# SURGICAL TREATMENT OF ISCHEMIC STROKE

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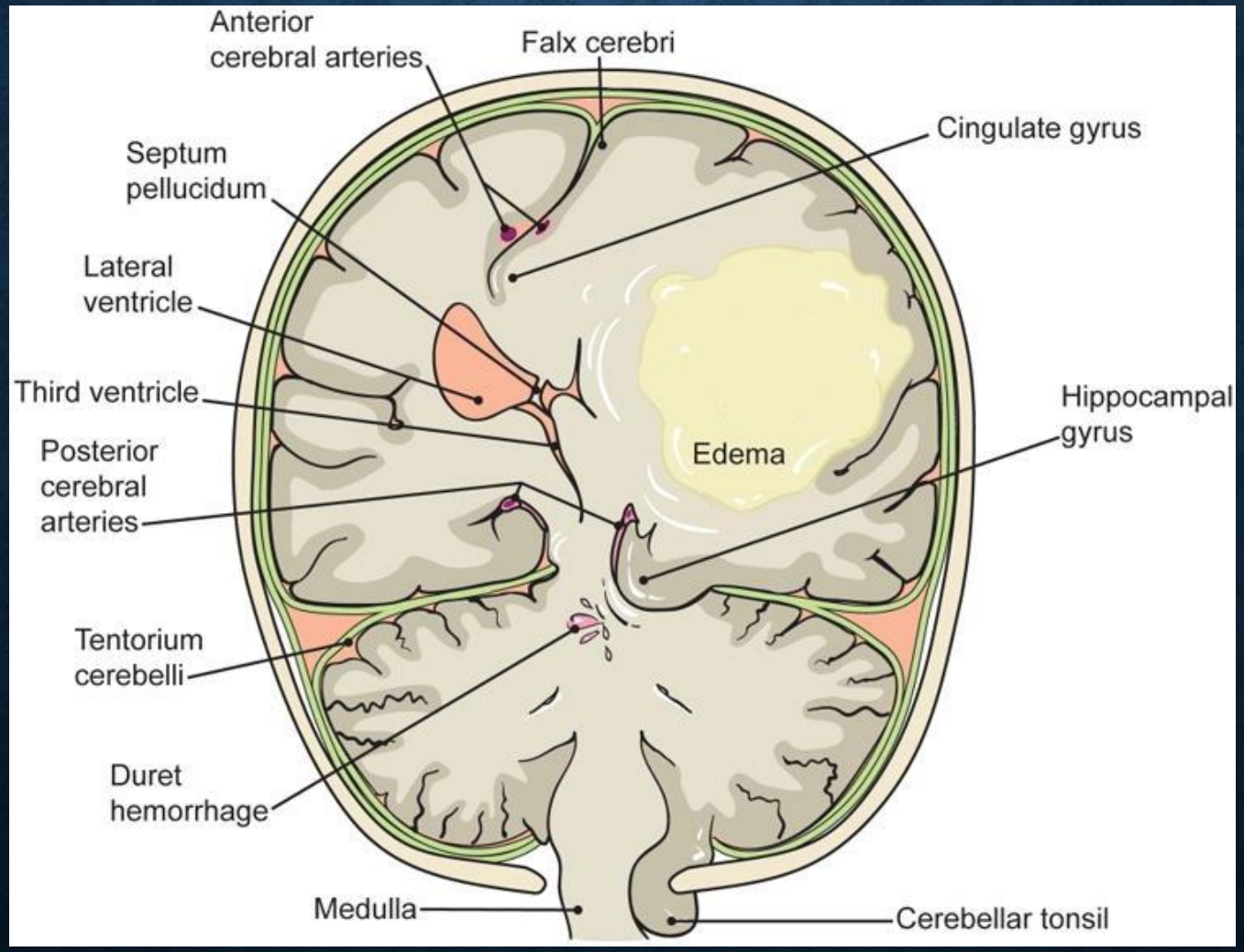
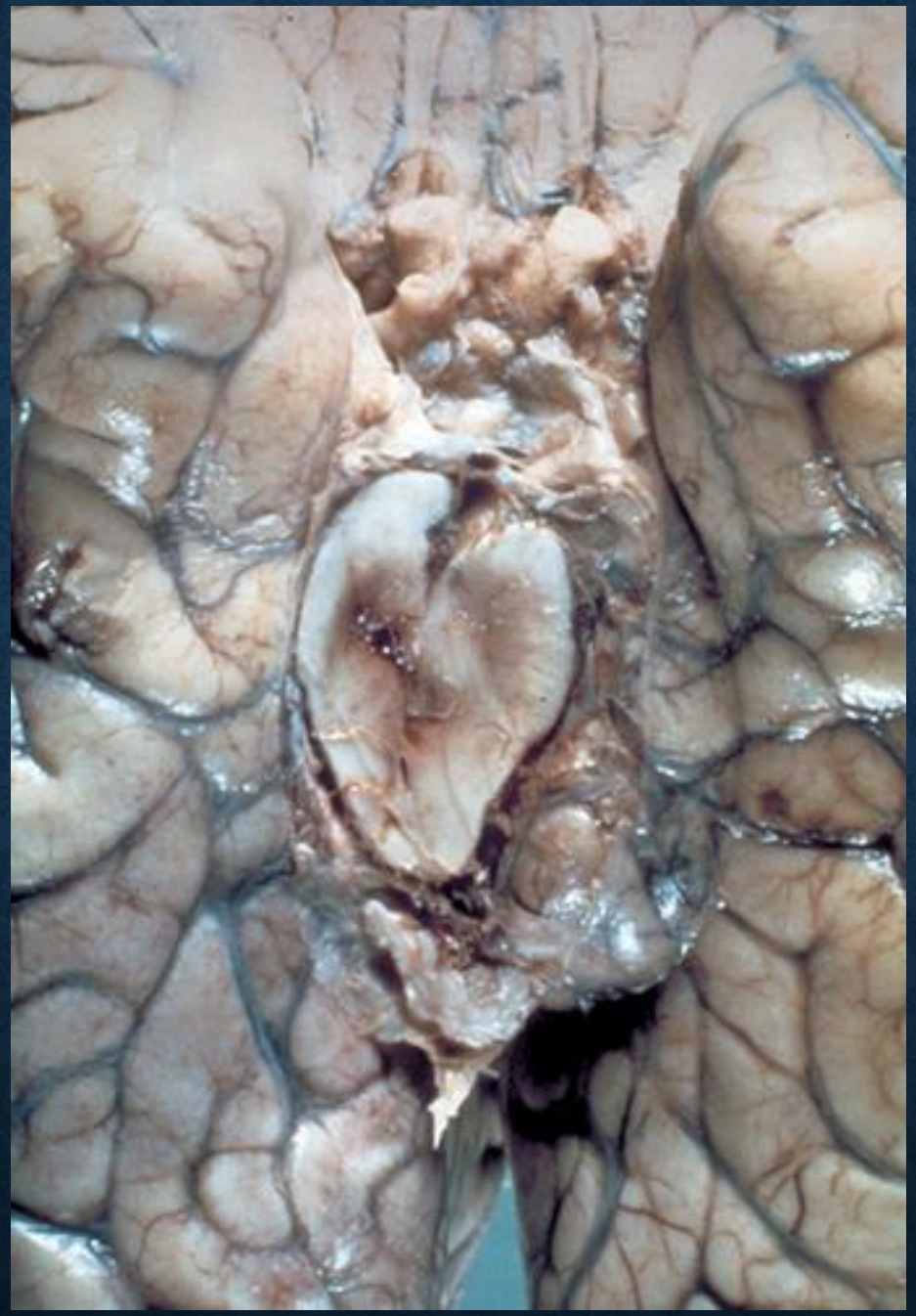
- The malignant edema associated with these events usually reaches a peak 2 to 4 days following the ictus, but can manifest as early as within the first 24 hours.
- The distribution of mortality rates is bimodal, with an early peak within the first 3 to 6 days, followed by a second peak during the 2nd and 3rd weeks after stroke.

