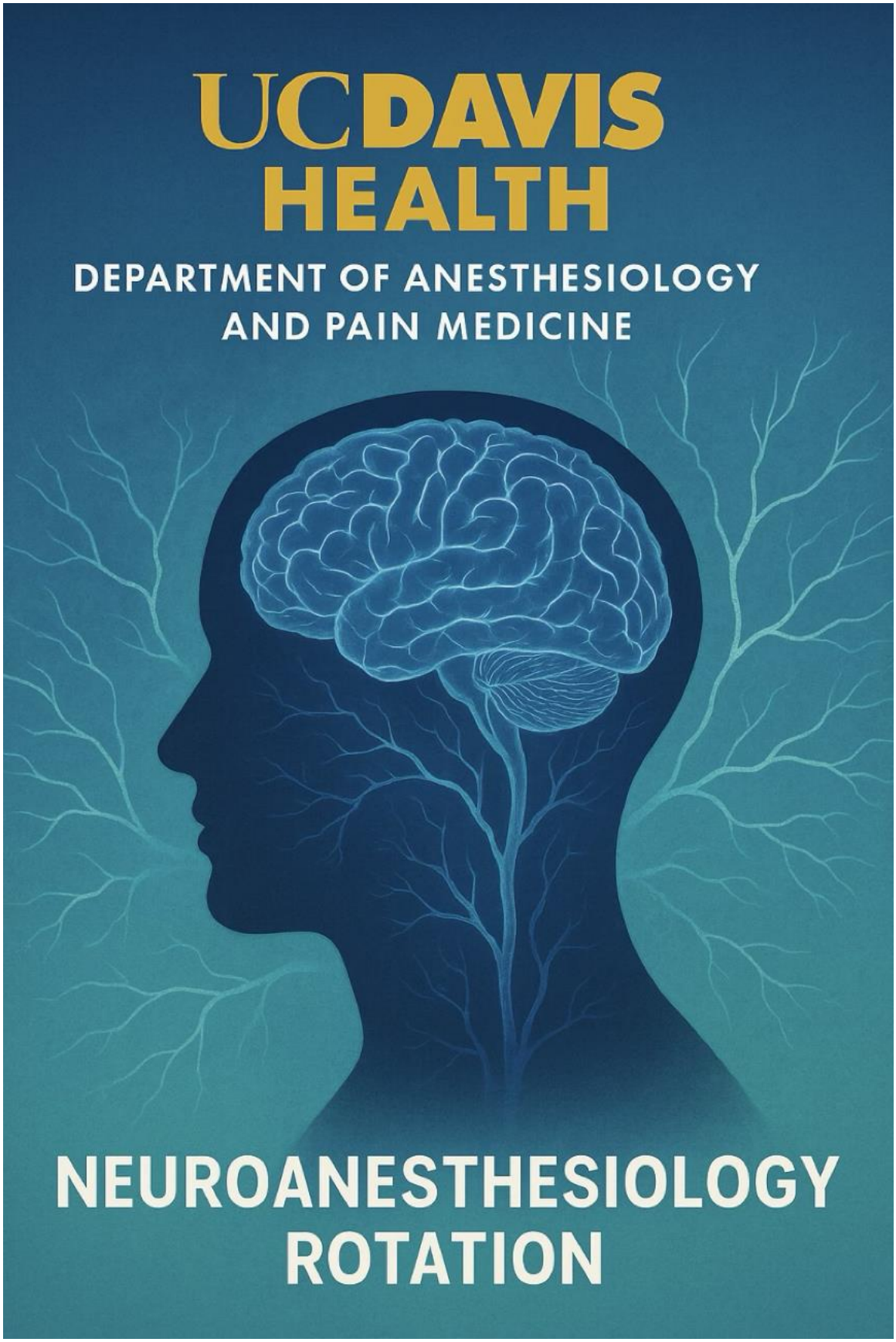
UC DAVIS
HEALTH
DEPARTMENT OF ANESTHESIOLOGY
AND PAIN MEDICINE
NEUROANESTHESIOLOGY
ROTATION

UC Davis Neuroanesthesiology Rotation Guide

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PART I: CORE CONCEPTS

1. Introduction and Rotation Overview

Welcome

Welcome to your neuroanesthesiology rotation! This is your time to grow and take ownership of your learning. We can't do it for you, but we're here to support, guide, and cheer you on. We're glad to be part of your journey.

