SURGICAL ANATOMY & APPROACHES TO BRAINSTEM GLIOMA
Introduction

- Brainstem comprises of-
  - Midbrain (Mesencephalon),
  - Pons and
  - Medulla

- Highly complex neural structure both anatomically and functionally

- Cranial nerve nuclei and numerous fascicles and pathways as well as reticular formation- all playing important roles in securing normal central nervous function and regulation of bodily homeostasis
**Historical considerations**

- Because of its difficult access and functional importance, in the past, the brainstem was seldom explored by neurosurgeons, with its injury often conducive to deep coma.

- For many years, a tumor growing inside the brainstem was considered malignant in itself and managed empirically as a homogeneous group with radiation therapy as well as adjunctive chemotherapy.
Historical considerations

- Bailey et al (1939) - ‘BSG are a hopeless problem for treatment’
- Dandy (1962) - ‘There is little indication for attempting any enucleation of the tumour in this region’
- Baker (1964) - published a series of pts with ‘subependymal gliomas’
- Pool (1968) - operated BSG, some of them having a long-term survival
Historical considerations

- Gradual advancement in microsurgical technique, sophisticated imaging technology, most importantly availability of MRI
- Identification of subcategories of tumours which appear to have low-grade pathologies and offer a better prognosis
- Different series on BSG since then
A Basal view of the brain stem

B Dorsal view of the brain stem, rhomboid fossa
Surgical anatomy - Dorsal aspect

- Floor of IV ventricle –
  - Rhomboid
  - Pons- rostral 2/3rd
  - Medulla- caudal 1/3rd
**SURGICAL ANATOMY-DORSAL ASPECT**

Three parts-

- Superior/ pontine
- Intermediate/ junctional
- Inferior / medullary part
- Median sulcus
- Sulcus limitans –
  - Median eminence (M)
  - Vestibular area (L)
- Median eminence -
  - Facial colliculus
  - Hypoglossal triangle
  - Vagal triangle
  - Area postrema
- Striae medullares

Rhoton
Brainstem glioma (BSG) - Epidemiology

- Approx. 1% of all primary brain tumours, 10-20% of pediatric brain tumours
- 75% occur in children, 25% in adults
- Median age at presentation - 6.5 yrs, adults - 3rd - 4th decade
- M=F
- Approx. 75% diffuse, 25% focal
- Most focal tumours occur in midbrain
- Pontine tumours are usually diffuse and high grade
# Brain Stem Tumour Classification System

<table>
<thead>
<tr>
<th>Author and Year</th>
<th>Method Used to Create System</th>
<th>Classification System</th>
</tr>
</thead>
</table>
| Epstein, 1985         | CT                           | Intrinsic  
|                       |                              | Diffuse                                
|                       |                              | Focal                                  
|                       |                              | Cervicomedullary                       
|                       |                              | Exophytic                              
|                       |                              | Anterolat into cerebellopontine angle  
|                       |                              | Posterior & into brachium pontine      
|                       |                              | Disseminated                           
|                       |                              | Positive cytological findings          
|                       |                              | Positive myleographic finding          |
| Epstein & McCleary, 1986 | CT, MRI, SURGICAL OBSERVATION | Diffuse                             
|                       |                              | Focal                                  
|                       |                              | Cerebellomedullary                     |
| Stroinket al, 1987    | CT                           | Group 1: dorsal exophytic glioma       
|                       |                              | Group 2: intrinsic brainstem tumours   
|                       |                              | 2a hypodense, no enhancement          
|                       |                              | 2b hyperdense, contrast enhancing, exophytic 
|                       |                              | Group 3: focal cystic tumour w/contrast enhancement 
|                       |                              | Group 4: focal intrinsic isodense lesion w/ contrast enhancement |
| Barkovich et al, 1990 | MRI                          | Location (midbrain, pons, medulla)    
|                       |                              | Focality (diffuse or focal)            
|                       |                              | Direction and extent of tumour growth  
<p>|                       |                              | Degree of brainstem enlargement        |</p>
<table>
<thead>
<tr>
<th>Study</th>
<th>Imaging Modality</th>
<th>Tumor Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albright, 1996</td>
<td>MRI</td>
<td>Exophytic growth, Hemorrhage and necrosis, Evidence of hydrocephalus, Focal (midbrain, pons, medulla), Diffuse</td>
</tr>
<tr>
<td>Fischbein et al., 1996</td>
<td>MRI</td>
<td>Midbrain, Diffuse, Focal, Tectal, Pons, Diffuse, Focal, Medulla, Diffuse, Focal, Dorsal exophytic</td>
</tr>
<tr>
<td>Choux et al., 2000</td>
<td>CT &amp; MRI</td>
<td>Type i: - diffuse, Type ii: - intrinsic, focal, Type iii: - exophytic, focal, Type iv: - cervicomedullary</td>
</tr>
</tbody>
</table>
## Brain stem tumour classification

