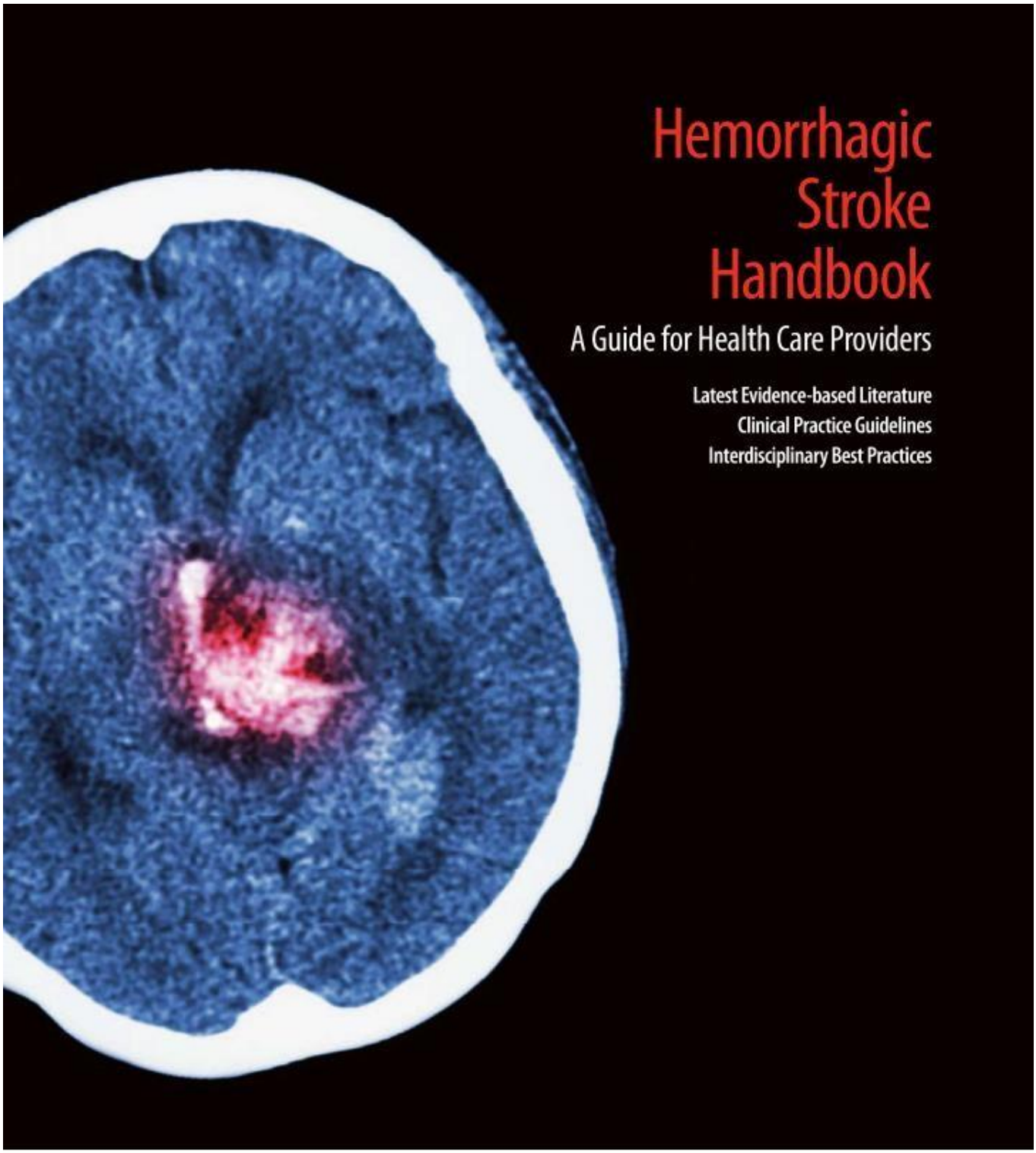

Hemorrhagic Stroke Handbook

A Guide for Health Care Providers

Latest Evidence-based Literature
Clinical Practice Guidelines
Interdisciplinary Best Practices

WakeMed
Stroke Program

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The policies and practices below are also reviewed by interdisciplinary committees, including but not limited to the Stroke Taskforce (monthly meeting) and the Neurocritical Care Committee (meets every other month). The policies and practices are updated annually as mandated by new evidence, and as these expert groups identify areas of necessary change. The authors above reach out as needed to key stakeholders and leaders in the WakeMed community to further our interdisciplinary effort towards excellence in stroke care.

This handbook is reviewed and updated annually.

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Introduction and Overview

WakeMed Health and Hospitals strive to provide the best evidence-based stroke care to all our patients. We follow guidelines from the American Heart/American Stroke Association as the framework of care for our patients. Where not specifically addressed below, please know that we use national guidelines to direct our stroke patient care and protocols[1,2]. To ensure alignment across WakeMed policies and procedures across our administration, physician, and nursing staff, this handbook supports the WakeMed Administrative Patient Care policy for Code Stroke Process & Associated Elements. The audience of this handbook includes clinical staff supporting stroke patient populations and units/departments.

In areas where care is less defined and structured, we discuss protocols in an interdisciplinary fashion. This handbook captures those areas of care and is designed to highlight our goal to standardize care and ensure consistent high-quality care as we continue our goal of becoming a top 10 stroke program. In addition to standardized approaches, we always care for each patient as an individual, taking into consideration unique factors when making any plan of care decisions, and aligning with our core mission to put the patient and their family at the top of everything we do. Please also see references.

1) Handbook of Neurosurgery, Dr. Greenberg, 9th edition
2) AHA/ASA guidelines ICH: Greenberg 2022
3) AHA/ASA guidelines aneurysmal SAH: Hoh 2023

Pre-Hospital Stroke Care

WakeMed Health and Hospitals Locations and Care Overview

1) WakeMed Raleigh serves as a location where the full scope of patient care can be provided.
    a. This includes but is not limited to the administration of IV thrombolytic, embolectomy procedures, post-IV thrombolytic, and post-embolectomy care.
    b. Critical Care services are available 24/7 along with Intensive Care Units
    c. Neurosurgical services are available 24/7 to perform procedures including but not limited to hemicraniectomy, and care of the SAH, ICH, and SDH patients.
2) WakeMed Cary serves as a location where patients can have the administration of IV thrombolytic, embolectomy procedures, and receive post-IV thrombolytic, and post-embolectomy care in noncomplex patients.
    a. Critical Care services are available 24/7 along with an Intensive Care Unit.
    b. Neurosurgical services are limited, and patients will need transfer to WakeMed Raleigh if more complex surgical services are anticipated per Neurosurgery discretion.
3) WakeMed North serves as a location where non-complex, non-IV thrombolytic, and non-embolectomy stroke patients can be cared for. Patients receive emergent stroke care including the administration of IV-Thrombolytic
    a. Teleneurology services are available from 8 AM – 12 PM for in-patient needs.
    b. Complex patients need to be transferred to WakeMed Raleigh, including those who receive IV thrombolytic.
4) WakeMed Brier Creek, Wendell, and Garner serve as free-standing emergency departments where patients receive emergent stroke care including the administration of thrombolytic IV.

a. Patients requiring in-patient services will be transferred to WakeMed Raleigh or North, depending on the subsequent need for higher-level care.

5) WakeMed Apex serves as a free-standing emergency department where patients can receive emergent stroke care including the administration of IV thrombolytic.
    a. Patients requiring in-patient care will be transferred to WakeMed Cary for subsequent higher- level care.

Transfer Algorithms and Criteria

Based on the capabilities of the facilities as described above and discussions between the Emergency Department and the receiving higher-level of care facility, a decision will be made to ensure the patient is sent to the most appropriate hospital for subsequent care. Refer to the WakeMed ED Inter-Facility Transfer Algorithm.

