What does the neurosurgeon need to know?

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Learning Objectives

. To be aware of the range of neurosurgical procedures for which pre-operative imaging is requested

. To understand what information the neurosurgeon requires from the imaging studies
Background

Preoperative imaging is an integral component of the neurosurgical operation and an important link between radiologists and neurosurgeons. Preoperative imaging may be requested for cranial or spinal procedures. For spinal procedures localization of pathology to vertebral body level is crucial. Location within the spinal canal in relation to adjacent structures is important, as is foreknowledge of the presence of cysts or vascularity. In cranial surgery knowledge of likely surgical approach will help the radiologist alert the neurosurgeon to potential pitfalls. Size of lesion, presence or absence of tumour infiltration, vascularity, necrosis and proximity to eloquent brain are all important.
Imaging Findings OR Procedure Details

In this exhibit case examples are used to illustrate categories of neurosurgical procedures, with relevant neurosurgical questions highlighted in each case.

**Functional MRI**:  
Functional magnetic resonance imaging or functional MRI (fMRI) is a procedure that measures brain activity by detecting associated changes in blood flow. This technique relies on the fact that cerebral blood flow and neuronal activation are coupled. When an area of the brain is in use, blood flow to that region also increases.

Below is an example of how Functional MR can help in decision making. A 30 year old male presented with seizures. CT and MRI showed a left parietal lobe lesion. The neurosurgeon asked for a functional MRI examination to localize Broca’s area. The fMRI shows that Broca’s area is posterior to the lesion (arrow in figure 1). The patient went on to have a complete resection of the lesion rather than partial resection (debulking) or a biopsy.

**Stereotactic navigation**:  
The use of stereotactic navigation (figure 3) in brain or spinal surgery has now become the standard of care. Depending on the nature and location of the lesion, CT, MRI or both modalities may be required for planning and surgery.

In cranial surgery stereotactic imaging offers help not only in precisely localizing the lesion but also by highlighting the proximity of nearby structures that the surgeon should be mindful of.

For example:

a) During resection of a posterior fossa lesion knowledge of the location of the transverse sinus is very important. Injury to the transverse sinus may cause significant bleeding, and may also lead to air embolism. In figure 4, the close proximity of the lesion to the transverse sinus laterally was something that the surgeon had to be mindful of.

b) Mid thoracic spinal lesions are hard to localize pre operatively. Asking for a stealth scan and placement of skin marker (arrow in figure 5) is helpful.
c) When the aim is to perform a minimally invasive procedure, such as a biopsy of an intra cranial lesion, stereotactic navigation ensures accurate localisation (figure 6).

d) The use of stereotactic navigation in spinal surgery is increasing. It can be used in the localization of a spinal lesion or to identify bony landmarks for spinal fusion surgeries (Figure 7)

**Aid in lesion resection/ Pre operative discussion**

Pre operative discussions between radiologist and neurosurgeon are important aspects of surgical planning

1) In this case of an 18 year old female, the tumour was centered on the left thalamic region. The dilemma for the neurosurgeon was whether to offer debulking or a biopsy. Image review (Figure 9) between the radiologists and neurosurgeons suggested that the tumour could be safely debulked. (coronal plane post contrast image T1 weighted image)

2) In this case of an 81 year old man, the neurosurgeon wished to know the location of the tumour in relation to the superior sagittal sinus (SSS). The extent of surgical resection depends on which part of the SSS is involved and whether the SSS is patent. The anterior 1/3 of the SSS can be sacrificed at operation, but if the middle third of the SSS is involved and the SSS is patent then surgical resection will be limited. Images showed that the middle third to SSS is abutted by the tumour but there is no evidence of tumour invading SSS. (Figure 10)

3) Resection of an arteriovenous malformation (AVM) requires extensive pre operative radiological work up. The surgeon needs to know whether the area of brain associated with the AVM is eloquent or non-eloquent, the size of the nidus, whether venous drainage is superficial or deep, whether there are any flow related aneurysms on the feeding vessels or intranidal aneurysms within the AVM, and whether preoperative embolization of the feeding vessels would make the operation less hazardous. Radiological information will also help in deciding whether the AVM should be treated by open surgery, by endovascular embolisation, by stereotactic radio surgery or should be managed conservatively.

In this case the patient had a large left frontal AVM (figure 10). The nidus was within the left frontal lobe, with the largest diameter measured at 5cm (figure 11). The main feeders were from the left frontal MCA (figure 12), but flow is also seen from perforating vessels from the carotid bifurcation, as well as collateral flow from the anterior cerebral artery
(ACA). The AVM was Spetzler-Martin grade 3 (table 1) and it was decided to proceed with surgical resection.

