Skull Base Trauma & CSF Leaks
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Kristen Lloyd Baugnon, M.D.
Department of Radiology and Imaging Sciences
Division of Neuroradiology

Objectives
- Describe patterns of skull base fractures
- Identify complications requiring multidisciplinary treatment
  - Algorithm for CSF Leak Diagnosis and Evaluation
- Develop a checklist

Detection of skull base fx
- Can be challenging if nondisplaced
- NCCT Clues:
  - Pneumocephalus
  - Blood in sinuses/mastoids
  - Overlying ST swelling
  - Freq missed: Occipital condyle, ACF, tbone

Skull base trauma
- Up to 16% of CHI
  - High velocity impact
  - Penetrating trauma <10%
- Assoc w complex facial and orbital fractures
  - Detection important
  - Tx depends on IC injury and complications
  - Multidisciplinary care

Detection of skull base fx
- Thin section bone algorithm MDCT with reformat
  - Coronal, Sagittal, tbone
  - 3D VR reformats
  - Curved MIP reformats
  - Beware of pseudofractures!
Suture diastasis

Patterns of SB Fracture
- Patterns seen depend on direction of impact
- Many different classification systems
  - Location in skull base (ACF, MCF, tbone, PCF)
  - Assoc complications
- Fractures often complex/mixed

Anterior cranial fossa trauma

Anterior skull base fractures
- Direct frontal trauma
- “Frontobasal” fractures
  - Frontal (upper 1/3 face)
  - Basal (ant skull base)
- Type I-III fractures
  - Type I – medial, linear
  - Type II – lateral
  - Type III – mixed, comminuted
- Types II&III more assoc with complications

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Middle cranial fossa trauma

Central skull base fractures
- Oblique pattern: frontal impact extending to central skull base
  - Facial fxs, type II/III FB fxs, CSF leak
  - Transverse: lat impact
    - CN and vascular injury
    - Often assoc with tbone fxs
    - Anterior vs posterior

Central skull base fractures
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  - Transverse: lat impact
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    - Often assoc with tbone fxs
    - Anterior vs posterior

Central skull base fractures
- Anterior Transverse fx

Central skull base fractures
- Posterior Transverse fx

Posterior skull base trauma

Posterior skull base fractures
- Lateral and/or posterior blow to occiput
  - Occipital bone, +/- ext to petrous t bone and FM
  - No simple classification scheme
  - T bone fxs described independently
Clivus fractures

- Central and posterior skull base fractures
- High mortality
  - Brainstem, NV
- Transverse
  - Lateral blow
  - CN/ICA injury (CN VI)

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Complications of SB trauma

- Depend on location
- Intracranial
- Vascular (MCF & PCF)
- CN
  - ACF: CN II (Anosmia)
  - MCF: CN II, III, IV, V, VI
  - Bone: CN VII, VIII
  - PCF: CN IX, X, XI, XII
- CSF leak (ACF, MCF)

Intracranial injury

- IC injuries common – high velocity impact
- Multicompartmental hemorrhage, parenchymal contusions, DAI
Intracranial injury: MCF

- Anterior MCF epidural hematoma
  - Greater wing sphenoid fx
  - Benign – venous (sphenoparietal sinus)
  - Self limited

- Lateral MCF epidural – middle meningeal artery

Venous epidural hematoma

Arterial epidural hematoma

Intracranial injury: PCF

- Posterior Fossa Epidural Hematoma (PFEDH)
- Most common IC comp assoc with posterior skull base fx
- Venous etiology
- Children
- Can expand rapidly
- May require decompression

Vascular Injury: Venous

- Traumatic venous sinus thrombosis
- 55% of fx through jugular bulb/sigmoid sinus
- Transverse and sagittal sinus less common
- ↑ ICP, venous hemorrhage, infarct (7%), dural AVF

CTA/CTV

Delgado AJE et al. Radiology 2010

Delgado AJE et al. Radiology 2010
Traumatic dural venous sinus thrombosis vs extrinsic compression

Vascular injury - BCVI
- Common comp (8.5%)
  - MCF & PCF
- ICA injuries
  - York et al: Fractures through carotid canal
  - ICA injury: 35% PPV
    - Modified Denver criteria
  - CTA
- Stroke risk decreases with anticoagulation
- Vertebrobasilar injuries
  - Clivus, occiput, occipital condyle

Vascular injury: CC Fistula
- Traumatic direct connection between ICA and cav sinus
- High flow fistula
- Exophthalmos, bruit, chemosis, vision loss, ophthalmoplegia
- Acute or delayed
- DSA diagnostic & therapeutic

Cranial Nerve Injury: ACF
- Anosmia (CN I)
- Overall incidence of 7%, increased in ACF injuries
  - Esp cribiform plate
  - Frontal lobe contusions
  - CSF leak and repair
- Only 10% recover sense of smell, often delayed
Cranial nerve injury: MCF
- Acute or delayed presentation
  - Delayed: Stretching/edema, better prognosis
- Optic nerve canal: II
- SOF: III, IV, V1, VI
  - Orbital apex syndrome
- Sella: bitemporal hemianopsia (chiasm)
- Cav sinus/clivus: III, IV, V1, V2, VI

CN Injury: PCF
- Jugular foramen: IX, X, XI
- Hypoglossal canal (occipital condyle): XII

CSF Leak
- 10-30% of skull base fxs
- Comminuted fxs
  - Type II/III FB fxs, tegmen, sphenoid
  - Pneumocephalus
  - CSF otorrhea & rhinorrhea
- Often resolves spontaneously
  - Surgery for persistent leak
- Delayed presentation