<table>
<thead>
<tr>
<th>Type of brainstem glioma</th>
<th>Features</th>
<th>Comparison with other classifications</th>
<th>Surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intrinsic only</td>
<td>The tumour is well within the brainstem axis without any breech of parenchyma</td>
<td>Epstein et al. Focal (&lt;2cm), cervicomedullary Stroink et al. Group iii, iv Choux et al. Type ii, iv Tumour &gt;2cm could still be expanding variety ** based on contrast enhancement and radiology only, clinical features could not be taken into consideration *** based more on anatomical localization, clinical features not mentioned again.</td>
<td>Yes Radical excision</td>
</tr>
<tr>
<td>Expanding variety</td>
<td>• Well delineation on Gd-MRI • Slow progression of clinical symptoms (&gt;6 months) • Good preservation of motor function with independent daily living • Size may be &gt;2cm</td>
<td>Epsein et al: diffuse Stroink et al J1a Choux et al: type i Tumourlokin focal but &gt;2cm are still consider diffuse</td>
<td>No</td>
</tr>
<tr>
<td>Diffuse infiltrative variety</td>
<td>• No margin of delineation on Gd-MRI • Rapid progression of symptoms</td>
<td></td>
<td>No</td>
</tr>
<tr>
<td>Ventrally located</td>
<td>Pure ventral location</td>
<td>May be kept as focal in other classifications, but author prefer not to operate in view of difficult location ans associated high risk of complications.</td>
<td></td>
</tr>
</tbody>
</table>

Not that the classification for exophytic tumour is the same as proposed by earlier authors but has been included here to provide completeness.

BSG- Pathogenesis

- Molecular biology-
  - Mutation of p53, a tumour suppressor gene
  - Amplification of mutated EGFR gene
  - Trisomy 1q, deletion of chr 19

- NF – I -
  - More indolent course
Imaging

- CT-
  - Diffuse - hypodense lesion on NCCT that enlarge the pons (diffuse pontine hypertrophy) and displace IVth ventricle posteriorly, inhomogenous post-contrast enhancement
Imaging

CT-

- Focal midbrain tumours (tectal plate glioma) may not be seen on NC + CECT head, leading to a false diagnosis of late onset aqueductal stenosis.

- MRI is an accurate and noninvasive method of diagnosis that can be indicated in all cases of late onset hydrocephalus and aqueductal obstruction, especially in adults.
Imaging

MRI-

- Imaging modality of choice
  - Precise localization
  - Together with clinical picture, suggest the microscopic pathology of tumour, with a relatively high degree of probability
Imaging

MRI-

- Diffuse BSG-
  - Hypo on T1, hyper on T2, with hyperintensity extending into adjacent midbrain/medulla, inhomogenous contrast enhancement within or around the tumour
  - Contrast enhancement in only 1/3\(^{rd}\) cases
  - No significant difference in prognosis with/without contrast enhancement
Imaging

- MRI-
  - Focal BSG-
    - Well circumscribed, of limited size, may be partially cystic, without associated oedema/infiltration
    - Midbrain > Medulla > Pons
    - Hypo on T1, hyper on T2, nidus of focal enhancement
    - Usually pilocytic astrocytomas
Imaging