- Mortality during the first peak is primarily due to transtentorial herniation from edema-related increased intracranial pressure (ICP) within a fixed-volume skull.





# ICP MANAGEMENT

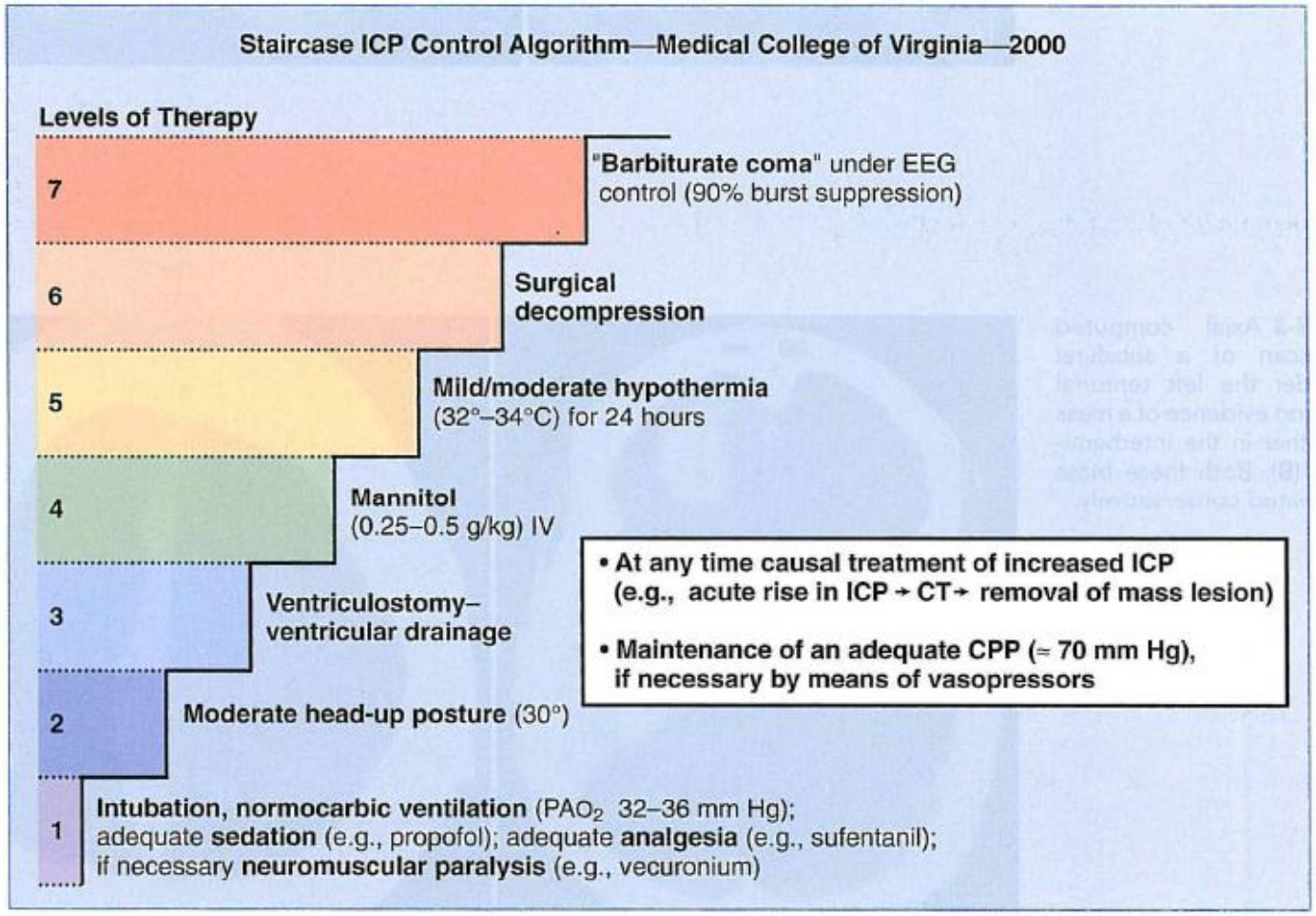



**FIGURE 335-1** Algorithm used at the Medical College of Virginia for the stepwise management of elevated intracranial pressure (ICP). CPP, cerebral perfusion pressure; CT, computed tomography; EEG, encephalographic.

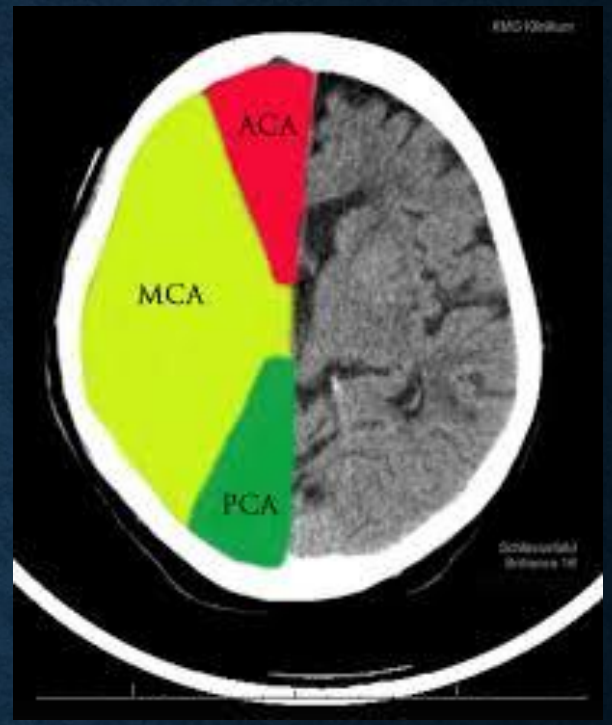
# ICP MANAGEMENT

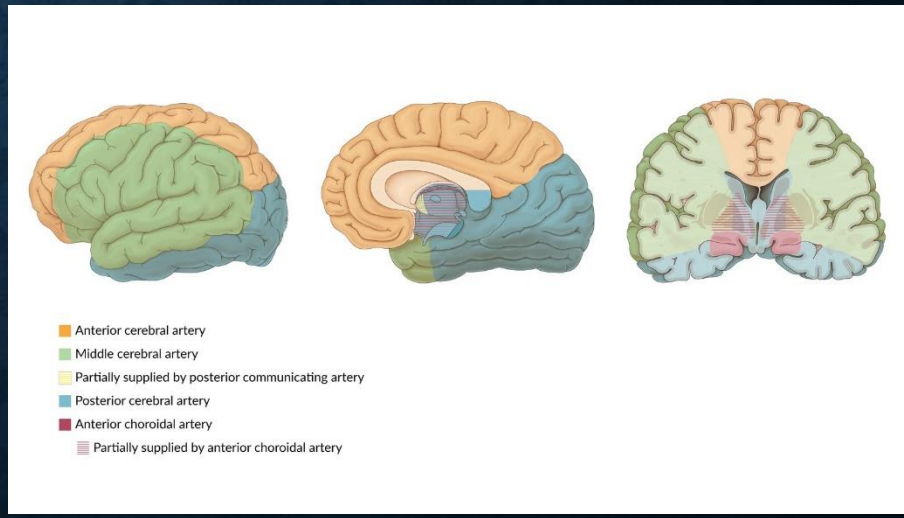
**Table 1. Tiered Treatment of Intracranial Hypertension**