Rotation Structure

The neuroanesthesiology rotation consists of four weeks dedicated to the perioperative care of neurosurgical patients. You will:

- Participate in 3-4 neurosurgical cases per week
- Attend weekly neurosurgical conference
- Complete one academic project related to neuroanesthesia
- Maintain a case log with reflections
- Receive mid-rotation and end-rotation feedback

Learning Environment

Our approach emphasizes:

- **Progressive responsibility** - Starting with simple cases and advancing to complex ones
- **Direct supervision** - Faculty available for all cases
- **Deliberate practice** - Focused skill development
- **Cognitive apprenticeship** - Think aloud with your attending

Resident Action: Review your assigned cases 24 hours in advance and prepare focused pre-reading for each procedure.

2. Competency Framework and Learning Objectives

The rotation aligns with ACGME and ABA expectations, cultivating competence across six domains:

Patient Care

- Conduct comprehensive preoperative evaluations with focused neurologic assessment
- Formulate and execute anesthetic plans for patients with neurological disease
- Manage anesthesia for a spectrum of neurosurgical procedures, ensuring hemodynamic and neurological optimization
- Interpret intraoperative neuromonitoring and adjust management accordingly
- Perform detailed postoperative assessments, addressing neurologic function and anesthesia-related complications

Medical Knowledge

- Explain core neuroanatomy, neurophysiology, neuropharmacology, and neuroprotection principles
- Describe the pathophysiology of common neurosurgical disorders and the perioperative impact of anesthetics
- Anticipate and manage neurosurgery-specific perioperative complications
- Correlate anesthetic agents with effects on cerebral blood flow, metabolism, intracranial pressure, and evoked potentials

Practice-Based Learning and Improvement

- Integrate current evidence and reflective practice to enhance patient outcomes
- Incorporate feedback from anesthesiology and neurosurgery faculty into subsequent cases
- Engage in self-directed study to remediate knowledge or skill gaps
- Participate in case discussions, morbidity-and-mortality conferences, and quality-improvement initiatives

Interpersonal and Communication Skills

- Communicate complex perioperative neurologic issues clearly to patients, families, and colleagues
- Collaborate effectively with neurosurgeons, nursing staff, and neuromonitoring specialists
- Deliver concise, structured handoffs and lead communication during critical events

Professionalism

- Demonstrate respect, compassion, and integrity in all professional interactions

- Uphold patient confidentiality and obtain informed consent consistent with ethical standards
- Assume accountability for meticulous documentation and timely follow-up

Systems-Based Practice

- Navigate institutional resources to provide high-value, cost-effective neuroanesthetic care
- Recognize and engage the expertise of other healthcare professionals to optimize outcomes
- Apply institutional protocols to complex cases and advocate for system-level safety improvements

3. Fundamentals of Neurophysiology

Cerebral Blood Flow (CBF) Regulation

CBF is regulated by:

- **Pressure Autoregulation:** Maintains constant CBF between MAP 50-150 mmHg
- **Chemical Regulation:** PaCO2 (strongest factor), PaO2, pH
- **Metabolic Coupling:** CBF increases with cerebral metabolic rate (CMRO2)

Anesthetic Effects on Brain

Different anesthetics have varying effects on cerebral physiology:

Agent	CBF	CMRO2	ICP	Autoregulation	EEG Effect
Propofol	↓↓	↓↓↓	↓↓	Preserved	Dose-dependent suppression
Volatile Agents	↑↑	↓↓	↑	Impaired	Dose-dependent suppression
Ketamine	↑↑	↑	↑	Variable	Dissociative pattern
Dexmedetomidine	↓	↓	↓	Preserved	Resembles natural sleep
Opioids	nc	↓	nc	Preserved	Minimal direct effect