**MRI-**
- Dorsally exophytic
- BSG-
  - Intra-IVth ventricular
  - Resemble vermian astrocytoma with involvement of IVth ventricular floor
Practical decisions regarding treatment of BSG

MRI brain

- Diffuse lesion, (Usually pontine, high grade, clinically aggressive)
  - No need of biopsy
  - Steroids, CSF diversion if needed
  - DIRECT RT+CT

- Lesion not diffuse on MRI
  - Regardless of location, have a significant probability of being **low grade**
Practical decisions regarding treatment of BSG

Lesion not diffuse on MRI

- Cervico-medullary
  - Usually low grade, Astrocytoma & ganglioglioma
  - Radical surgery

- Focal midbrain, Tectal plate
  - ETV ± Biopsy
  - Periodic followup

- Focal medullary
  - Upto 50% low grade astrocytoma
  - Surgery may be considered weighing the risks

- Cystic
  - Usually pilocytic astrocytoma
  - Cyst decompression With radical excision of nodule

- Dorsally exophytic
  - Usually low grade, astrocytoma
  - Surgical excision flush with IV th ventricular floor
<table>
<thead>
<tr>
<th>Location</th>
<th>Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dorsal midbrain (tectum mesencephalii)</td>
<td>Supracerebellar infratentorial</td>
</tr>
<tr>
<td>Ventral midbrain</td>
<td>Pterional trans-sylvian</td>
</tr>
<tr>
<td>Lateral midbrain</td>
<td>Subtemporal transtentorial</td>
</tr>
<tr>
<td>Ventrolateral pons (cerebellopontine angle)</td>
<td>Retromastoid retrosigmoid</td>
</tr>
<tr>
<td>Dorsal pons and medulla oblongata</td>
<td>Midline suboccipital transventricular</td>
</tr>
<tr>
<td>Lower medulla oblongata &amp; cervicomedullary junction</td>
<td>Midline suboccipital &amp; c1 laminectomy</td>
</tr>
</tbody>
</table>
Intraoperative monitoring

- Cranial nerves-
  - EMG monitoring – III, IV, V, VI, VII, IX, X, XI, XII
  - BAEP
- SSEP and MEP
Anaesthesia for brainstem surgery

- Multimodal monitoring – SpO2 & EtCO₂ monitoring, CVP line, arterial line, trans-esophageal echocardiography, etc.
Anaesthesia for brainstem surgery

- During brain stem surgery, traction of cranial nerves and stimulation of nuclei and connecting pathways may cause severe alterations in blood pressure and heart rate, sudden respiratory drive despite the surgical level of anesthesia.

- Extreme bradycardia and ventricular arrhythmia can be life-threatening and must be treated promptly by immediate interruption of surgical stimulation before any pharmacological intervention.
Surgical technique-

- Almost all BSTs are dorsally located, therefore should be approached through posterior fossa
- Position-prone(preferred)/sitting
- Midline skin incision
- Suboccipital craniotomy±cervical laminotomy
- Y –shaped dural opening
Surgical technique-

- Vermis coagulated and split at appropriate level
- Cerebellum held to the sides using self-retaining retractors (avoid excessive side retraction – pseudobulbar palsy)
- IV\textsuperscript{th} ventricle approached after division of medullary velum
Surgical technique-

- Pontine - bulge in IVth ventricular floor
- Medullary- medulla will be ballooned
- Midbrain - precentral cerebellar vein and arachnoid over vein of galen complex may need to be divided
Safe entry zones to brainstem - Rationale

- The brain stem is densely composed of important neural structures such as nuclei and neural tracts.

Causes of morbidity following brainstem surgery:
- Direct damage during removal of the lesion,
- Selection of an entry route into the brain stem, and
- The direction of brain stem retraction.

In most cases, the optimal surgical route can be established by use of the 2-point method, in which an imaginary line drawn from the center of the lesion to the point nearest the surface of the brain defines the least disruptive approach.