Because of the large feeding vessels from the Left MCA it was decided that pre operative embolization would be helpful. Post embolization images indicated a significant decrease in flow to the AVM nidus (figure 13).

**TABLE 1**

**Spetzler-Martin AVM grading system**

The Spetzler-Martin AVM grading system allocates points for various features of intracranial AVM's to give a score between 1 and 5 in order to estimate the risk of surgery for that patient.

<table>
<thead>
<tr>
<th>AVM size</th>
<th>Adjacent eloquent cortex</th>
<th>Draining veins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 3 cm = 1</td>
<td>Non-eloquent = 0</td>
<td>Superficial only = 0</td>
</tr>
<tr>
<td>3-6 cm = 2</td>
<td>Eloquent* = 1</td>
<td>Deep veins = 1</td>
</tr>
<tr>
<td>Over 6 cm = 3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Grade 1 and 2 are generally more amenable to surgery. Grade 3 can be treated with surgery or radiotherapy. Grade 4 and 5 have increased risk with surgery and are recommended for stereotactic radiosurgery.*

4) Some complex cases require detailed CT and MR imaging prior to surgery to better plan the extent of resection, and also to decide whether a combined procedure with a head and neck surgeon or a plastic surgeon would be appropriate.

a) This 47 year old patient had an intra orbital, intra osseous meningioma. CT imaging (figure 14)with thin section reconstructions was requested, to assess the extent of involvement of the base of skull. MRI (figure 15) was obtained to evaluate the intra cranial and dural involvement.

b) In this second case, a 48 year old male patient had a large scalp and left face squamous cell carcinoma (SCC), involving the external auditory canal and eroding the adjacent temporal bone (figure 16). The location of the lesion required further definition using high resolution CT as well as MRI of the base of skull and face. Imaging revealed involvement of left zygomatic bone, bony and cartilaginous parts of external auditory canal, pinna, pre-
auricular skin and fat, parotid gland, temporalis muscle and TMJ joint. MR also showed tumour extending through the temporal bone and abutting and involving the dura of the middle cranial fossa (figure 17).

5) Cerebral catheter angiography is important in planning the management of a cerebral aneurysm. As well as defining the anatomy of the aneurysm it may highlight details missed on CT angiography (CTA). This 45 year old woman presented with a sub-arachnoid haemorrhage. CTA showed a 7mm right internal carotid artery aneurysm. Cerebral catheter angiography was performed to better define the aneurysm and also to help determine whether endovascular or surgical treatment was appropriate. The angiogram showed that the multilobulated and broad based aneurysm (figure 18) was unsuitable for endovascular treatment. It also identified two other aneurysms (figure 19) on the contra lateral side, which had not been evident on CTA. The patient subsequently had surgical clipping of the acutely ruptured right ICA aneurysm, with a further procedure electively to secure the left-sided aneurysm.

**Identifying important anatomical landmarks for the surgeon**:\(^2,3\)

When it comes to microsurgery locating a lesion, intra operatively, can be difficult. In such circumstances neurosurgeons rely on the knowledge of known normal anatomical landmarks which can help them identify the lesion.

1) In this case, a 53 year old male patient had a scan prior to resection of a posterior fossa dural arterio venous fistula (DAVF). In the preoperative discussion the close proximity of the trigeminal nerve to the dural AVF was identified (figure 20). At surgery it was difficult for the surgeon to identify the DAVF. Knowledge of the relationship between the fifth cranial nerve and the DAVF helped identify the fistula, and complete resection of DAVF (figure 21)

2) Thoracic DAVFs are particularly hard to identify intra operatively. It is very important for the radiologist to obtain the best possible images to define the anatomy of the lesion. The spinal angiogram is the gold standard examination in this situation. The reporting radiologist should consider how the surgeon might identify the lesion intra operatively. In this case, the interventional radiologist placed a coil over the transverse process at the level of the DAVF as a marker (figure 22). The coil was easily identified during intra operative fluoroscopic imaging (figure 23) and the DAVF to be easily identified.

**Role in Trauma**:\(^2\)

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1) Spinal imaging and the quality of the radiological report plays a major role in the management of spinal trauma. The Thoraco lumbar spine trauma classification (TLICS) and the sub axial cervical spine injury classification (SLIC) are used by spinal surgeons in the management of the fractured thoraco-lumbar and cervical spine respectively. Both of these classifications rely on detailed information from CT or MRI, or both. The imaging findings guide the surgeon in deciding whether the spinal fracture can be managed surgically or conservatively.