Resident Tip: Remember the "VAPID" mnemonic for anesthetic effects on brain:

- **V**olatile agents: ↑CBF, ↓CMRO2
- **A**nesthetics (IV: propofol, thiopental): ↓CBF, ↓CMRO2, ↓ICP
- **P**rotection: Burst suppression on EEG (barbs, propofol)
- **I**ncreased ICP: Ketamine caution
- **D**epress neuromonitoring: Volatile agents

Brain Protection Strategies

Neuroprotection principles include:

- Maintaining adequate cerebral perfusion pressure (CPP)
- Avoiding hyperthermia
- Glucose control (avoid both hyper- and hypoglycemia)
- Reducing metabolic demand (mild hypothermia, anesthetic depth)
- Optimizing oxygenation
- Managing seizure risk

4. Neuromonitoring Principles

Common Neuromonitoring Modalities

Somatosensory Evoked Potentials (SSEPs)

- **Pathway:** Peripheral nerve → dorsal column → thalamus → sensory cortex
- **Measurements:** Amplitude, latency
- **Anesthetic Sensitivity:** Moderate (volatile agents have dose-dependent depression)
- **Clinical Use:** Spine surgery, vascular cases

Motor Evoked Potentials (MEPs)

- **Pathway:** Motor cortex → corticospinal tract → alpha motor neurons → muscle
- **Measurements:** Presence/absence, amplitude
- **Anesthetic Sensitivity:** High (dramatically affected by volatile agents and neuromuscular blockade)
- **Clinical Use:** Spine surgery, motor pathway monitoring

Electromyography (EMG)

- **Type:** Free-running and triggered
- **Anesthetic Sensitivity:** Moderate (affected by neuromuscular blockade)
- **Clinical Use:** Nerve root monitoring during spine surgery

Electroencephalography (EEG)

- **Measures:** Cortical electrical activity
- **Anesthetic Sensitivity:** Direct depression with most anesthetics
- **Clinical Use:** Depth of anesthesia, seizure detection, cerebral ischemia

Electrocorticography (ECoG)

- **Measures:** Direct cortical electrical activity
- **Anesthetic Sensitivity:** High
- **Clinical Use:** Epilepsy surgery, functional mapping

Microelectrode Recording (MER)

- **Measures:** Single neuron activity

- **Anesthetic Sensitivity:** Extremely high
- **Clinical Use:** DBS electrode placement

Anesthetic Considerations for Neuromonitoring

- **TIVA Advantages:** Propofol-based TIVA provides stable neuromonitoring conditions
- **Neuromuscular Blockade:** Generally avoid during MEP and EMG monitoring
- **Signal Loss Protocol:** Follow systematic approach (see section 15)

Resident Action: Before each case, confirm with the neuromonitoring team which modalities will be used and adjust your anesthetic plan accordingly.

Self-Assessment: What anesthetic techniques would you use for a case requiring both MEPs and SSEPs? Why?

PART II: CRANIAL PROCEDURES

5. Asleep Craniotomy

Overview and Indications

Asleep craniotomy is performed under general anesthesia for tumor resection (meningiomas, glioblastomas, metastases), vascular malformations, or abscess drainage. Unlike awake craniotomy, it doesn't require intraoperative patient participation for functional mapping.

Preoperative Assessment

1. **Neurological Evaluation**
    - Review neurosurgical clinic notes for deficits and elevated ICP signs
    - Document baseline neurological function
    - Assess for seizure history and anticonvulsant regimen
2. **Laboratory Testing**
    - CBC, BMP, coagulation profile
    - Type and screen (consider cross-matching for vascular tumors)
    - Evaluate anticonvulsant levels if applicable
3. **Special Considerations**
    - Check glucose if diabetic or on steroids (target 70-180 mg/dL)
    - Evaluate cardiopulmonary reserve for positioning challenges

Resident Action: Document baseline neurologic status in detail and discuss blood product requirements with your attending.

