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Neuroanesthesia Crisis Manual

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PREFACE

The purpose of this crisis manual is to be a resource for anesthesiologists and to prepare them for stressful situations that may arise during neurosurgical procedures. It is meant to be a reference only and a cognitive aid in emergency situations. It is NOT a guideline or a protocol that anesthesiologists are obligated to follow. This manual may provide a vehicle for input and practical strategies when facing critical events with neurosurgical patients.

We based the content on our literature review, accepted guidelines, algorithms, academic resources and by experiences learned in practice.

This manual introduces our mental model and decision-making frame. It provides methods to manage these emergencies, especially when treatment requires multiple tasks performed simultaneously by different individuals.

The manual will provide a team with a checklist of the tasks that need to be completed.

Limitations:
During our literature review, we focused on an adult population. However, most of the principles apply to pediatric cases with appropriate considerations (including doses) adjusted for this population.

Recommendation:
Implementation and management of emergency situations can vary according to institutions, regulations, team compositions, or updated evidence. We suggest the readers adapt within their own organization and discuss with the neurosurgical teams. This manual should be a living document. As future evidence changes procedure, an update of the manual will be necessary. Once you reach consensus start implementing your own manuals in your neurosurgical operating rooms using simulation-based training.

For more information on how to implement Emergency Manuals check: https://www.implementingemergencychecklists.org
**How to use the NeuroAnesthesia Crisis Manual?**

When using the manual, we recommend delegating one person to verify that important steps are not missed when following this guide.

**Two pages will be used to cover each crisis.** The first will include information about the patient at risk, the prevention strategies that could be implemented and the signs, symptoms, and differential diagnosis for each one. The second page is devoted to the treatments actually performed.

**Note:** The author and editors disclaim all liability from the use of the material, each clinician is responsible for the interpretation and use of the manual in the clinical setting.

We dedicate The Neuroanesthesia Crisis Manual to the patients that give us their trust daily.
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1. ACCIDENTAL EXTUBATION IN PRONE POSITION

**Signs**

- Drop or complete loss of EtCO₂
- Gas reservoir of machine empty
- Machine does not deliver adequate inspiration tidal volumes, maximal leakage

**Special Consideration**

Critical moments of neurosurgery require **deep anesthesia** and **neuromuscular blockade**. **AVOID** valsala maneuvers.

**Initial Assessment**

- Switch to **MANUAL/BAG** ventilation
- Increase **FiO₂ to 100%**
- Increase fresh gas **flow to maximum**
- Consider use of oxygen- “flush” button for maximum flow
- Test to see if manual (bag) ventilation is possible
- Feel resistance during manual ventilation. If no resistance: significant problem

**CHECK** circuit for leaks:
- Connections to the anesthesia machine
- Connections to the endotracheal tube
- Listen for leaks

**When Preparing to Turn a Patient Ask Neurosurgeon to:**

- **Flood surgical field with saline**
- Remove surgical Instruments
- Pack the wound with a saline soaked swab
- Cover the wound with adhesive dressing
- Release clamp
- Hold the head in neutral position
## 1. ACCIDENTAL EXTUBATION IN PRONE POSITION

### Treatment

#### Complete Extubation
- Announce EMERGENCY to the team
- Ask for HELP
- Ask for Difficult Intubation Cart

#### Stop Procedure
- Notify Neurosurgeon: prepare for turning
- Ask for a stretcher
- Increase Oxygen flow to 100% FiO$_2$

Immediate oxygenation/ventilation options in Prone:
- Insert a **Supraglottic Airway Device** (2$^{\text{nd}}$ generation/intubating supraglottic airways are preferred)
- **Attempt bag mask ventilation** in prone with high-flow, 100% FiO$_2$, consider use of nasal/oral airway

(If oxygenation is easy to maintain, consider one intubation attempt in prone position. Consider use of flexible intubation endoscope / video laryngoscope (if provider is highly skilled and if the approach is feasible))

#### Prepare for turning
- Secure IV access
- Airway management in Supine Position

#### Partial Extubation (Diagnosed by: depth of tube, capnography, ventilation parameters, presence of leak)
- Increase fresh gas flows and FiO$_2$ to 100%

- Advance endotracheal tube (through **Bougie** or Endotracheal **Tube Catheter**, consider use of **flexible intubation endoscope**) in prone position

- Check for correct tube position

- If adequate ventilation and endotracheal intubation is achieved, announce that situation is safe and continue surgery

- If ventilation and intubation is not achieved:
  - **Prepare for turning**
  - **Maintain oxygenation** via: endotracheal tube or supraglottic airway device (2$^{\text{nd}}$ generation/intubating supraglottic airways are preferred) or bag mask ventilation in prone position (consider use of oral/nasal airway)
  - **Turn to supine position**
  - Airway management in supine position
2. DECISION MAKING AFTER PROLONGED PRONE POSITION FOR EXTUBATION

Risk Factors

**Surgery associated risks:** surgery > 6 hours, ↑ blood loss, ↑ IV fluid, C-spine surgery  
**Patient associated risks:** Age > 70 yrs, obesity, obstructive, sleep apnea, chronic obstructive pulmonary disease, rheumatoid arthritis, hemoglobin < 10 mg/dl, difficult airway, neuromuscular disease, malnutrition, hypoalbuminemia

Prevention

Consider colloids over crystalloids for fluid resuscitation  
Cuff pressure measurements during procedure, aim for < 20 cm H₂O  
Avoid Extreme Neck Flexion

Airway Edema Assessment Options

Laryngoscopic assessment of pharynx/larynx (prefer video laryngoscope with hyperangulated blade, look for evidence of edema)  
Cuff Leak Test  
Airway Ultrasound  
Sufficient reflexes (cough, gag, and swallow)  
Physical examination:  
  - Neurologic status (Coma Recovery Scale-Revised Visual Subscale)  
  - Inspection of neck, eyes, and tongue for edema

Extubation Criteria

**Patient conditions**  
No signs of airway edema / obstruction  
Slow emerge from anesthesia, consider using Remifentanil iv infusion to allow tube tolerance)  
Sufficient spontaneous ventilation with adequate, regular respiratory efforts  
Hemodynamic and metabolically stable  
Sufficient protective reflexes (gag, swallow, cough)  
Reversal of neuromuscular blockade (TOF > 90%)  
Normothermia

**Other**  
Adequate location for extubation (monitoring, difficult airway equipment readily available)  
Help and skilled personnel available
2. DECISION MAKING AFTER PROLONaed PRONE POSITION FOR EXTUBATION

**PLAN**
Assessment of: Airway, patient’s condition, extubation potentially successful, equipment and skilled personnel

**PREPARE**
Optimize patient and other factors (equipment, personal, location)
Suction secretions without trauma

**Is Patient Safe to Extubate?**

**No**
- Postpone extubation
- Transfer to ICU
- Consider Tracheostomy

**Yes**

**PerForm Extubation**
Options:
1. Remifentanil technique
2. Exchange Catheter

**POSTEXTUBATION CARE**
Comprehensive documentation and handover
Monitoring and care by skilled / qualified personnel
Advanced airway management equipment readily available
3. **NEUROGENIC PULMONARY EDEMA**