For non-WakeMed hospitals, calls for transfer are initiated through the Transfer Center with patients accepted on a case-by-case model. This allows for the early involvement of experts and facilitates decision-making while maintaining standard practices and communication.

Emergent ED Care

Important Order Sets and Orders:

- EDSO Code Stroke
- ED Intracerebral Hemorrhage (Non-Traumatic)
- Anticoagulation Reversal Orders

Initial Care

- When a patient is identified as a code stroke patient, a common algorithm is followed until a patient can be categorized as ischemic or hemorrhagic stroke.
- Once a patient is identified as a hemorrhagic stroke by CT head, neurosurgery is involved in the patients' care.

Reversal Agents for Medication Associated Bleeds

1. Warfarin
    a. INR >10 in the absence of bleeding
        i. Vitamin K 2.5 mg PO x1
        ii. Repeat PT/INR in the AM
    b. INR <10 in the absence of bleeding
        i. Repeat PT/INR in the AM
        ii. No reversal agent indicated.
    c. Major, life-threatening bleeding
        i. Vitamin K 10 mg IV x1
        ii. INR 2-4
            1. 4 factor PCC (Kcentra) 25 units/kg IV x1
        iii. INR 4-6
            1. 4 factor PCC (Kcentra) 35 units/kg IV x1 iv. INR >6

1. 4 factor PCC (Kcentra) 50 units/kg IV x1

2. Heparin

d. Protamine IV

i. Dose variable depending on total dose of heparin received.

ii. 1 mg of protamine IV for every 100 units of heparin administered in the previous 2-3 hours (up to 50 mg as single dose) 3. Enoxaparin

a. Protamine IV

i. Dose variable depending on total dose of enoxaparin received.

ii. Dosed within 8 hrs: protamine 1 mg IV per 1 mg of enoxaparin (up to 50 mg as a single dose)

iii. Dosed within 8-12 hours: protamine 0.5 mg IV per 1 mg of enoxaparin (up to 50 mg as single dose)

3.Dabigatran

a. Idarucizumab (Praxbind) 5g IV x1

4. Factor Xa inhibitors (Apixaban, Rivaroxaban, Edoxaban)
    a. 4 factor PCC (Kcentra) 50 units/kg IV x1
5. Aspirin and P2Y12 inhibitors (Clopidogrel, Ticagrelor, Prasugrel)
    a. Discontinue offending agent.
    b. Routine platelet transfusion should be AVOIDED as it can cause harm (exceptions include emergent neurosurgical procedure or severe thrombocytopenia)
    c. Consider DDAVP 0.4 mcg/kg IV x1.
6. IV thrombolytic
    a. Cryoprecipitate 10 units (2 pooled units)
    b. Pharmacologic reversal options
        i. Aminocaproic acid 5 g IV x1, followed by 1g/hr x20 hours ii. Tranexamic acid 1g IV x1

Immediate Blood Pressure Considerations

The general SBP goal for patients found to have hemorrhagic stroke will be < 150. SBP should not be lowered below 130 as it can be harmful. Specific goals are discussed in more detail of the related stroke type section. It is very important to strive to achieve blood pressure goal within one hour of hemorrhage discovery. Sustained control is also essential.

Intracerebral Hemorrhages

Important Order Sets and Orders:

- Hemorrhagic Stroke/Intracranial Hemorrhage Orders
- ICU Core Admission Orders
- Neurosurgery Admission Orders
- Anticoagulation Reversal Orders

General Information

- Second most common form of stroke (~10% of strokes), and most deadly
- Incidence is noted to be ~1.6 fold greater among Black and Mexican Americans compared to non-Hispanic White patients.
- Unlike ischemic stroke: smooth progressive onset over minutes to hours, often with severe headache, vomiting, and alterations in level of consciousness
- CT non-contrast is the diagnostic imaging of choice.
- ICH enlarges in > 33% of cases within the first 3 hours of onset, thus the need for a 6-hour stability head CT. Can also consider a 24-hour scan for stability in select populations. Hematoma expansion beyond 24 hours is rare.
    - Hematoma expansion and worse prognosis is found in patients on anticoagulation, patients with elevated cardiac troponins, and patients with anemia.
    - Hematoma expansion imaging markers include heterogeneous densities within the hematoma, irregularities at the hematoma margins, and spot sign on CTA or CT contrast.
- Within the first few hours of ICH onset, consider CTA, CTV, diagnostic angiogram, or contrasted. MRI/MRA if suspicion of underlying abnormality (AVM, dural sinus thrombosis, neoplasm)
    - Especially consider CTA/CT venogram for:
        - Lobar ICH and age < 70 years old
        - Deep/posterior fossa ICH and < 45 years or age 45-70 without history of HTN
        - If CTA and MRI/MRA are negative, reasonable to consider digital subtraction angiography o Especially consider digital subtraction angiography for spontaneous intraventricular hemorrhage and NO detectable parenchymal hemorrhage.
    - If negative imaging, repeat in 2-3 months. If still negative, follow MRI every 6 months for 1 year to rule out a tumor.
- Patients with pure IVH, younger population 15-45yrs, and > 45yrs with Hx of hypertension and lobar ICH, require diagnostic cerebral angiography. If negative, repeat in 2-3 months. If still negative, follow MRI every 6 months for 1 year to rule out a tumor.

(The American Heart Association statement on “Palliative and End-of-Life Care in Stroke” discusses palliative care, and it is recommended that in the absence of known pre-existing DNR wishes, the decision to withdraw support should not be made until at least the second full day of hospitalization after ICH).

Surgical Considerations

- Surgery is controversial for supratentorial location. Historically data suggested potential mortality benefits, decreased length of stay, but not necessarily functional improvement. Recent data suggests potential for functional benefit in carefully selected patients.
- On a case-by-case basis, especially for lobar based hemorrhages, neurosurgery may consider early evacuation. Timing of when to go for surgery remains controversial and will be per the judgement of the neurosurgeons.
- ICH evacuation may be considered as a lifesaving measure.
- Especially for patients with ICH volume > 20-30 mL and GCS 5-12, minimally invasive surgery (with or without thrombolysis) plus medical management may be considered.
- Patients in coma, or large ICH with significant midline shift, or elevated ICP refractory to medical management: decompressive craniectomy with or without ICH evacuation may reduce mortality.

- For patients with cerebellar hemorrhage, decreased mortality may be seen with surgery for patients with hemorrhage volume >15 mL or if neurologic deterioration, brainstem compression, or hydrocephalus.

Candidates for surgery

Favorable factors for surgery in SUPRATENTORIAL ICH

- Age < 75
- Premorbid mRS 0-1
- Admitted < 24 hours from symptom onset, intervention within 36 hours.
- Acute spontaneous supratentorial ICH
- GCS 5-13 and/or paresis no better than anti-gravity in 1-2 limbs
- Hematoma volume 30-80cc (AP*LAT*HT/2)

Unfavorable factors for surgery in SUPRATENTORIAL ICH

- Poor baseline function
- Minimally symptomatic patients, such as GCS 14/15
- Irreversible coagulopathy
- Thalamic or brainstem hemorrhage
- Primary IVH or extensive IVH
- Medically unstable for surgery

The decision to operate must be individualized based on patient's neurologic condition, size and location of hematoma, patient's age, and the patient's expressed preferences (e.g., by a "living will") and the family's wishes concerning "heroic" measures in the face of catastrophic illness.

Blood Pressure Management

- It is appropriate to lower SBP < 150 and it is important to avoid lowering SBP <130 as this can be harmful.
- Cardene is the preferred agent.
- It is most important to limit blood pressure variability and achieve smooth, sustained blood pressure control to reduce risk of hematoma expansion and yield better functional outcome. Treatment is best initiated within 2 hours of ICH onset with *target reached within 1 hour of hemorrhage discovery.*
- INTERACT -II & ATACH-2 trials have shown that rebleeding occurs despite blood pressure control, and that reducing SBP < 130mm Hg is associated with increased incidence of adverse renal events probably from hypoperfusion.

