Cranial Trauma Procedures

Last updated: December 19, 2020

GENERAL PRINCIPLES

INDICATIONS FOR SURGERY

See p. TH127 >>

SUBDURAL FIST THROUGH FONTANEL – see p. TH133 >>

PREOPERATIVE

- correct coagulopathy - fresh frozen plasma (for prolonged PT/aPTT), cryoprecipitate (for fibrinogen ≤ 1.5 g/L), thrombocyte transfusions (for platelets < 100,000).
- add antiepileptic (AED)
- antibiotic prophylaxis.
- tetaus immunization status should be checked and updated (esp. lacerations, contaminated wounds).
- if suspect vascular lesion (e.g. young person with deep bleed):
  1) order CTA
  2) plan craniotomy so will have proximal control (e.g. by dissecting Sylvian fissure).
  3) start evacuating blood clot furthest from suspicious area and may leave small clots.

ANESTHESIA

- even if patient is in coma it is unwise to begin full anesthetic support (only exception is patient thought likely to expire during time taken to organize these precautions, which can usually be done while theater is prepared).
- if head is rotated for surgery:
  - make sure neck veins are not twisted.
  - head above heart level if BP permits.
  - Soft-point head fixation device is used if unstable C-spine fracture is present but careful with skull fractures.
- drape to allow extension of surgical incision beyond actual confines of wound, for EVD ad drain exit, or to allow possible scalp rotation procedures.
- patients with high ICP are very vulnerable to incidents of respiratory obstruction, hypercarbia, systemic hypoxia.
  N.B. once intracranial hematoma begins to be removed blood pressure may fall precipitously (esp. if multiple injury has produced hypovolemia, masked by effects of raised ICP).
- ICP monitor (or venricular drain) usually is placed intraoperatively in patients with GCS ≤ 8.

TECHNIQUE

- whole head is shaved (e.g. for placement of ICP monitor on contralateral side).
- never make small trauma craniotomy (brain may swell and may need to leave bone flap out); big trauma flap is never wrong choice (postoperative brain swelling may strangulate brain against tight craniotomy bone edges).
- Dr. Mathem likes dural tack-ups placed before opening dura (if time permits) – place stitch under bone – helps with hemostasis (during the case) and dural closure.
- after evacuating mass lesion, leave ICP monitor in (even if removed bone flap).
- send selected removed blood clots for pathology (may find tumor, vascular lesion).
- malignant cerebral edema – see below >>

POSTOPERATIVE

- CT is obtained ≤ 24 hours postoperatively.

COMPLICATIONS

Infection (meningitis, subdural empyema, meningitis, brain abscess).
- risk factors – open scalp fractures, violated parasinus sinuses (esp. with CSF leak).
SCALP WOUNDS

SCALP AVULSION
- often contaminated with pieces of dirt - should be thoroughly cleaned and inspected for puncture wounds to ensure removal of unsuspected foreign bodies.

SCALP LACERATIONS

- Require scalp's rich vascular supply:
  1) scalp lacerations may be source of significant bleeding.
  2) most uncomplicated lacerations can be closed (after cleansing and debridement) and antibiotics are usually not needed.
  3) even very large scalp avulsions can survive: 
     - if avulsion remains attached to rest of scalp by tissue bridge, it should be reattached to surrounding tissue.
     - if avulsion is completely detached from scalp it should be treated as any other amputated part and reimplanted ASAP.
     - small scalp defect is repaired by rotating portion of scalp.
     - large scalp defect requires skin graft or vascularized free flap.

HEMOSTASIS methods:
  1) direct digital compression of bleeding vessels against skull; scalp kraujagyslės išsidėstę tarp dviejų tampų aponeurozės - odos ir aponeurozės (galea):
     a) pateista tik oda - kraujavimą lengva sustabdyti spaudžiamuoju tvarsčiu.
     b) pateista oda ir galea - žiaud plačiai žiojia, o iš jų kraštų periforiniakia kraujojusia ( kartušiu nepatiršetimai įkildė kiaušį į uždėtą storg tvarį) - kraujavimą galima sustabdyti tik stipriausiai prispaudžiant žiaudos kraujotis prie kaulo; to naudoti negalima, jei yra nestabilus (stabilus) lūžimas ties žiaudą - tokia atveju prispaudžiamą prie kaulo a. temporalis (virš arcus zygomaticus).
  2) infiltration of wound edges with LYODAINE + EPINEPHRINE.
  3) ligat wound edges with PROLIFERATIVE INTRADERMAL SUTURE (easily to confuse with intradermal suture). 
  4) if galea is lacerated, it can be pulled up with clamp and its edges folded over lacerated skin edges to tamponade bleeding vessels.

5) Runary scalp clips (plastic - do not interfere with CT) - easy to apply rapidly to wound edges - useful in unstable patients.

6) definitive method - wound closure after proper debridement and irrigation.

Once hemostasis is obtained, wound is copiously irrigated:
- blood clots & debris should be removed (tissue away).
- careful digital exploration of scalp wound, palpate galea and underlying cranium to detect any remaining debris, disruptions, or bony step offs - shear injuries may deposit contaminants at sites distant from apparent injury.
- subgaleal emissary vessels drain directly into diploe veins → venous sinuses → potential to intracranial infections.

N.B. stellate lacerations are particularly prone to infection.

base of laceration must be directly visualized (easy to confuse galea disruption or periosteum tear with skull fracture) - by clipping away small area of hair parallel to edges of wound (alternatively, antibiotic ointment can be applied to hair immediately surrounding wound and used to plaster hair away from injury site). 

if there has been prolonged exposure to skull, exposed portion of bone should be rongeured until active bleeding appears ( nidus of dead bone is source of osteomyelitis): 

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- bacterial disruption results in wound gaping - large galea lacinations must be closed (interrupted absorbable 2-0 sutures) - to prevent edges of wound from pulling apart as muscles within galea contract.
- Bättina susisitį sužalojus aponeurozė!
- other scalp layers do not require separate suturing - dermis & skin are repaired in single layer with interrupted or vertical mattress sutures of 3-0 ecaton or polypropylene.
- N.B. sutures must be tied more tightly than elsewhere, so that hemorrhage is controlled (wound hematoma is particularly undesirable complication in scalp!). 
- if galea is not involved, scalp lacinations can be repaired with staples.
- if laceration begins on forehead and extends upward beyond hair line, surrounding hair should not be removed (this would obliterate useful landmark for cosmetic closure → malalignment of two laceration edges).
- when repairing bald scalp, use intradermal suture.
- accidentally embedded hair within repaired laceration delays healing - by interfering with proper granulation (by producing inflammatory reaction or by serving as nidus of infection).
Compression of growing fractures over large lacerations (colloction dressing to small ones)
   - when compression dressing is applied, ears must be padded with cotton to prevent pressure necrosis of auricular cartilage

**SKULL FRACTURES**

**DEPRESSED SKULL FRACTURES**

Used sources:

- laceration is always present along the fracture line, and it is an essential factor for the development of a skull, the most common site
- even though reported to occur after the first year of life (most often during infancy), and almost never occur after 8 years of age.
- although fractures may form in any part of the skull, the usual presentation of the growing fracture is over the skull vault in the parietal region. Dural tears are repaired
- bony fragments are reassembled into the skull. If infection develops, the growing fracture usually presents a progressive diastatic enlargement of the fracture line. Although skull fracture is a common occurrence in the pediatric age groups, the incidence of growing fracture is only 0.05 to 1% among compound skull fractures treated with primary bone fragment replacement, regardless of the degree of contamination of the wound at the time of surgery.

**Patient Selection**

- the usual presentation of the growing fracture is a proptosis, sive, often pulsatile, lump on the head. Neurological symp-
toms such as seizure, hemiparesis, and mental retardation are less frequent. Often cranial fractures treated with primary bone fragment replacement, regardless of the degree of contamination of the wound at the time of surgery.
- skull fracture is also known as a leptomeningeal cyst. "Growing" fracture is
- occipital, and a palpable mass or widening of the fracture line is the somatic, and a palpable mass or widening of the fracture line is the
- occasional, shunt surgery is performed to decompress cyst and treat localized dilatation of ventricles.

**Clinical Part**

- growing fracture is a rare complication of skull fracture occurring in infancy and early childhood. This rarely compli-
cation of skull fracture is also known as a leptomeningeal cyst. “Growing” fracture is somewhat of a misnomer, but it is characterized by progressive diastatic enlargement of the fracture line. Although skull fracture is a common occurrence in the pediatric age groups, the incidence of growing fracture is only 0.05 to 1% among skull fractures in childhood.

