2.2%)</td>
<td></td>
</tr>
</tbody>
</table>

### Degree of Resection: Learning Curve

- **Tumor location – sagittal plane**
  - Upper clivus *: n=10, 40% vs. n=13, 62.3%
  - Middius *: n=1, 100% vs. n=6, 100%
- **Tumor location – coronal plane**
  - Midline Laminarized*: 94.9% vs. 75%
- **Tumor volume**
  - <20-30 cm³: 86% vs. 80%
  - >80 cm³: 66.7% vs. 60.7%
- **Primary Previously treated**
  - 92.6% vs. 43.6%

### CTM Approach: recurrent chordoma

- MRI: tumor in right lateral clivus with partial encasement of basilar artery and petrous ICA; extension to foramen rotundum and foramen ovale
- Surgery: Endoscopic transclival, right transpterygoid, left transmaxillary
  - CTM allowed access as far as the parapharyngeal ICA
  - Subtotal resection due to significant lateral extension of tumor
- Postop Imaging: near GTR with possible small residual along the left lateral margin of the clivus and jugular bulb (ipsilateral to the transmaxillary approach)
**Odontoid Resection: Indications**

- Basilar invagination with brainstem compression: rheumatoid pannus
- Access to tumors of the C-spine & foramen magnum
- Vertebrobasilar aneurysms
- Trauma

**Transnasal Endoscopic Odontoid Resection: Advantages**

- **Direct access**
  - Better visualization
  - Access to skull base
- **Less morbidity?**
  - Airway obstruction
  - Swallowing
  - Palatal insufficiency
  - Postoperative pain
- **Decreased cost**
  - Shorter hospitalization

**Conclusion**

*Endonasal surgery is better for:*
- Pituitary tumors
- Craniopharyngiomas
- Olfactory groove meningiomas*
- Petrous apex lesions
- Chordomas
- C1/C2 decompression

**Controversy**

*Vascular Surgery?*

**ArterioVenous Malformation**

4 year old girl with large clival AVM with intraosseus nidus

**Aneurysm: Vertebral Artery**
Controversy

Do endoscopic endonasal approaches have fewer complications than open skull base surgery?


- 1193 patients from 17 institutions
- Mortality: 5%
- Complications: 36%
  - Wound: 20%
  - CNS: 16%
  - Orbit: 2%
  - Systemic: 5%
- Risk factors: medical co-morbidity, prior RT, intracranial extent

Common
CSF Leak
Sinonasal
Unknown
CNS

“Almost Never”
Vascular Injury

Morbidity

Time Series Plot of CSF Leaks

Septal Flap Reconstruction
Nasoseptal flap reconstruction of high flow intraoperative cerebral spinal fluid leaks during endoscopic skull base surgery.
Zanation AM, Carrau RL, Snyderman CH, Germanwala AV, Gardner PA, Prevedello DM, Kassam AB
Am J Rhinol Allergy 23, 518–521, 2009

- 70 consecutive patients
  - High flow leaks
  - Septal flap reconstruction
- CSF leak in 5.7% (4/70)
  - All repaired endoscopically
  - Risk factors:
    - pediatric, large defects, RT

Extracranial Pericranial Flap
Conclusion

Reconstruction of large dural defects remains a challenge.

Reconstruction with vascularized tissue is preferred.

Course Participant Survey of Endonasal Carotid Artery Injuries

Nicholas R. Rowan, MD; Benita Valappil, MPH; Meghan T. Turner, MD; Juan Fernandez-Miranda, MD; Eric W. Wang, MD; Paul A. Gardner, MD; Carl H. Snyderman, MD, MBA

Frequency of Carotid Injury

*20% of course participants with at least 1 injury in 12 months
**UPMC: ICA Injury**

- 7 ICA injuries in 2015 ESBS (0.3%)
  - 2/660 injuries during pituitary surgery (0.3%)
  - Most injuries (5/7) involved the left ICA
  - Most common diagnosis: chondroid neoplasm (chordoma, chondrosarcoma; 3/7)
  - Most common site: paraclival (5/7)

- 4/7 injured ICAs were sacrificed
  - No neurologic deficits
  - One perioperative mortality
  - 1/3 preserved ICAs developed a pseudoaneurysm that was treated endovascularly.

