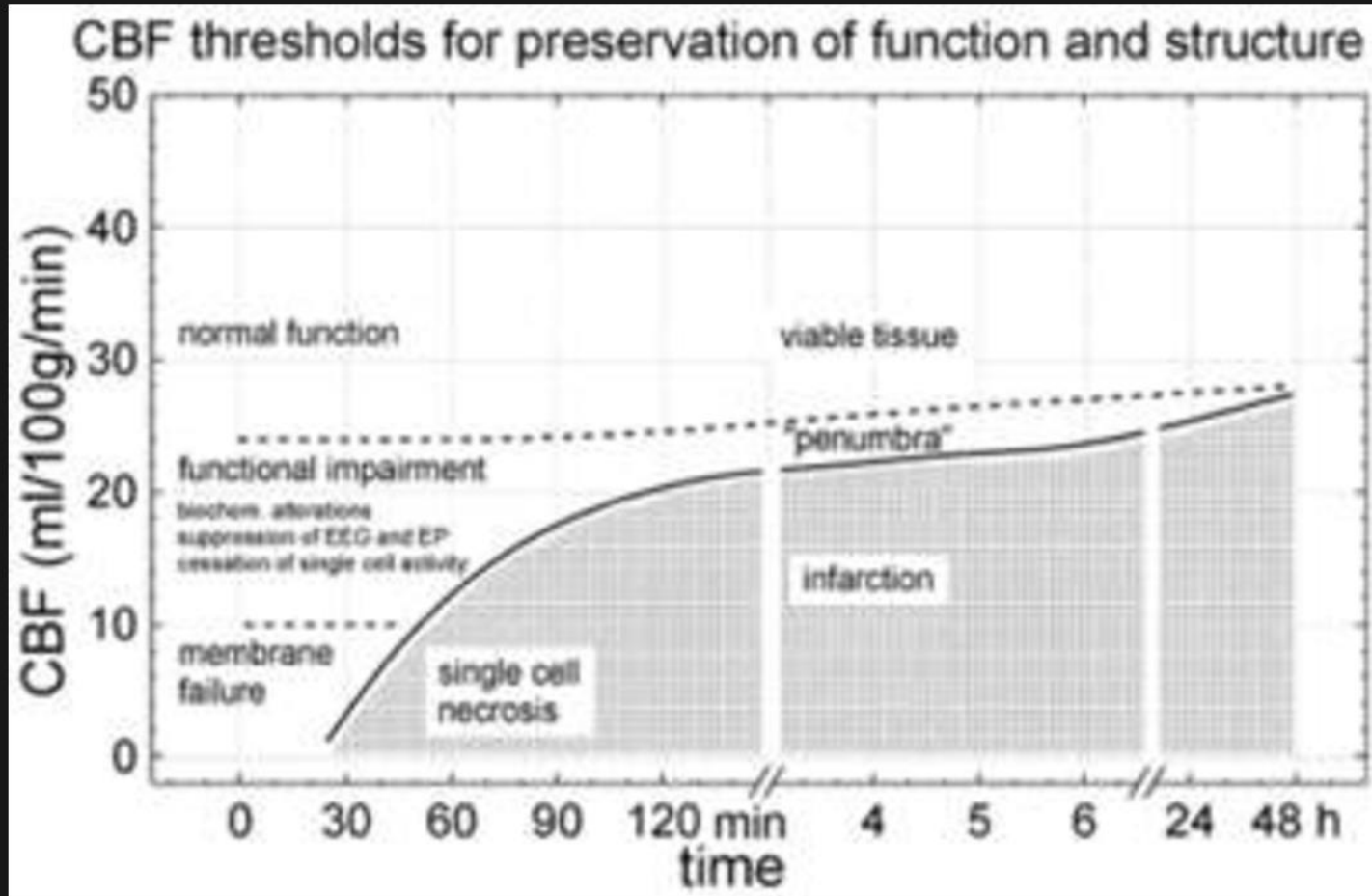


Neurosurgical Interventions

Satish Krishnamurthy MD, MCh



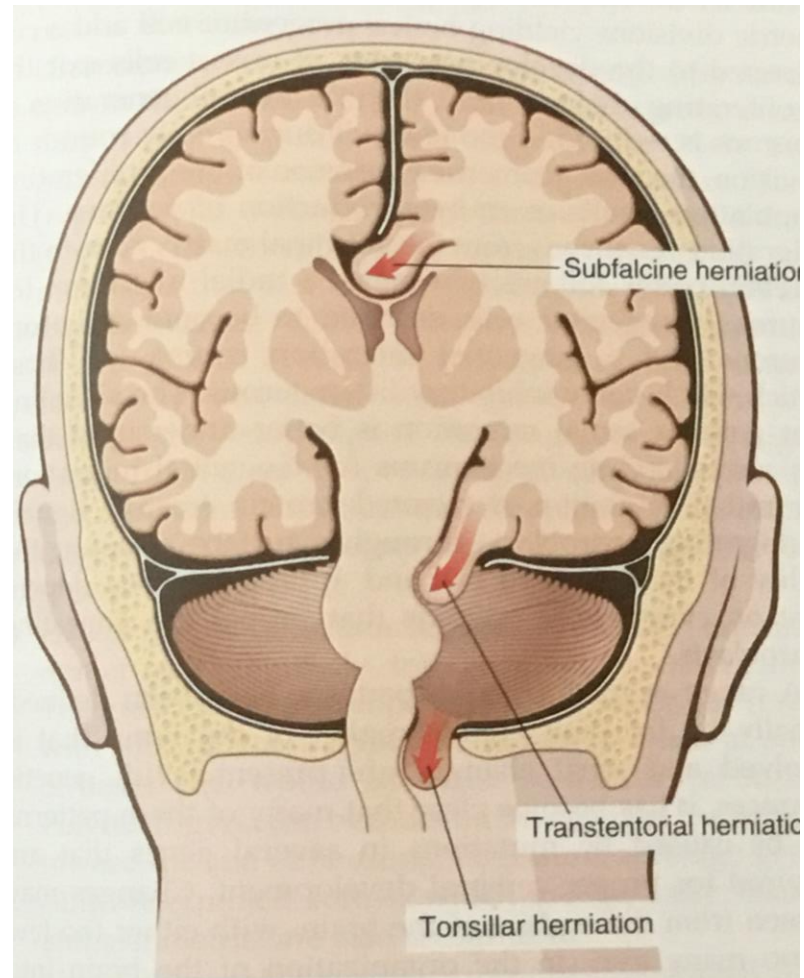
Regional cerebral blood flow is important



Some essential facts

- Neurons are obligatory glucose users
- Under anerobic conditions, there is increased lactic acid production
- High blood glucose levels lead to more acidosis and increased cell death
- Brain swelling in ischemic stroke is cytotoxic edema and in hematomas it is due to vasogenic edema. Timing of peak swelling is different.

Large space occupying lesions cause death by herniation



Strokes and hematomas alter the regional blood flow of the surrounding areas

- Volume of the hematoma or the infarcted brain will swell and compress the surrounding brain
- This decreases regional blood flow around the mass lesion
- Sustained reduction of the blood flow will lead to cell death

Different kinds of strokes

- Ischemic stroke
 - Large strokes
 - Ischemia in evolution
 - Secondary preventive surgery
 - Carotid disease
 - Moya Moya syndrome
- Hemorrhagic stroke
 - Aneurysmal
 - Arteriovenous malformation
 - Non aneurysmal intracerebral hematoma

Stabilize the patient

- Protect the airway and help breathing
- Early CT scan to understand pathology
 - Blood (hematoma) versus no blood (ischemia)
 - Where is the blood?
 - Subarachnoid
 - Intracerebral
 - Intraventricular
 - Hydrocephalus?
 - Herniation?