**LEPTOMENINGEAL CYST (S. GROWING FRACTURE)**

**Cranial Traumas Procedures Op320 (1)**
growing fracture. The dural laceration enlarges with the growing fracture. Computed tomography (CT) or magnetic resonance imaging (MRI) of the head demonstrates the dilation of the inner table near the growing fracture. Lack of resistance of both dura and skull leads to focal amplification of the bone pressure due to the pulsatile pressure at the edge of the fracture line. A rapidly developing infantile brain and associated pathological conditions such as brain edema or hydrocephalus also contribute to the dural laceration. The growth of the “growth” of the cranial defect is caused not only by the erosion due to progressive focal pressure, but also by an associated intracranial pathological change such as a cerebral edema, or the presence of an intracranial aseptic abscess.

The cranial defect should be closed with an autologous bone graft as soon as possible. Autologous bone grafts are well incorporated, and healing is excellent. Foreign materials such as methyl methacrylate should not be used for these patients. These flaps are not suitable for use in these patients, as they are often complicated by hydrocephalus.

To identify the dura, several bur holes are made away from the skull defect. The dural edge from the craniotomy flap is split at the diploic space with an osteotome, separating it into inner and outer pieces. The outer pieces of the craniotomy flap are obtained, one from each side of the growing fracture. The cranial defect is then repaired with cancellous bone flaps and cranial defect is removed, leaving a large enough amount of pericranium to be used for repair of the dural defect. Once the dura is identified at each bur hole site, the dura is separated from the underlying hemorrhagic contusion of the brain by removing the cranial edema, and all abnormal tissue is separated and transected using a sharp dissector. The cranial defect is then repaired using the periosteal graft. 

The cranial defect is then repaired by laying the split autologous bone grafts. Two pieces of the craniotomy flaps are used when the size of the cranial defect is large or the dura is diffusely adherent to the edge of the cranial defect. The craniotomy flaps are separated from the inner table of the skull toward the defect (Fig. 7–2C). The cranial defect is then repaired using the periosteal graft (Fig. 7–2D). Autologous bone grafts are well incorporated, and healing is excellent. Foreign materials such as methyl methacrylate should be avoided for cranial defect repairs.

The primary pathological change of these patients is usually limited to one parietal bone. Neuroimaging such as CT and MRI provide information regarding the sequence within the growing fracture and any intracranial pathological changes. Furthermore, if they are available from the time of initial trauma, it should be possible to demonstrate progressive pathological changes. It is not unusual that the initial neuroimaging shows hemorrhagic contusion, or subarachnoid hemorrhage. The time of discovery of the growing fracture, neuroimaging demonstrates the diagnosis of the fracture and onset of intracranial pathological changes.

Growth of the growing fracture may arrest after CSF diversion surgery by a decrease of the CSF pressure pulse, but this does not correct a dural closure defect. Placing a shunt for primary treatment in these patients is not advised unless hydrocephalus is present. Shunting for progressive cystic degeneration. It is not unusual that the initial neuroimaging shows hemorrhagic contusion, or subarachnoid hemorrhage. The time of discovery of the growing fracture, neuroimaging demonstrates the diagnosis of the fracture and onset of intracranial pathological changes.

Radiological Studies
X-ray films of the skull show wide diastases of the fracture line. If initial skull films are available, one can compare the films to confirm “growth” of the fracture line during the interval. When multiple fractures are noted in the same patient, healing of the fracture in one area may be noted as a growing fracture in another area. The fracture line can cross the coronal or lambdoid sutures but is usually limited to one parietal bone. Neuroimaging such as CT and MRI provide information regarding the sequence within the growing fracture and any intracranial pathological changes. Furthermore, if they are available from the time of initial trauma, it should be possible to demonstrate progressive pathological changes. It is not unusual that the initial neuroimaging shows hemorrhagic contusion, or subarachnoid hemorrhage. The time of discovery of the growing fracture, neuroimaging demonstrates the diagnosis of the fracture and onset of intracranial pathological changes.
Figure 7-2 (A) After the craniotomy, the intact dura mater is exposed around the dural defect, which is covered by the periosteum. Underneath the overgrowing periosteum is a cerebromeningeal cicatrix that is removed using bipolar cautery and sharp dissection until healthy white matter is exposed. (B) After all pathological tissues have been removed, the edge of the surrounding dura is separated from the intact cortical surface. (C) The previously removed periosteum is used to repair the dural defect. A watertight closure is achieved with 4-0 sutures. (D) The bone grafts are split at the diploic space between the inner and outer tables by means of an osteotome. (E) The obtained split bone flaps are used to repair the cranial defect. The bone flaps are secured to each other and to the edge of the cranial defect with nylon sutures or stainless steel wires.

Specific Considerations

The growing fracture may extend toward a dural venous sinus such as the superior sagittal or lateral sinus. Although these venous sinuses were spared from direct injury at the initial trauma, direct exposure of them is not advised or necessary. When the fracture line extends perpendicularly to these sinuses, the closest end to the sinus does not need dural repair. However, if the growing fracture is parallel and near to the sinus, dural repair may be difficult due to the lack of enough dural edge next to the sinus. In these cases, one may repair the dural defect with a periosteal graft sutured to the periosteum of the skull above the sinus.

Postoperative Management

Including Possible Complications CSF diversion shunting has been recommended for persistent postoperative CSF leakage from the craniotomy wound. It is justified if coexisting hydrocephalus is evident, or if CSF leakage occurs despite adequate repair of the growing fracture. A lumpectominal shunt or temporary lumbar CSF drainage is to be considered under these circumstances.
TWIST DRILL CRANIOSTOMY (FOR CHRONIC SUBDURAL HEMATOMA)

- hole is drilled at 45° angle to skull over thickest part of hematoma (unless this lies over motor strip); possible under local anesthesia at bedside.
- twist drill is used to perforate dura and to release subdural hematoma.
- thin rubber catheter is gently guided* into subdural space, tunneled under scalp, and brought out through stab incision (connect to closed drainage system without suction for 24-72 hours).
- postop → see below >>

BURR HOLE WASHOUT (BHW), s. CRANIOTOMY

(FOR CHRONIC SUBDURAL HEMATOMA)

Principles of chronic SDH treatment (incl. indications, surgery types) → see p. TDiH13 >>

INDICATIONS
- subacute / chronic SDH – BHW is the procedure of choice. see p. TDiH13 >>
- sometimes even acute SDH can be evacuated through burr holes (e.g. unstable patient with low Hb – nonclotting hematoma); but usually, if patient is minimally symptomatic (e.g. headaches), – may wait until hematoma liquefies (usually 10-14 days).

PROCEDURE

POSITION
- supine position; towel roll under ipsilateral shoulder.
- head on gel donut / horseshoe / subdural head holder slightly rotated to the contralateral side.

Dr. Graham likes subdural head holder – keeps head straight vertical (helps with drainage during procedure) and permits access to posterior region.

ANESTHESIA
- a) local anesthesia at bedside
- b) monitored local anesthesia or general anesthesia in OR (best results!)