### Risk Factors

**Acute Cerebral or Cervical Spine Cord Insult:**
- Aneurysmal subarachnoid hemorrhage
- Traumatic brain injury/cervical injury
- Intracranial hemorrhage
- Intracranial tumours
- Seizures
- Postoperative intracranial surgery
- Meningitis

### Signs

**Central Neurologic Injury** + **Sudden Dyspnea**

**Other signs:**
- Tachypnea
- Tachycardia
- Pulmonary crackles and rales on auscultation, "B" lines in lung US
- Cyanosis
- Pink frothy sputum
- Respiratory failure

### Assessment

- Arterial blood gases: \( \downarrow \text{PaO}_2 / \text{FiO}_2 < 200 \)
- X-Ray: Bilateral infiltrates
- **Point of Care Ultrasound:**
  - Cardiac US: Assessment of left ventricular function
  - Lung US: B-lines
  - Inferior Vena Cava measurement
- EKG: Ischemia findings

### Differential Diagnosis

- Cardiogenic Pulmonary Edema
- Aspiration Pneumonia
- Ventilator Associated Pneumonia
- Ventilator Induced Lung Injury
- Transfusion Related Acute Lung Injury
- Sepsis
- Pneumothorax
3. NEUROGENIC PULMONARY EDEMA

**Treatment**

1. **Oxygenation:**
   \[ \uparrow \text{FiO}_2 \]
   Mechanical or Non-Invasive Ventilation if no contraindications
   (Keep PEEP < 15 cm H\textsubscript{2}O) / avoid AutoPEEP
   Request the ICU Ventilator if needed
   Use a muscle relaxant agent if needed

2. **Treat primary brain injury-associated intracranial hypertension** (examples):
   - Decrease ICP (if it has Increased, see crisis #8 page 22
     Intracranial Hypertension)
   - Evacuate hematoma
   - Treat seizures
   - Acute hydrocephalus: External ventricular drain

3. **Avoid increase in intracranial pressure:**
   - Ensure adequate anesthesia depth according to surgical procedure
   - Avoid bronchoscopy unless absolutely necessary

4. **Maintain adequate cerebral perfusion:**
   **Hemodynamic support:** Phenylephrine, Norepinephrine infusions
   Avoid hypotension, goal MAP \( \geq 70 \text{ mm Hg} \)
   Caution with therapies: diuretics and high PEEP
   Maintain hemoglobin > 10 g/dl
   Maintain normocapnia
   Maintain normal temperature

5. **Monitor patient's intravascular volume status and fluid responsiveness to guide fluid management in the setting of pulmonary edema:**
   - Pulse wave pressure variability < 13
   - Focused cardiac US:
     IVC Distensibility index < 18%,
     < 3 B-lines in each lung region
     LVEF visual assessment normal or increased

6. **Circulation:** Consider Dobutamine and inotropes if necessary

7. **Other Options:**
   - **Diuretics:** Furosemide
   - **Corticosteroids** (Brain tumors/Multiple Sclerosis) **NOT IN TRAUMATIC BRAIN INJURY**
   - Beta and alpha adrenergic blockers, according to hemodynamic profile

8. **Transfer to ICU**
   Considerations for Brain-Dead Organ Donors:
   - Nitric Oxide (NO) if pulmonary hypertension is suspected
   - ECMO
4. CARDIAC ARREST IN PRONE POSITION

Reversible Causes

- **Air Embolism** *(see crisis #5 Air Embolism, page 16)*
- **Parasympathetic Reflex - Surgical Stimulation**
- **Sudden Increase in ICP** *(see crisis #8 intracranial hypertension page 22)*
- **Prone Position**
- **Intracranial Hypotension** *(Check Drains, see crisis #10 intracranial hypotension page 26)*
- **Medications** *(Dexmedetomidine, Remifentanil, Phenytoin, Beta-blockers)*
- **Local Anesthesia Toxicity**
- **Spinal Shock**
- **Anaphylaxis**
- **Auto-PEEP**
- **Brain Irrigation** with Warm ($42^\circ$C) or Cold ($20^\circ$C) Saline

<table>
<thead>
<tr>
<th>Hypovolemic Disorders</th>
<th>Tension Pneumothorax, Tamponade, Cardiac</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypoxia</td>
<td>Toxins</td>
</tr>
<tr>
<td>Hydrogen (Acidosis)</td>
<td>Thrombosis, Pulmonary</td>
</tr>
<tr>
<td>Hypo/Hyperkalemia</td>
<td>Thrombosis, Coronary</td>
</tr>
<tr>
<td>Hypo/Hyperthermia</td>
<td>Tension Pneumocephalus</td>
</tr>
</tbody>
</table>

Effectiveness of CPR

- Start reverse CPR compressions (see figures): Perform sterile CPR as soon possible
- Guide compressions
  - $\text{EtCO}_2 > 20 \text{ mmHg}$
  - Arterial line diastolic blood pressure $> 40 \text{ mmHg}$
  - Push chest at least $5 \text{ cm}$
  - Allow recoil
  - Rotate person compressing the chest

**Defibrillation on Prone:**
- Pads on Postero-lateral (left mid axillary line + right scapula)
- or bi-axillary position
4. CARDIAC ARREST IN PRONE POSITION

Treatment

Confirm Cardiac Arrest (Pulse-Monitors)

Activate Code Blue (Ask for HELP-Crash Cart-a Stretcher and Board for Support)

Ask Surgeon to STOP PROCEDURE

Start Effective CPR in Prone

(Compressions at least 100-120 mmHg
Ventilation 10 mmHg)

Minimize Interruptions
Check Rhythm and pulse/ 2 min

Check Rhythm

<table>
<thead>
<tr>
<th>Shockable Rhythm</th>
<th>No Shockable Rhythm (PEA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shock</td>
<td>Epinephrine 100 mcg (0.1 mg)</td>
</tr>
<tr>
<td>(Biphasic Defibrillator 200 J)</td>
<td>Every 3-5 minutes first doses up to 1 mg, then 1 mg</td>
</tr>
<tr>
<td>Every Cycle</td>
<td></td>
</tr>
</tbody>
</table>

Continue CPR

Epinephrine 100 mcg (0.1 mg)

Every 3-5 min First Doses

Up to 1 mg, then 1 mg Every Cycle

Amiodarone 300 mg (first dose, Second 150 mg. Start after Second Shock

Treat Reversible Causes

When Possible TEE (Preferable) /TTE

Continue CPR

Treat Reversible Causes

Minimize CPR Interruptions/Allocate Expert in TEE/TTE to it:

If Possible TEE (Preferable) /TTE

Is there Wall Motion?