Where critical neural structures are sparse and no perforating arteries are present.
Safe entry zones to brainstem

- **Suprafacial triangle**-
  - MLF medially,
  - VII nerve caudally
  - SCP & ICP laterally

- The brain stem can be retracted either *laterally* or *rostrally* with relative safety

Safe entry zones to brainstem

- **Infrafacial triangle**
  - MLF medially,
  - Striae medullares caudally,
  - Facial nerve laterally

- The brain stem can be retracted only laterally
## Structures potentially damaged by brainstem retraction

<table>
<thead>
<tr>
<th>Position relative to surgery</th>
<th>Superficial triangle</th>
<th>Interfacial triangle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Structure</td>
<td>Symptom</td>
</tr>
<tr>
<td>Lateral</td>
<td>Superior cerebellar peduncle</td>
<td>Hemiataxia</td>
</tr>
<tr>
<td></td>
<td>Trigeminal nuclei</td>
<td>Sensory motor impairment of face</td>
</tr>
<tr>
<td>Medial</td>
<td>MLF</td>
<td>Gaze palsy, nystagmus</td>
</tr>
<tr>
<td>Rostral</td>
<td>Sup. Cerebellar peduncle 3rd &amp; 4th nerves and nuclei</td>
<td>Hemiataxia</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Occulomotor &amp; trochlear palsy</td>
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<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caudal</td>
<td>Nucleus of 6th nerve PPRF</td>
<td>Abducces palsy Lateral gaze palsy Facial nerve palsy</td>
</tr>
<tr>
<td></td>
<td>Facial nerve</td>
<td></td>
</tr>
<tr>
<td>Ventral</td>
<td>Mediallemniscus</td>
<td>Ataxia, depth perception impairment Analgesia, thermanesthesia Motor impairment</td>
</tr>
<tr>
<td></td>
<td>Lateral spinothalamic tract</td>
<td></td>
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<tr>
<td></td>
<td>Corticospinal tract</td>
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</tbody>
</table>
Safe entry zones to brainstem - Anterolateral aspect

- Midbrain - lateral mesencephalic sulcus
- Pons - peritrigeminal area
- Medulla - retro-olivary sulcus

Recalde R.
MICROSURGICAL ANATOMY OF THE SAFE ENTRY ZONES ON THE ANTEROLATERAL BRAINSTEM RELATED TO SURGICAL APPROACHES TO CAVERNOUS MALFORMATIONS.
Tumour decompression

- Conventional suction technique frequently causes brainstem dysfunction manifested by bradycardia & arrhythmia.

- CUSA causes movement of adjacent structures only within 1mm of vibrating tip, allowing for extensive and quick dissection adjacent to or within the substance of brainstem.
Surgical technique - Focal tumour

- Essential that rostral & caudal pole of the tumor be completely exposed
- Incise the lower vermis to obtain adequate separation of tonsils to view the entire posterior surface of IVth ventricle
- Important to view the median raphe, calamus scriptorius and the obex
Surgical technique-
Focal tumour

- Incision at an area where tumor is most superficial
- It also must be away from the midline and at least 1.5cm rostral to the obex- avoids injury to cranial nerve nuclei X-XII
- Incision <1cm
Surgical technique - Focal tumour

- Use of plated bayonet (very small plates at the tip) as ‘microretractor’
- CUSA at a low setting
- Careful identification of white matter interface
- Minimal manipulation of adjacent normal tissue
Surgical technique - Cervicomedullary tumour

- Suboccipital craniotomy + osteoplastic laminotomy
- Expose both rostral and caudal extent of the tumor.
- USG guidance to know extent of tumor prior to opening the dura - entire tumor should be within the confines of the operative exposure.
Surgical technique-
Cervicomedullary tumour

- The rostral end of a benign cervicomedullary tumor invariably expands posteriorly at the obex.
- Tumor is, in fact, displacing the medulla rostrally rather than extending into it.
- This explains why these tumor present with cervical myelopathy rather than LCN dysfunction.
- Conceptually, these tumor should be regarded as ‘intramedullary spinal cord tumours’.
Surgical technique - Cervicomedullary tumour