PROCEDURE

- Burr holes are placed over thickest aspects of hematoma; ideally, at superior temporal line (just above temporals muscle; if needed, OK to go through muscle).
- make 2 (1-3) burr holes.
  - e.g. frontal and parietal burr holes - if needed, can be incorporated into craniotomy.
  - studies show that patients do well with just 1 burr hole but difficult to irrigate through 1 hole! If holes are placed too near extremes of hematoma, drainage may be blocked by pathologic membranes.
- coagulate dura with bipolar cautery.
- irrigate dura in cruciform manner* with a #15 or #11 blade (*do not cut to the edge of bone – leave some dura – easier to stop bleeding if it happens) – watch for motor color thin fluid.
- cut with Bovie to completely open up burr holes.
  - if clearly see blood through dura, may open dura with Bovie (avoiding bipolar & blade stick).
- if thick dark clot is found → thorough copious washout; attempt to scrape (mobilize) clot with Penfield #3, #4, hockey-stick.
- may need additional burr holes or even mini craniotomy; alternative – if significant part of clot was evacuated and brain reexpanded, – may finish and follow with CT (repeat BHW if needed – less mortality than craniotomy).
- attempt to fenestrate with bipolar visible pathologic membranes (but they may ooze blood nonstop?).
- irrigate with sterile saline via Becker catheter inserted subdurally in all directions (except supero-superiorly towards sagittal suture – not to disrupt bridging veins)
- irrigate until returning fluid is clear and free of old clot fragments.
- see for brain re-expansion; often, brain does not re-expand right away → drain

Drain reduces 2-3-fold subdural hematoma recurrence (8-9% vs. 20-24% without drain) and mortality:

<table>
<thead>
<tr>
<th>Recurrence</th>
<th>Drain</th>
<th>No drain</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.3%</td>
<td>24%</td>
<td>0.003%</td>
<td></td>
</tr>
<tr>
<td>Mortality at 6 months</td>
<td>0.0%</td>
<td>0.042%</td>
<td></td>
</tr>
</tbody>
</table>

Santarius T. Use of drains versus no drains after burr-hole evacuation of chronic subdural haematoma: a randomized controlled trial. Lancet 2009; 374: 1067 – 1073

Drain location

A. Subdural drain
- ventriculostomy catheter (Dr.s. Graham, Holloway) use round 7F JP drain – it is more traumatic than EVD catheter.
- insert through posterior (parietal)* or anterior (frontal)* burr hole and advance anteriorly (i.e. direct drain towards frontal pole) – when brain reexpands postop, last
B. Subgaleal drain – not positioned in direct contact to cortical structures, bridging veins, or hematoma membranes

- use flat 10F JP drain; make sure holes are over burr holes (sometimes as difficult as flat 10F JP drain has long tapering part that has no holes; alternative – use fluted / channelled 10F drain)
- tunnel drain under galea from anterior burr hole to posterior and the further posterior.

N.B. There is no difference in recurrence rates (7.7-8.1%)* and outcomes with subdural and subgaleal drains but subdural drains have reduced risk of infection, intracranial hemorrhage, brain injury, empyema, and epilepsy.

*there are studies that show even lower recurrence rate (8.3% vs. 12%) with subgaleal than subdural drain.

Dr. Graham Holloway et al. Subperiosteal vs Subdural Drain After Burr Hole Drainage of Chronic Subdural Hematoma: A Randomized Clinical Trial (cSDH-Drain Trial). Neurosurgery 0:1, Oct 2019

CLOSED

- both burr holes are covered with cranial plates and screws; do not seal off burr holes – allows subdural excess fluid to get absorbed in subgaleal space.
- tunnel drain under skin as far as you can posteriorly.
- galea is approximated with 2-0 Vicryl in interrupted fashion except small gap in upper (anterior) incision → sterile saline is gently injected through the drain allowing intracranial air to be expelled through galeal gap (= table is brought into Trendelenburg position, anesthesia applies Valsalva maneuver) → galea closed completely.
- drain is connected to closed drainage system (“transfer pack” or “bile bag”) put on gravity drainage without suction or JP bulb with thumbtite gentle suction – Dr. Graham: suction creates negative intracranial pressure – may cause Bradycardia, lightheadedness.
- simple running 3-0 Monocrly, bacitracin ointment.

POSTOPERATIVELY

- postoperative seizures are reported in 10%-15% patients (many surgeons use prophylactic anticonvulsants for 7-30 days after operation).
- hCT next day
- CT often (92%) shows residual subdural collection – should be left alone (unless it continues to exert significant mass effect); thus, recommendation is not to do postop head CT until ≥ 3 days postop (unless patient deteriorates)
- flat bed regimen as long as subdural drain is present (to prevent sucking air intracranially) + adequate IV hydration to promote brain re-expansion.
- alternatively, subdural drain may be connected to JP bulb (with minimal suction) → galea closed completely.
- drain complications:
  - drainage into chest (to promote brain re-expansion).
  - 10% patients (many surgeons use prophylactic anticoagulants for 7-30 days after operation).
  - occult CSF leak → see p. TrH13
  - other burr holes (membranectomy*) → see p. TrH13
  - drain complications: puncturing cortex*, causing hematoma, subdural empyema, etc)
  - drain is connected to closed drainage system (“transfer pack” or “bile bag”) put on gravity drainage without suction or JP bulb with thumbtite gentle suction – Dr. Graham: suction creates negative intracranial pressure – may cause Bradycardia, lightheadedness.
  - simple running 3-0 Monocrly, bacitracin ointment.

Dr. Holloway et al. Subperiosteal vs Subdural Drain After Burr Hole Drainage of Chronic Subdural Hematoma? Lessons from a Multicenter Prospective Cohort Study. Neurosurgery 85:486, Oct 2019

- if drainage is sub-optimal (< 50 cc) tPA can be instilled through drain.
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Dr. Holloway et al. Subperiosteal vs Subdural Drain After Burr Hole Drainage of Chronic Subdural Hematoma? Lessons from a Multicenter Prospective Cohort Study. Neurosurgery 85:486, Oct 2019

SPECIAL FINANCIAL DISCLOSURES

If SDH recurs after burr hole drainage

Risk factors:
1. Patient factors: alcoholism, seizure disorders, coagulopathy, ventriculoperitoneal shunt.
2. Radiologic factors: poor brain reexpansion postoperatively, significant subdural air, greater midline shift, heterogeneous hematomas (layered or multi-localized), and higher-density hematomas.
3. Surgical factors: lack of or poor postoperative drainage.

Further workup:
1) MRI, CTA of brain – for vascular abnormalities
2) MRI of spine, myelogram – for occult CSF leak (Dr. Holloway would do blood patch even if spine looks unremarkable)

Treatment:
1) correct causes
2) repeat burr hole washout.
3) medications (TXA, APOTROPIN, DEX, etc) → see p. TrH13
4) craniotomy with partial removal of enveloping membranes (membranectomy*) or shunting of subdural cavity into pleural or peritoneal cavity.

Reoperation rates (for hematoma reaccumulation) = 12-22%.
**ACUTE EPIDURAL HEMATOMA EVACUATION**

**IMMEDIATE EXPLORATORY BUR HOLES**

*conservatively uncontrollable ICP↑ with rapid patient deterioration in ED (consciousness↓ + asymmetric findings) → think of brain compression* → emergency BURR HOLES.

*if skull fracture is present – most commonly epidural hematoma.

It is life-saving procedure - unless burr hole is done patient will die or be damaged: you and patient have nothing to lose and everything to gain - inelegant burr hole now will do much more good than elegant operation one hour or more later.

**STRATEGY**

If CT is unavailable – side of burr hole is chosen:

<table>
<thead>
<tr>
<th>Feature</th>
<th>Hematoma Side</th>
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<tbody>
<tr>
<td>First (or only) dilated pupil</td>
<td>Ipsilateral 94%</td>
</tr>
<tr>
<td>Most abnormal motor response</td>
<td>Contralateral 82%</td>
</tr>
<tr>
<td>Skull fracture</td>
<td>Ipsilateral 66%</td>
</tr>
</tbody>
</table>

– also can be helpful - scalp wound side, M-echo signal dislocation, pineal gland dislocation (on X-ray).

• position patient supine – allows approach to both skull sides.

1. **First burr hole** - low in temporal region, just above zygoma (one finger’s breadth anterior to tragus and one finger’s breadth above zygomatic process).

   – skin incision is started perpendicular to zygomatic process and curved so it can be incorporated into scalp flap.

   – inexperienced surgeons often make this burr hole too high, near temporal crest (this may fail to disclose hematoma in temporal region and is also difficult to incorporate into suitable bone flap).

   – superficial temporal artery will likely be transected (cauterize or pick up with hemostat & tie).

**BILATERAL CHRONIC SDH**

- many experts do bilateral BHWO.
- modern Japanese (and now also UPMC) – do MRI prep with intention to BHWO on one side only; if hematoma on the “conservative” side looks iso- or hypodense on T1, there is 25-fold increased chance that the second side will also need BHWO.

*if you see clearly brain surface, leave that “membrane” alone – do not violate arachnoid (→ CSF leak)
2. If initial temporal burr hole is negative, other openings are made:
   a) close to fracture-line
   b) in region of any scalp wound (in absence of fracture)
   c) frontal (1 cm anterior to coronal suture [still behind hairline] and 3 cm from midline; skin incision is parallel to midline, periosteum here is directly beneath galea) and parietal (at parietal boss – most prominent point in parietal bone).

   N.B incision & burr holes should, if possible, be made in such sites that can be incorporated into “question mark” flap; burr hole must be adjacent to, but not over, skull fracture.