Intracranial Pressure Management

- EVD is reasonable for patients with hydrocephalus, especially with reduced level of consciousness (not for cerebellar ICH, as a sole management)
- Patients with GCS ≤ 8, or evidence of significant IVH or hydrocephalus: consider ICP monitoring and treatment.
- Intraventricular r-tPA appears to have a low complication rate, but the overall safety and benefit are uncertain (2-5mg of alteplase in normal saline is administered through an intraventricular catheter by neurosurgery service, every 8 hours for up to 4 days, the catheter is clamped for 2 hours after injection.)
- Corticosteroids should NOT be routinely used to decrease ICP as it is ineffective and can cause harm.
- Continuous hyperosmolar therapy appears to have no benefit for outcome. See section below on management of increased ICP.

Anticoagulation

- For nonvalvular a-fib: Restarting anticoagulation can be considered, but long-term anticoagulation with warfarin after warfarin-associated lobar ICH carries a relatively high risk of recurrence.
  - Consider if anticoagulation can be avoided, consider LAA closure for certain patients.
  - Utilize the CHADs2VASC score and HASBLED scores to compare risk and benefit and involve patient and family in decisions.
  - Avoidance of oral anticoagulation (OAC) use for at least 4-8 weeks after OAC-associated ICH in patients without mechanical heart valves may decrease the risk of recurrent ICH (Level IIb)
- Mechanical heart valves: consider 2 weeks off anticoagulation (to observe ICH, or to evacuate a SDH or clip an aneurysm)
- Patients requiring hemodialysis after ICH: heparin-free dialysis may be used.
- Antiplatelet therapy after ICH is not associated with a substantially increased risk of recurrent ICH.
- The probability of having an ischemic stroke at 30 days following cessation of warfarin for a median of 10 days using Kaplan-Meier survival estimates are approximately 2.9% for patients who had originally been treated with warfarin for prosthetic heart valves, 2.6% for those treated for atrial fibrillation, and 4.8% for those treated for cardioembolic stroke

Seizure Considerations

- Treat clinical seizures, or seizures on EEG in patients with altered mental status.
- Continuous EEG monitoring is probably indicated when depression of mental status is out of proportion to the degree of brain injury.
- Prophylactic AEDs are not recommended in most patients who have not had seizures.

Etiologies

ICH occurs as a consequence of vascular pathologies. Efforts will be made to find the stroke etiology and target secondary stroke prevention for individualized risk factors. The most common factors to consider include:

- Hypertension
- Diseases leading to arteriosclerosis/lipohyalinosis.
- Cerebral amyloid angiopathy
- Medications such as anticoagulation, antiplatelets, NSAIDs
- Smoking, alcohol use, drug use (especially sympathomimetic drugs)
- Coagulopathic diseases

Hemostasis and Coagulopathy in Patients with ICH

- See hospital coagulopathy reversal protocol

Outcome and Prognosis

- See ICH score below.
- Overall, the 30-day mortality rate is ≈ 44%, which is like SAH (≈46%)
- Patients with lobar hemorrhages tend to fare better than deep ICH (basal ganglion, thalamus) with only ≈ 11% mortality in 26 patients.
- Patients on anticoagulation for a-fib fare worse than those who are not.

- 15-45 years of age population group, the overall survival (including those treated medically) is 87%. (Extremely important in this group to have further diagnostic workup with CTA, angiography, and MRI brain to determine the underlying cause.)
- The American Heart Association statement on "Palliative and End-of-Life Care in Stroke" discusses palliative care, and it is recommended that in the absence of known preexisting DNR wishes, the decision to withdraw support not be made until at least the second full day of hospitalization after ICH. It should be also kept in mind that decision for DNR does not mean reduction in other medical and surgical options for care without careful discussion with family.

Special ICH Populations

- Venous Hemorrhage is due to cerebral venous thrombosis (CVST)
- When a hemorrhage is recognized because of CVST, the standard of care is initiation of full dose anticoagulation. The preferred agent will be heparin, using a no bolus protocol to try and reduce the risk of hemorrhage extension.
- Please see algorithms in the appendix for the most complicated patients in this population who may require NeuroIntervention.

Special Considerations

- Early, aggressive mobilization within the first 24 hours after ICH appears to worsen 14-day mortality and *should be avoided*. After 24-48 hours, rehabilitation involving stretching, functional tasks, and other activities can be considered.

ICH Score

Feature	**Finding**	**Points**
GCS	3-4	2
	5-12	1
	13-15	0
Age	≥ 80 years	1
	< 80	0
Location	Infratentorial	1
	Supratentorial	0
ICH volume	≥ 30cc	1
	<30cc	0
Intraventricular blood	Yes	1
	No	0
"ICH Score" = Total Points		0-6

ICH Score	**30-day mortality**
0	0%

1	13%
2	26%
3	72%
4	97%
5	100%
6	?100%

Aneurysmal Subarachnoid Hemorrhages

By default, WakeMed's management of aneurysmal subarachnoid hemorrhage follows the Neurocritical Care Society's recommendations and the AHA/ASA updated guidelines.

Our SAH and DCI order sets are based upon these recommendations.

Important Order Sets and Orders

- Subarachnoid Hemorrhage Orders
- ICU Core Admission Orders
- Neurosurgery Admission Orders
- Anticoagulation Reversal Orders
- Delayed Cerebral Ischemia Orders

SAH Scores

- SAH will be graded by neurosurgeon or neurointerventionalist, via modified Fisher grade and Hunt and Hess upon evaluation and documented within the first 24hours.
- These scores will be subsequently carried through intensivist documentation to help standardize classification, communicate vasospasm risk, and coordinate prognosis information.

Timing of Aneurysm Treatment

- In general, an aneurysm should be secured within 24hrs and no longer than 72hrs from time of bleed.
- In patients with poor prognosis (Hunt and Hess grades 4 and 5) treatment may be delayed to allow for clarification of goals of care.
- If there is an unavoidable delay in obliteration of aneurysm and no other medical contraindications, short term therapy with tranexamic acid or aminocaproic acid will be considered to reduce risk of early rebleeding.

Surgical Clipping versus Coiling

- Endovascular/coil embolization is preferred for posterior intracranial circulation aneurysms.
- Microsurgical clipping versus coil embolization are both well-established options. For a patient with aneurysm judged to be technically amenable to both endovascular coiling and neurosurgical clipping, endovascular coiling should be considered.
- Ultimately, open surgical aneurysm clipping versus endovascular embolization decision is per discussion of NeuroInterventionalist/neurosurgeon and the family.
- Stenting of ruptured aneurysms is only considered when less risky options have been excluded.

Blood Pressure Management

- All aneurysmal SAH patients need to have an arterial line placed in the ICU (left radial preferred, as the right may be used in NeuroIntervention).
- Goal is SBP < 150 while awaiting treatment of the aneurysm.
- Chronically hypertensive patients and those with ICP monitoring may have different goals based on their specific clinical scenarios.

Intracranial Pressure Management

- In rare cases, space-occupying hematoma may benefit from emergency surgery, such as with temporal lobe ICH or posterior fossa ICH.
- SAH associated with symptomatic hydrocephalus should be managed by CSF diversion (EVD or lumbar drain). In the chronic phase, symptomatic hydrocephalus may require permanent CSF diversion.
- EVD with ICP monitoring for patients with Hunt and Hess grade 2 or greater to be considered by neurosurgery.
- ICP management per neurosurgery in patients with ICP > 22 sustained for 5 minutes.
- EVD is strongly considered for patients with high Hunt and Hess grade 4 and 5, to see if they would improve to a better grade after hydrocephalus has been adequately treated.
- If verbal or written consent cannot be obtained for EVD placement, the Neurosurgery note must state reasoning for Emergent Consent (i.e., unable to reach family, etc.).