Preparation for neurosurgical intervention

- Control blood pressure
 - Less than 140 systolic for hematomas to prevent increase in bleeding. Less aggressive for ischemic stroke.
 - Significant number of patients even with non aneurysmal ICH will increase in hematoma for 24 hours.
- Normalize coagulation parameters
 - Recombinant factor VIIa

Newer antithrombotics



Guideline for Reversal of Antithrombotics in Intracranial Hemorrhage

A Statement for Healthcare Professionals from the Neurocritical Care Society and Society of Critical Care Medicine

Jennifer A. Frontera¹ · John J. Lewin III² · Alejandro A. Rabinstein³ · Imo P. Aisiku⁴ · Anne W. Alexandrov^{5,6} · Aaron M. Cook⁷ · Gregory J. del Zoppo⁸ · Monisha A. Kumar⁹ · Ellinor I. B. Peerschke¹⁰ · Michael F. Stiefel¹¹ · Jeanne S Teitelbaum¹² · Katja E. Wartenberg¹³ · Cindy L. Zerfoss¹⁴

Published online: 29 December 2015
© Springer Science+Business Media New York 2015

Guideline for Reversal of Antithrombotics in Intracranial Hemorrhage: Executive Summary. A Statement for Healthcare Professionals From the Neurocritical Care Society and the Society of Critical Care Medicine

Jennifer A. Frontera, MD, FNCS¹; John J. Lewin III, PharmD, MBA, FASHP, FCCM, FNCS²; Alejandro A. Rabinstein, MD, FNCS³; Imo P. Aisiku, MD, MBA, FCCP⁴; Anne W. Alexandrov, PhD, RN, ANVP-BC, FAAN^{5,6}; Aaron M. Cook, PharmD, BCPS⁷; Gregory J. del Zoppo, MD, MS⁸; Monisha Kumar, MD⁹; Ellinor I. B. Peerschke, PhD, FAHA¹⁰; Michael F. Stiefel, MD, PhD¹¹; Jeanne S. Teitelbaum, MD^{12,13}; Katja E. Wartenberg, MD¹⁴; Cindy L. Zerfoss, MSN, RN, ACNP-BC¹⁵

TABLE 2. Summary of Recommendations for Reversal of Antithrombotic Agents in Patients With Intracranial Hemorrhage

Antithrombotic	Reversal Agent
Vitamin K antagonists	If INR \geq 1.4: vitamin K 10 mg IV, plus 3- or 4-factor PCC IV (dosing based on weight, INR, and PCC type) or fresh frozen plasma 10–15 mL/kg IV if PCC not available
Direct factor Xa inhibitors	Activated charcoal (50g) within 2 hr of ingestion, activated PCC (FEIBA) 50 U/kg IV or 4-factor PCC 50 U/kg IV
DTIs	For dabigatran reversal: Activated charcoal (50g) within 2 hr of ingestion, and idarucizumab 5 g IV (in two 2.5g/50mL vials) Consider hemodialysis or idarucizumab redosing for refractory bleeding after initial administration For other DTIs: Activated PCC (FEIBA) 50 U/kg IV or 4-factor PCC 50 U/kg IV
Unfractionated heparin	Protamine 1 mg IV for every 100 units of heparin administered in the previous 2–3 hr (up to 50 mg in a single dose)
LMWHs	Enoxaparin: Dosed within 8 hr: protamine 1 mg IV per 1 mg enoxaparin (up to 50 mg in a single dose) Dosed within 8–12 hr: protamine 0.5 mg IV per 1 mg enoxaparin (up to 50 mg in a single dose) Minimal utility in reversal > 12 hr from dosing Dalteparin, nadroparin, and tinzaparin: Dosed within 3–5 half-lives of LMWH: protamine 1 mg IV per 100 anti-Xa units of LMWH (up to 50 mg in a single dose) or rFVIIa 90 μ g/kg IV if protamine is contraindicated
Danaparoid	rFVIIa 90 μ g/kg IV
Pentasaccharides	Activated PCC (FEIBA) 20 U/kg IV or rFVIIa 90 μ g/kg IV
Thrombolytic agents (plasminogen activators)	Cryoprecipitate 10 units IV or antifibrinolytics (tranexamic acid 10–15 mg/kg IV over 20 min or ϵ -aminocaproic acid 4–5 g IV) if cryoprecipitate is contraindicated
Antiplatelet agents	Desmopressin 0.4 μ g/kg IV \times 1 If neurosurgical intervention: platelet transfusion (one apheresis unit)

DTI = direct thrombin inhibitor, FEIBA = factor eight inhibitor bypassing activity, INR = international normalized ratio, LMWH = low molecular weight heparin, PCC = prothrombin complex concentrates, rFVIIa = recombinant factor VIIa.