3. If no hematoma is found on one side → proceed in analogous order on other skull side.

4. If no hematoma is found on supratentorially ± occipital fracture → bilateral occipital burr holes.

   • if epidural hematoma is not found – consider subdural hematoma. see p. TdH13 ??

TECHNIQUE

• on occasion, procedure may be performed in ED (under sterile conditions!)
• shave entire scalp (if time permits).
• usually no local anaesthetic is necessary.
• 3–4 cm scalp incision, incise right down to bone (if available, cutting cautery is used to incise galea and temporals muscle); do not stop to stop scalp bleeding.
• scrape back pericranium (periosteum) using periosteal elevator (or similar instrument, e.g. handle of scalpel) to expose skull.
• insert self-retaining retractor - this will stop all bleeding.
• persisting bleeding (from skin or muscle) must be controlled before proceeding.
- perforate bone using perforator - do no more than just perforate skull - this will create conical hole - dark clot will ooze out; dura will not be seen as it is stripped away by clot.

- enlarge perforation using burr (hole becomes nearly cylindrical); clot will immediately ooze out:

- suck clot away by applying sucker to burr hole:
  - N.B. do not insert sucker into cavity - that will cause more bleeding and might damage brain.

- to remove clot adequately, it may be necessary to enlarge hole with rongeur (i.e. to do craniectomy).
- be ready to cope with BP drop (as Cushing reflex is relieved).
- middle meningeal artery (if identified to be torn) is cauterized, waxed into bone, or secured in some manner.
- bone edges are waxed.
- Gelfoam is placed in opening to prevent blood from subgaleal space from entering cranial cavity.
- it is now safe to transfer patient for definite neurosurgical help.
  - leave scalp retractor in with voluminous sterile dressing (but some surgeons suture scalp before transfer).
  - leave in endotracheal tube and leave drip up.
  - send CT scans and any blood that has been cross matched with patient.

CRANECTOMY
- unusual (method best suited for non-neurosurgeons)
CRANIAL TRAUMA PROCEDURES

CRANIOTOMY

INDICATIONS
see p. 31411 >

APPROACH
- body is supine; head is placed on donut.
- careful with head head clamps - may propagate existing skull fractures.
- calvarium is opened over site of hemorrhage.
- if patient presents with clinical signs of herniation, rapid burr hole is made over hematoma → hematoma is partially evacuated (pressure relief until entire epidural blood clot can be evacuated).

“Question Mark” skin flap (frontotemporoparietal craniotomy) - best for classical anterior temporal hematoma:
- incision is started at zygoma, 1 cm anterior to auricle; continued parietally upward and backward (“question mark”), finished frontally not far from midline at hairline.
- initial burr hole is made over zygoma.

“Horse Shoe” skin flap - for more posterior hematoma:

PROCEDURE
- hematoma evacuation.
- inspection of dura → bleeding control:
  - arterial sites - coagulation/ligation/clipping; it may be necessary to follow middle meningeal artery to foramen spinosum, where it can be controlled by plugging foramen with cotton, bone wax, or swab stick.
  - dural venous sinus - tamponade with muscle + head-of-the-bed elevation; diploic vein bleeding is controlled with bone waxing.
- if dark subdural hematoma shines through dura (or preoperative CT demonstrated contusions beneath EDH) → open dura to explore subdural space.
- epidural tack-up sutures are placed from dura to craniotomy bone edge ± to center of craniotomy flap - to tamponade epidural bleeding from areas beyond craniotomy edges and to prevent recurrence.
- occasionally, epidural Jackson-Pratt drains are employed for as long as 24 hours.

POSTOPERATIVELY
ACUTE SUBDURAL HEMATOMA EVACUATION

Indications for surgery – see p. TiH13

IMMEDIATE EXPLORATORY BUR HOLE

- dura at burr hole is raw and cut in cruciate manner (using SMALL SCAFFEE).

**Cautions:** cutting dura in cruciate manner produces four corners of dura that may be shrunk using cautery to expose what lies beneath

- if only outer dural layer is incised initially, membrane is placed between dural leaves – dura is elevated away from brain – inner dural layer is incised (avoid injury to underlying brain but brain supposed to be separated by subdural clot).

- if subdural hematoma has been present for some time, there will be membrane (just deep to dura) that must also be incised carefully.

- solid subdural blood is cautiously aspirated (liquid blood is allowed to escape).

- burr hole may be enlarged with rongeur, but craniotomy is required to adequately remove fresh subdural blood (pressure release via burr holes serves only as temporizing treatment).

- cautionary irrigation (with saline) to rinse out blood clots.

CRANIOTOMY

**CRANIOTOMY**

- make initial burr hole (even before opening entire incision), open dura → early decompression (gentle suction + irrigation) to forestall herniation.

- burr hole evacuation is insufficient for acute SDH → large question mark-shaped flap

**CRANIOTOMY** should encompass nearly extent of hematoma:

- exposure should include sylvian fissure (likely source of ruptured cortical vessel).

- if hematoma extends near temporal fossa, bone flap may be hinged on temporalis muscle, but dura is turned toward sagittal sinus.

- if exact SDH location is known, linear scalp incision may be used (reduced surgical time).

- may fenestrate dura in mesh-like fashion rather than opening it to prevent brain herniation through wound.

- remove blood (biopsy forceps, Penfield 3, gentle suction, irrigation) and surrounding "subdural membranes."

- organized hematoma peels off surface of brain.

- segments of hematoma, not directly exposed, can be irrigated and gently loosened with suction and Penfield #3.

- explore areas under dura along entire perimeter by depressing brain gently with widest ribbon (narrow ribbon cuts into brain).

- beware pulling on bridging veins

1) arterial bleeding → bipolar electrocautery.

2) venous oozing → Gelfoam, Surgicel, bridging veins → tamponade with muscle pieces.

- intraoperative ultrasound may locate INTRAPARENCHYMAL CLOTS (also may require evacuation).

- if associated brain injury and edema are present → place ICP monitor, consider bone flap removal.

- bone flap management:

  a) bone flap is replaced
  b) bone flap is replaced loosely ("hinge craniotomy").
  c) leave bone flap out (craniotomy)

- NB: craniotomy is never wrong with slightest anticipation of (postoperative) brain swelling

- subgaleal (subdural) drain is placed.

MALIGNANT CEREBRAL EDEMA

See below

POSTOPERATIVELY

- obtain CT within 24 hours of removing acute SDH (symptomatic recurrent / residual hematoma → repeat operative intervention).

DECOMPRESSIVE CRANIOTOMIES

- allow brain to swell → reduced ICP → prevention of cerebral herniation and death.

References

- R. Jandial “Core Techniques in Operative Neurosurgery” (2011), procedure 12


- E. Sander Connolly “Fundamentals of operative techniques” (2010), ch. 20


- Roberto C. Heroes “Kemp’s operative neurosurgery” (2003), no info in this book

- Nudel “Neurosurgery Tricks of the Trade – CRANIAL” (2014), ch. 107 (p. 505-511)


Suggested further reading:


1. Primary decompression – prophylactic measure during emergency evacuation of traumatic mass lesion when bone is not replaced in anticipation of postoperative elevated ICP.

2. Secondary decompression – therapeutic to elevated ICP refractory to medical treatment (e.g. in severe TBI, malignant MCA stroke, some nontraumatic pediatric cases with refractory ICT such as Reyes syndrome) – surgery is lifesaving but not restorative (of what is lost).

- some experts do not include age in making the decision whether to proceed with decompressive craniectomy; however, on the basis of data suggesting that old age does correlate with poor outcomes after decompressive craniectomy for TBI, they temper the expectations of outcomes in older patients.

Two issues to talk to family:
1) primary brain injury is so severe that, if patients survive, they are most likely to remain severely disabled.
2) how do people feel about survival with severe neurological disability for themselves? “How do you feel about surgical intervention that may leave you severely disabled?”

- it is important for family to know dire prognosis to avoid unrealistic expectations (older patients, patients with limited brainstem reflexes and low GCS from time of injury are at greatest risk for poor outcome).

**GUIDELINES FOR THE MANAGEMENT OF SEVERE TRAUMATIC BRAIN INJURY (4°) ed 2020 Update**

- incorporated RESCUEicp data + DECRA 12-month data -- 3 new, 1 retained, 1 removed level 2A recommendations.
- both RESCUEicp and DECRA are class 1 studies with good quality evidence.
- both RESCUEicp and DEcRA studied secondary craniectomy.