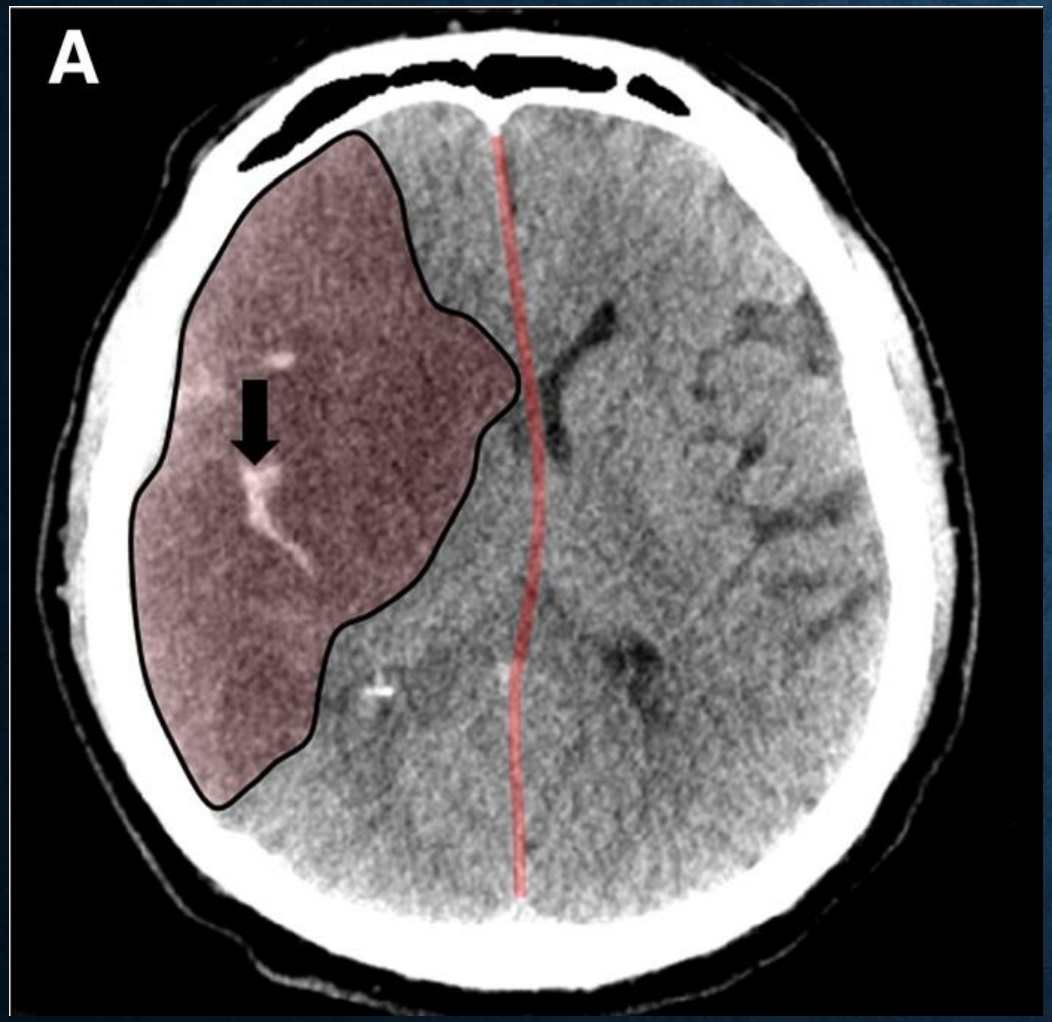
| Tier | Intervention | Risks/Considerations |
|---|---|---|
| 1 | Elevate head of bed to 30° | Hypotension |
| | Mechanical ventilation to maintain oxygenation and $Paco_2$ 35–40 mm Hg | |
| | Normovolemia | |
| | Propofol (2–4 mg/kg/h) | Hypotension, propofol infusion syndrome |
| | Timely evacuation of intracranial mass lesions | Surgery-associated risks, postoperative hemorrhage, cerebral edema |
| | Treatment of seizures | Specific drug side effects |
| 2 | Increase sedation | Hypotension, propofol infusion syndrome |
| | Neuromuscular blockade | Myopathy, neuropathy |
| | Hyperosmolar agents | |
| | Mannitol | Hypotension, hyperosmolarity |
| | Hypertonic saline | Optimal osmolar load unknown |
| | Normothermia | |
| | Cerebrospinal fluid drainage via an external ventricular catheter | Risks of external drain insertion including bleeding and infection |
| 3 | Induced hypertension to increase cerebral perfusion pressure | Acute lung injury secondary to vasopressors and overzealous fluid resuscitation |
| | Moderate therapeutic hypothermia | Arrhythmia, infection, fluid and electrolyte abnormalities |
| | Short-term, moderate hyperventilation ($Paco_2$ 30–35 mm Hg) | Cerebral ischemia |
| 4 | Barbiturates | Hypotension, increased duration of mechanical ventilation, infection |
| | Decompressive craniectomy | Bleeding, infection, risk of survival with poor outcome |

Complications of treatment increase from tier 1–4 level interventions.

- Anterior Circulation:
  - ACA (Anterior Cerebral Artery)
  - MCA (Middle Cerebral Artery)
- Posterior Circulation
  - PCA (Posterior Cerebral Artery)
  - SCA (Superior Cerebellar Artery)
  - AICA (Anterior-Inferior Cerebellar Artery)
  - PICA (Posterior-Inferior Cerebellar Artery)