Establish if there is a source of hemorrhage

- CT angiography is an effective method to help diagnose aneurysms and arteriovenous malformations.
 - Occasionally this is all the patient's condition will allow
- Digital subtraction angiography is the gold standard.
 - More detailed planning and help in having other options available.

Ischemic penumbra

- MRI scan helpful in delineating the area of stroke (what is dead with DWI) and area at risk for stroke (perfusion scan). This is the penumbra.
- Area at risk can also be determined by CT perfusion scans with diamox challenge
- PET scan with oxygen extraction ratios

Bedside procedures

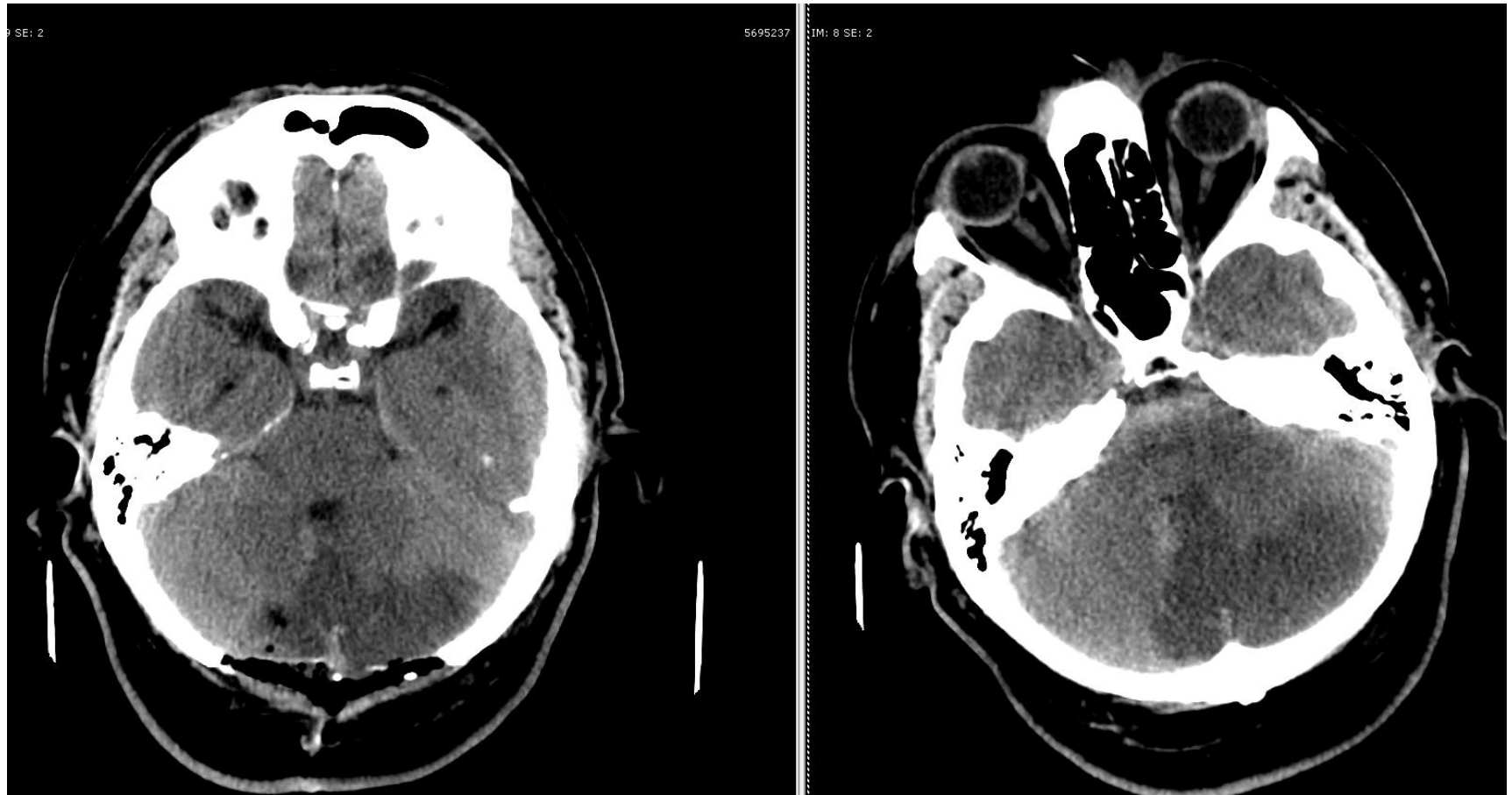
- Insertion of emergent external ventriculostomy at the bedside
 - Used frequently for hydrocephalus due to aneurysm rupture
 - Used for intraventricular hemorrhage associated with hypertensive ICH
 - CLEAR trials with intraventricular tPA
 - Cerebellar strokes and hematomas
 - Minimally invasive ICH evacuation