**BENEFITS & DISADVANTAGES, TRIALS**

- when performed correctly, decompressive craniectomy can reduce ICP, increase cerebral blood flow and oxygenation, and reduce therapeutic intensity levels, potentially preventing cerebral herniation and death.

- Decompressive craniectomy decreases mortality but does not improve good outcomes!

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**TIMING OF SURGERY**

- Early ICP > 20 mm Hg for 15 min over a 1-h period despite the optimization of not 1 treatments within the first 72 h of care; intracranial mass lesions excluded

**EXCLUSIVELY BIFRONTAL DC**

- Mortality the same but more worse outcomes and less good outcomes with early DC

**GO2S-E12 mno**

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<th>Surgical N = 82</th>
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<td>Upper good rec</td>
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**DC fewer ICUs during hospitalisation**

<table>
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**DC’ patients had fewer hours than medical patients with ICP above 25 mm Hg after randomization (median, 5.0 vs 7.0 h); P = 0.05 but had a higher rate of adverse events (26.3% vs 9.2%; P = 0.08).**

**Level IIA recommendations** – to improve mortality and overall outcomes.

1. NEW – Secondary DC performed for late refractory ICP elevation is recommended to improve mortality and favorable outcomes.

2. NEW – Secondary DC performed for early refractory ICP elevation is not recommended to improve mortality and favorable outcomes.

- N.B. (recommendation #2 should not be extrapolated to primary DC in which the bone flap is left off when an intracranial mass lesion is evacuated early after injury.

3. A large frontotemporoparietal DC (not less than 12 x 15 cm or 15 cm in diameter) is recommended over a small frontotemporoparietal DC for reduced mortality and improved neurological outcomes in patients with severe TBI.

4. NEW – Secondary DC, performed as a treatment for either early or late refractory ICP elevation, is suggested to reduce ICP and duration of intensive care, though the relationship between these effect and favorable outcome is uncertain.

- Removed recommendation: “Bifrontal DC is not recommended to improve outcomes as measured by the Glasgow Outcome Scale-Extended (GOSE) score at 6 months post-injury in severe TBI patients with diffuse injury (without mass lesions), and with ICP elevation to values > 20 mm Hg for more than 15 minutes within a 1-hour period that are refractory to first-tier therapies. However, this procedure has been demonstrated to reduce ICP and to minimize days in the intensive care unit (ICU).”

- The most important conclusion of these studies is that choosing to perform a DC is not a simple decision and that the potential benefits should be balanced against the complications and likely outcomes on a case-by-case basis (e.g. doing MRI to determine brainstem injury).

Unanswered questions:
1) relative risks and benefits of lateral DC vs bifrontal DC (should DC be tailored to the intracranial pathology?)
DECREA (Decompressive Cranietomy in Diffuse Traumatic Brain Injury)


Australian & New Zealand & Saudi Arabia multicenter trial: randomly assigned 155 patients (15-59 yrs) with severe diffuse TBI (Marshall class III-IV, moderate diffuse injury) and intracranial hypertension refractory to first-tier therapies: a) early (within 72 hrs) decompressive bifrontotemporal craniectomy b) standard medical management:

- intracranial hypertension: spontaneous (not stimulated) ICP > 20 mm Hg for > 15 minutes

- first-tier therapies: sedation, normalization of PaCO2, osmotherapy, neuromuscular blockade, and CSF drainage (EVD)

- second-tier options: mild hypothermia (to 35°C), barbiturates

- exclusion criteria: not deemed suitable for full active treatment, diluted unresponsive pupils, mass lesions (unless too small to require surgery), SCl, cardiac arrest at the scene of the injury.

- outcome at 6 months (evaluated by telephone by trained assessors who were unaware of study group assignments):
craniectomy led to lower ICPS and shorter ICU stays (no significant between-group difference in the total time in the hospital):

- rates of death were similar in the craniectomy group (19%) and the standard-care group (18%).
- craniectomy led to neurological outcomes worse than with standard medical therapy (70% vs. 51%; N.B. cannot be explained by more patients surviving in vegetative state as death rate was similar).

Such difference disappeared after post hoc adjustment for pupil reactivity at baseline.

- obtaining lower ICP is not necessarily translated into improvement in clinical outcome (i.e. having lower ICP after procedure cannot be considered as “substantial benefit” to patient).
- benefit provided by lowering ICP was likely offset by surgical morbidity.

Pediatric trials — see p. T120

TYPES

Primary DC – done during the craniotomy for hematoma evacuation (in anticipation of refractory ICP)

Secondary DC – done for refractory ICP.

1. Frontotemporoparietal hemicraniectomy
2. Bifrontal craniectomy
3. Suboccipital craniectomy
4. Cushing’s subtemporal decompression, temporal lobectomy (debridement of contused brain)
   - complete temporal lobectomy performed within 2 hours of the development of clinical signs of transtentorial herniation in 10 patients with unilateral hemispheric swelling and a GCS < 7*
   - resulted in 40% functional independence.
   - “all patients had displacement of the brainstem, compression of the contralateral peduncle, and progressive obliteration of the parasellar and interpeduncular cisterns on CT, along with fixed pupillary dilation...”

UNLISTED VS. LISTED

1) even in cases of bifrontal contusions* good ICP control can be obtained with unilateral surgery.
2) surgery on side of larger intraparenchymal injury
3) in unilateral surgery, larger decompression can be obtained without manipulation or exposure of sagittal sinus.
4) unilateral surgery enables more extensive decompression low in temporal region.
5) opening into frontal sinuses (look at CT) can be more easily avoided in unilateral decompression.
6) cranialplasty after unilateral decompression is simpler and safer.

Bifrontal approach is required only for bifrontal extraxial mass lesions.

- hemicraniectomy can be performed bilaterally, however, it is difficult to position the head to do this.
- diffuse brain edema with no mass lesion or midline shift
  a) nondominant hemisphere (unilateral DC)
  b) bifrontal DC.

BEFORE SURGERY

1) check poses! 2) type and cross pRBC, FFP, platelets 3) give AED, MAINTAIN ANTIBIOTIC (add 500 mg of METRONIDAZOLE if air sinus involved) 4) ventilate to PAGCO: 25–30 mmHg 5) ask to have plenty of hemostatic agents ready (before incision!) – Surgicel, large pieces of Gelfoam, large amounts of Surgifoam/FloSeal (it takes time to mix them!!!), Avitene, peroxide soaked cotton bolls or cottontails.

PRINCIPLES

- exposure of internal carotid artery in neck for proximal control is always considered when injury to intracranial portion of artery is suspected.
- large craniectomies - to prevent brain stranulation over bone edges.
- minimal brain debridement.
- deep bone fragments should not be chased.
- adequate brainstem decompression - squamous portion of temporal bone and lateral greater wing of sphenoid are removed; anterior temporal lobectomy is performed if needed.
adequate venous drainage decompression – craniectomy extends over vein of Labbé, over parasagittal bridging veins.

- dural outlay substitutes (e.g. DuraGuard) for dural closure – cover entire craniectomy defect (not just dural gaps) – prevents dura scarring to scalp flap (easier plane dissection during cranioplasty). N.B. dural openings must not be large (some leave dura intact just excoriate its surface – inadequate for decompression).

- trauma patients are often coagulopathic - risk of EVD is high in the absence of the tamponading effects of a bone flap – leading to subgaleal drains.

- to prevent compression of large cortical veins as the brain herniates against the dura, may use vascular tunnelling technique (Cooksey) - place Guillotina rolls as supporting pillars between the dura and cortex on one side of large cortical vessel traversing underneath the dura.

- galea and skin should be closed with closely spaced sutures to prevent CSF leak.

**BONE FLAP MANAGEMENT**

a) wash with bacitracin irrigation, saturate with sterile solution (e.g. RPMII medium 1640 www.invitrogen.com/GIBCO), steriley wrap and double bagged (e.g. intestinal bags which are then placed in a sterile plastic container), and store at −30°F (−80 Celsius) for later use.

b) implant into subcutaneous pocket in abdominal left lower quadrant to avoid contamination by feeding tube placement and to decrease confusion with appendix scar, indicated if the patient’s own skull is preferred and the patient does not live in the area where he/she is having surgery; bone flap may be split in half for patient’s comfort, risk of resorption, rhadomyolysis, and infection.

c) place back into skull defect without securing ("floating" craniectomy) – not recommended!

d) discard (if bone is fragmented or grossly contaminated)

**COMPLICATIONS**

- treatment of wartime penetrating head injury has evolved over the last century from Cushing’s recommendation of aggressive brain debulking and watertight dural closure in World War I to minimal brain debulking with maximal surrounding bone removal instituted by Israeli physicians during the Lebanon War of 1982 with improvement in long-term seizure outcomes.