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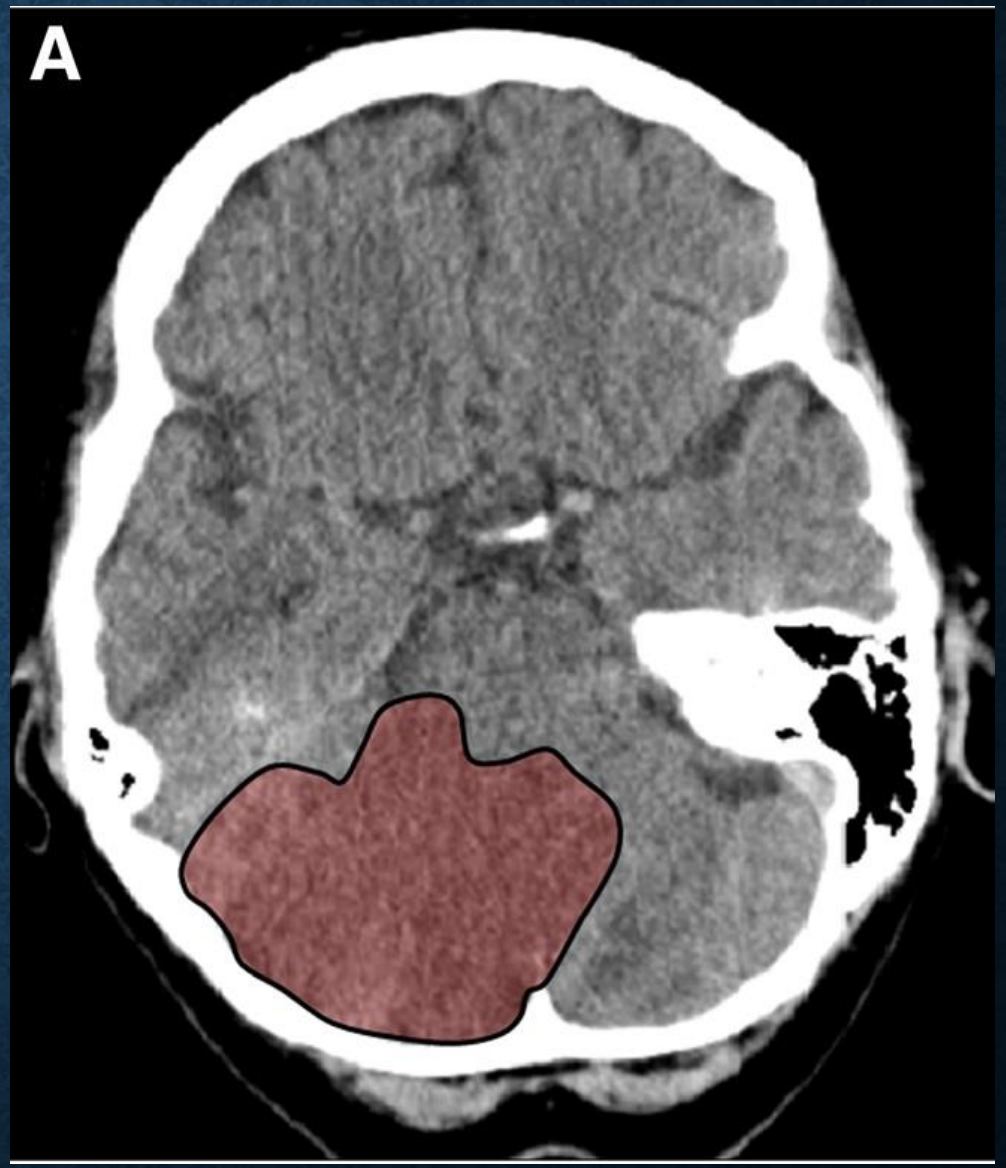
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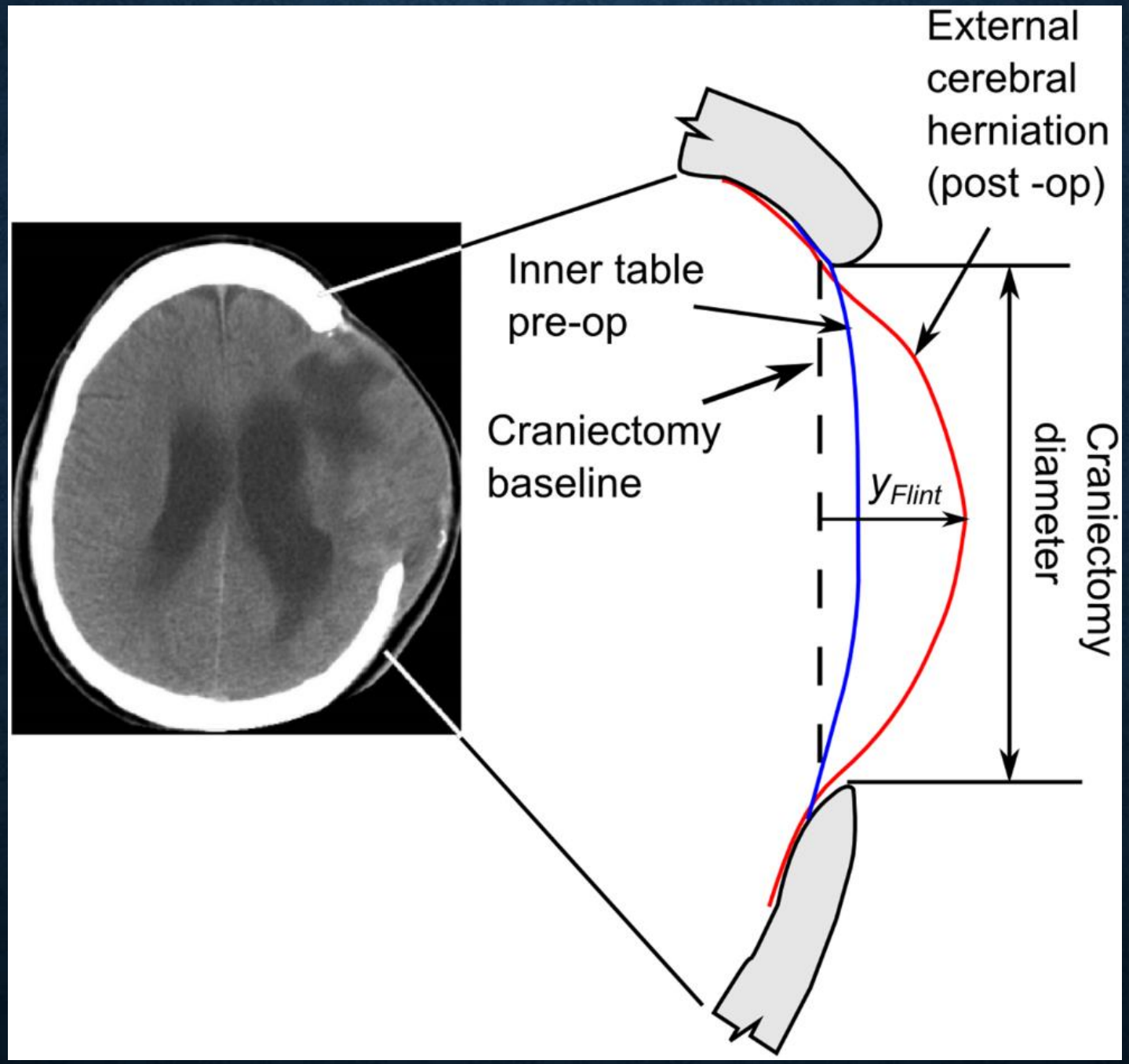
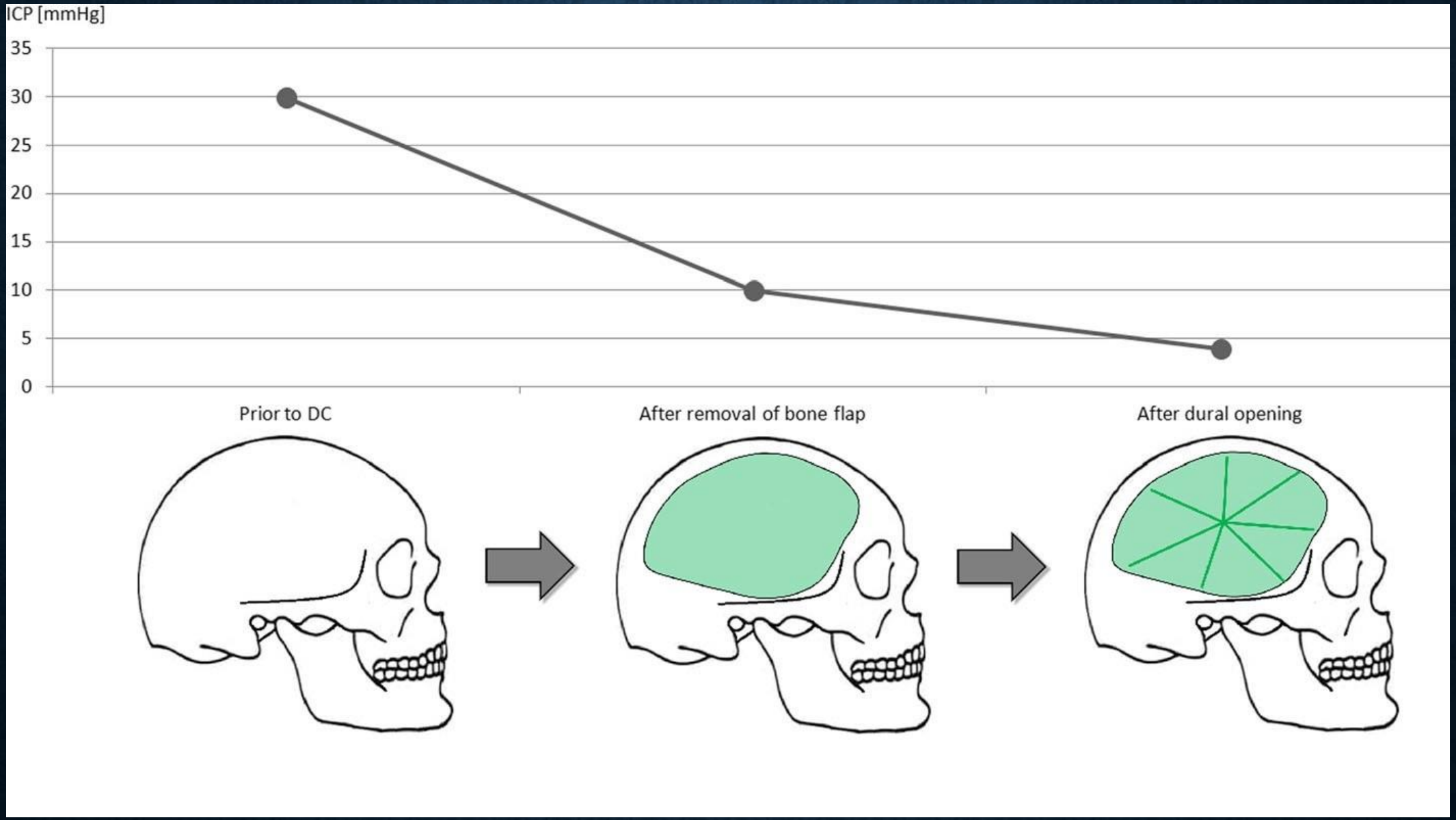
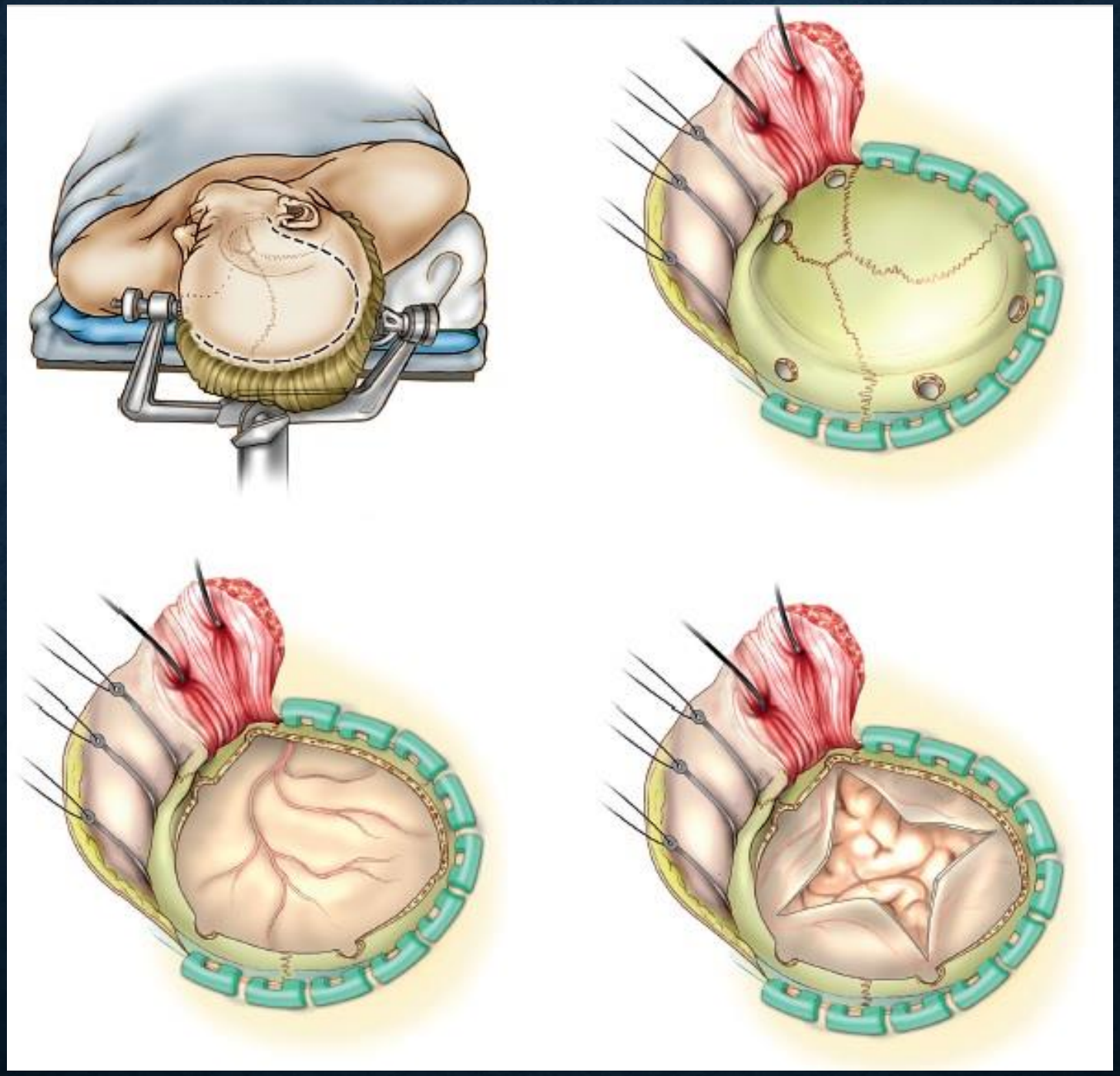
# PREDICTORS OF PROGRESSION TO MALIGNANT EDEMA