Anesthetic Technique

Induction and Airway

- Establish two large-bore IVs (≥18G)
- Consider arterial line placement before induction
- Use video laryngoscopy for patients with high ICP risk
- Secure ETT with tape (avoid ties that may obstruct venous drainage)
- Avoid excessive hypertension or hypotension during laryngoscopy

Positioning

- Communicate with surgeons during head fixation (Mayfield pins)
- Deepen anesthesia before pin placement (remifentanil 0.5-1 mcg/kg or propofol 0.5-1 mg/kg bolus)
- Ensure all pressure points are padded
- Elevate head 15-30° to promote venous drainage
- Monitor for venous air embolism risk in semi-sitting positions

Maintenance

- **TIVA preferred for cases with neuromonitoring:**
  - Propofol 75-150 mcg/kg/min
  - Remifentanil 0.05-0.2 mcg/kg/min
  - Consider dexmedetomidine 0.3-0.7 mcg/kg/hr for hemodynamic stability
- **If neuromonitoring not required:**
  - Low-dose volatile agent (<0.5 MAC) acceptable
  - Supplement with IV agents to minimize cerebral vasodilation

Resident Tip: Anticipate hypertensive response with Mayfield pin placement. Have a remifentanil bolus drawn up and ready to administer.

Intraoperative Management

ICP Management

- Maintain normocapnia (PaCO2 35-40 mmHg)
- Gentle hyperventilation (PaCO2 30-32 mmHg) only for acute ICP crisis
- Mannitol 0.25-1 g/kg IV if requested for brain relaxation
- Ensure adequate depth before dural opening to prevent coughing

Hemodynamic Goals

- Maintain SBP 100-140 mmHg (adjust based on patient's baseline)
- Use phenylephrine or norepinephrine for vasopressor support
- Ensure adequate venous drainage by avoiding extreme neck rotation and compression

Fluid Management

- Aim for euvolemia using normal saline or Plasmalyte
- Avoid hypotonic solutions (e.g., LR) to prevent cerebral edema
- Use SVV or other dynamic parameters to guide fluid administration

Intraoperative Issues

- **Hemodynamic Changes:** May signify brain stem manipulation
- **Venous Air Embolism (VAE):** Monitor for sudden drop in EtCO2, hypotension
- **Seizures:** Ensure anticonvulsant administration (levetiracetam 1000 mg IV)
- **Cerebral Edema:** Osmotic therapy, mild hyperventilation, head elevation

Postoperative Considerations

Emergence

- Smooth emergence is crucial to prevent ICP spikes
- Consider lidocaine (1-1.5 mg/kg IV) to blunt cough reflex
- Maintain SBP control during emergence
- Evaluate for immediate new neurological deficits

Postoperative Care

- Most patients require NSICU admission
- Vigilance for development of new deficits or deterioration
- Monitor for seizures, especially in first 24 hours
- Anticipate possible delayed emergence due to anesthetic effects vs. neurosurgical complications

Resident Action: Provide detailed neurological status in your NSICU handoff, emphasizing any intraoperative events that could impact recovery.

Key Learning Points

1. ICP management combines positioning, ventilation control, and osmotic therapy
2. Hemodynamic control must balance adequate cerebral perfusion against bleeding risk
3. Smooth emergence prevents dangerous ICP spikes
4. Early recognition of postoperative complications is critical

Clinical Connection: Compare hemodynamic management in asleep craniotomy with goals during DBS procedures. Both require careful blood pressure control but with different targets.

6. Awake Craniotomy

Overview and Indications

Awake craniotomy is performed to map eloquent cortex (language, motor areas) during tumor resection or epilepsy surgery. The patient remains awake during critical portions to enable functional testing, minimizing postoperative neurological deficits.