- Midline myelotomy
  - ‘True’ midline to be identified
  - Identify DREZ bilaterally
- If tm is solid-cystic, myelotomy to be placed first at tumor-cyst junction → cyst removed prior to tumor excision.
- If tumor is non-cystic, myelotomy where tumor is most voluminous & closest to the pial surface.
Surgical technique-Cervicomedullary tumour

- Myelotomy to be terminated 1 cm proximal to the caudal pole of the tumor→tumor is least voluminous here, removed by gradual upward dissection
- At the rostral pole, tumor invariably subpial and bulging posteriorly at the obex
Surgical technique - Cervicomedullary tumour

- USG to guide the extent of tumor excision - to confirm bulk of tumour is removed
- Don’t chase small questionable fragments
- If deterioration of SSEP/MEP during the procedure, interrupt the dissection and move to another area
Surgical technique - Cystic tumour

- Bulge into the IVth ventricle
- “Collapse” of the cyst cavity and surrounding neural tissue following cyst evacuation → difficulty in identifying the solid nodule
- ‘Hand-held’ retractor compared to fixed
- Avoid frequent manipulation of retractor
- Use of LASER
Surgical technique-
Dorsally exophytic tumour

- Mostly benign, arising from subependymal tissue and grow posteriorly in the area of ‘least resistance’ - through the floor of IVth ventricle

- Major technical complication-injury to neural structures immediately below the ependymal lining
Surgical technique- Dorsally exophytic tumour

- Remove tumor “flush” with the floor of IVth ventricle.
- Do not pursue tumour inside the brainstem.
- Low grade astrocytoma, ganglioglioma.
- Facial colliculus injury.
## Complication avoidance & management—Cervicomedullary tumour surgery

<table>
<thead>
<tr>
<th>Complication</th>
<th>Avoidance</th>
<th>Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kyphoscoliosis</td>
<td>- Osteoplastic laminotomy</td>
<td>Correction &amp; fusion (late post-op)</td>
</tr>
<tr>
<td></td>
<td>- Conservative extent of bone removal based upon USG guidance</td>
<td></td>
</tr>
<tr>
<td>Sensory (posterior column) deficit</td>
<td>- True midline myelotomy</td>
<td>Physiotherapy, Rehabilitation</td>
</tr>
<tr>
<td></td>
<td>- SSEP</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Initiation of myelotomy at the most bulky portion of the tumor using USG guidance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Myelotomy to end 1 cm short of tapering caudal end of the tumor</td>
<td></td>
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</table>
## Complication avoidance & management – Cervicomedullary tumour surgery

<table>
<thead>
<tr>
<th>Complication</th>
<th>Avoidance</th>
<th>Management</th>
</tr>
</thead>
</table>
| Motor deficit               | - Avoid chasing small questionable fragments in ventrolateral aspect of the resection cavity  
                              | - USG guidance                                                             | Physiotherapy                       |
|                             | - MEP                                                                     | Proper nursing                      |
|                             |                                                                          | Rehabilitation                      |
| Cardiovascular instability  | Close anaesthetic monitoring and prompt discontinuation of maneuver       |                                     |
### Complication avoidance & management – Focal BSG surgery

<table>
<thead>
<tr>
<th>Complication</th>
<th>Avoidance</th>
<th>Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cr nv V palsy</td>
<td>- Careful inspection of IVth ventricular floor to detect area of greatest bulge/tumour erosion to be used as entry into the tumour</td>
<td>Corneal lubrication, Tarsorrhaphy</td>
</tr>
</tbody>
</table>
| VI,VII       | - Careful inspection of erosion site  
- Localize median raphe and incise away from midline  
- Safe entry zone landmarks | Corneal lubrication, Tarsorrhaphy, Corrective surgery for LR palsy |
| VIII         | BAER      | Hearing aid |
## Complication avoidance & management – Focal BSG surgery