**Predisposing Factors**

- Anatomical variations
  - Dehiscence of ICA
  - Variable pneumatization
  - Lateral septations
  - Tortuous ICA (acromegaly)

- Surgical difficulties
  - Scarring (prior surgery, RT, bromocriptine)
  - Tumor invasion of cavernous sinus

- Surgical mistakes
  - Aggressive instrumentation
  - Misdiagnosis of pseudoaneurysm
  - Monopolar electrocautery

**Recommendations: Management**

- Team surgery: maintain endoscopic view
- Focal packing with hemostatic material
- Maintain cerebral perfusion: *no hypotension*
- Focal bipolar electrocautery
- Interventional neuroradiology
  - Carotid stent
  - Permanent occlusion
- Cerebral perfusion study
  - Vascular bypass?

**Conclusion**

Carotid injuries are not increased with endonasal surgery.

Prevention is the best treatment.

**Controversy**

Does endoscopic endonasal surgery decrease neurocognitive morbidity?
“Axial changes (brain edema, contusion) were seen in 30% of patients in the first postoperative period (72 hours). Subsequently, extra-axial changes began to resolve but axial changes became more prevalent. After 6 months, only axial changes persisted (encephalomalacia).”

**Matched Pair Study: Olfactory Groove Meningiomas**

- University of Toronto & UPMC: 2003-2012
- Matching of EEA and Open
  - volume of tumor
  - timing of postoperative scan

**EEA**

<table>
<thead>
<tr>
<th>Post-Operative Imaging</th>
<th>Approach (p value)</th>
<th>Edema (p value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLAIR Signal</td>
<td>0.02</td>
<td>0.004</td>
</tr>
<tr>
<td>Porencephalic Cave</td>
<td>0.09</td>
<td>0.56</td>
</tr>
<tr>
<td>TOTAL CHANGE</td>
<td>0.02</td>
<td>0.01</td>
</tr>
</tbody>
</table>

EEA is associated with less flair change on postop MRI after adjusting for preop edema.

EEA is associated with less anatomic dead space (porencephalic cave).

Neurocognitive function?
Conclusion

If neurocognitive function is better with endonasal approach, it is the preferred approach.

Malignant Neoplasms

- Squamous cell carcinoma
- Adenocarcinoma
- Adenoid cystic carcinoma
- Nasopharyngeal cancer
- Chordoma
- Chondrosarcoma
- Hemangiopericytoma
- Melanoma
- Esthesioneuroblastoma
- Neuroendocrine carcinoma
- Sinonasal undifferentiated carcinoma (SNUC)

The endoscope provides additional treatment options…

- Complete oncolgical resection
- Debulking prior to radiochemotherapy
  - Relief of symptoms
  - Assess tumor extent
  - Modify RT ports?
  - Improved RT response?
- Palliation
- Salvage surgery

Endoscopic Resection of Sinonasal Neoplasms

- Is it technically feasible?
  - Anatomy
  - Instrumentation
- Can it be done safely?
  - Less morbidity
  - Different morbidities
- Are oncolgical outcomes comparable or better?

Conclusion

- 36 studies: 609 patients
- Open vs endoscopic:
  - No difference in locoregionl control and metastasis-free survival
  - Improved overall survival
    - All patients (p=0.01)
    - Kadish C/D (p=0.04)
    - Hyams III/IV (p=0.001)
  - Increased DSS
    - All patients (p=0.004)
    - Hyams III/IV (p=0.002)

Oncological principles are preserved.

Oncological results of endonasal surgery are equivalent.
A New Surgical Paradigm

“Every act of creation is first an act of destruction.”
Pablo Picasso

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