- Yes (Pseudo-PEA)
  - Is there an occult VF that Appeared Asystole?
    - Yes: Provide a Shock
    - No: Is there evidence of Tamponade, PE or Air in RV/Exsanguination? If positive, treat
  - No (True-PEA) Epinephrine

If CPR is Not Effective: TURN TO SUPINE

ROSC Post-Cardiac Arrest Care

<table>
<thead>
<tr>
<th>Neurosurgeon</th>
<th>Anesthesiologist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stop stimuli</td>
<td>Anesthesiologist</td>
</tr>
<tr>
<td>Flood Surgical Field</td>
<td>Turn Off anesthetic, if feasible</td>
</tr>
<tr>
<td>Remove Surgical Instruments</td>
<td>Increase FIO₂ to 100%</td>
</tr>
<tr>
<td>Pack the Wound with Saline Soaked Swab</td>
<td>Stop infusions</td>
</tr>
<tr>
<td>Cover Wound Adhesive Dressing</td>
<td>Check ETT position, circuit integrity, machine connections</td>
</tr>
<tr>
<td>Release Clamp (first), then</td>
<td>Start new IV fluids wide open</td>
</tr>
<tr>
<td>Release Pins</td>
<td>Review administered medications</td>
</tr>
<tr>
<td>Hold Head</td>
<td>Verify tube secretions or obstruction</td>
</tr>
<tr>
<td>Get Horseshoe or</td>
<td>Request expert to perform emergent TEE/TTE</td>
</tr>
<tr>
<td>Free Type Support for Head</td>
<td>Discuss Reversible Causes with the team</td>
</tr>
<tr>
<td></td>
<td>Check surgical field and drains</td>
</tr>
</tbody>
</table>
5. AIR EMBOLISM

Patients at Risk

Surgical field above heart level: sitting, lateral, prone
Posterior fossa procedures
Deep brain stimulator procedures
Cervical laminectomy
Craniosynostosis
Posterior spinal fusion
Hypovolemia
Spontaneous ventilation
Hydrogen peroxide for wound irrigation
Use of NO₂

Prevention

Look for PFO (TEE)
Good care of IV lines
Euvolemia
Adequate irrigation
Use of waxing

Signs and Symptoms

<table>
<thead>
<tr>
<th>Patient Awake</th>
<th>Patient Asleep</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coughing</td>
<td>Hypoxemia</td>
</tr>
<tr>
<td>Gasping respiration</td>
<td>Hypotension</td>
</tr>
<tr>
<td>Acute dyspnea</td>
<td>↓ EtCO₂ (sudden decrease of CO₂)</td>
</tr>
<tr>
<td>Tachypnea</td>
<td>ECG changes</td>
</tr>
<tr>
<td>Breathlessness</td>
<td>Arrhythmias</td>
</tr>
<tr>
<td>Light-headedness</td>
<td>Abnormal heart sounds ( precordial doppler)</td>
</tr>
<tr>
<td>Wheezing</td>
<td>Tachycardia</td>
</tr>
<tr>
<td>Chest pain</td>
<td>↑ CVP</td>
</tr>
<tr>
<td>Altered sensorium</td>
<td>Jugular venous distention</td>
</tr>
<tr>
<td></td>
<td>Acute right heart failure (TTE)</td>
</tr>
<tr>
<td></td>
<td>Cardiac arrest</td>
</tr>
</tbody>
</table>
5. **AIR EMBOLISM**

### Treatment

Announce EMERGENCY to the team

Ask Neurosurgeon to **STOP PROCEDURE**

**Ask for Help** - Crash Cart

**Change position** to Trendelenburg (tilt left side)

↑ **FIO₂** to 100%

Administer bolus of IV fluids

Stop NO₂ (if used)

Ask the Neurosurgeon to:
- **Flood** the wound with saline
- **Wax** bone edges
- **Cover exposed areas** with large pieces of wet sterile sponges

Verify that there is no AIR in IV lines

**RAPID ASPIRATION THROUGH CENTRAL LINE**

Start vasopressors (if hypotension)

Compression of both Jugular veins

If patient has cardiac arrest, start CPR (**see crisis # 4 Cardiac Arrest Prone Position, page 14**)

Consider TEE for monitoring (other monitors: precordial Doppler, TTE)

Consider hyperbaric oxygen therapy (in case of cerebral arterial gas embolism)

Keep hemodynamic and ventilator support, if necessary

Transfer to ICU
6. ANEURYSM RUPTURE DURING CLIPPING

Risk Factors

- Hypertension (history or presented with high blood pressure)
- Recent rupture
- Smoking history
- Large size

Prevention

**Before surgery:**
- Reserve FFP, red blood cells
- Apply pads
- Reserve ICU
- Double suction setting
- Adenosine available in the OR
- Have crystalloids with pressure bag ready
- Use Neuromonitoring if possible (BIS, NIRS, Evoked Potentials), when applicable

**During surgery:**
- Use osmotic therapy to optimize surgical access
- Adequate use of neuromuscular agents when transferring intubated patients
- At the moment of Durotomy, keep MAP 20% below baseline (Avoid big changes in transmural tension)

Avoid

**Sympathetic responses:** intubation
**Abrupt changes in ICP:** coughing, gagging, hypotension, hyperventilation
**Excessive drainage of CSF:** large dose Mannitol, valsalva
**Hypertension** at the moment of Durotomy

Signs

**Sudden changes without other explanation**

**Clinical:** hypertension, bradycardia, arrhythmias, and blown pupil

**Surgical:** evidence of bleeding, brain bulge

**Monitors:** Suddenly increased intracranial pressure (ICP), sudden unexplained changes on the monitors
6. ANEURYSM RUPTURE DURING CLIPPING

Treatment

Announce EMERGENCY to the team

Continue to communicate with the Neurosurgeon
  Suggest the most senior surgeon in the room to take over
  Verify double suction setting
  Suggest using cotton to suppress bleeding

↑ \( \text{FiO}_2 \) to 100%

Request red blood cells to blood bank

Management of MAP (Goal 60 to 80 mmHg)
Controlled decrease of MAP (SHORT PERIOD OF TIME) (for approx. 3 minutes)
- Propofol 1 -2 mg/kg or
- Thiopental 5-10 mg/kg or
- Esmolol 1 mg/kg or
- Labetalol 10 mg IV initially, then 20 mg IV q10min; do not to exceed 300 mg

↓ Cerebral metabolic rate: (propofol 1 -2 mg/kg or Thiopental 5-10 mg/kg)

Keep intravascular volume: crystalloids, transfusion if applicable

Sustain hemodynamic changes with vasopressors, titrate accordingly

Efforts to Stop Bleeding:
  – Temporary clip
  – Compression of ipsilateral Carotid Artery (for Anterior Circulation Aneurysms)
  – Cardiac Arrest
    – Adenosine 1\textsuperscript{st} dose: 6 mg, 2\textsuperscript{nd} dose: 12 mg
    – Rapid ventricular pacing

Consider seizure prophylaxis Levitiracetam 20 mg/kg in 100 cc NaCl 0.9% in >15 minutes or Phenytoin: 20 mg/kg in 30 min. Start EEG

Ventilation and hemodynamic support
Transfer to ICU
7. ANEURYSM RUPTURE DURING COILING

**Patients at Risk**
- Hypertension (history or presented with high blood pressure)
- Recent rupture
- Small aneurysms
- Presence of smaller associated aneurysm
- Past medical history: COPD, coronary artery disease/smoker/hyperlipidemia