**SLICS (Subaxial Cervical Spine Injury Classification and Severity Scale)**

It is a composite score of Morphology, DLC and Neurological Status.

<table>
<thead>
<tr>
<th>Morphology</th>
<th>Disco-ligamentous complex (DLC)</th>
<th>Neurological status</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 No abnormality</td>
<td>0 Intact</td>
<td>0 Intact</td>
</tr>
<tr>
<td>1 Compression</td>
<td>1 Indeterminate</td>
<td>1 Root injury</td>
</tr>
<tr>
<td>2 + Burst fracture</td>
<td>2 Disrupted</td>
<td>2 Complete cord injury</td>
</tr>
<tr>
<td>3 Distraction</td>
<td></td>
<td>3 Incomplete cord injury</td>
</tr>
<tr>
<td>4 Rotation/translation</td>
<td></td>
<td>+1 Continuous cord compression (in setting of neuro-deficit)</td>
</tr>
</tbody>
</table>

**Treatment**

SLICS <= 3: non-operative

SLICS = 4: consider for operative or non-operative intervention

SLICS >=5: operative

Figure 24 and 25 show that the patient all three columns of cervical spine involved.

Scoring on the basis of SLIC criteria the above injury scored 2 for morphology, 2 for DLC disruption and 3+1 for neurological status. Therefore, the patient had surgical fixation of the injury.
TLICS (Thoracolumbar Injury Classification and Severity Score)\textsuperscript{5}

It is the composite score of Morphology, PLC and Neurological Status.

<table>
<thead>
<tr>
<th>Morphology</th>
<th>Posterior Ligamentous complex (PLC)</th>
<th>Neurological status</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 No abnormality</td>
<td>0 Intact</td>
<td>0 Intact</td>
</tr>
<tr>
<td>1 Compression</td>
<td>2 Suspected Indeterminate</td>
<td>2 Root injury</td>
</tr>
<tr>
<td>2 + Burst fracture</td>
<td>3 Injured</td>
<td>2 Complete cord / conus medullaris injury</td>
</tr>
<tr>
<td>3 Rotation/translation</td>
<td></td>
<td>3 Incomplete cord / conus medullaris injury</td>
</tr>
<tr>
<td>4 Distraction</td>
<td></td>
<td>3 Cauda equina</td>
</tr>
</tbody>
</table>

Treatment

TLICS <= 3: non-operative

TLICS = 4: consider for operative or non-operative intervention

TLICS >=5: operative

Figure 26,27 and 28 show fracture of T10 vertebral body, with suspected injury to posterior ligamentous complex but no evidence of middle column involvement.

On the basis of TLICS scoring system patient score 2 for morphology, 2 for suspected PLC injury and 0 because of intact neurolgy. Therefore this patient was managed conservatively.

2) In head trauma, if the frontal sinus wall is fractured then it is important for the neurosurgeon to know the extent of the fracture. High resolution imaging may be required to evaluate the extent of bony involvement. A surgeon may request an MRI with CSF flow studies to evaluate whether the Dura is breached and leaking CSF. This information helps the surgeon decide whether the patient needs a large bifrontal craniotomy and repair of the dural defect, or whether conservative management is appropriate. Imaging helps determine whether an ENT surgeon should be involved in the management.
Penetrating Injury\textsuperscript{2,3}: 

Management of intra cranial penetrating injuries is complex. Below are examples where cerebral angiography was performed following a penetrating injury leading to different management.

1) This patient presented after an accidental nail gun injury. A nail penetrated the right orbit. CT scan revealed the nail penetrating the right cerebral hemisphere. A catheter angiogram was obtained to evaluate the position of nail in relation to the intra cranial vessels. The nail tracked superior to the right MCA bifurcation. A few branches of MCA were displaced with no evidence of occlusion. Patient had surgical removal of the nail.

2) Patient had a knife penetrating through his right orbit as a result of a gas explosion. He had a DSA performed prior to surgery, which revealed that the knife has passed lateral to the cavernous sinus and inferior to the M1 segment of right MCA. The cutting edge of the blade was pointing superiorly. The posterior cerebral artery (PCA) was significantly indented by the cutting edge of the knife. The lack of clarity of the vessel beyond this point suggested periarterial extravasation. After discussion between the interventional neuroradiologist and the neurosurgeon it was decided to occlude the PCA at the point of indentation using endovascular coils, in the knowledge that this would likely cause an infarct, in order to avoid catastrophic bleeding on removal of the knife. The knife was subsequently removed at open operation.
**Fig. 1:** Functional MR brain(axial image) showing the location of lesion (arrow) away from speech area.