**POSTOP**

- head CT ASAP

- after decompressive craniectomy, the new ICP treatment threshold is > 15 mmHg

- patient need protective helmet if out of bed and a sign at the bedside "No bone flap!"

**HISTORY**

- postoperative care

**INTRAOP COMPICATIONS**

1) venous sinus injury

2) precipitous external herniation (malignant cerebral edema) intraoperatively (soon after decompression) – see below

**POSTOP COMPLICATIONS**

(up to 50-55%)

1) decompressive procedures may aggravate cerebral edema formation → increased secondary injury.

2) expansion of hematoma after decompression.

3) wound complications are most common source of surgical morbidity:

a) traumatic injury to skin at incision → Wound dehiscence

b) infection

c) CSF leak (open durotomy + CSF absorption problems [CSF is absorbed passively due to pressure gradient, at least 5 mmHg, across arachnoid granulations, which is lost after craniectomy])

4) abnormities in CSF absorption (subdural hygroma and hydrocoephalus) – due to ruptured arachnoid creating a one-way valve for CSF flow, pressure gradients between hemispheres due to reduction of ICP and decompression of one hemisphere, and alterations in the brain’s shape as a result of surgery.

- CSF absorption is disturbed after craniectomy (CSF is normally absorbed passively due to pressure gradient, at least 5 mmHg, across arachnoid granulations, which is lost after craniectomy)

- definitive treatment is cranioplasty; VPS may not be successful due to low ICPs

- routine early postop CT should be considered in cases with skull flap remote to site of decompression, esp. no ICP monitor was placed.

- normal postural ICP change was abolished for the entire follow-up period, ie, there was no difference between ICP in supine and sitting position (P = .67).

- intracranial pressure changes

- mean ICP gradually decreased from 7.8 ± 2.0 mmHg to 1.8±3.3mmHg (P=.02) during the first month.

- normal postural ICP change was abolished for the entire follow-up period, ie, there was no difference between ICP in supine and sitting position (P = .67).

- ICP drops by 5-10 mmHg going from supine to standing

- intracranial pulse wave amplitude (PWA) was markedly reduced and decreased from initially 1.2 ± 0.7 mm Hg to 0.4 ± 0.3 mm Hg (P = 0.5)

**PROCEDURES**

- skull fracture compound to side of decompression is significant risk factor for postoperative EVD - routine early postop CT should be considered in cases with skull flap remote to site of decompression, esp. no ICP monitor was placed.

- skull fracture contralateral to side of decompression is significant risk factor for postoperative EVD - routine early postop CT should be considered in cases with skull flap remote to site of decompression, esp. no ICP monitor was placed.

- skull fracture compound to side of decompression is significant risk factor for postoperative EVD - routine early postop CT should be considered in cases with skull flap remote to site of decompression, esp. no ICP monitor was placed.

- skull fracture compound to side of decompression is significant risk factor for postoperative EVD - routine early postop CT should be considered in cases with skull flap remote to site of decompression, esp. no ICP monitor was placed.
A. entire skin incision is completed. In rapidly deteriorating patient with acute SDH/EDH:

- pulse wave propagation is believed to be an important driver of CSF flow and emerging evidence also supports its role in other intracranial fluid movements, such as glymphatic flow; hence, the reduced intracranial PWA may contribute to development of complications related to CSF flow (gyroma, hydrocephalus, “syndrome of the trephined”) occurring after DC.

Subsequent cranioplasty also carries the risk of infection, cerebral swelling, and resorption of the bone flap.

**DECOMPRESSIVE HEMICRANIECTOMY (“TRAUMA FLAP”) / FRONTOTEMPOROPARIETAL CRANIECTOMY**

**PLANNING**

- patient is positioned supine.
- towel roll under ipsilateral shoulder.
- head turned to contralateral side (do not compress jugular veins!).
- N.B. in setting of trauma, it is important to position patient with **cervical spine precautions** (if cervical spine fracture – position patient on bean bag).

**HEMIDRYPHERESIS**

B. head on foam headrest / gel donut - allows for repositioning of head intraoperatively if venous outflow obstruction is suspected; but pinning in Mayfield frame is most convenient.

N.B. it is very important to make large craniectomy but not to damage venous sinuses – draw midline and transverse sinus projection on scalp (thus, highly recommended to shave the scalp to have good landmarks; if leaving hair on [e.g. in less emergent cases, such as MCA stroke], mark scalp and incision before pining the patient and while keeping head in neutral position)

C) Dr. JRC likes to pin the patient – greater access and stability (e.g. do not need assistant to stabilize head when cutting with footplate or elevating bone flap).

- AP axis of head is placed horizontal to floor (unless C-spine not cleared or if neck too immobile – one may compensate for this by rotating table)
- N.B. pins are contraindicated in skull fractures (skull fractures parallel to the plane of CT imaging can be missed)
- N.B. mark incision (esp. midline) before pining the patient (see above) or else it is difficult to see midline.

Pin just below equator.

**PROCEDURE**

**SKIN INCISION**

- protect superficial temporal artery - to preserve blood supply to flap.
- incorporate scalp lacerations if feasible.

In rapidly deteriorating patient with acute SDH/EDH, immediate temporal decompression is performed by incising skin and temporals muscle down to bone just anterior to ear and above zygoma → burr hole and, if necessary, small craniectomy are created to partially decompress temporal lobe, before entire skin incision is completed.

A. **LARGE (REVERSE) QUESTION MARK**

- starts 1-2 cm anterior to tragus at temporal root of zygoma, curves posteriorly above and gently behind ear (or just superior to pinna) to asterion;
- posterior extent of the incision should be more than 15 cm behind the keyhole;
- sweeps around parietal boss to few centimeters lateral to sagittal suture and forward to widow’s peak;
- may cross over to opposite frontal region in curvilinear fashion along hairline for 3-4 cm.
N.B. one wants scalp incision away from craniotomy edge – postop scalp shrinks and drags scar over dura (cranioplasty is easier if scalp scar is over the bon). Plus, it is safer to mark/make incision paramedian and not in midline (to leave margin of error if midline was not clearly marked, plus, during surgery it may be difficult to visualize sagittal suture); posterior corner may hug the lambdoid suture.

B. Ludwig G. Kempe hemispherectomy incision (midline sagittal incision with “T-bar” extension)

- spares STA, posterior auricular and occipital arteries, unlike large reverse question mark incision:
  - starts at widow’s peak and is carried posteriorly along the sagittal suture toinion;
  - “T-bar” extension is started 2 cm anterior to tragus at temporal root of zygoma, curving slightly above ear and then incised superiorly to meet midline sagittal suture (approximately 1 cm behind the coronal suture) 
  - advantages over “?” craniotomy - much better healing (preserved vascular supply, no pressure on posterior incision), also allows for easy surgical access to contralateral side by placing second “T-bar” extension if bilateral surgical access is needed.

**Skin incision is carried down to cranium; incise temporalis muscle with Bovie along skin incision.**
- expose superior portion of temporalis fascia (along temporal line) and make incision leaving fascial cuff for reconstruction (only if planning to place the bone flap back at the end of procedure; otherwise elevate full thickness myocutaneous flap leaving naked bone).
- musculocutaneous flap is reflected anteriorly (i.e. temporalis muscle is elevated off bone using periosteal / Bovie) and fixed with scalp hooks/towel clamps.
- ideally, muscle dissection extends down to root of zygoma and as far below keyhole as possible, to maximize temporal decompression achieved.

**BURR HOLES AND BONE FLP**

- may use 14 mm perforator at calvarium – quick; at keyhole and zygoma need to use Acorn drill bit as bone there is very thin (until perforator reaches disengagement depth, dura is already shredded).
- bur holes placed at:
  1) pterion or keyhole (exposing frontal and temporal dura) – absolutely necessary
  2) just above the posterior root of zygoma – absolutely necessary (all other bur holes are optional)
  3) about 1-2 cm above asterion (to avoid transverse sinus)
  4) inferotemporal boss
  5) superior to parietal boss
  6) additional one or two bur holes 2 cm off midline on ipsilateral side of craniectomy.