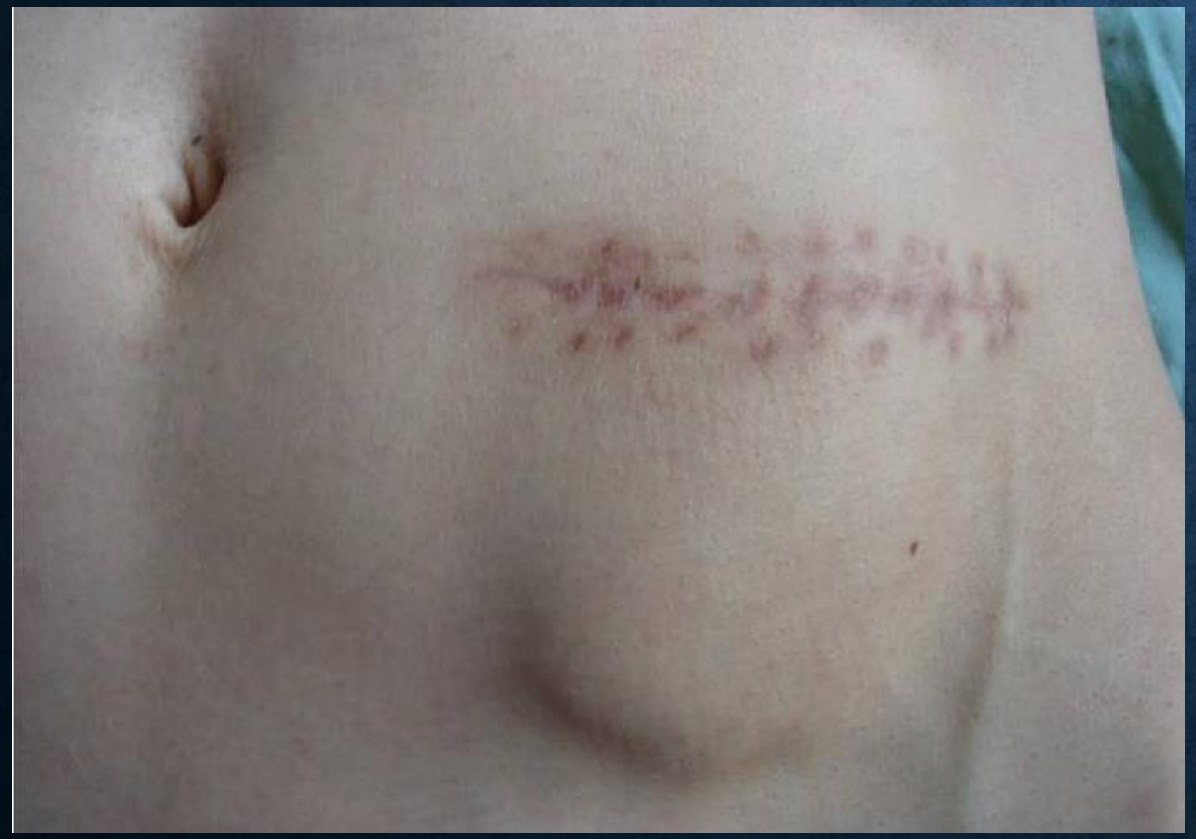
- Size of the stroke (the most important). An infarct volume greater than 145 cc measured by DWI within 14 hours of stroke onset has high sensitivity (100%) and specificity (94%) for predicting progression to life-threatening edema. Combining DWI with ADC, can increase specificity to almost 100%
- CT showing stroke volume >50% of the MCA territory
- National Institutes of Health Stroke Scale (NIHSS) >20 on admission
- Development of nausea/vomiting within 24 hours of onset of infarction
- Systolic blood pressure ≥180 mm Hg 12 hours after the onset
- History of hypertension or heart failure

- Timing of decompressive surgery is important prognostically; once ICP becomes unmanageable and brainstem compression signs are noted, DC may be lifesaving but at the expense of severe neurological impairment. Early decompression results in profound decreases in the mortality rate and improvement in functional outcome 6 months later. Decompressive surgery should be considered very shortly after failure of maximal medical therapy for ICP control