**Avoid**
- **Sympathetic Responses**: Intubation
- **Abrupt changes in ICP**: Coughing/gagging/hypotension/hyperventilation
- Caution with osmotic therapy
- **Suddenly decrease in brain parenchyma volume (↓ICP)**: large dose Mannitol

**Signs**
- **(Sudden changes no explanation)**
  - **Clinical**: hypertension, bradycardia, arrhythmias, blown pupil
  - **Radiographic**: dye extravasation, prolongation of contrast dye transit time, mechanical perforation, diversion of blood flow
  - **Monitors**: sudden increase ICP, sudden changes in monitors
7. ANEURYSM RUPTURE DURING COILING

**Treatment**

Announce EMERGENCY to the team  
Ask for Help (CT-Scan-Neurosurgeon-request OR available)

↑FiO\textsubscript{2} to 100%

Request red blood cells to blood bank and platelets if needed

**Management of MAP** (Goal 60 to 80 mmHg)  
- **Propofol** 1 - 2 mg/kg or  
- **Thiopental** 5 - 10 mg/kg or  
- **Esmolol** 1 mg/kg or  
- **Labetalol** 10 mg IV initially, then 20 mg IV q10min; do not to exceed 300 mg

↓ Cerebral metabolic rate: (Propofol 1 - 2 mg/kg or Thiopental 5 - 10 mg/kg)

**Management of ICP**

**No Signs of Herniation:**  
Avoid hyperventilation if there is hypotension  
Once the rupture is solved, start management of ICP (see Crisis #8, page 22)

**Signs of Herniation:**  
Manage ↑ ICP (see Crisis #8 Intracranial Hypertension, page 22)

**Prompt Reverse heparin:** get ACT or consider time since last dose of Heparin.  
(Protamine Sulfate 1 mg for each 100 units of Heparin given)

Continue to communicate with the Neurosurgeon:  
**Endovascular treatment:** Partial or complete packing of aneurysmal sack with Coils is feasible? embolization to seal?

**Surgical treatment:** Ventriculostomy or emergent Craniotomy and Clipping or Decompressive Hemicraniectomy  
**Prepare for surgery:** get ACT, get CT-Scan, prepare for transport, consider ventriculostomy catheter: drain at 15 - 20 cm H\textsubscript{2}O above Tragus

**Consider seizure prophylaxis:** Levetiracetam 20 mg/kg in 100 cc NaCl 0.9% in >15 minutes or Phenytoin: 20 mg/kg in 30 min. Start EEG

Ventilation and hemodynamic support  
Transfer to ICU or Operating Room
# 8. INTRACRANIAL HYPERTENSION

## Patients at Risk
- Severe Traumatic Brain Injury
- Hemispheric Stroke
- Intracranial Hemorrhage
- Severe Intracranial Hypertension
- Acute Hydrocephalus
- Meningitis

## Signs

**Intracranial Pressure**: >20 mmHg (>5min) if Measured

**Signs of Herniation**:  
- Hypertension, bradycardia, irregular respirations or apnea
- Pupillary dilation

**Loss of Brainstem Reflexes**:  
- Blinking, gagging, pupils reacting to light,
- Loss consciousness
- Respiratory depression
- Dysrhythmias
- Cardiac arrest
8. INTRACRANIAL HYPERTENSION

Treatment

**Physiologic therapies**
- Head elevation: 20 - 30°
- Neutral neck positioning to ensure venous drainage
- **Hyperventilation (as a bridging therapy):** *(PaCO₂ 30-35) short time (5 -10 min without hypotension)*
  - ↑FIO₂ to 100%
- Keep adequate blood pressure: MAP 90-110 mmhg
- Decrease intrathoracic pressure (low PEEP)
- Keep temperature control (normothermia)
- Check normoglycemia (80-150 mg/dl)
- Minimize tracheal suctioning
- Measure electrolytes and arterial gases.

**Avoid valsalva maneuvers:** Maintain deep anesthesia and/or use muscle relaxant agent.

**Pharmacologic treatment**
- Mannitol 0.5-1 g/kg
- **Hypertonic Saline over 20 min:** *(NaCl 3% 3 mL/kg or NaCl 7.5% 2 mL/Kg)*
- Furosemide 10 to 20 mg
- Propofol Bolus 1-2 mg/kg  OR
- Thiopental 5-10 mg/kg initial dose
- Anesthesia inhaled agents MAC < 1, if it is not improving, CHANGE FOR TIVA
- Consider Dexamethasone (if vasogenic edema is suspected)

**Consider EEG monitoring** and decide the use of:
- Phenytoin 20 mg/kg in 30 min initial dose  or
- Pentobarbital 10mg/kg over 30 min then 5 mg/kg/h x 3 h then 1-4 mg/kg/h
- or levetiracetam 20 mg/kg 100 cc NaCl 0.9% in >15 minutes

**CT- SCAN**
- Consider: ventricular drainage, Decompressive Craniotomy
- Start deep sedation and consider additional monitoring (NIRS, EEG, TCD)
- Keep ventilation and hemodynamic support
- Transfer to ICU
## 9. DELAYED AWAKENING

### Risk Factors

#### Surgical associated risks
- Frontal brain resection
- Posterior fossa
- Tumor size > 30 mm
- Midline shift > 3 mm
- Cerebral edema
- Proximity to the Ascending Reticular Activating System
- Temporary occlusion of arteries
- Hematoma exceeding 2-3 cms
- Neuroendoscopic procedure
- Transsphenoidal surgery with use of Oxymetazoline
- Hypothermia

#### Patient associated risks
- Epileptic patients
- Parkinson Disease
- Obese
- Elderly
- Porphyria
- Mucopolysaccharide Disease
- Hypothyroidism
- Renal failure
- Liver failure

#### Medications
- Narcotics
- Muscle relaxants
- Toxins (Alcohol, etc)
- Antiepileptic medications
- Anticholinergic agents
- Nasal Oxymetazoline
- Benzodiazepines
- Barbituric agents
- Anti-epileptic agents (AEA)
- Parkinson medications
- Dexmedetomidine
- Haloperidol
9. DELAYED AWAKENING

Verify

- Vital signs (ABCD)
- All anesthetic agents and opioids are stopped
- TOF >90%
- Check: Pupils, lateralizing signs
- Check: Blood gases (Na, K, Ph, P₅ CO₂) and glucometry, temperature, Mg++, Ca+, BUN
- Check: Amount of CSF drainage
- Review medications

Treatment

Consider:
- Opioid reversal: Naloxone 40 mcg IV and repeat every 2 minutes Up to 2 mg
- Benzodiazepines reversal: Flumazenil 0,1 mg Iv q 2 min until 1 mg
- Anticholinergic medications: Physostigmine 1 mg (rate 1mg/min)

EMERGENT CT-SCAN
- Don’t extubate
- Inform Neurosurgeon – Consult Neurology if necessary
- Consider brain monitors: BIS, NIRS TCD, accordingly