Decompressive craniectomy Supratentorial strokes



Decompressive craniectomy

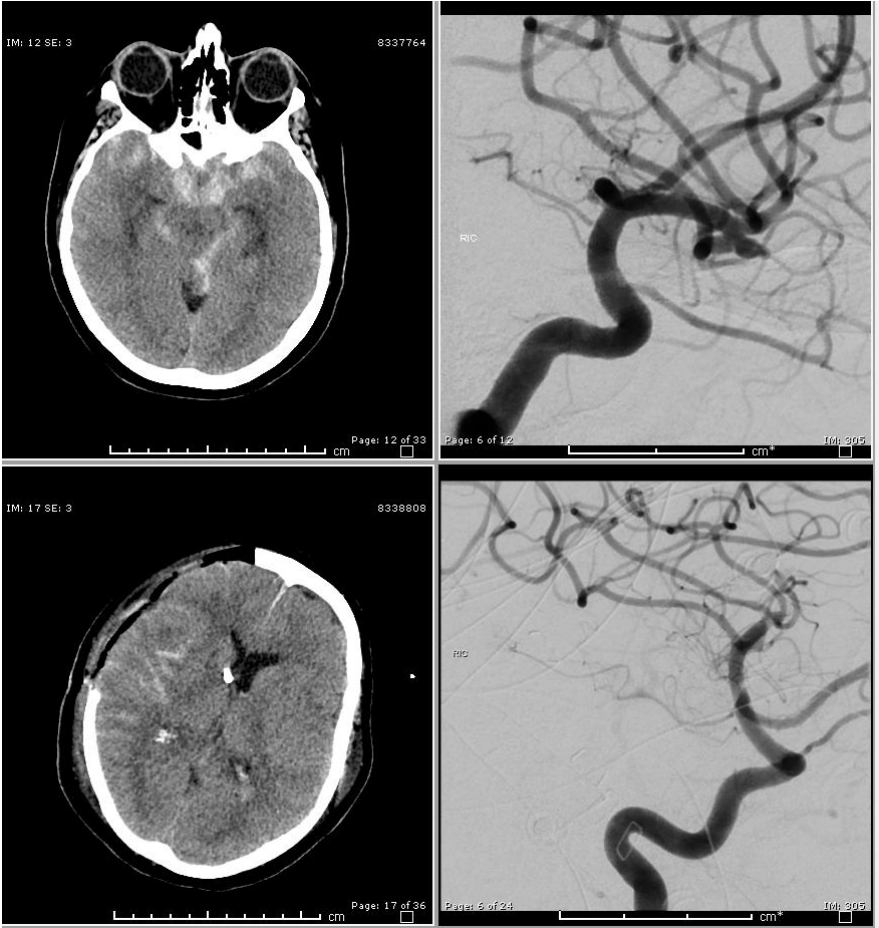
Cerebellar strokes



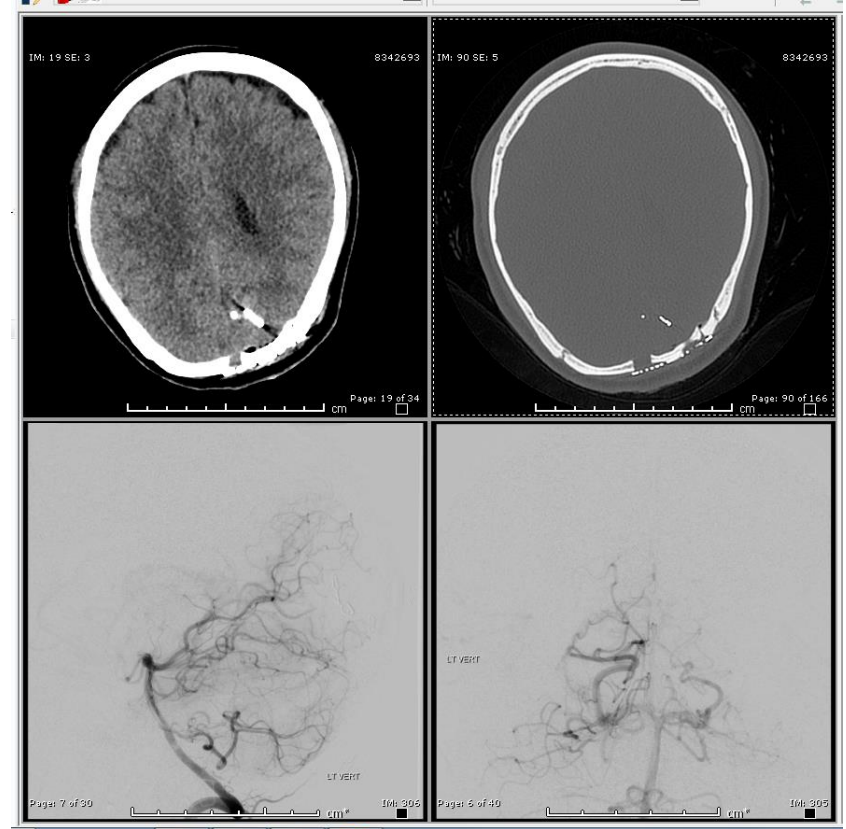
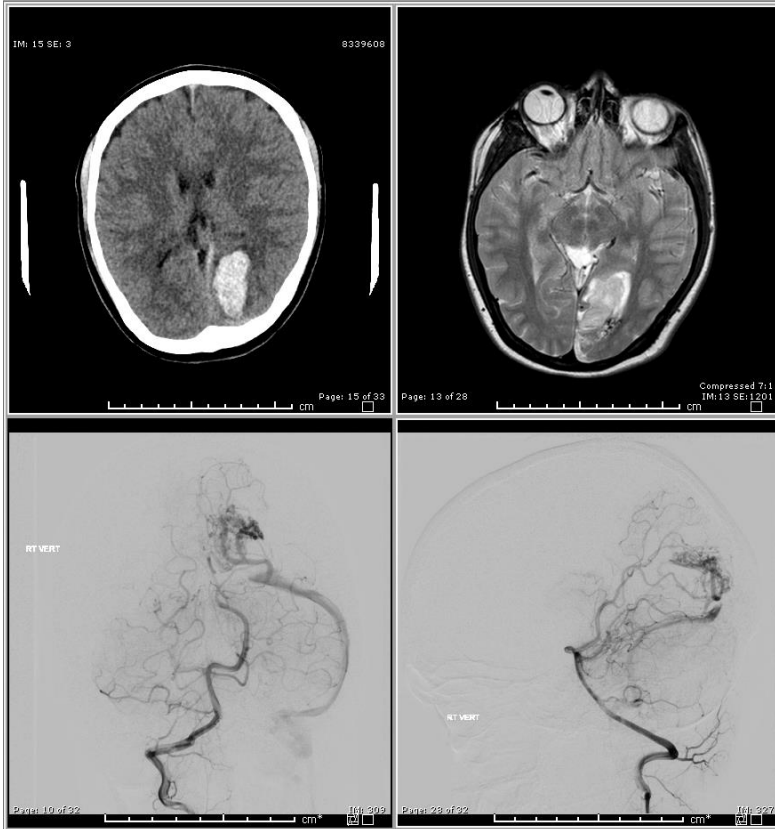
Hematoma evacuation

- Lobar hematomas more than 30 ml
- Cerebellar hematomas more than 30 ml and when they are causing hydrocephalus
- Basal ganglia hematomas
- Hematomas associated with venous thrombosis
- Hematomas result in edema with a peak at 7 days