External
cerebral
herniation
(post -op)
Inner table
pre-op
Craniectomy
baseline
$y_{Flint}$
Craniectomy
diameter


ICP [mmHg]
35
30
25
20
15
10
5
0
Prior to DC
After removal of bone flap
After dural opening

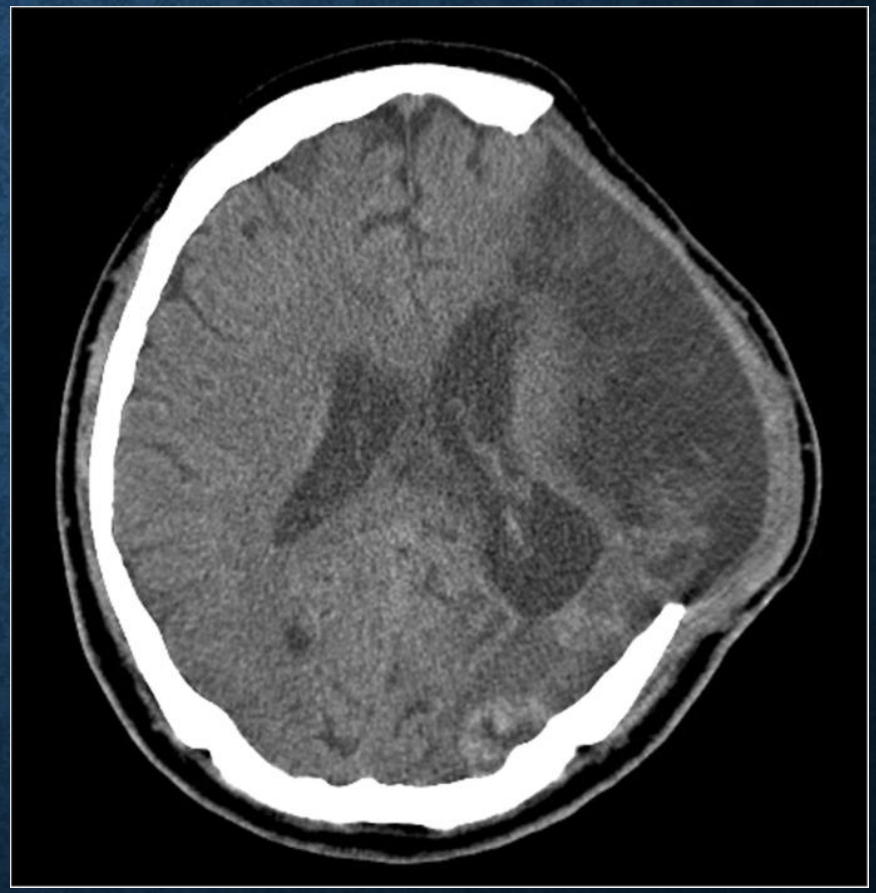




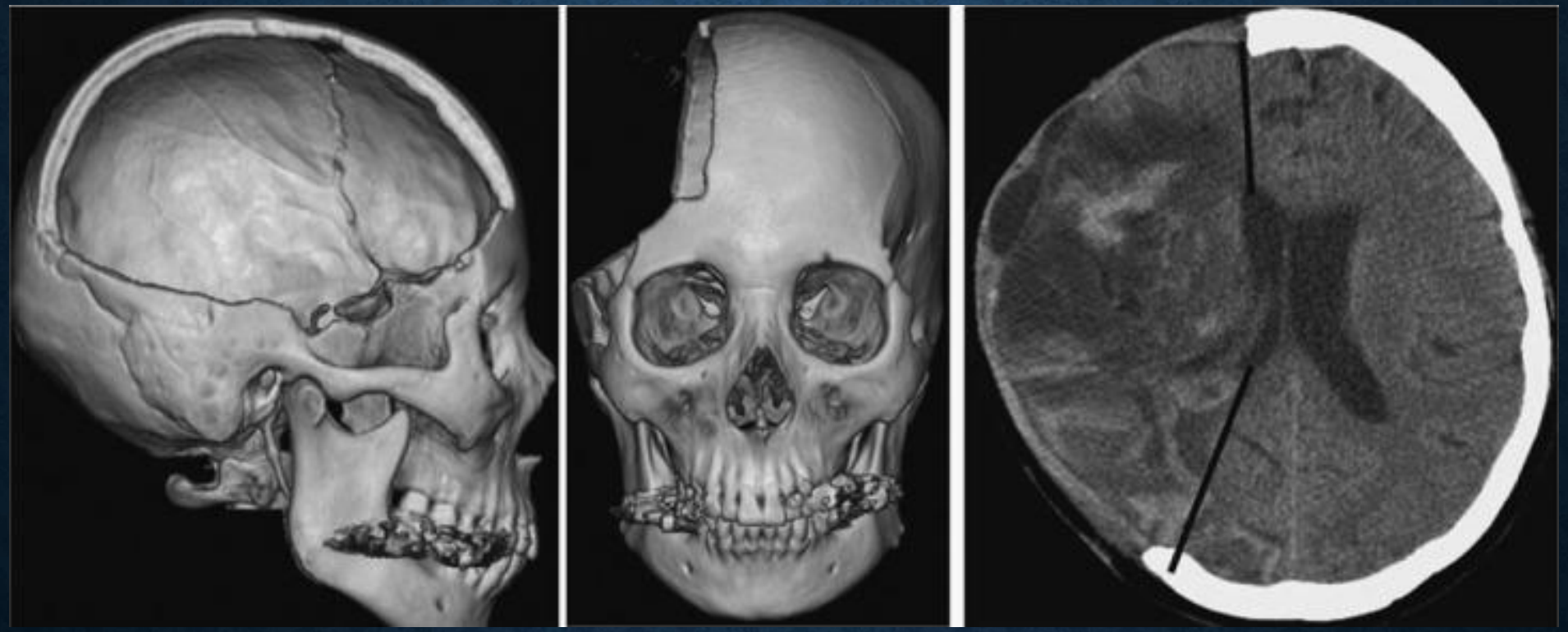
# OPTIONS FOR THE REMOVED BONE FLAP

- Discard it: this may be the best option when the bone flap has been contaminated as a result of an open traumatic scalp laceration
- Place it in a separate subcutaneous pouch in the patient's abdomen for later retrieval and reimplantation into the skull. This is especially helpful if the patient's own skull is preferred and the patient is not at the facility where the cranioplasty to replace the bone is likely to be performed
- Store it externally for future re-implantation: saturate with sterile preservative solution and then place within sterile storage and store in an ultralow temperature freezer (-80 °C)