Seizure Prophylaxis

- Prophylactic antiseizure medication should not be routinely used but should be considered and may be reasonable for high-risk SAH patients (ex: ruptured middle cerebral artery aneurysms, intraparenchymal hemorrhage, high-grade SAH, hydrocephalus, cortical infarction)
- In those same high-risk SAH patients, cEEG monitoring is reasonable to consider for detection of seizure.
- For patients with aSAH who present with seizures, treatment with antiseizure medication for <= 7 days is reasonable to reduce complications in the perioperative period, but beyond 7 days is not effective for reducing future SAH-associated seizure risk
- When choosing antiepileptic medication, phenytoin should be avoided as it may worsen outcomes.
- In general, Levetiracetam is the preferred first line agent.

Delayed Cerebral Ischemia (DCI) and Vasospasm

- Monitoring / Prevention ○ Nimodipine is standard of care and should be used in all patients with aneurysmal SAH. Administer within 24 hours of patient arrival:60mg q4hours. If the dose drops the patient's blood pressure this can be changed to 30mg q2 hours. Tx should continue for 21 days total.
    - Triple-H therapy (hypertension, hypervolemia, and hemodilution) is NOT recommended.
    - Balloon angioplasty before development of spasm is NOT recommended.
    - Goal is euvolemia with strict avoidance of hypovolemia.
    - Avoid hypomagnesemia and hyperglycemia.
    - Any neurological decline should be evaluated for potential DCI/Vasospasm

- Perfusion imaging with CT or MRI can be useful to identify regions of potential brain ischemia.
- Routine serial TCDs may be low yield at our facility at this time.

With any significant exam changes, the RN should notify the Neurointerventionalist directly via RapidConnect. The Intensivist will then notify the Neurosurgeon if also involved.

- Treatment when DCI is suspected.
  - Delayed Cerebral Ischemia order set should be followed.
  - Initial fluid challenge
  - Induction of hypertension via vasopressors is recommended for patients with DCI unless BP is elevated at baseline or cardiac status does not allow. Initial plan is to keep SBP > 160, with the intention of raising SBP > 180 if not effective. If no improvement at SBP > 180-page NeuroInterventionalist.
  - Balloon angioplasty and intra-arterial administration of vasodilators are frequently utilized if patient does not get better with hypertensive therapy. Contact NeuroInterventionalist on call if that is the case.

Hyponatremia Complications and Management

- Fluid-restriction is not used in management of hyponatremia in SAH.
- Normal Na goal, unless directed otherwise by neurosurgery
- Salt tabs may be used up to 3g PO every 6 hours with the addition of 1.8% or 3% saline after that.
- Fludrocortisone may be of use in cerebral salt wasting.

Outcome and Prognosis

- SAH is a disease with high mortality and morbidity especially in high grade Hunt and Hess 4 and 5 patients, with mortality rate of 60-70% and 70-100% respectively.
- Discussions around prognosis should be discussed on rounds or with NeuroInterventionalist. Bringing palliative care into the multidisciplinary discussion early is likely to be helpful in high grade patients.

Acute Subdural Hemorrhage

General Information

- The magnitude of impact damage makes this lesion more lethal than EDH, and acute SDH is often associated with underlying brain injury.
- Symptoms may be due to compression of the underlying brain with midline shift in addition to parenchymal brain injury and possibly cerebral edema.
- Common causes of acute SDH
  - Accumulation around parenchymal laceration (usually frontal or temporal lobe) ○ Surface or bridging vessel torn from cerebral acceleration-deceleration during violent head motion.
- On CT, appears as a crescentic mass of increased density adjacent to inner table, edema often present.
- Membrane formation begins about 4 days after injury.
- Differences from EDH: SDH is more diffuse, less uniform, and usually concave over brain surface, often less dense (from mixing with CSF), and bridging subdural veins (from brain surface to the skull) may be seen (cortical vein sign).

- May occur in patients receiving anticoagulation therapy, usually with, but sometimes without history of trauma. Receiving anticoagulation therapy increases risk of acute SDH 7-fold in males and 26-fold in females.

Density Changes on CT

- Acute – hyperdense; time frame 1-3 days
- Subacute – isodense; time frame 4 days to 2-3 weeks
- Chronic – hypodense/CSF density; time frame >3 weeks to 3-4 months

Treatment

- Discuss with on-call neurosurgeon.
- Indications for surgery – less than 4h had 40% mortality rate, >4h 90%.
  - Thickness> 10mm on CT or midline shift 5mm regardless of GCS
  - GCS drops by ≥ 2 points from injury to admission
  - Pupillary changes
- Other factors to consider.
  - Presence of Anticoagulants or platelet inhibitors- reversal prior to operating to increase safety of surgery
  - Location of hematoma – SDH high over convexity is less life threatening than temporal/parietal of same volume that has midline shift.
  - Patient's baseline function, DNR status
- Admit to Neuro ICU for at least 24h (pre-op or patients requiring close monitoring and post-op)

Blood Pressure Management

- SBP < 150

Anticoagulation

- Full anticoagulation after 14 days if stable CT

Intracranial Pressure Management

- Consider for GCS < 8 with ASDH if not taken to OR

Seizure Prophylaxis

- Levetiracetam PO or IV bid x 7 days

Outcome and Prognosis

- Mortality 50-90%
- Age – 82% mortality in patients aged > 65 yrs., 5% functional recovery.
- GCS on admission
  - GCS 3 – 90% mortality, 5% functional survival
  - GCS 4 – 76% mortality, 10% functional survival

- GCS 5 – 62% mortality, 18% functional recovery
- GCS 6&7 – 51% mortality, 44% functional recovery

- Postoperative ICP – patients with peak ICPs < 20 mm Hg had 40% mortality rate and no patients with ICP>45 had functional survival.

Chronic Subdural Hemorrhage

General Information

- Chronic SDHs tend to occur in the elderly, average age of 63 yrs.
- Head trauma identified in < 50%, sometimes trivial trauma
- Risk factors include alcohol abuse, seizures, CSF shunts, coagulopathies (including therapeutic anticoagulation), and patients at risk for falls.
- Are bilateral in 20-25% of cases.
- Hematoma thickness tends to be larger in older patients due to a decrease in brain weight and increase in subdural space with age.
- Classically contain dark "motor oil" fluid which does not clot. When fluid is clear, the collection is termed subdural hygroma.
- Patients may present with minor symptoms of headache, confusion, language difficulties, or TIA-like symptoms or they may develop coma, hemiplegia, or seizures.
- See appendix for criteria regarding which patients can be admitted to the hospitalist team, and which patients need ICU level care.

Treatment Options

- Surgical evacuation of hematoma
  - Several techniques for craniotomy – performed in OR – two burr holes, single "large" burr hole, single burr hole with subdural drain, craniotomy with excision of subdural membrane (without removal of deep membrane adherent to surface of brain); may include placement of subdural or subgaleal drain
    - Twist drill craniotomy – performed at bedside - with placement of SEPS drain or ventricular catheter.
- Endovascular embolization of middle meningeal artery has shown increasing benefit in subacute/chronic cases in randomized control trials. This can be done as stand-alone treatment or in conjunction with surgery.
  - Designed to prevent recurrence which can be as high as 20%. Consult NeuroInterventionalist
- Admit to Neuro ICU for at least 24h (pre-op or patients requiring close monitoring and post-op)

Blood Pressure Management

- SBP < 160

Seizure Prophylaxis

- Levetiracetam PO or IV bid x 7 days

Outcome and Prognosis

- There is clinical improvement when subdural pressure is reduced to close to zero, which usually occurs after about 20% of the collection is removed.