Clipping of aneurysm and hematoma evacuation



Excision of AVM and hematoma evacuation



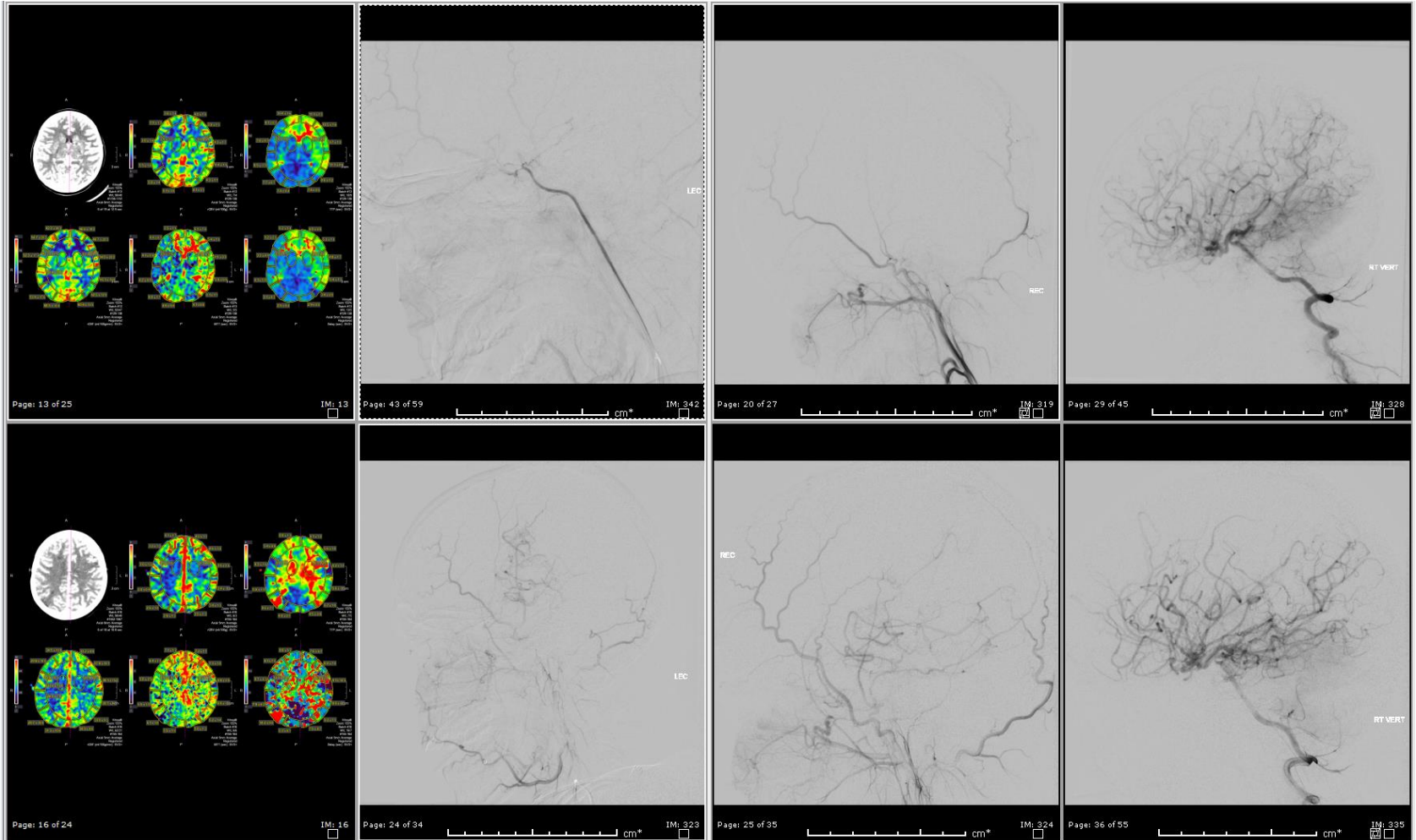
Surgeries to improve cerebral blood flow

- Carotid endarterectomy
 - Routinely screen for carotid disease in patients with risk factors and in the context of stroke
 - CTA neck is better study than ultrasound of the carotids
 - Demonstrates the neck vessels through the skull base
 - Identification of tandem stenosis

Example of skull base ICA stenosis



Moya Moya disease



Take home points

- Stabilize the patient and get an early CT scan
- Control blood pressure
- Normalize coagulation parameters
- Mannitol to help lower ICP and help transfer
- Early transport to comprehensive stroke center
- Early surgery and definitive treatment improves survival and outcomes.

- Thank you!