Differential Diagnosis
- Hypoglycemia: give Dextrose 50% 50 cc IV
- Hypothermia: start re-warming
- Cerebral ischemia/stroke: MRI, hemodynamic support, consult Neurology
- Vasospasm: Request TCD
- Cerebral hemorrhage: CT-Scan and discuss with Neurosurgery according to findings
- Tension Pneumocephalus: Emergent surgical intervention
- Rupture Aneurysm: CT-Scan and discuss with Neurosurgery according to findings
- Seizure Disorder: Start EEG
- Cerebral Hypotension (Trendelemburg positioning, (see Crisis #10 Intracranial Hypotension, page 26)

Continue ventilation and hemodynamic support
Transfer to ICU
## 10. POSTOPERATIVE INTRACRANIAL HYPOTENSION

### Patients at Risk
- Brain or spine trauma
- Spine surgery
- VP shunts
- Postoperative drainage of brain hematoma
- Any Craniotomy
- Intraoperative drainage of CSF

### Signs
- Delayed recovery from anesthesia
- Mydriasis and non-reactive **BILATERAL pupils**
- Absence of decerebration and decortication reflexes
## 10. POSTOPERATIVE INTRACRANIAL HYPOTENSION

### Treatment

**Inform Neurosurgeon**

**TRENDELENBURG POSITION -30 degrees**

IV Fluid challenge (250-500 cc)

Clinical condition should improve in 30 minutes or less

Hemodynamic and ventilator support

If there is no change in neurologic response: CT-Scan (see Crisis #9 Delayed Awakening, page 24)
## 11. POSTOPERATIVE SEIZURES

### Patients at Risk

<table>
<thead>
<tr>
<th>Category</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Metabolic:</strong></td>
<td>hypoglycemia, hypocalcemia, hypophosphatemia, hyponatremia, uremia</td>
</tr>
<tr>
<td><strong>Drug Withdrawal:</strong></td>
<td>Alcohol, barbiturics, benzodiazepines, opioids</td>
</tr>
<tr>
<td><strong>Brain Injury:</strong></td>
<td>Traumatic brain injury, stroke, subarachnoid hemorrhage, intracranial</td>
</tr>
<tr>
<td></td>
<td>hemorrhage, infections</td>
</tr>
<tr>
<td><strong>Brain surgery:</strong></td>
<td>Glyomas, cortical stimulation, brain tumours, surgery in motor cortex</td>
</tr>
<tr>
<td><strong>Others:</strong></td>
<td><strong>ANTIEPILEPTIC DRUG (AED) WITHDRAWAL,</strong> younger age, hyperventilation,</td>
</tr>
<tr>
<td></td>
<td>changes in AED, pain, stress, fever, infection, local anesthetic toxicity</td>
</tr>
</tbody>
</table>
11. POSTOPERATIVE SEIZURES

**SUPPORTIVE MEASUREMENTS**
- **Airway:** Secure and support
- **Monitors:** Respiratory, cardiac, temperature, EEG
- **IV:** Secure IV access and drop blood samples for: Blood gases, Na, Ca, Mg, PO₄, BUN, AED levels, alcohol, toxic panel
- **Glucometer:** if < 60 mg/dl, 50 ml Dextrose 50%, consider Thiamine 250 mg, for Alcohol Consumption or impaired nutrition
- **Oxygen and Observe:** Maintain oxygenation and perform neurologic exam

**ASK FOR HELP!**

**FIRST 5 minutes**

**BENZODIAZEPINE TRIAL**
- **Lorazepam:** 0.1 mg/kg max 4 mg Repeat Once or
- **Midazolam:** 5 mg IV or IM, Intranasal, Buccal (2.5 mg for fragile, elderly or severe comorbidities) or
- **Diazepam:** 0.15-0.2 g/kg max 10 mg/dose

**Check exams and treat reversible causes**

**5 – 20 minutes**

**ANTI EPILEPTIC DRUG (AED)**
- **Levetiracetam:** 20 mg/kg in 100 cc NaCl 0.9% in >15 minutes or
- **Phenytoin:** 20 mg/kg in 30 min or
- **Phenobarbital:** 20 mg/kg in 30 min

**STAT 20 MINUTES EEG**

**If Seizures Continue After 20 minutes**

**GENERAL ANESTHESIA**
- Prepare for RSI
- Propofol Infusion

**EMERGENT CT-SCAN**

Ventilation and hemodynamic support
- Transfer to ICU
- Continue AED infusions, consider continuous EEG

**Call Neurologist or epileptic clinic consult**
12. INTRAOPERATIVE SEIZURES

## Risk Factors

<table>
<thead>
<tr>
<th>Patient associated risks:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>History of seizures</td>
<td></td>
</tr>
<tr>
<td>Preoperative seizures</td>
<td></td>
</tr>
<tr>
<td>Young patients</td>
<td></td>
</tr>
<tr>
<td>Uncontrolled diabetes</td>
<td></td>
</tr>
<tr>
<td>Hyponatremia</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Surgery associated risks:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade ii gliomas</td>
<td></td>
</tr>
<tr>
<td>Frontal lobe surgery</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Moment in surgery:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain mapping</td>
<td></td>
</tr>
<tr>
<td>Tumour resection</td>
<td></td>
</tr>
<tr>
<td>Cortical stimulation</td>
<td></td>
</tr>
</tbody>
</table>

### Withdraw of Anti-Epileptic Drugs

**Avoid:**

- Etomidate
- Ketamine
- Hyperventilation
- Flumazenil
12. INTRAOPERATIVE SEIZURES

Treatment

Announce EMERGENCY to the team

Ask the surgeon to stop cortical stimulation

Irrigate cold saline on the brain or surgical field

If seizures stopped, continue procedure.

If seizures don’t stop:

Basic support measurements:
  Patent airway
  Assist ventilation
  Cardiovascular stability

Medications:
  Propofol: 0.5 mg/kg
  Midazolam 1 or 2 mg bolus

Talk to neurosurgeon and neurophysiolist:

Assess if you can continue with micro or macro recording. (If it is safe, continue with the procedure)

If seizures recurred, ABORT PROCEDURE

Remove head from frame and pins

Repeat Midazolam 1 or 2 mg
Start Levetiracetam 20 mg/kg in 100 cc NaCl 0.9% In >15 minutes or Phenytoin: 20 mg/kg in 30 min

Continue seizures management (see crisis #11 Postoperative Seizures, page 28)
## 13. INTRAOPERATIVE STROKE

### Risk Factors

**Patients associated risks:**
- Atrial fibrillation
- Elderly ($>$ 65 y/o)
- MI ($<$ 6 months)
- Acute renal failure
- Smoker
- Cardiac valve disease
- Previous stroke ($<$ 9 months)
- History of brain radiotherapy

**Procedure:**
- Carotid endarterectomy
- Carotid stent
- Aneurysm clipping or coiling
- Intraoperative hypotension

**Neck surgery:**
- Neck rotation and extension
- Arthritis cervical spine
- Tumors involving Carotid Artery
- Intraoperative hypotension
- Patient sitting position

### Signs

<table>
<thead>
<tr>
<th>Awake Patient:</th>
<th>Patient under General Anesthesia:</th>
<th>Emergency from general anesthesia:</th>
</tr>
</thead>
<tbody>
<tr>
<td>New neurologic deficit</td>
<td>Changes in neuromonitors NIRS (drop $&gt;$20%), Unexpected changes in TCD or SSEP Angiographic evidence of new bleeding or thrombosis Unexplained hemodynamic changes</td>
<td>New neurologic deficit Delayed awakening (see crisis #9 delayed Awakening, page 24)</td>
</tr>
</tbody>
</table>
13. INTRAOPERATIVE STROKE