PF

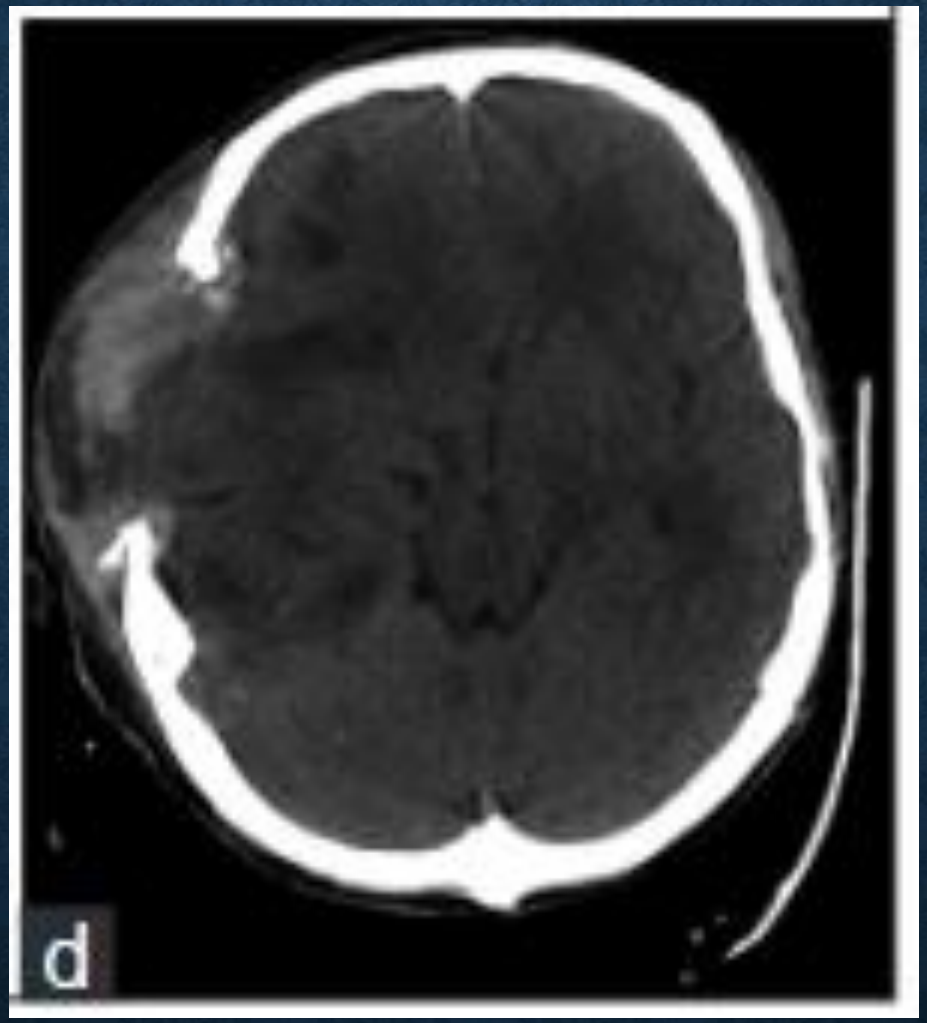


Bone openings need to be large (> 12cm diameter, often > 15 cm)



# POTENTIAL COMPLICATIONS

- Herniation of the brain through the opening, compressing and lacerating the brain on the bone edges (risk may be reduced by making generous craniectomy)
- Post-op injury to the brain from inadvertent external pressure applied to the now relatively less protected brain
- Post-op fluid collections: hygromas or hematomas at the operative site, on the contralateral side or interhemispheric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- Decompressive craniectomy (DC) was first used to treat ischemic stroke-related malignant edema in the 1970s and early 1980s. For the following two decades, several retrospective uncontrolled series were published addressing the question of whether DC provided benefit

| Modified Rankin Scale | |
|---|---|
| **0** | No symptoms |
| **1** | No significant disability. Able to carry out all usual activities, despite some symptoms. |
| **2** | Slight disability. Able to look after own affairs without assistance, but unable to carry out all previous activities. |
| **3** | Moderate disability. Requires some help, but able to walk unassisted. |
| **4** | Moderate severe disability. Unable to attend to own bodily needs without assistance, and unable to walk unassisted. |
| **5** | Severe disability. Requires constant nursing care and attention, bedridden, incontinent. |
| **6** | Dead |

# TRIALS

- **DESTINY**
  - Decompressive Surgery for the Treatment of Malignant Infarction of the MCA
- **DECIMAL**
  - Decompressive Craniectomy In Malignant MCA Infarction
- **HAMLET**
  - Hemicraniectomy After MCA Infarction With Life-Threatening Edema Trial

# META-ANALYSIS

- The pooled analysis demonstrated the positive effects of decompressive craniectomy with an ARR of 51.2%, when comparing patients with mRS 0-4 versus 5-6 at 12 months. DC reduced the risk of death from 71% to 21.5%.
- These data suggest that the previous concern that DC improves survival while leaving the majority of patients in a severely debilitated state was false.

# TRIALS

- **HeADDFIRST**
  - Hemicraniectomy and Durotomy upon Deterioration From Infarction-Related Swelling Trial
- **HeMMI**
  - Hemicraniectomy for Malignant MCA Infarction
- **DEMITUR**
  - Decompressive surgery for the treatment of Malignant Infarction of the MCA

# META-ANALYSIS

- Yang: In this review mortality was significantly decreased in the setting of early DC, though the number of patients surviving with a mRS outcome of 4-5 was not statistically different for craniectomy or best medical therapy.

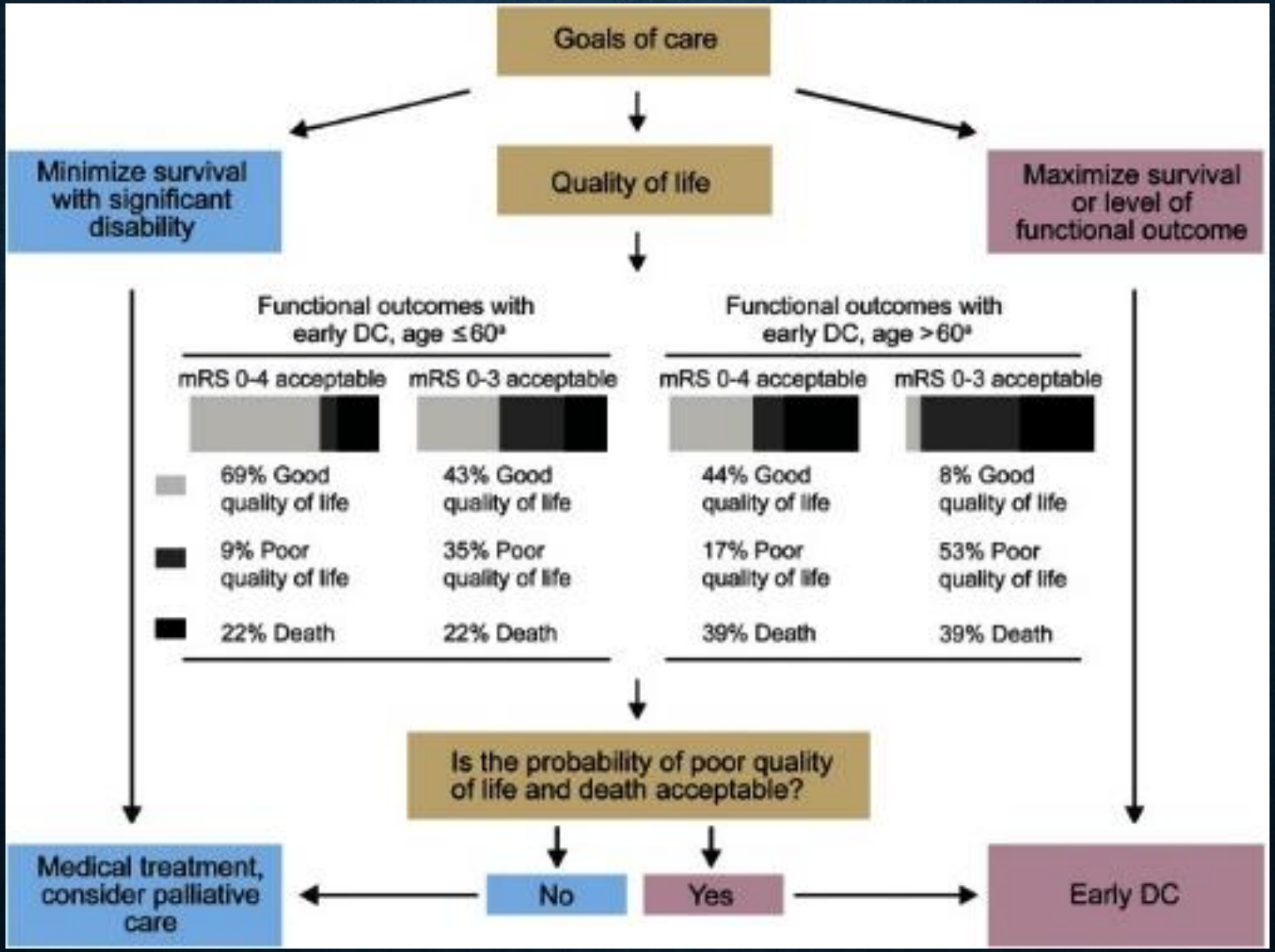
# IMPROVEMENT IN MIDLINE SHIFT IS A POSITIVE PROGNOSTIC PREDICTOR FOR MALIGNANT MCA INFARCTION PATIENTS UNDERGOING DC

- Improved midline shift was a significant predictor of 30-day mortality.