- Patients who have high subdural fluid pressure tend to have more rapid brain expansion and clinical improvement than patients with low pressures.
- Residual subdural fluid collections after treatment are common but clinical improvement does not require complete fluid resolution on CT. CT shows persistent fluid in 78% of cases on POD#10 and in 15% after 40 days and may take up to 6 months for complete resolution.
- Overall mortality with surgical treatment is 0-8%

Epidural Hemorrhages

General Information

- EDH = 1% of all head trauma admissions, half the incidence of SDH
- Male: female 4:1
- Commonly result of temporoparietal skull fracture →disrupts middle meningeal artery as it enters the skull through the pterion ○ 85% of all EDH are arterial source (MMA); blood enters at pterion, dissects dura from inner table.
- Textbook presentation (occurs in 10-27%):
    - ○ LOC from initial impact →Lucid interval (hours) →Neuro decline (obtunded, contralateral hemiparesis, ipsilateral pupillary dilatation)

Morbidity and Mortality

- Those without a lucid interval have double the mortality rate of those with one.
- When treated/managed within hours, mortality 5-10%. Without evaluation and management, 20-55% mortality
- Presence of bilateral Babinski or decerebrate posturing pre-op portends worse prognosis.
- Temporal lobe lesions are more likely to deteriorate.

Conservative Indications

- < 15 mm at maximal thickness
    - ○ AND volume < 30 cm^3
    - ○ AND midline shift < 5mm
    - ○ AND GCS > 8
    - ○ AND no focal neuro deficits

Conservative Management

- Admit for observation with q1hr neuro checks (monitored bed if available)
- May use several days steroid taper.
- Follow up non-contrast head CT in 1 week if stable.
- Repeat non-contrast head CT in 1-3 months if any symptoms (headache, pupillary changes)

Surgical Indications

- EDH volume > 30 cm^3 regardless of GCS

- Acute EDH + GCS < 9 + anisocoria = surgical evacuation ASAP
- Local mass effect
- Herniation – drowsiness, anisocoria, hemiparesis
    - o More common in peds. Medical management of posterior fossa EDH not recommended.

Special Cases

- Delayed EDH
    - 9-10% of all EDH will have a delayed presentation, risk factors include.
    - Lowering of ICP medically or surgically
    - Rapidly correcting shock (rapid increase in blood pressure)
    - Coagulopathies
    - Therefore, repeat head CT is important despite stable neuro exam. Patients are often asymptomatic and ICPs stable though EDH is enlarged on CT.
- Posterior Fossa
    - Approximately 5% of EDH, more common in young patients with occipital bone fracture.
    - Lower threshold for surgery indication.
- Special attention to patients with concurrent EDH + SDH lesions. Up to 90% mortality in this population.

Traumatic Hemorrhages

The neurosurgery and trauma teams work closely to develop protocols where care overlaps. Please see Appendix, Trauma Services: Neurosurgical Emergencies for the WakeMed algorithm that highlights intracerebral hemorrhage care in trauma cases.

Sedation and Analgesia

- Analgosedation (Analgesic-based sedation or analgesia-first sedation) should be used as the primary strategy to control pain and agitation according to current recommendations from the Society of Critical Care Medicine
    - Analgesia monotherapy may be effective to control both pain and sedation
    - If sedation is needed, an emphasis on light sedation should be used to limit overall drug exposure of sedating medications.
    - Pain and sedation should be assessed using validated, objective scoring tools.
    - WakeMed endorses use of the Critical Care Pain Observation tool (CPOT) to objectively assess pain in ICU paints, and the Richmond Agitation and Sedation Scale (RASS) to objectively assess sedation.
    - Goal CPOT <2 and goal RASS -2 to +1 are targets for most intubated patients requiring continuous analgesia or sedation in the absence of an indication for deeper sedation.
    - Neurocritical care patients may have an indication for deeper levels of sedation (. i.e., RASS -4 to -5), including in the following scenarios:
        - Refractory Status Epilepticus
        - Need for neuromuscular blockade
        - Refractory ICP control
        - ARDS

- Sedative medications may also be needed in addition to analgesics in neurologically injured patients, including in the following scenarios:
    - Traumatic brain Injury
        - Elevated ICP
        - ARDS/ventilator compliance
            - Status Epilepticus
- Propofol is the preferred sedative medication in intubated neurologically injured patients due to its fast onset and offset, ease of titration, and anticonvulsant properties.
    - ○ Titration should be based off an objective RASS score, goal RASS -2 to +1 unless the patient has an indication for deep sedation as mentioned above (i.e., status epilepticus, refractory ICP control)
    - Q48h triglycerides levels will be checked in patients on propofol to assess for risk of accumulation.
- Dexmedetomidine may be used as an adjunctive agent for the treatment of severe alcohol withdrawal, or to facilitate extubation in patients failing SAT/SBT due to agitation or over sedation.
- Benzodiazepines should not be used first line for ICU sedation given the increased risk of delirium, ICU length of stay and time of the ventilator.
    - ○ Roles for benzodiazepines should be limited to treatment of seizures, alcohol withdrawal, refractory ICP management, in patients requiring deep sedation who cannot tolerate propofol
- Barbiturate Coma
    - Pentobarbital may be considered for induced coma in patients with refractory intracranial hypertension or refractory status epilepticus.
        - Continuous EEG will be used for these patients as well as assessment of vital signs, LFTs, infectious markers.
        - Levels do not need to be sent while the drug is infusing given the delay in sample time to result time.
        - Pentobarbital levels should be ordered once the infusion is discontinued to assess drug clearance.

Medical Management of Increased Intracranial Pressure

- Medical management should be considered in parallel process while deciding if a patient needs more definitive surgical management of increased ICP. Please see individual sections for surgical considerations
- Sodium goals: There is limited data on sodium targets for neurologically impaired patients. Hypernatremia has been associated with increased mortality in critically ill patients and higher risk of AKI. Therefore, higher sodium targets should be used in select patients deemed to have higher risk of malignant edema. Continuous hyperosmolar therapy appears to have no benefit for outcome.
    - For ICH and SAH patients, bolusing will depend on neurologic changes.
    - Preferred medical management is with hypertonic solutions. Mannitol is available as well as second preference.
    - Consider osmolar gap over serum osmol for monitoring.
- When monitoring ICP, the goal for most patients will be < 22.

Timing of Starting Antiplatelets or Anticoagulation

Where not specified above in individual sections, interdisciplinary discussions will be had with neurosurgery in consultation to determine when antiplatelets and anticoagulation can be used.

DVT Prevention

Intracranial Hemorrhage

- UFH 5000 units SC TID starting 48 hrs. from time of hospital admission with stable repeat CT head

Aneurysmal Subarachnoid Hemorrhage

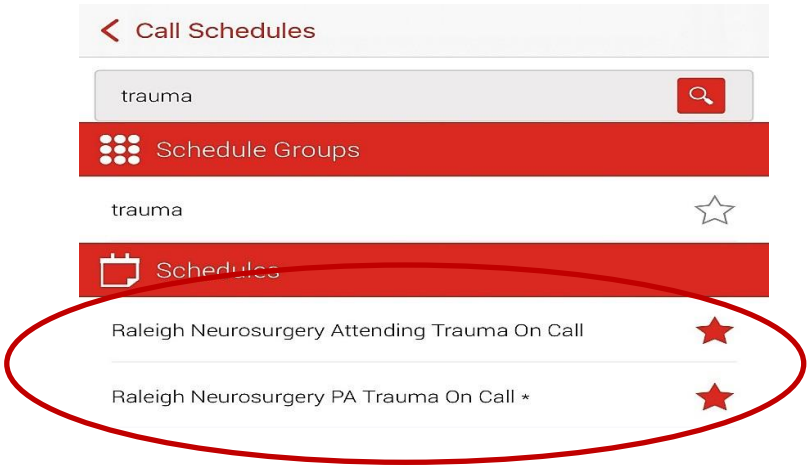
- Enoxaparin 40 mg SC daily once aneurysm is secured.
- Consider UFH 5000 units SC TID if CrCl <30 ml/min.