Primary Indications:

- Tumor resection near eloquent cortex
- Epilepsy surgery requiring functional mapping
- Language or motor mapping during lesion resection

Preoperative Assessment

Patient Selection

- Assess patient's ability to cooperate during procedure
- Evaluate for anxiety, claustrophobia, or PTSD that might impair cooperation
- Review seizure history (type, frequency, triggers)
- Explain the procedure in detail, emphasizing the awake portion

Airway and Physical Assessment

- Thorough airway exam, anticipating possible urgent airway intervention
- Baseline neurological function, particularly related to mapped functions
- Consider trial of positioning to ensure patient comfort

Resident Tip: Building rapport with the patient preoperatively is essential. Take extra time to answer questions and address concerns about the awake portion.

Medication Review

- Continue antiepileptic medications on morning of surgery
- Review all medications for seizure threshold effects
- Evaluate need for anxiolytic premedication (balance against need for cooperation)

Anesthetic Technique

Awake craniotomy typically employs the **sedated-awake-sedated (SAS)** technique:

Initial Sedation Phase

- Propofol (25-100 mcg/kg/min) + remifentanil (0.05-0.1 mcg/kg/min)
- Consider dexmedetomidine (0.2-0.7 mcg/kg/hr) for its minimal respiratory depression
- Avoid benzodiazepines, which may interfere with mapping
- Local anesthetic scalp block performed by surgeon
- Sedation during positioning, head fixation, and craniotomy

Awake Phase

- Transition to awake state 10-15 minutes before mapping
- Maintain verbal contact with patient
- Use minimal or no sedation during mapping
- Ensure patient comfort with positioning, draping, and monitoring

Re-Sedation Phase

- Resume sedation after mapping completion
- Lighter sedation than initial phase usually sufficient
- Focus on patient comfort during closure

Resident Action: Practice weaning sedation in a controlled manner. Develop a verbal script for guiding patients through the transition to the awake phase.

Intraoperative Management

Room Setup

- Position anesthesia machine for direct patient visualization
- Request clear drapes to maintain visual and verbal contact
- Ensure IV access and monitoring equipment won't interfere with mapping
- Prepare rescue airway equipment (LMA, nasal airways)

Airway Management

- Most cases managed with nasal cannula and spontaneous ventilation

- Consider high-flow nasal oxygen (HFNO) for patients with OSA risk
- Have nasal airways available for upper airway obstruction
- Position for possible urgent airway intervention

Intraoperative Complications

- **Seizures:**
  - First-line: Surgeon applies cold saline irrigation
  - Second-line: Small propofol bolus (10-30 mg)
  - Reserve benzodiazepines for refractory seizures (may impair further mapping)
- **Agitation/Anxiety:**
  - Verbal reassurance and coaching
  - Small doses of dexmedetomidine (0.1-0.2 mcg/kg) if needed
  - Consider procedure termination if unmanageable
- **Nausea/Vomiting:**
  - Ondansetron 4 mg IV
  - Avoid metoclopramide (extrapyramidal effects may confound mapping)
  - Reduce temporal lobe traction if possible

Resident Tip: During the awake phase, maintain a calm demeanor and speak clearly to the patient. Your composure directly impacts the patient's cooperation.

Postoperative Considerations

- Smooth transition to PACU with continued monitoring
- Watch for seizures, which have higher incidence postoperatively
- Ensure early resumption of antiepileptic medications
- Perform detailed neurological assessment to identify new deficits

Key Learning Points

1. Success depends on detailed preoperative preparation and patient selection
2. The sedated-awake-sedated technique balances comfort with necessary consciousness
3. Communication skills are as important as technical anesthesia knowledge
4. Rescue plans for airway emergencies and seizures must be immediately available

Clinical Connection: The awake patient cooperation required during cortical mapping parallels the awake phase of DBS procedures, though the tested functions differ.

Self-Assessment: How would you manage a patient who becomes agitated during the awake phase of surgery? What pharmacologic and non-pharmacologic approaches could you employ?

7. Transsphenoidal Pituitary Surgery

Overview and Indications

Transsphenoidal pituitary surgery is performed to resect pituitary adenomas via an endoscopic approach through the sphenoid sinus. This approach avoids brain retraction but creates unique anesthetic challenges including airway management, endocrine complications, and potential CSF leaks.

