Diagnostic Imaging of Intracranial Tumors in Adults

Brook J Hill, Harvard Medical School, Year IV
Gillian Lieberman, MD, Beth Israel Deaconess Hospital and Harvard Medical School
Patient P.W.

- P.W. is a 63 year-old female who complains of 1 month of progressive headache and confusion. She also reports constantly misplacing objects, increasing forgetfulness, feeling very tired, and “leaning to the left” while walking.

- Physical exam: Slight left facial droop; LEU finger-to-nose and rapid alternating movements abnormal; unsteady tandem gait with lean to left. Otherwise normal.

- Head CT at an OSH revealed a right frontal mass.
Indications for Imaging

- Signs and/or symptoms suggestive of intracranial neoplasm:
  - PROGRESSIVE neurologic dysfunction
  - New onset seizures (or change in character)
  - Signs/symptoms of elevated intracranial pressure (ICP)
  - Known systemic tumor with possible intracranial metastasis
Focal vs. General Signs/Sx

• Focal:
  – Focal seizures (25-50%)
  – Weakness
  – Sensory abnormalities
  – Gait changes
  – Speech disturbances
  – Visual defects

• General:
  – Papilledema (59%)
  – Generalized convulsions (25-50%)
  – Headache (50%)
  – Mental changes
  – Nausea and vomiting
  – Signs/Sx of herniation

Focal signs/sx are caused by localized brain damage, while general signs/sx are caused by elevated ICP.
Mental Changes Associated with Intracranial Tumors

- **Psychomotor retardation**
  - Impersistence in routine tasks
  - Inertia
  - Reduction in the range of mental activity
  - Reduced initiative and spontaneity
  - Blunted affect

- **Sleep disturbances**
  - Insomnia
  - Early rising
  - Excessive daytime sleepiness

- **Cognitive disturbances**
  - Forgetfulness
  - Lack of concentration

- **Language disorders**
- **Concreteness**
- **Faulty insight**
- **Frank dementia**

- **Social disturbances**
  - Disheveled appearance
  - Inappropriate behavior
  - Loss of inhibitions
  - Indifference to social practices

- **"Psychological" symptoms**
  - Depression
  - Hypomania
  - Euphoria
  - Emotional lability
Menu of Tests Available

- MRI
- CT
- SPECT
- PET
- X-Ray
MRI

- First-line diagnostic test for imaging of suspected intracranial tumors
- Multiplanar, high resolution, high contrast
- Standard protocols: T1, T2, proton density (PD)
- Advanced protocols: FLAIR, DSC, others
CT

- Generally not recommended to diagnose or follow intracranial tumors
- Single plane (axial)
- Lower resolution than MRI
- Less soft-tissue contrast
- However, CT is the first-line test for suspected intracranial hemorrhage
MRI vs. CT

**Benefits of MRI:**
- Greater soft tissue contrast (e.g., white vs. grey matter)
- More sensitive to soft tissue abnormalities (i.e., can detect small differences in water content)
- Smaller amount of contrast needed
- Better tumor characterization (e.g., subacute vs. chronic hematomas, vascular lesions, cystic contents)
- Multiplanar imaging
- Lack of beam hardening artifact near bony structures
- No ionizing radiation
- Compatible with orthopedic implants, vascular clips excluding aneurysm clips, dental fillings, and ventricular shunts

**Benefits of CT:**
- Superior visualization of bony/calcific structures
- More rapid image acquisition
- Easier monitoring of acutely ill patients
- Compatible with pacemakers, ferromagnetic aneurysm clips, intraocular foreign bodies, and virtually all prostheses
- Better tolerated by claustrophobic patients
SPECT

• **Single Photon Emission Computed Tomography**
• A multislice nuclear medicine study - “Brain scan”
• $^{99m}$Tc-hexamethyl-propylenamine-oxime ($^{99m}$Tc-HMPAO)
• Provides functional information about regional cerebral blood flow (rCBF), which helps:
  – determine tumor burden both before and after surgery
  – distinguish between viable tumor, necrosis, and edema after surgical resection
• Also used in dementia, cerebrovascular disease, epilepsy, encephalitis, and trauma
• Readily available, relatively inexpensive, and well-tolerated
• Limitations:
  – Inherently poorer resolution than PET, CT, and MRI
  – Absolute quantification of blood flow is not possible
  – Involves ionizing radiation
PET

- **Positron Emission Tomography**
- Also a multislice nuclear medicine study
- Blood flow, oxygen uptake, and glucose consumption
- Provides functional information about the metabolic profile of tumors, enabling the radiologist to:
  - estimate aggressiveness of tumors (correlates with metabolic activity)
  - distinguish viable recurrent tumor from radiation necrosis after surgical resection
- Better spatial resolution than SPECT
- Limitations:
  - Poor spatial resolution compared to CT and MRI
  - Expensive and therefore not universally available
  - Involves ionizing radiation
X-Ray

• “Historical” test for intracranial tumors, but common findings still important:
  – Erosion of dorsum sellae (elevated ICP)
  – “J-shaped” sella (chronic hydrocephalus)
  – Tumor calcification
  – Cranial vault erosion
  – Enlargement of middle meningeal groove (e.g. meningioma)
X-Ray: Erosion of Dorsum Sellae