Traumatic Brain Injury

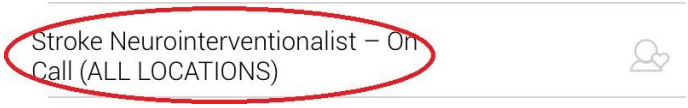
- Initiate within the first 48-72 hrs. of admission if no contraindications and stable repeat CT head
  - Weight </=60 kg and CrCl >30: enoxaparin 30 mg daily, doses may be changed based on current injuries and/or anti-Xa levels
  - Weight >60 kg and CrCl >30 (must meet both criteria): enoxaparin 40 mg daily, doses may be changed based on concurrent injuries and/or anti-Xa levels.
  - Any weight and CrCl <30: heparin 5000 units subcutaneous BID

Getting In Touch with Providers On-Call

- Neurosurgery Trauma Attending.
  - Go to Call Schedules Option
  - Search in RapidConnect for Raleigh Neurosurgery Attending Trauma on Call

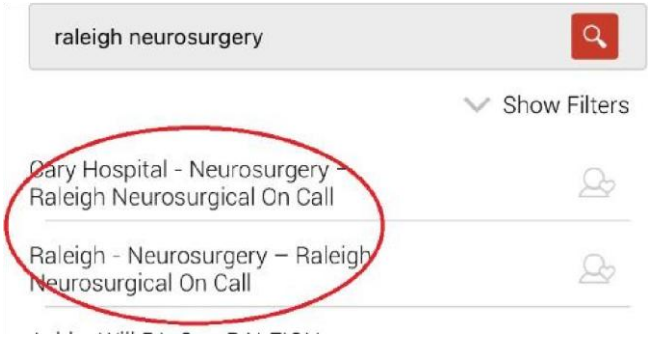


- Stroke NeuroInterventionalist on-call ○ Search in RapidConnect for Stroke NeuroInterventionalist – On Call (ALL LOCATIONS) NEVER text information for an acute stroke, always call.



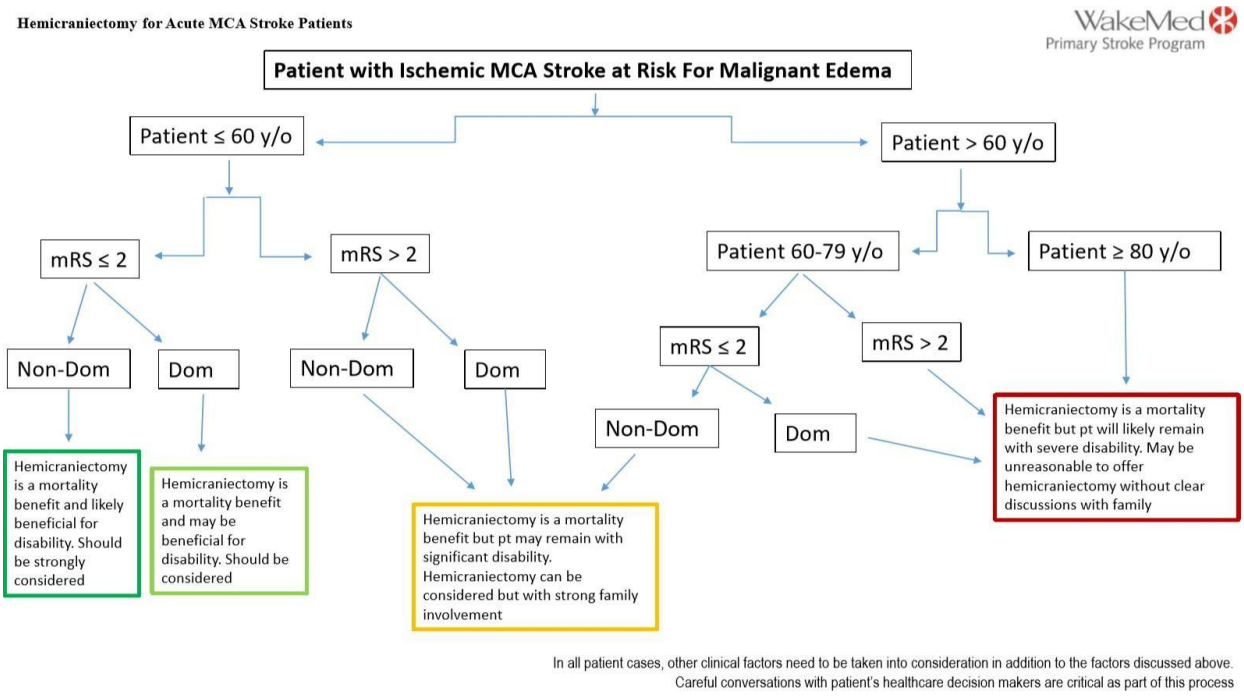
- Neurosurgery for emergent questions such as hemicraniectomy
  - Search in RapidConnect for Raleigh Neurosurgery Attending Trauma On Call
  - For routine questions, please search Raleigh Neurosurgery and pick the on

call attending by location.



Appendix

Hemicraniectomy Patient Considerations



Trauma Services: Neurosurgical Emergencies-Shared Policy/Algorithm

Parent Policy:	Title:	Standard Operating Procedure
InsertLinkToParentPolicy	Neurosurgical Emergencies- Shared	Effective Date: 06/24/2025

PURPOSE:
To define life threatening neurosurgical emergencies that warrant the response of a Neurosurgical Service within 30 minutes of notification. Cary Hospital neurosurgical emergencies require teleconsultation of a Neurosurgical Service from a Level I Trauma Center. Inclusive to this guideline is the "off-site radiology interpretation policy".

Contributing Specialties:
- Neurosurgery
- Trauma surgery

Guideline:

I. Emergent, Urgent, and Non-Urgent consult definitions & procedures:

a. Emergent definition- Injured patients with the presence of any of the following should be evaluated on an emergent basis by a neurosurgeon on trauma call.
   i. Threatened loss of life because of a neurosurgical injury: examples include but not limited to:
      1. GCS<9 with abnormal head CT
      2. GCS 9-12 with abnormal head CT (hematoma, contusion, edema or compressed basal cisterns).
         a. ICP monitoring may be indicated after neurosurgical evaluation and/or ICU level care.
      3. Spinal cord injury with neurologic deficits
      4. Trauma surgeon discretion

b. Emergent consult procedure- The neurosurgeon should initiate active evaluation and review the case (ranging from remote radiographic review to in person evaluation as determined by direct discussion between the neurosurgical and trauma attending) and be available to be present for active participation in resuscitation and treatment in the hospital within 30 minutes of notification, upon request of the trauma attending. The time of return call shall be documented in the medical record. A neurosurgery APP may act as a consultant so long as there is documentation of communication with neurosurgery attending.

c. Urgent definition- Injured patients with the following require urgent attention and triage but do not meet the threshold for emergent evaluation and should be evaluated on an urgent basis by a neurosurgeon on trauma call.
   i. Injured patients with the following should be considered for urgent neurosurgical consultation:
      1. GCS<9 with normal head CT with no clear etiology for altered mental status
         a. ICP monitoring may be indicated after neurosurgical evaluation

and/or ICU level care.

d. Urgent consult procedure- The neurosurgeon should initiate active treatment to deliver appropriate and timely care to the injured patient. This includes radiographic review, communication with the trauma service regarding a treatment plan, and preparation for definitive operative management as warranted. The neurosurgical consultant must be available for direct evaluation and treatment in the hospital within 12 hours or as deemed necessary between services.