  The improved midline shift of >0.83 cm indicated survival at 30 days.

# CLINICAL SIGNIFICANCE OF DC SURFACE AREA AND SIDE

- Total DC area and removal rate was larger in bilateral DC than unilateral DC but clinical outcome was not influenced by DC side. DC area more than 160 $cm^2$ and DC surface removal rate more than 46% were more important than DC side.


Goals of care
Minimize survival with significant disability
Quality of life
Maximize survival or level of functional outcome
Functional outcomes with early DC, age ≤60[a]
Functional outcomes with early DC, age >60[a]
mRS 0-4 acceptable
mRS 0-3 acceptable
mRS 0-4 acceptable
mRS 0-3 acceptable
69% Good quality of life
43% Good quality of life
44% Good quality of life
8% Good quality of life
9% Poor quality of life
35% Poor quality of life
17% Poor quality of life
53% Poor quality of life
22% Death
22% Death
39% Death
39% Death
Is the probability of poor quality of life and death acceptable?
Medical treatment, consider palliative care
No
Yes
Early DC

NICE National Institute for Health and Care Excellence

Consider decompressive hemicraniectomy (which should be performed within 48 hours of symptom onset) for people with acute stroke who meet all of the following criteria:

- clinical deficits that suggest infarction in the territory of the middle cerebral artery, with a score above 15 on the NIHSS
- decreased level of consciousness, with a score of 1 or more on item 1a of the NIHSS
- signs on CT of an infarct of at least 50% of the middle cerebral artery territory:
  - with or without additional infarction in the territory of the anterior or posterior cerebral artery on the same side **or**
  - with infarct volume greater than 145 $cm^3$, as shown on diffusion-weighted MRI scan.

# EFFECTS OF DC VERSUS STANDARD TREATMENT IN PEOPLE OVER 60

- Mortality
  - There was a statistically significant reduction in mortality after 1 year with DC compared with standard treatment (RR 0.52, CI 95%).
- Disability
  - In the people who survived, DC led to a statistically significant increase in the number of people with a score of 3 or less on the mRS, rather than a higher score, at 1 year compared with standard treatment (RR 3.18, CI 95%).

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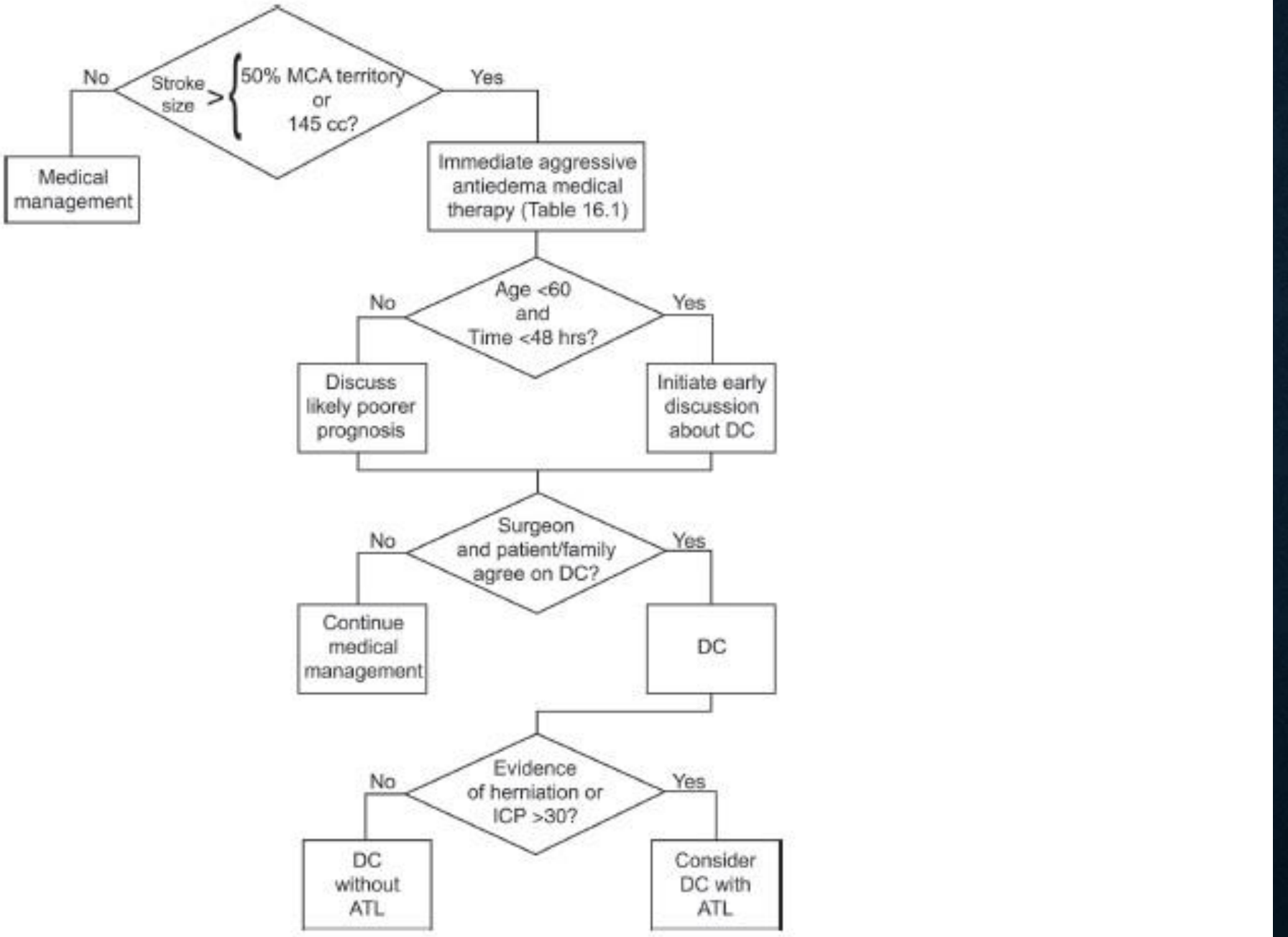
- Mortality
  - There was a statistically significant reduction in mortality after 1 year with DC compared with standard treatment (RR 0.34, CI 95%).
- Disability
  - In the people who survived, DC led to an observed increase in the number of people with a score of 3 or less on the mRS, rather than a higher score, at 1 year compared with standard treatment (RR 1.52, CI 95%).

NICE National Institute for Health and Care Excellence

**Table 1: Criteria for consideration of decompressive craniectomy in stroke patients as outlined by NICE guidelines 2019**

| |
|---|
| Clinical deficits that suggest infarction in the territory of the MCA, with a score >15 on the NIHSS |
| Decreased level of consciousness, with a score of 1 or more on item 1a of the NIHSS (level of consciousness) |
| Signs on CT of infarction of at least 50% of the middle cerebral artery territory: |
| With or without additional infarction in the territory of the anterior or posterior cerebral artery on the same side or |
| With an infarct volume >145 $cm^3$, as shown on diffusion-weighted MR imaging |

| | | | |
|---|---|---|---|
| Acute ischemic stroke | "Malignant" infarct-associated cerebral edema | Lowers mortality in all age groups<br>Improved functional outcomes in patients <60 y<br>Higher incidence of survival with moderate to severe disability in patients >60 y | Controlled case series<br>Randomized controlled trials<br>Systematic reviews/meta-analyses<br>Recommended by consensus guidance |


Stroke size > 50% MCA territory or 145 cc?
No
Yes
Medical management
Immediate aggressive antiedema medical therapy (Table 16.1)
Age <60 and Time <48 hrs?
No
Yes
Discuss likely poorer prognosis
Initiate early discussion about DC
Surgeon and patient/family agree on DC?
No
Yes
Continue medical management
DC
Evidence of herniation or ICP >30?
No
Yes
DC without ATL
Consider DC with ATL