Treatment

Announce EMERGENCY to the team
If it is possible, STOP procedure
Talk to the Neurosurgeon
Activate Stroke protocol (If available)
Allocate one person to assess neuro-status: NIHHS score and record time

Maintain:

Hemodynamics (ABCD, intubate if needed*)
   *Intubate if: GCS ≤ 8, agitation, decline of Level of consciousness, vomiting, respiratory failure
Normal glucose level (80-150 mg/dl)
Normal level of \( P_{CO_2} \)
Normal temperature
Normal oximetry > 94%
Hemoglobin levels > 10g/dl
Adequate oxygenation
Get an ACT if Heparin has been used
Get stat labs: INR/PTT, CBC, Fibrinogen

Perform an EMERGENT CT-SCAN or Angiography (or dMRI) according to situation

Ischemic Stroke:
- Increase MAP, do not exceed < 185/110. AVOID HYPOTENSION!
- Consider stent
- Mechanic or pharmacologic thrombolysis
- Discuss with surgeon options: Abciximab or intra-arterial Vasodilators
- Consider Aspirin 81 mg/d and Clopidogrel 75mg/d, statins according to situation

Hemorrhagic Stroke:
- Decrease MAP, maintain Systolic Blood pressure < 140-150 mmHg
- Elevate head 30 degrees
- Reverse Heparin (Per ACT) with: Protamine 1 mg for every 100 IU of Heparin
- Consider transfusing platelets in those with Aspirin and Clopidogrel
- Consider cryoprecipitate (6-8 units)
- Discuss with the surgeon: attempt of Coil or Balloon Occlusion on site of hemorrhage

Other considerations:
- Obtain a 12-lead ECG
- Perform a point of care ultrasound: Carotid imaging, left ventricle assessment
Keep adequate oxygenation and hemodynamic support
Transfer to ICU
14. HYponatremia: Cerebral/Renal Salt Wasting Syndrome

Patients at Risk

- Subarachnoid hemorrhage
- Traumatic brain injury
- Brain tumors
- Brain infarction
- Intracranial hemorrhage
- Arteriovenous malformation
- Meningitis
- Intracranial surgery

Diagnosis

**HYponatremia** (plasma levels of \( \text{Na}^+ < 135 \text{ mEq/L} \))

**HyPOVOLEMIA** (tachycardia, hypotension, thirst, dry mucous membranes, ↓ CVP)

**HyPO-OSMOLARITY** (Plasma osmolality < 275 mOsm/Kg)

Urinary \( \text{Na}^+ > 40 \text{ mMol/L} \)

Fractional excretion of urate after correction: high

Classification of Hyponatremia

<table>
<thead>
<tr>
<th>Plasma Levels of ( \text{Na}^+ ) (mEq/L)</th>
<th>Mild: ( \text{Na}^+ ) 130-135</th>
<th>Moderate: ( \text{Na}^+ ) 125-129</th>
<th>Severe: ( \text{Na}^+ ) &lt; 125</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symptoms</td>
<td>Moderate-chronic: nauseas, fatigue, gait and attention deficit, falls. <strong>Severe acute:</strong> vomiting, headache, seizures, coma, death, respiratory arrest, neurogenic pulmonary edema, brain herniation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>Acute &lt; 48 hours</td>
<td>Chronic &gt; 48 hours</td>
<td></td>
</tr>
</tbody>
</table>

Differential Diagnosis

- Diuretics
- Osmotic therapy
- Hyperglycemia
- Media contrast diuresis
- Addison's disease
Treatment

Draw blood sample: repeat electrolytes, glucose levels, uric acid

Measure urine osmolality, density and Na+, uric acid

Treat HYPOVOLEMIA first: Hydrate patient with NaCl 0.9 % (Normal Saline)

If severe and/or acute hyponatremia:

**NaCl 3% 100 cc IV bolus** over 20 minutes
Repeat Maximum 2 more times if the rise in Plasma Na+ ≤ 5 mEq/L

**Aims of Na⁺ Correction:**
- ↑ 3-5 mEq/L over first 2-4 hours
- ↑ 6-8 mEq/L over 24 hours

**LIMITS**
- ↑ 10 mEq/L 24 hours (8 mEq/L in patients with hypokalemia, alcoholism, malnutrition, liver disease)

Repeat plasma levels of Na⁺ every 2 hours until Na⁺ stabilized, then every 6 hours

Monitor volume status and treat hypovolemia, fluids and urinary output

Treat underlying cause, if possible

Refractory cases: **Fludrocortisone 0.1-0.2 Mg** orally twice a day

If patient awake: oral salt supplementation
15. HYPONATREMIA: SYNDROME OF INAPPROPRIATE ANTIDIURESIS (SIAD)

Patients at Risk

<table>
<thead>
<tr>
<th>Patients at risk</th>
<th>Neuro patients at risk</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Carcinomas:</strong></td>
<td>Head trauma</td>
</tr>
<tr>
<td>Lung &gt; head &gt; neck &gt; pancreas &gt; prostate &gt; duodenum</td>
<td>Post craniotomy (pituitary, craniopharyngiomas, hypothalamus)</td>
</tr>
<tr>
<td><strong>Pulmonary disease:</strong></td>
<td>Brain tumors</td>
</tr>
<tr>
<td>COPD, asthma, pneumonia, empyema</td>
<td>Stroke</td>
</tr>
<tr>
<td><strong>Medications:</strong></td>
<td>Cavernous sinus thrombosis</td>
</tr>
<tr>
<td>– Desmopressin or vasopressin</td>
<td>CNS infection</td>
</tr>
<tr>
<td>– High doses oxytocin</td>
<td>AIDS</td>
</tr>
<tr>
<td>– Chlorpromazine</td>
<td>Hydrocephalus</td>
</tr>
<tr>
<td>– Carbamazepine</td>
<td>Psychosis</td>
</tr>
<tr>
<td>– Vincristine</td>
<td>Malformations</td>
</tr>
<tr>
<td>– Fluoxetine</td>
<td>Guillain-barre syndrome</td>
</tr>
<tr>
<td>– Angiotensin converting enzyme inhibitors</td>
<td>Subarachnoid hemorrhage</td>
</tr>
<tr>
<td>– Dopamine antagonist</td>
<td></td>
</tr>
<tr>
<td>– Omeprazole</td>
<td></td>
</tr>
<tr>
<td>– 3’4’ Methylenedioxymethamphetamine “Ecstasy”</td>
<td></td>
</tr>
</tbody>
</table>

Neuro patients at risk

Head trauma
Post craniotomy (pituitary, craniopharyngiomas, hypothalamus)
Brain tumors
Stroke
Cavernous sinus thrombosis
CNS infection
AIDS
Hydrocephalus
Psychosis
Malformations
Guillain-barre syndrome
Subarachnoid hemorrhage