e. Non-Urgent- The neurosurgeon on call may also be consulted for other neurosurgical injuries. The timeliness of the neurosurgical response should be based on discussion between the trauma team and the neurosurgeon team in each case.

f. Brain Injury Guideline (BIG):

CT Findings	BIG 1	BIG 2	BIG 3
Skull fx	no	non-displaced	displaced
EDH or IVH	no	no	any size
SDH or IPH	≤ 4mm	>4mm , <7.9mm	≥8mm
SAH	≤ 3 sulci, <1mm	1 hemisphere, > 3 sulci, 1-3 mm	Bilateral or > 3mm

i. BIG 1 inclusion- No anticoagulation/antiplatelets (other than ASA), GCS 14-15 at baseline, Non-focal neuro
   1. Observe in ED for 6 hours
   2. Discharge home with good follow up
ii. BIG 2- Managed by Trauma
iii. BIG 3- Managed by Trauma, Consult Neurosurgery

Guidelines of Care:

II. Anticoagulation Reversal:
- a. Reversal for anti-platelet medication (acetylsalicylic acid, clopidogrel, ticagrelor, prasugrel)
  - i. None required
- b. Reversal for anticoagulant (warfarin)
  - i. Non-life-threatening hemorrhage: FFP
  - ii. Life-threatening hemorrhage: 4 factor PCC (active bleeding or going to the OR)
- c. Reversal of novel anticoagulants (rivaroxaban, apixaban, dabigatran)
  - i. Non-life-threateninghemorrhage: None required
  - ii. Life-threatening hemorrhage: idarucizumab or 4 factor PCC (active bleeding or going to the OR)
  - iii. Discussion with Neurosurgery warranted

III. Pharmacologic Prophylaxis for DVT:
- a. Enoxaparin sodium in normal prophylactic doses may start if items below are met or as directed by neurosurgery
  - i. On HD#2 or >24 hours from injury
  - ii. Stable CT with no new or increase in size of bleed

IV. Seizure Prophylaxis:
- a. Levetiracetam will be administered prophylactically, to admitted patients, for 7 days if:
  - i. Acute trauma with SDH or cortical hemorrhage
  - ii. Not to be given in SAH or hemorrhage in the deep structures and cerebellum
- b. Levetiracetam dosing is based on the patient's exam
  - i. For patients with a poor exam, intubated, or with history of seizing meeting above criteria, the full loading dose 60mg/kg to max 4500mg is recommended.
  - ii. For patients in whom the exam can be followed, the prophylactic dose is 1000mg twice a day

V. Raleigh Campus
- a. Ventriculostomy Use:
  - i. Monitoring will be strongly considered for patients with a GCS ≤8 and a motor score of <4
  - ii. Ventriculostomy will be strongly considered over parenchymal monitors
  - iii. Repeat head CT in patients in whom it is deemed indicated
    1. 6 hours after injury
    2. < 6 hours at request of Neurosurgery

- b. TBI management (when concerns for increased ICP):
  - i. Consider intracranial monitoring device
  - ii. Avoidance of hypoxemia or hypotension

iii. Avoidance of hyponatremia (Na<140)
    1. Utilize 3% hypertonic saline infusion
iv. Avoidance of use of free water and dextrose
v. Elevate head of bed >30°
vi. Remove c-collar as soon as possible
    1. May buttress sides of neck if indicated
vii. Maintain normo-carbia (except in acute herniation syndrome)
viii. Provide adequate pain control and sedation
    1. Prefer Fentanyl and Propofol
    2. Benzodiazepines should be avoided unless medically indicated and in consultation with neurosurgery
ix. Utilize hypertonic bolus
    1. If Na <160 mEq/L give 23% saline
    2. Mannitol should not be used simultaneously with hypertonic saline
x. In the case of persistent increased intracranial pressure on adequate sedation
    1. Utilize neuromuscular blockade

VI. Cary Hospital

a. <u>TBI management:</u>
    i. Avoidance of hypoxemia or hypotension
    ii. Avoidance of use of free water and dextrose
    iii. Remove c-collar as soon as possible
        1. May buttress sides of neck if emergent
    iv. Provide adequate pain control
        1. Avoid benzodiazepines
        2. Minimal sedation unless medically indicated and with consultation with neurosurgery

b. <u>Acute Spine Injury:</u>
    i. No neurological deficits
        1. Consult Spine on call
    ii. Neurological deficits
        1. If due to spinal cord injury consult Spine on call and initiate transfer to Level I trauma center
        2. If possibly due to nerve root or peripheral nerve damage (e.g. brachial plexus) then consult Spine on call and discuss if can be managed at WakeMed Cary (if other injuries also allow)

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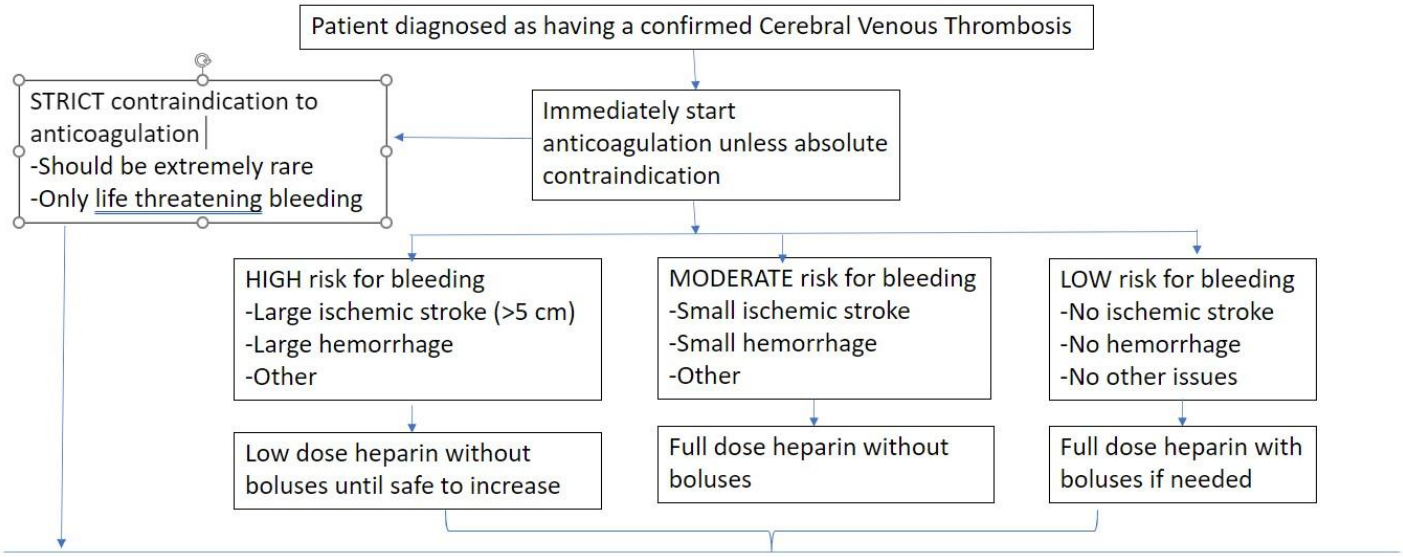
Cerebral Venous Thrombosis with Serious Complications Algorithm



The majority of patients will be placed on heparin; monitor response for at least 24 hours. Patient should be therapeutic on heparin to be considered appropriately medically treated.

In the rare, complex patient who is felt to have significant, clinical deterioration (directly related to CVT worsening), a **collaborative discussion** between neurointerventional team, ICU team, and neurology should be held to discuss potential need for endovascular therapy – direct tPA approach.