<table>
<thead>
<tr>
<th>Complication</th>
<th>Avoidance</th>
<th>Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>IX-XII palsy</td>
<td>- Identify obex and incise floor 1.5 cm rostral to it if no ependymal erosion is present</td>
<td>Prolonged ventilation and tracheostomy</td>
</tr>
<tr>
<td>Cr nv palsies</td>
<td>- Ependymal incision &lt; 1 cm&lt;br&gt;- Use of plated bayonet&lt;br&gt;- Stay within the tumour, inspect carefully for the interface</td>
<td></td>
</tr>
<tr>
<td>Post-op hypoventilation, hypercarbia &amp; brainstem hypoxia</td>
<td></td>
<td>Persistent mechanical ventilation, slow weaning, tracheostomy</td>
</tr>
</tbody>
</table>
## Complication avoidance & management – Cystic BSG surgery

<table>
<thead>
<tr>
<th>Complication</th>
<th>Avoidance</th>
<th>Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retraction injury</td>
<td>- Avoid excessive retractor manipulation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Hand-held retractor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Laser</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Avoid CUSA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Don’t chase questionable fragments</td>
<td></td>
</tr>
</tbody>
</table>
## Complication avoidance & management – Dorsally exophytic BSG surgery

<table>
<thead>
<tr>
<th>Complication</th>
<th>Avoidance</th>
<th>Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brainstem nuclei injury in general</td>
<td>- Good visualization of ependyma above and below the tumour</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>- Avoid resection below the ependymal floor</td>
<td></td>
</tr>
</tbody>
</table>
Peri-operative care

- Perioperative steroids (methylprednisolone)
- Elective ventilation for at least 48 hours
- Mechanical ventilation till recovery of ventilation & normal cough reflex
- LCN paresis- NG/feeding gastrostomy
- V, VII nv paresis- temporary tarsorrhaphy
- Good nursing care
- Physiotherapy
- Post-op brainstem injury mostly reversible if surgical technique is proper
Role of stereotactic biopsy

- Diffuse glioma is an infiltrative, highly aggressive lesion which is always malignant regardless of the histology at the time of biopsy, associated with a very poor prognosis, MR appearance is reliable → No role of biopsy for these lesions (Epstein, McCleary, 1986)

- No role of open surgery/stereotactic biopsy in diffuse tumor because of typical MRI characteristics and clinical presentation (Isamat, 1999)

- Risks of biopsy far outweigh the remote possibility of diagnosing something other than a glioma
Role of stereotactic biopsy

- Majority of focal, dorsally exophytic and cervicomedullary BSG are benign and resectable by direct surgery with low morbidity and good outcome

Role of stereotactic biopsy

- Reserved to
  - When the diagnosis is uncertain, to rule out inflammatory pathology like TB
  - Focal intrinsic endophytic lesion- well limited masses within the brainstem surrounded by neural tissue and therefore do not reach the surface
Role of GKRS


- 20 patients
- 10-18 Gy
- Median follow up- 78 months
- Tm disappeared in 4 pts, decreased in size in 12 pts
- Minimal peri & post- procedural morbidity
Take home message

- BSG are a heterogenous group of neoplasm
- Importance of MRI in diagnosis and planning of treatment
- Minimize complications by operating upon ‘benign’ lesions in the presence of minimal neurological dysfunction
- Knowledge of ‘safe entry zones’
Take home message

- Diffuse tumor almost invariably malignant and should not be operated upon → Direct RT + CT
- Focal medullary tumor
  - Likely to be benign
  - Surgery associated with significant morbidity
  - If laterally located & appears to be approachable with acceptable risks, resection is appropriate. If more centrally located → Stereotactic biopsy + Irradiation
  - Role of primary radical excision still unclear
Take home message

- Dorsally exophytic tumor-
  - Likely to be benign
  - Radical excision
  - Do not enter brainstem

- Cervicomedullary tumor-
  - Likely to be benign
  - Radical excision

- Cystic tumor –
  - Radical excision

- Focal pontine tumor-
  - Radical excision if tm is close to the surface
Thank you