- bone flap perimeter:
  - just the floor of middle fossa above mastoid air cells to get as low as possible (beware transverse sinus) → extending back 1 cm beyond the lambdoid suture* → around parietal boss (crossing lambdoid again) toward midline; leaving 2-3 cm lip of bone adjacent to sagittal suture → coronal suture is crossed and the drill is taken as low as possible in the frontal fossa near the midline → staying as low as possible, the orbital roof is followed posteriorly towards the keyhole burr hole.

  *this leaves a small amount of bone posteriorly on which the head can rest post-op — decompressive craniectomy led to significant improvement in the visibility of mesencephalic cisterns and a significant decrease in midline shift; this change in cistern visibility correlated with the distance between the lower craniectomy border and cranial base.


- several burr holes (at least three) are made to create bone flap that is 12 × 15 cm (smaller bone flaps would not sufficiently decompress brain but may be sufficient for EDH or SDH evacuation when brain edema is not expected) – use ruler to measure back from keyhole to ensure anteroposterior extent of bone flap is 15 cm.

- large burr hole is placed in temporal squamosa at zygoma root; additional burr holes can be placed posterior (parietal) and 1.5 cm off midline (frontal).
• flap should extend 1.5 cm from midline, 1-2 cm above transverse sinus – to decompress vein of Labbé, parasagittal bridging veins

in especially urgent cases (recent anisocoria and underlying SDH), making cruciate opening in dura through first burr hole may provide some relief of intracranial hypertension.

• dura over anterior frontal lobe is commonly torn (typically in emergencies and older patients) - it is good practice to assume that dura may be incompetent in frontal area and to begin to strip dura and elevate bone flap away from this site.

• Dr. Villanueva makes parasagittal bone cut from front to back (rationale – dura is more commonly is damaged at the beginning of cut – so better to tear SSS anteriorly).

• fate of bone flap – see above >>

TEMPORAL FLOOR

• after removal of bone flap, remaining TEMPORAL BONE must be cut with rongeur down to floor of middle cranial fossa (subtemporal craniectomy) to provide maximal decompression of lateral brainstem.

N.B. bite with rongeur (not twist or torque) during bone removal low in middle fossa; aggressive maneuvers with rongeur can open or displace skull base fractures → uncontrolled bleeding.

• sphenoid wing is removed with rongeurs or high-speed drill
hyperdensity seen above the left frontal lobe is part of the Jackson protruding beyond the previous boney and the remaining interhemispheric subdural hematoma. The brain Decompressive hemicraniectomy. Note the extensive boney decompression from the frontal bone to the occiput

Head CT ASAP:

- Options

DURAL OPENING:
- several choices:
  a) only vertical slit incisions ("pie cutting") – if expect malignant cerebral edema (e.g. in GSW) so will be difficult to close even scalp flap. slide brain ribbon through slit and then suction tip over brain ribbon – evacuate clot; if brain looks collapsed after clot evacuation, may connect cuts by horizontal dural cut (so result is H).
  b) H incisions
  c) C flap
  d) C-shaped with spoke-wheel relief cuts 1-cm short of the craniotomy edge with dural releasing incisions made at intervals up to the bone margin to avoid strangulation of the brain on the dural edge
  e) multiple radial incisions (in stellate fashion) to provide maximal cerebral decompression:

open dura slowly (!!! – risk of sudden cardiovascular collapse; H: adequate resuscitation by anesthesia - central line is a must).

remove hematomas (gentle scraping and sucking), obtain hemostasis (bipolar), irrigate copiously.

arterial blood exiting from middle fossa in large amounts warrants exploration and often arises from middle meningeal artery or sphenoid wing. H: slightly more conservative temporal craniectomy provides bone to which the dura can be tacked, which may stop bleeding; consider waxing foramen spinosum, peroxide soaked cotton balls or cottonoids.

large frontal and temporal contusions can be removed with gentle suction and bipolar cautery.

ultrasonic can be used to identify intracerebral hematomas that do not come to surface.

CLOSURE:
- using dural substitute (DuraGuard, SepraFilm).

Options:
A. Duraaplasty – suturing graft to dural edges.
B. Leave durotomy open to permit brain expansion ("rapid-closure DC"); cover brain with onlay dural substitute to protect brain surface and reduce adhesions to scalp flap - leaves of dura are folded over dural substitute (do not suture patch to dura!)

epidural tack-up sutures to bone edge.

subgaleal drains are placed over surface of dural substitute and tunneled externally; at least two Jackson-Pratt drains (patients often do not clot properly, and without tamponading effect provided by bone flap, risk of EDH is high).

N.B. routine prolonged use of drains is needed!!

galea is closed with numerous, closely spaced interrupted 2-0 absorbable braided sutures.

skin is closed with running 4-0 absorbable monofilament suture / staples – to prevent CSF leak

sterile head wrap (not tight if bone removed + label side of head without bone)

POSTOP

Head CT ASAP:

Decompressive hemicraniectomy. Note the extensive bony decompression from the frontal bone to the occiput and the remaining interhemispheric subdural hematoma. The brain parenchyma on the left can be seen protruding beyond the previous boney-boundary indicating how severe the intracranial hypertension was. The hyperdensity seen above the left frontal lobe is part of the Jackson-Pratt subgaleal drain:
DECOMPRESSIVE BIFRONTAL CRANIECTOMY (KJELLBERG)

pronounced “Shellberg”


INDICATIONS

Level II A recommendation

- bifrontal DC is not recommended to improve outcomes (as measured by GOS-E score at 6 months post-injury in severe TBI patients with diffuse injury and with ICP > 20 mm Hg for > 15 minutes within a 1-hour period that are refractory to first-tier therapies).
- demonstrated to reduce ICP and to minimize days in ICU.

PROCEDURE

- supine position with the head in 15-30 degrees of flexion.

INCISION

- bicoronal (Souttar) incision - starts at root of zygoma, 1-2 cm anterior to tragus, extends superiorly to or just behind coronal suture, and ends at root of opposite zygoma, 1-2 cm anterior to tragus.
- Dr. Villanueva uses wavy (vs. straight) incision – scar does not interfere with chewing.
- myocutaneous flap is brought forward over the orbital rim.
  - dissect out the supraorbital nerves from the supraorbital notch on either side (if the supraorbital notch is closed, a small osteotome can be used to open it so that the supraorbital nerve can be freed) - allows further advancement of the myocutaneous flap.

HOLE

- bur holes are placed in:
  1) pterion (keyhole)
  2) root of zygoma
3) just below superior temporal line
4) over superior sagittal sinus (last bur hole to make) – if a large single bone flap is planned

** posteriorly – behind coronal suture**

Dr. Villanueva extends even further to parietal bossings – the adequate decompression of sagittal sinus.

** alternatively, strip of bone can be left over sagittal sinus for protection.

- bilateral frontal and subtemporal craniectomies are performed, exposing frontal and anterior temporal lobes.
- anteriorly, drill passes just above the orbital rims and nasal bridge.
- additional (optional) removal of squamous portion of temporal bone and greater wing of sphenoid bone is accomplished with rongeur, removing bone to floor of middle fossa.
- immediately after removing bone put lap pad with \( H_2O \) over entire dura – air embolism prophylaxis (in case SSS was damaged) plus hemostatic.
- if frontal sinus is entered, it must be cranialized (dissect the flap of pericranium to cover it).

A. One bone flap:

B. Two bone flaps:

** N.B. if midline bone strip is too wide, it can damage the brain!**

Variant without temporal decompression (avoiding zygomatic bur hole):

- some experts insist, that the division of the anterior superior sagittal sinus and falx is crucial.
- dural cuts:
  a) standard Kjellberg open fish-mouth cuts made along floor of anterior fossa with release of inferior aspect of interhemispheric falx and then curved up (along posterior bone edge) towards SSS
  b) mitral valve-type dural incisions – parallel to superior sagittal and parallel to posterior bone edge (some recommend connecting bilateral incisions along floor of anterior fossa with release of inferior aspect of falx).
c) bifrontal cruciate incisions

POSTERIOR FOSSA DECOMPRESSIVE CRANIECTOMY

- **Incision**: midline skin incision from above inion to ≈ C2 spinous process.
- **Bone opening**: laterally to sigmoid sinuses, superiorly to transverse sinus.
- **C1 laminectomy**: typically performed as well.
- **Dural opening**: “Y” shaped incision.