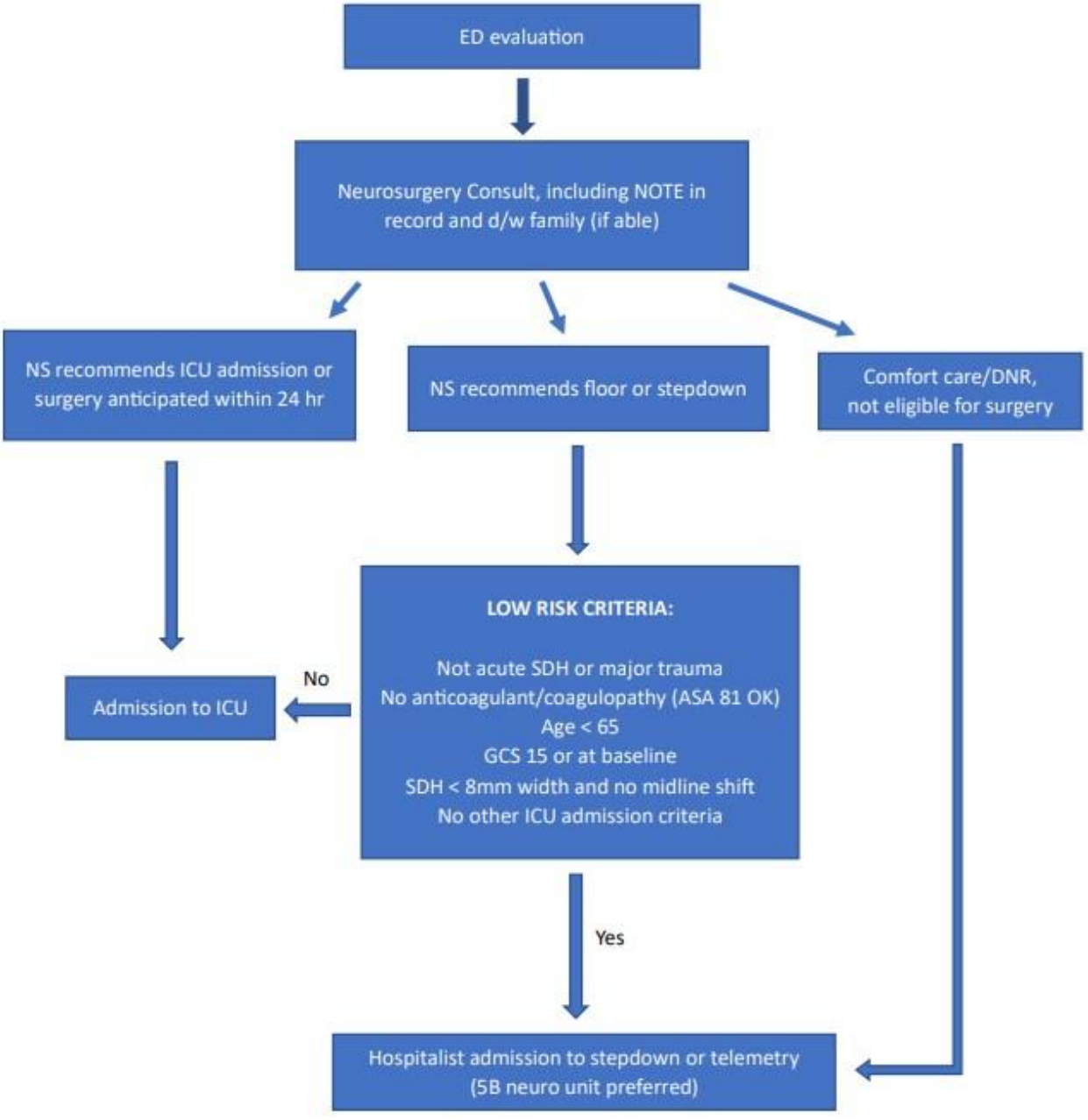
Higher risk patients appropriate for aggressive therapy will likely have deep vein involvement, GCS < 9, ICH or altered state

This is anticipated to be needed rarely (~ 1-2 patients/year)

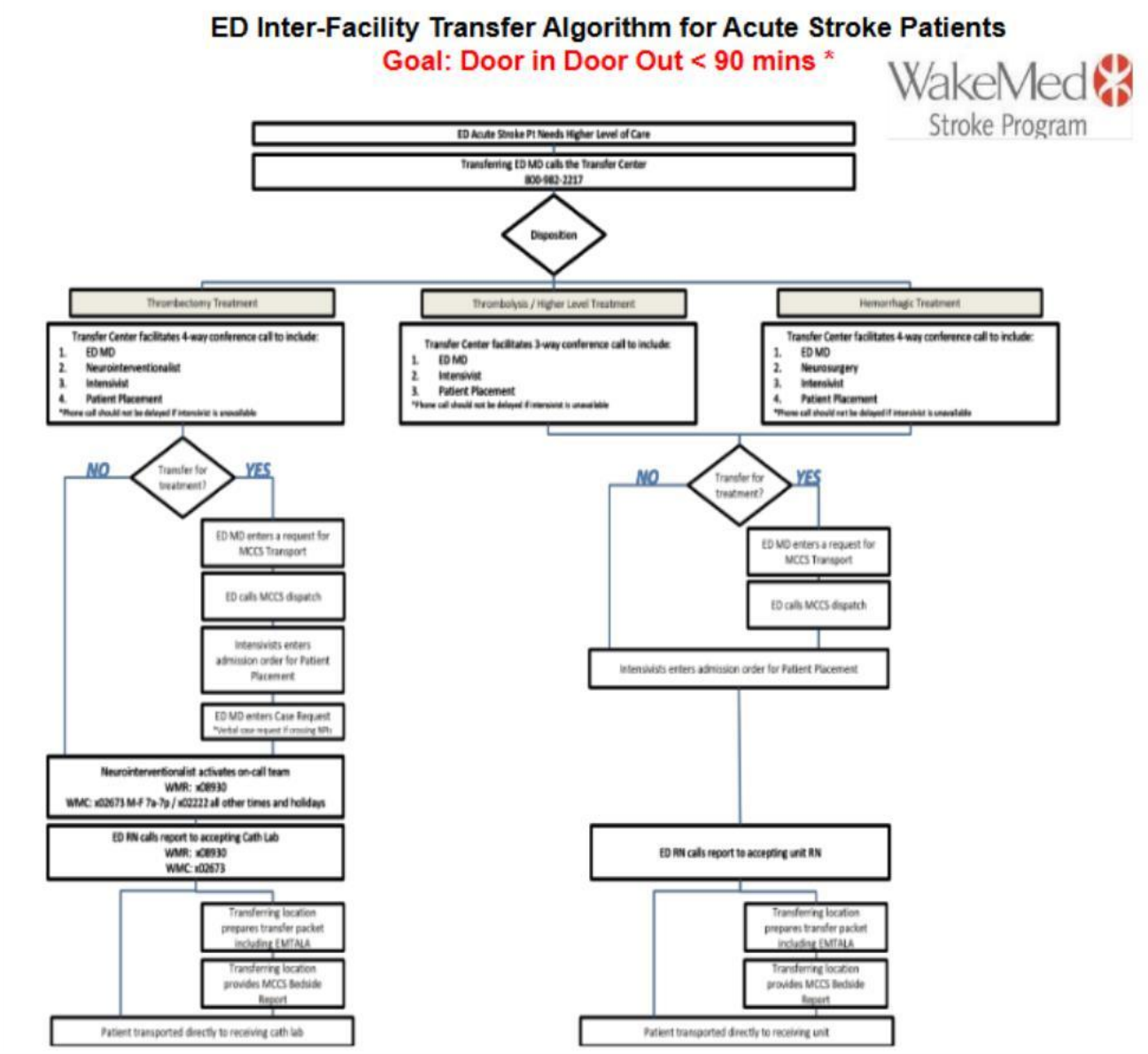
Subdural Hematoma Admission Algorithm

updated August 2023

General Guideline for Admission of Patients with Subdural Hematoma on Imaging



ED Inter-Facility Transfer Algorithm



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