Diagnosis

**HYPONATREMIA** (Plasma levels of Na+ < 135 mEq/L)
**EUVOLEMIA** (OR SLIGHTLY HYPERVOLEMIC)
**HYPO-OSMOLARITY** (Plasma Osmolality < 275 mOsm/Kg)
**Urinary Na+ > 40 mMol/L**
Fractional excretion of urate after correction: Normal

Classification of Hyponatremia

<table>
<thead>
<tr>
<th>Plasma Levels of Na⁺ (mEq/L)</th>
<th>Mild: Na⁺ 130-135</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Moderate: Na⁺ 125-129</td>
</tr>
<tr>
<td></td>
<td>Severe: Na⁺ &lt; 125</td>
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</tbody>
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<th>Symptoms</th>
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<td>Severe acute: vomiting, headache, seizures, coma, death, respiratory arrest, neurogenic pulmonary edema, brain herniation</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Time</th>
<th>Acute ≤ 48 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chronic &gt; 48 hours</td>
</tr>
</tbody>
</table>

Differential Diagnosis

Heart, liver or kidney failure
15. HYponatremia: Syndrome of Inappropriate antidiuresis (SIAD)

Treatment

Draw blood sample: repeat electrolytes, glucose levels, uric acid

Measure urine osmolality, density and Na+, uric acid

Fluid restriction: 500 cc below average daily urine volume

If severe and/or acute hyponatremia:

**NaCl 3% 100 cc IV bolus** over 20 minutes
Repeat for a maximum of 2 more times if the rise in plasma is Plasma Na+ < 5 mEq/L

**Aims of Na⁺ Correction:**
- ↑ 3-5 mEq/L over first 2-4 hours
- ↑ 6-8 mEq/L over 24 hours
- **LIMITS** ↑ 10 mEq/L 24 hours (8 mEq/L in patients with hypokalemia, alcoholism, malnutrition, liver disease)

Repeat plasma levels of Na+ every 2 hours until Na+ stabilized, then every 6 hours

Eliminate reversible causes: (stop medications that increase risk)

Monitor volume status and treat hypovolemia, fluids and urinary output

Treat underlying cause, if possible

**Refractory cases:**
1. Demeclocycline
2. Urea
3. Vaptans (caution/controversial treatment, consult an expert)
4. Fludrocortisone
5. Lithium (caution/controversial treatment, consult an expert)
16. **HYPERNATREMIA: DIABETES INSIPIDUS**

### Patients at Risk

- **Brain:** tumors, trauma, infections,
- **Neoplasm:**
  - Brain: Craniopharyngiomas, Pituitary Adenoma, Meningioma
  - Cancer: lung, breast, Lymphoma, Leukemia
- **Surgery of Hypothalamus or Supraoptic Region**
- **Induced by:** Phenytoin, Ethanol, Lithium
- **Chronic renal failure**
- **Hypercalcemia**
- **Hypokalemia**

### Diagnosis

**HYPERNATREMIA** (Plasma Levels of $\text{Na}^+ > 145 \text{ mEq/L}$)

**POLYURIA** (> 30 cc/Kg/24 hours or > 2 cc/Kg/h)

**POLYDIPSIA**

Urinary specific gravity < 1005

### Classification of Hyponatremia

<table>
<thead>
<tr>
<th>Plasma levels of $\text{Na}^+$ (mEq/L)</th>
<th>Severe: $\text{Na}^+ &gt; 160$ (mEq/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Symptoms</strong></td>
<td><strong>Severe / acute: seizures, coma, death, high fever, intracranial hemorrhage, thrombosis of dural sinuses</strong></td>
</tr>
</tbody>
</table>
| **Time**                              | **Acute < 48 hours**
|                                       | **Chronic > 48 hours** |
16. HYPERNATREMIA: DIABETES INSIPIDUS

Treatment

Draw blood sample: repeat electrolytes including Ca\(^++\), glucose levels, kidney function
Measure urine osmolality, density and Na\(^+\), uric acid

**Volume Replacement** with NaCl 0.9% **Normal Saline**

If Hypernatremia is severe and/or acute:
- **Dextrose 5% IV bolus** 500 cc and consider hemodialysis

If it is not severe or chronic:
- **Aims of Na\(^+\) Correction:**
  - ↓ 2 mEq/L/h
  - ↓ 10 mEq/L over 24 hours until plasma Na\(^+\) = 145 mEq/L

**Na\(^+\) Correction:**
1. **Calculate the Water Deficit (WD) and correct over 48 hours:**
   \[
   \text{Water Deficit} = \left( \text{TBW} \times \frac{\text{Plasma Na}^+}{140} \right) - I
   \]
   \[
   \text{TBW} = 0.5 \text{ (Female)} \text{ or } 0.6 \text{ (Male)} \times \text{Lean Body Weight}
   \]
2. **Calculate the change in Na:** estimate the effect of 1 liter of infusate on serum Na\(^+\)
   \[
   \text{Change in Na} = \frac{\text{Infusate Na}^+ - \text{Serum Na}^+}{\text{TBW} + I}
   \]
3. **Select replacement solution**
   - **Solution** | **Infusate Na\(^+\) (mmol/L)**
     - 5% Dextrose | 0
     - 0.45% NaCl | 77
     - 0.9% NaCl | 154
     - Ringer Lactate | 130

Repeat plasma levels of Na\(^+\) every 4 hours until na\(^+\) stabilized, then every 8 hours
Monitor volume status and treat hypovolemia, fluids and urinary output.
Eliminate reversible causes: (stop medications that increase risk)
Treat underlying cause, if possible
Start intake of water as soon as patient is awake

Other Therapies:
1. **Vasopressin:** 5 units SUBCUTANEOUS every 6 to 8 hours  or
2. **Desmopressin:** 1 mcg SUBCUTANEOUS p.r.n.  or
   - Intranasal spray 1 BID (10 mcg/spray)  or
   - Tablets 0.1-0.3 mg p.o. BID
## Classification of Agents

### Osmotic Agents (>650 mOsm/L)

**Risk of compartment syndrome**

- Total parenteral nutrition
- Mannitol
- Calcium chloride -gluconate
- Potassium
- Sodium bicarbonate
- Ampicillin

### Vasoconstriction Agents

**Risk of local ischemia**

- Norepinephrine (NE)
- Epinephrine (EPI)
- Dopamine (DA)
- Dobutamine (DBA)
- Methylene Blue (MB)
- Vasopressin (V)
- Phenylephrine (PE)

### pH Related Agents

**Risk of ischemia and coagulation or compartment syndrome**

- Phenytoin (purple glove syndrome)
- Sodium Thiopental
- Vancomycin
- Amiodarone
# 17. EXTRAVASATION OF INTRAVENOUS ACCESS

## Treatment

1. **Stop the “iv” infusion**
2. **DO NOT REMOVE THE CATHETER**
3. **ASPIRATE** through the catheter
4. Injection **REVERSAL AGENTS through the catheter**.
5. Remove the catheter
6. Elevate affected limb
7. Apply **WARM** or **COLD** compresses as indicated
8. Surgical consult

### OSMOTIC AGENTS

**(&gt;650 mOsm/Lt)**

**Risk of Compartment Syndrome**

1. **HYALURONIDASE**
   - 15-25 Units.
   - Intradermal and through catheter

2. Topical **Nitroglycerin**
   - 2% Strips over area or Nitroglycerin patch over the area.

3. **COLD COMPRESSES**:
   - For 20 min, 3-4 times a day, 48 to 72 hours.