Suspected CSF Leak
- Beta 2 transferrin (beta trace protein) assay
  - First screening test “gold standard”
  - Protein specific to CSF
  - Unequivocal evidence to support use
    - High sensitivity and specificity
    - Patient collects in test tube
    - Stores room temp or fridge
    - Requires only a few drops (0.5 -1 cc)
  - Limitations:
    - Intermittent or no leak (unable to collect)
    - False positive (rare!)
    - Liver failure

Imaging evaluation
- Goals of imaging:
  - LOCALIZE the leak
  - Characterize size of defect
  - Assess for meningocele
  - Confirm diagnosis
  - Assess for underlying cause
- No definite imaging gold standard
  - Difficult diagnosis
  - Lacking randomized controlled trials
  - CT/MRI/cisternography (NM, CT, MR)

HRCT
- Standard of care – first line
- Localize osseous defect (s): 95% Sensitivity
- Do not need active leak to see defect
- Images used for intraop guidance
- MDCT : Thin slices (< 1mm) with reformats
  - Image sinuses and mastoids
  - Manipulate data on workstation, optimize W/L settings
  - Measure defect in multiple planes
    - Correlates with size of defect within 2 mm in 75% in one study
HRCT – Imaging findings

- Osseous defect with fluid level in sinus or mastoid

HRCT – Imaging findings

- Nondependent soft tissue in nasal cavity or ME cavity, adj to bony defect
  - Concerning for cephalocele
  - Consider MRI

HRCT

- If only one defect, and positive B2 transferrin
  - Surgery
- Limitations:
  - Defect does not necessarily = leak
  - Multiple osseous defects with adjacent sinus opac

42 yo F w remote h/o trauma

CT - cisternogram

- Pt needs to be actively leaking (or able to elicit)
- Technique:
  - Pre-Cisternogram CT:
    - Supine MDCT with thin sections (reformats)
    - Blood, inspissated secretions, osteogenesis
  - LP: 5-7 cc of intrathecal contrast
  - Head down and provocative maneuvers
  - Post-Cisternogram CT:
    - Direct coronal in prone position (elicit leak)
    - Supine MDCT with thin section reformats

CT Cg - Findings

- Bony defect
- ↑ density adjacent to bony defect (measure ROI if no visible change)
- Pooling of high density in adjacent sinuses
CT cg findings

- “Souffle” effect
- Contrast washout
- Dependent drainage
- Movement with position

CT-cg Findings ROI Measurement

Pre ROI = -12
Post ROI = 69

CT-Cg Limitations

- Invasive
  - Small but inherent risk of infection/lumbar CSF leak
- Intrathecal contrast risk
- Radiation
- Time intensive interpretation
- Limited usefulness in slow flow or intermittent leaks

MR – Cg

- Noninvasive & nonionizing
- Indicated if suspected encephalocele
- Nondependent soft tissue adjacent to bony defect
- Completely opacified sinus or ME (lobulated) adjacent to bony defect
- Heavily T2w FS FSE sequences
- High resolution 3D T2 w SSFP (GRE) sequences
  - i.e. CISS, FIESTA, SPACE
- Thin (3 mm) T1 axial, sag, coronal
- Sensitivity (85-89%), best combined w HRCT

MR – Cg Imaging Findings

- Continuous column of T2 hyperintense CSF extending from SA space to extracranial soft tissues
- Frank herniation of brain tissue

MR – Cg with IT Gad

- Promising studies
- Sensitivity: up to 100% for high flow
- Selculuk et al: 60-70% sens for intermittent or suspected leaks
  - Delayed imaging up to 24 hours later
- No ionizing radiation
- Ease of interpretation
- Improved contrast resolution
- Assess cephaloceles
MR – Cg with IT Gad - Limitations

- Off label use, not FDA approved in US
  - Many studies from outside US
  - No unexpected adverse effects (HA, meningitis) with doses and agents used (up to 107 pts in one study)
  - No long term safety or large trials yet
    - Study in 2016 with Avg 4.2 yr F/u, no long term adverse effects
  - Consider carefully, only in pts with nl renal fxn
- Still need HRCT!


MR – Cg with IT Gad

- Technique:
  - Mult osseous defects, no/intermittent leaks, postop
  - HRCT first
  - Off-label use consent
  - Pre-gad MR Cg sequences with T1 and T2w images
  - LP – 0.5 ml intrathecal gadopentetate dimeglumine in 4 cc sterile, pres free saline, or CSF
  - Scan at 1 hour, then again at 4-24 hours, as needed
    - Fat sat T1w post in multiple planes

45 yo F w h/o int leak, mult potential osseous defects bilat

Cor T2W MR Cg Cor T1W FS MR Cg w IT Gad

Summary: Algorithm for Work-up of CSF leak

- Positive: HRCT
  - Single osseous defect
  - Suspect Meningo-encephalocele
  - MR Cisternogram
- Negative: No imaging; unlikely to be CSF leak
  - No further imaging; post likely site of CSF leak
  - CT Cisternogram
- Unable to collect fluid
  - HRCT
  - MR Cisternogram, consider Intrathecal contrast if high suspicion

Summary: SB Trauma

- Complex
- Even linear nondisplaced fractures can be assoc with complications
- CTA/CTV:
  - Carotid canal
  - Cavernous sinus
  - Jugular foramen/sigmoid sinus
  - Clivus
  - Occipital condyle

Skull base fractures: Checklist

- Posterior table frontal sinus
- Anterior skull base
- Skull base foramina (ON, SOF, FR, FO, IAC, hypoglossal canal)
- Carotid canal
- Sigmoid sinus/jugular foramen
- Clivus
- Occipital condyle
References


References, cont


References, cont