Normal Sella:  Elevated ICP:

• Erosion of lamina dura (ld) of dorsum sellae (ds), often the earliest bony change with elevated ICP
• Erosion into cancellous bone (white arrow) underlying sella
• Sella can reossify and remodel upon relief of elevated ICP

X-Ray: “J-Shaped” Sella

Normal Sella: 

Chronic Hydrocephalus:

- Truncated dorsum sellae (ds)
- Large anterior clinoid process (acp)
- Deep sulcus chiasmaticus (sc)
- J-shape caused by direct pressure form dilated third ventricle

X-Ray: Tumor Calcification

- Tumors that often calcify:
  - Craniopharyngioma (40-80%)
  - Meningioma (15%)
  - Glioma (10-15%)
  - Lipoma

- Physiologic calcification:
  - Pineal (50%)
  - Choroid (50%)
  - Dura
  - Arachnoid granulations
  - Basal ganglia
  - Corotid arteries

http://www.pathology.vcu.edu
X-Ray: Tumor Calcification

• Expansile radiolucent mass in sella tursica (open arrows)

• Dystrophic soft-tissue calcification

• Erosion of dorsum sellae

• Tissue diagnosis = Craniopharyngioma

http://www.pathology.vcu.edu
X-Ray: Cranial Vault Erosion

- **PATHOLOGIC TUMORS:**
  - Epidermoid cyst, hamangioma, eosinic granuloma, multiple myeloma
  - Metastases (virtually always **LYTIC** in the skull, even if sclerotic elsewhere in the body)

- **BENIGN CHANGES:**
  - Venous lakes, enlarged parietal foramina, parietal thinning

- **OTHERS:**
  - Pagets, osteomyelitis, leptomeningeal cyst

*Meningioma, however, typically causes increased bone density due to trophic effects on the inner table.*
MRI (MP RAGE) with Gadolinium Contrast:
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PACS, BIDMC
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MRI (MP RAGE) with Gadolinium Contrast:
Describing the Lesion

- Size and Shape
- Location
- Number
- Density
- Enhancement
- Edema
- Mass Effect
Describing the Lesion: Location

• Intra-axial vs. Extra-axial:
  – Intra-axial = within the brain parenchyma
  – Extra-axial = outside the brain parenchyma
  – Step #1 in differentiating intracranial tumors
  – Not always possible to differentiate

• Supratentorial vs. Infratentorial:
  – Supratentorial = above the tentorium cerebelli
  – Infratentorial = below the tentorium cerebelli
Describing the Lesion: **Density**

- **CT:**
  - Compare attenuation of lesion with that of surrounding normal parenchyma (25-40 HU)
  - Higher attenuation = cells (30-60 HU), hemorrhage (85 HU if acute), calcification
  - Lower attenuation = fluid (0 HU if CSF), fat (-100 HU)

*Because tumor often is the same attenuation as normal parenchyma, many tumors are missed on CT.*

- **MRI:**
  - Compare signal intensity on T1, T2 etc. with normal parenchyma
  - **T1:**
    - High signal = adipose, proteinaceous fluid, contrast, low flow
    - Low signal = bone, calcifications, fluid, air, high flow
  - **T2:**
    - High signal = fluid, hemorrhage, low flow
    - Low signal = bone, calcifications, air, high flow
Describing the Lesion: **Enhancement**

- Compare images taken before contrast administration with those taken after contrast administration
- “Nonenhancing, Homogenous, Ring, Heterogenous, Serpentine”
- Normal blood-brain barrier (BBB) does NOT allow passage of iodine or gadolinium contrast
- BBB breakdown can be seen in infarction, infection, abscess, neoplasia, and trauma
- Neovascularity can be seen in tumor, infarction, infection

In general, malignant tumors enhance; benign tumors do not.
Describing the Lesion: Edema and Mass Effect

- **Edema Pattern:**
  - “Vasogenic, ischemic, cytotoxic, periventricular interstitial”

- **Mass Effect:**
  - Midline shift
  - Herniation (uncal, transtentorial, etc.)
Patient P.W. – MRI Findings

- 4 x 4.5 cm solitary mass
- Irregular border
- Right frontal lobe (intra-axial)
- Low signal core (necrosis)
- Heterogenous, ring enhancement
- Vasogenic edema pattern
- Mild midline shift
Patient P.W. – MRI Findings

- DDx (imaging alone):
  - Glioblastoma multiforme
  - Anaplastic astrocytoma
  - Metastatic tumor
  - Lymphoma
  - Tuberculoma
  - Abscess

- DDx (imaging + history):
  - Glioblastoma multiforme
  - Anaplastic astrocytoma
  - Metastatic tumor
  - Lymphoma

- Treatment = surgical excision
Pre-Op:

- T1, no gadolinium

Post-Op Day (POD) #1:

- POD #1: tumor bed with high signal (acute hematoma + Surgicel)

POD #83:

- POD #83: tumor bed with low signal (resolving hematoma)

POD #194:

- POD #194: tumor bed enlarged with mixed signal (fluid + Gliadel wafers s/p second excision)

All Images from PACS, BIDMC
Pre-Op:

POD #1:

POD #83:

• **T1 + gadolinium**

• **POD #83**: linear enhancement surrounding region of XRT (radiation necrosis); 2 x 2 cm heterogenously enhancing mass anteromedial to original tumor bed (recurrent tumor)
• POD #139 (1 Day s/p resection of recurrent tumor): tumor bed with areas of no signal (air) and heterogenous signal (Gliadel wafers + Surgicel + blood)

• POD #194: Gliadel wafers; enhancing tumor bed margins with no signs of recurrence
Pre-Op:

POD #1:
• T2
• POD #1: extensive vasogenic edema surrounding tumor bed

POD #83:
• POD #83: vasogenic edema of anterior right frontal lobe surrounding site of recurrent tumor
• POD #194: fluid-filled resection site with no surrounding edema

POD #139

POD #194

All Images from PACS, BIDMC
FLAIR MRI

- **Fluid Attenuated Inversion Recovery**
- Heavily T2 weighted
- CSF signal is nulled by sampling the MR image at an appropriate time after magnetization inversion, when longitudinal magnetization of CSF is zero
- Similar to STIR, except used for CSF instead of fat
- Allows better characterization of lesions adjacent to CSF-filled structures
- Clinically useful in several situations:
  - Intraxial brain tumors: differentiation between tumor and edema
  - Tumor follow-up: identification of residual tumor at the resection margin
  - Acute subarachnoid hemorrhage, Herpes encephalitis, Tuberous sclerosis, Mesial temporal sclerosis
- Limited by inability to fully suppress CSF signal when contaminated by blood/protein
Pre-Op:

- FLAIR MRI

POD #83:

- POD #83: Increased signal in tumor bed and region overlying resection site (fluid + blood/protein) as well as anterior frontal white matter (edema)

POD #139:

- POD #139: Heterogenous signal in tumor bed immediately post-op with persistent surrounding edema

POD #194:

- POD #194: High signal in tumor bed (fluid + blood/protein); white matter edema resolved

All Images from PACS, BIDMC
DSC MRI

• **Dynamic Susceptibility Contrast-Enhanced MRI**
• A.K.A. “Susceptibility” MRI
• Uses gradient echo or echo planar imaging techniques to enable measurement of regional cerebral blood volume and regional cerebral blood flow
• Provides **functional** information in addition to structural information
• Multiple clinical uses in brain tumors:
  – Provides additional information about the microvascular structure of gliomas (flow and permeability properties)
  – Noninvasively grade gliomas
  – Determine optimal biopsy sites
  – Distinguish radiation necrosis from tumor regrowth
  – Plan and follow irradiation, chemotherapy, and antiangiogenic therapy
• **DSC MRI**

• **POD #1:** High signal in resection site (blood) with peripheral areas of very low signal (Surgicel)

• **POD #83:** Persistent high signal in resection site

• **POD #139:** Heterogenous, but mainly very low signal in resection site (mostly Surgicel + Gliadel with some blood)

All Images from PACS, BIDMC
T1:

POD #83: No visible lesions.

POD #194: 2x2 cm low signal lesion in the left insular cortex.
**T1 + gadolinium:**

**POD #83:** No visible lesions.

**POD #139:** No visible lesions.

**POD #194:** 2x2 cm heterogenously enhancing lesion in left insular cortex (recurrent tumor).
T2:

POD #83: 8x8 mm region of increased signal in left insular cortex.

POD #139: 10x10 mm region of increased signal in left insular cortex.

POD #194: 2x2 cm region of increased signal in left insular cortex.
FLAIR:

POD #83: 8x8 mm region of increased signal in left insular cortex.

POD #139: 10x10 mm region of increased signal in left insular cortex.

POD #194: 2x2 cm region of increased signal in left insular cortex.
DSC:

POD #83:
Barely visible 8x8 mm region of increased signal in left insular cortex.

POD #139:
Subtle 10x10 mm region of increased signal in left insular cortex.

POD #194:
2x2 cm region of increased signal in left insular cortex.
MRI vs. CT

FLAIR MRI (POD #139):

10x10 mm region of increased signal in left insular cortex.

CT (POD #150):

No visible lesions.

Images from PACS, BIDMC
Summary

- Indications for intracranial imaging:
  - Progressive neurologic dysfunction, Seizures, Elevated ICP, Known cancer with possibility of metastases
- Tests available:
  - MRI, CT, SPECT, PET, X-ray
- MRI is first-line test
- SPECT and PET are functional studies and are good for follow-up
- Describing the lesion:
  - Size, Shape, Location, Number, Density, Enhancement, Edema, Mass Effect
- FLAIR MRI: Nulls CSF signal, allowing better characterization of lesions adjacent to or within CSF
  - Excellent for early detection of recurrent tumor
- DSC MRI: Provides functional information about regional blood volume and regional blood flow
  - Allows noninvasive grading of gliomas
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References