PENETRATING BRAIN INJURIES

- **Systemic antibiotics + tetanus prophylaxis + seizure prophylaxis**
- **Rapid local debridement**: clean from bone fragments, necrotic brain, debris, foreign objects.
- **Debridement of devitalized brain**: gentle (use combination of suction and irrigation).
- **Exploration for hemorrhage and necrotic tissue** (recent data question practice of pursuing bone chips spread deeply into brain).

N.B. retained fragments have not been associated strongly with infection, most authors **remove fragments only if they are accessible**! (secondary removal is performed only for unusually large retained fragments - complication rate for repeat exploration may exceed rate of complications of retained fragments).

- **Watertight closure**: after hemostasis, all layers of wound are closed tightly (drains are added when hemostasis is not absolute).

Options (class III) for penetrating TBI:

a) small entrance bullet wounds → local wound care and closure.

b) extensive wounds with nonviable (devitalized) scalp, bone, dura → more extensive debridement before primary closure or grafting to secure a watertight wound.

c) significant fragmentation of the skull → debridement with either craniectomy or craniotomy.

d) significant* mass effect → debridement of necrotic brain tissue and safely accessible bone fragments, evacuation of intracranial hematomas.

N.B. in the **ABSENCE OF SIGNIFICANT MASS EFFECT**, surgical debridement of the missile track in the brain is not recommended (class III evidence - outcomes are not measurably worse in patients who do not have aggressive debridement); routine surgical removal of fragments lodged distant from the entry site and reoperation solely to remove retained bone or missile fragments are not recommended.**

e) open air sinus injury → watertight dura closure — any repairs requiring duraplasty can be at the discretion of the surgeon as to material used for closure.

- **the question of timing of surgery has not been adequately studied to make evidence-based recommendations but general practice is to operate promptly.**

N.B. CSF leak is the variable most highly correlated with intracranial infection after PBI (CSF leak increases risk of infection 10-20 fold); Highest risk of CSF leak - transventricular trajectories (suggesting a course of CSF drainage in such cases), trajectories through air sinuses (suggesting sinus cranialization in such cases).

**significant** - displacement of the midline > 5 mm, compression of basilar cisterns from edema or hematoma, deteriorating clinical condition.
**GUNSHOT WOUNDS**

**Military vs. civilian penetrating brain injury (PBI):**

- Most PBIs incurred on the battlefield are from *shrapnel*, not bullets, like most civilian PBIs.
- Most PBIs on the battlefield by a high-velocity bullet never make it to medical care - extremely damaging cerebral injuries that these bullets inflict (field usage under battle conditions requires the corpsman to identify the injured who have a low probability of surviving and not to prioritize them for rapid transport).
- Wounds are much more likely to be contaminated on the battlefield.
- Suicides are much less frequent.
- Most injuries in the military setting occur in the blood vessel bed; requires aggressive debridement no longer appears to be supported.
- Most studies cannot report a clinical advantage in mortality vs. civilian setting.
- Injuries in the military setting occur primarily in young men in excellent physical condition; vs. civilians across a broader age range.
- Literature reports a mortality under wartime conditions in the 20% range (8-43%; military gunshot wounds have 2.5-4 times higher mortality than from shrapnel wounds) vs. 94% for civilian cases.

**Fast surgery** often represents “damage control” surgery - quick removal of mass lesions, e.g., hematoma, parenchymal debridement without overly aggressive pursuit of deep and small bone or foreign fragments hematoma, and quick decision with respect to decompressive craniectomy, deep imbedded bone fragments and foreign bodies are not chased.

- Scalp incision (during primary craniotomy) is better to locate away from penetration wound so that least possible scarring will overlie site of any future cranioplasty.
- The argument for delaying cranial closure of bullet holes did not indicate worse outcome.

**v**

- Delayed **debridement of first few centimeters of tract** - reports from Middle East conflicts in which patients were treated without any debridement but with only simple skin closure of bullet hole did not indicate worse outcome.
- Second or third operations are sometimes necessary for further debriement of necrotic brain tissue; deep imbedded bone fragments and foreign bodies would often deliver themselves to battlefield and civilian trauma.
- Ultrasound is helpful in finding retained fragments or hematomas.
- N.B. bullet is not removed unless it is easily accessible.
- N.B. - bullet retrieval exceeds benefit of its removal.
- Vigorous debridement and pursuit of intracranial fragments are not necessary to prevent infection, has no obvious efficacy in preventing epilepsy, and is associated with morbidity and mortality without resulting in any clear advantage in mortality.

**STAB INJURY**

a) jei ligiai pateko sau įtiktus žalosiai įprotėmis, tai sužeidimas vykstas priež. 12 valdau, žiaudu nėra stiprių sąlygų, nėra įmanoma įvertinti sausumoje ir impresinio likimo – pakanka pirminio chirurginio odos šakų sutvarkymo.
- **Current standard is only simple scalp incision;** jei šių reikalavimų neišlaikoma chirurginio odos žaizdos sutvarkymo.
- **Hard to control bleeding, ligation is dangerous**
- **Mentioned at least possible scarring will overlie site of any future cranioplasty.**
- **During primary craniotomy, through the Vietnam War:**
- **The argument for decompressive craniectomy, deep imbedded bone fragments and foreign bodies are not chased.**
- **Scalp incision (during primary craniotomy) is better to locate away from penetration wound so that least possible scarring will overlie site of any future cranioplasty.**
- **Literature reports a mortality under wartime conditions in the 20% range (8-43%; military gunshot wounds have 2.5-4 times higher mortality than from shrapnel wounds) vs. 94% for civilian cases.**
- **Fast surgery** often represents “damage control” surgery - quick removal of mass lesions, e.g., hematoma, parenchymal debridement without overly aggressive pursuit of deep and small bone or foreign fragments hematoma, and quick decision with respect to decompressive craniectomy, deep imbedded bone fragments and foreign bodies are not chased.
- Scalp incision (during primary craniotomy) is better to locate away from penetration wound so that least possible scarring will overlie site of any future cranioplasty.
- The argument for delaying cranial closure of bullet holes did not indicate worse outcome.

**DURAL VENOUS SINUS INJURIES**

- **Traumatic dural venous sinuses injuries carry high mortality (vs. slow sinus occlusions by tumor)** - hard to control bleeding, ligation is dangerous.
- **N.B. bullet is not removed unless it is easily accessible** (because risk of brain injury from bullet retrieval exceeds benefit of its removal).
- **N.B. bullet is not removed unless it is easily accessible** (because risk of brain injury from bullet retrieval exceeds benefit of its removal).

**Current standard is debridement of first few centimeters of tract – watertight dural closure**

- **Second or third operations are sometimes necessary for further debriement of necrotic brain tissue; deep imbedded bone fragments and foreign bodies would often deliver themselves to battlefield and civilian trauma.**
- **N.B. bullet is not removed unless it is easily accessible** (because risk of brain injury from bullet retrieval exceeds benefit of its removal).
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MALIGNANT CEREBRAL EDEMA

OMINOUS SIGN!
- May happen if patient had period of hypotension / hypoxia – maximally dilated and brain vessels with paralyzed autoregulation.
- May happen precipitously intraoperatively (soon after decompression) → external herniation

MANAGEMENT
- Make sure no venous outflow obstruction, make sure no tapes around neck.
- Elevate HOB.
- Avoid high SBP.
- Increase depth of anesthesia.
- Hyperventilate.
- Additional TANNSTOL.
- Place EVD.
- Suspect contralateral hematoma – empiric surgical exploration on other side without interim CT (esp. in setting of contralateral skull fracture).
- Avoid venous compression at sharp bone edges by making a gap in the bone above draining veins using a bone rongeur.
- Subtotal temporal and/or frontal lobectomies may be necessary.
- Primary scalp closure maybe difficult (if this possibility is suspected in advance, it is wise to obtain hemostasis and be prepared to close before dura is opened); plus:
  - If head damp (Mayfield, Sugita) was used, it should be released to give the scalp laxity to be mobilized toward the incision.
  - Dissection of the galea from the neighboring skull may be performed to provide more laxity.
  - Make incisions in the galea from the underside of the scalp without cutting the epidermis (relaxing incisions).

Viktor’s Notes℠ for the Neurosurgery Resident
Please visit website at www.NeurosurgeryResident.net