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**Fig. 2:** Functional MR brain (coronal image) showing distinction between the lesion and speech area.

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Fig. 3: General set up of stereotactic navigation system.

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**Fig. 4:** MR brain (axial image) showing the close relation between the lateral margin of lesion and right transverse sinus (arrow)

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Fig. 5: MR spine (sagittal image) showing a skin marker placed on skin (arrow), over the location of spinal lesion, to help localisation.

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Fig. 6: Image taken from pre operative stereotactic registration showing location of a deep intra cranial lesion and planned trajectory to obtain a biopsy.

© RBWH preoperative stealth image
Fig. 7: Image taken from intra operative stereotactic navigation for placement of a pedicle screw

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Fig. 8: MR brain (coronal image) highlighting the enhancing component of the lesion.

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Fig. 9: MR brain (coronal image) showing the lesion abutting the superior sagittal sinus.

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**Fig. 10:** Functional MR brain (axial image) showing large left frontal AVM.

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**Fig. 11:** Cerebral angiogram, reconstruction of left carotid injection. Approximating the size of the nidus to 5 cms.

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Fig. 12: Cerebral angiogram, left sided injection, showing large arterial feeder(s) from middle cerebral artery (long arrow) and venous drainage in to superior sagittal sinus (short arrow)

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**Fig. 13:** Post embolization cerebral angiogram showing obvious decrease of the flow to AVM nidus (arrow).

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Fig. 14: CT brain (axial image) showing involvement of left temporal bone (arrow).

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**Fig. 15:** MR brain (axial image) showing tumour involving the dura (arrow).

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Fig. 16: CT brain (coronal bone window image) showing involvement of external auditory meatus (long arrow) and floor of middle cranial fossa (short arrow)

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Fig. 17: MR brain (coronal image) showing dural involvement (arrow).

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**Fig. 18:** Cerebral angiogram reconstruction showing large multi lobulated and broad based aneurysm (arrow).

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Fig. 19: Cerebral angiogram reconstruction images, showing large (short arrow) and small (long arrow) aneurysms on left MCA

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**Fig. 20:** MR brain (axial image) showing proximity between left cranial nerve V (long arrow) and draining veins of DAVF (short arrow)

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**Fig. 21:** Intra operative image showing surgical clip over resected DAVF (blue arrow) and left cranial nerve V (red arrow)

© RBWH intra operative image from operating microscope
**Fig. 22:** Pre operative spinal angiogram showing a coil placed over the right T7 transverse process for identifying the DAVF

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Fig. 23: Pre operative fluoroscopic navigation identifying the coil (arrow) placed during pre operative angiogram.

© RBWH preoperative flouroscopic image
**Fig. 24:** MRI cervical spine (sagittal image) showing cervical spine fractures, involving all three spinal columns. Long arrow - fracture of C4 vertebral body, block arrow - cord signal change and short arrow - disruption of posterior ligamentous complex.

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**Fig. 25:** CT cervical spine, (sagittal image) with block arrow showing fractured C4 vertebral body, long and short arrows highlighting fractured C2 and C4 spinous processes respectively

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Fig. 26: MR thoracic spine (sagittal image) showing no evidence of cord signal change

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Fig. 27: MR thoracic spine (sagittal image) showing fracture of T10 vertebral body (arrow) and possible injury to PLC (block arrow)

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**Fig. 28:** CT thoracic lumbar spine (sagittal image) showing burst type fracture of T10 vertebral body (arrow).

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**Fig. 29:** CT head (axial bone window images) showing pneumocephaly (arrow) and anterior and posterior table of frontal sinus fractures (circled areas) extending into the base of skull. Therefore patient required surgical repair

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**Fig. 30:** CT head (axial bone window spot view) showing fractured anterior wall of frontal sinus (arrow) and intact posterior wall of frontal sinus. Patient was managed conservatively.

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Fig. 31: Lateral image of skull showing nail penetrating through the orbit.

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Fig. 33: Lateral image to skull showing large knife penetrating through right orbit.

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**Fig. 32:** Cerebral angiogram reconstruction (right carotid) showing nail passing superior to middle cerebral artery branches (arrow).

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Fig. 34: Cerebral angiogram reconstruction (right vertebral) showing the knife indenting the right posterior cerebral artery (arrow)

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Conclusion

Understanding those questions important to the neurosurgeon prior to operation should lead to more informed and useful radiological reports, which may reduce morbidity and improve patient outcomes.
References

1) Greenberg, MS. Handbook of neurosurgery. 7th ed. Florida: Thieme; 2010