4. Elevation of extremity

### VASOCONSTRICTION AGENTS

**Risk of local ischemia**

1. **PHENTOLAMINE**
   - (NE,EPI,DA,DBA,PE):
   - 5-10 mg in 20 cc saline, injected multiple times hypodermic needle or through the catheter.

2. Topical Nitroglycerin 2% strips

3. **HEAT proximal** to site, elevation

4. **TERBUTALINE**
   - (NE,EPI,DA,DBA):
   - 1 mg in 10 CC saline inject locally across sites

### PH RELATED AGENTS

**Risk of ischemia and coagulation or compartment syndrome**

1. **DRY HEAT**

2. Elevation of extremity

3. **HYALURONIDASE**

   - 15 units intradermal and/or through the catheter.

   **AVOID NEUTRALIZATION OF THE SUBSTANCE**
## NEUROCRISIS REPORT FORM

<table>
<thead>
<tr>
<th>Date (dd/mmm/yyyy)</th>
<th>Procedure:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Important Comorbidities:
- [ ] Diabetes
- [ ] Sleep apnea
- [ ] Coronary Disease
- [ ] Obesity
- [ ] Renal Failure
- [ ] COPD
- [ ] Other: ____________

### ASA:
- [ ] I
- [ ] II
- [ ] III
- [ ] IV
- [ ] V
- [ ] VI

### Population:
- Vascular:
  - [ ] Stroke
  - [ ] Carotid Surgery
  - [ ] Subarachnoid Hemorrhage
  - [ ] Aneurysm: Clipping
  - [ ] Other: ____________
- Oncology:
  - [ ] Brain Tumor
- Trauma:
  - [ ] Traumatic Brain Injury
  - [ ] Spine
- [ ] Spine surgery
- [ ] Functional Surgery (Parkinson, Dystonia, Depression)
- [ ] Hydrocephaly
- [ ] Epilepsy

### Position:
- [ ] Supine
- [ ] Prone
- [ ] Sitting
- [ ] Park Bench
- [ ] Lateral
- [ ] Out Patient
- [ ] In Patient
- [ ] Elective
- [ ] Urgent
- [ ] Emergent Surgery

### Anesthesia Technique:
- [ ] General
- [ ] Regional
- [ ] Sedation
- [ ] Awake
- Anticipated difficult airway: [ ] Yes [ ] No

### Preadmission clinic:
- [ ] Yes
- [ ] No

### Where did the event took place:
- [ ] OR
- [ ] PACU
- [ ] Patients room
- [ ] Neuroradiology
- [ ] Other: ____________

### Event

#### Airway
- [ ] Difficult Intubation
- [ ] Severe Laryngospasm
- [ ] Dental Trauma
- [ ] Trauma of Soft Tissue
- [ ] Accidental Extubation in Prone

#### Pulmonary
- [ ] Broncho aspiration
- [ ] Severe Bronchospasm
- [ ] Respiratory Depression
- [ ] Pulmonary Edema
- [ ] Pulmonary Embolism
- [ ] Respiratory Failure
- [ ] Hemorrhage
- [ ] Pneumothorax
- [ ] Residual Paralysis

#### Cardiovascular
- [ ] Arrhythmias (VT with pulse, SVT)
- [ ] Severe Bradycardia
- [ ] Anaphylactic Shock
- [ ] Hypovolemic Shock
- [ ] Cardiogenic Shock
- [ ] Hematoma in Puncture Site
- [ ] Refractory Hypertension
- [ ] Myocardial Infarction or MI
- [ ] CPR (Asystole, PEA, TV, VF)
- [ ] Atrial Puncture
- [ ] Air Embolism

#### Brain
- [ ] Seizures
- [ ] Stroke/TIA
- [ ] Delayed Awakening
- [ ] Intracranial Hypotension
- [ ] Awareness

#### Position related
- [ ] Periphery Nerve Lesion
- [ ] Burn
- [ ] Corneal Ulcers
- [ ] Position Related Complication

#### Anesthesia Technique related
- [ ] Subdural Injection
- [ ] Total Spinal
- [ ] Dural Rupture

#### Other:
- [ ] Other:
  - [ ] Mistakes
    - [ ] Wrong Medication
    - [ ] Medication Mistake: Dose, Velocity, Route, Concentration
    - [ ] Wrong Patient
    - [ ] Wrong Procedure
    - [ ] Wrong Anatomic Place

#### Other events
- [ ] Fall from the Bed
- [ ] Malignant Hyperthermia
- [ ] Hypoglycemia
- [ ] Deed
- [ ] Pseudocalcinesterase
- [ ] Allergic Reaction
- [ ] Extravasation of IV

### Neuro-related complication
- [ ] Re-intervention
- [ ] CSF Leak
- [ ] POP bleeding
- [ ] Pneumocephalus
- [ ] Delayed Awakening
- [ ] Vasospasm
- [ ] Brain Edema
- [ ] Electrolyte disturbance
- [ ] Air embolism
- [ ] Status Epilepticus
- [ ] New Neurologic deficits

### Because of this event:
- [ ] Patient had to be Admitted to an Unscheduled ICU
- [ ] Admitted to hospital (and was programmed as outpatient)

### This Event was Mainly Related to:
- [ ] Anesthesia
- [ ] Surgery
- [ ] Other:

### Did the Team Use a Cognitive Aid during the Crisis:
- [ ] Yes
- [ ] No

### Was the Event Debriefed:
- [ ] Yes
- [ ] No

### Human Factors that may have Contribute to the Event:
- [ ] Fixation Error
- [ ] Lack of Situation Awareness
- [ ] Not Enough Help
- [ ] Bad Communication
- [ ] Team Work Dynamics
- [ ] Not use of Cognitive Aids
- [ ] Other: ____________
Event analysis

Description and Analysis of Situation:

Classification of the event:
- INCIDENT (Event happened but no harm, no injuries)
- ADVERSE EVENT (Event happened and produce harm, New Sequels or Disability)
- COMPLICATION (Event Related to the Comorbidity of the Patient)
- NEAR MRS: The Event did not Happen, but Almost

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<thead>
<tr>
<th>Preventable</th>
<th>No Preventable</th>
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Basic Cause of Dead: ____________________________________________________________

Action that will be done to improve or lessons learned:

<table>
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<tr>
<th>Action</th>
<th>Who is responsible to do this Action</th>
<th>Time Frame to do implement Change</th>
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Person Responsible of the Analysis:

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EMERGENCY MANUALS

The purpose of this crisis manual is to be a resource for anesthesiologists and to prepare them for stressful situations that may arise during neurosurgical procedures. It is meant to be a reference only and a cognitive aid in emergency situations. It is NOT a guideline or a protocol that anesthesiologists are obligated to follow. This manual may provide a vehicle for input and practical strategies when facing critical events with neurosurgical patients.