Primary Indications:

- Pituitary adenomas (functioning and non-functioning)
- Pituitary apoplexy
- Rathke's cleft cysts

Preoperative Assessment

Endocrine Evaluation

- **Acromegaly:** Difficult airway due to macroglossia and mandibular hypertrophy
- **Cushing's Disease:** Hypertension, hyperglycemia, difficult IV access
- **Hypopituitarism:** Need for stress-dose steroids
- **Diabetes Insipidus (DI):** Baseline fluid/electrolyte status

Airway Considerations

- Thorough airway assessment, especially in acromegaly
- Consider awake fiberoptic intubation if significant airway concerns
- Develop clear extubation plan

Laboratory Testing

- Electrolytes (baseline sodium critical for detecting DI)
- Glucose (target 70-180 mg/dL)
- Hormone studies (cortisol, thyroid function)

Resident Action: Document endocrine status in detail. For acromegaly patients, evaluate airway thoroughly and discuss potential need for advanced airway techniques.

Anesthetic Technique

Induction and Airway

- Two peripheral IVs (≥18G)
- RAE ETT secured midline (away from surgical field)
- Video laryngoscopy for patients with acromegaly
- Consider arterial line based on comorbidities

Positioning

- Supine, head neutral or turned slightly to right
- Arms tucked at sides
- Surgeon may rotate table 180° for better access
- Ensure monitoring equipment and IV access remains visible

Maintenance

- TIVA preferred:
    - Propofol (50-150 mcg/kg/min)
    - Remifentanil (0.05-0.2 mcg/kg/min)
    - Consider dexmedetomidine (0.3-0.7 mcg/kg/hr)
- Avoid high-dose volatile agents to minimize PONV

Resident Tip: Be prepared for hypertensive responses when the ENT surgeon injects epinephrine-containing local anesthetic. Have short-acting agents (nitroglycerin 10-20 mcg IV or clevidipine) ready.

Intraoperative Management

Endocrine Management

- **Steroid Coverage:**
    - Hydrocortisone 100 mg IV for hypopituitarism or ACTH-secreting tumors
    - Continue steroid coverage through postoperative period
- **Diabetes Insipidus Monitoring:**
    - Track urine output hourly (>300 mL/hr may signal DI)

    - Monitor serum sodium (rising sodium with high urine output suggests DI)
    - Prepare to obtain urine specific gravity if DI suspected

Hemodynamic Goals

- SBP <140 mmHg to reduce bleeding risk
- Avoid hypotension that may compromise pituitary blood flow
- Manage hypertensive responses during ENT portion

Special Considerations

- **Throat Pack:** ENT will place to prevent blood from tracking into stomach; ensure removal before extubation
- **Nasal Packing:** Will restrict patient to mouth breathing postoperatively
- **Lumbar Drain:** Sometimes placed for CSF leak repair; maintain strict asepsis

Postoperative Considerations

Airway Management

- Smooth emergence to prevent disruption of surgical site
- Avoid coughing or bucking; consider lidocaine (1-1.5 mg/kg IV)
- NO bag-mask ventilation post-extubation (risk of pneumocephalus)
- Anticipate airway edema if prolonged surgery or multiple attempts

Endocrine Complications

- **Diabetes Insipidus:**
    - Usually occurs 12-24 hours postoperatively
    - Continue monitoring urine output and sodium
    - DDAVP may be required (collaborate with neurosurgery and endocrinology)
- **SIADH:**
    - Typically occurs 4-7 days postoperatively
    - Presents as hyponatremia with inappropriate urine concentration
    - Treat with fluid restriction

Other Complications

- **CSF Leak:** Clear nasal discharge, headache
- **Visual Changes:** Monitor for worsening of visual fields

- **Meningitis:** Fever, neck stiffness, altered mental status

Resident Action: Create a detailed PACU handoff covering:

- Endocrine status and DI precautions
- Base of skull surgical site (NO bag-mask ventilation)
- Post-extubation airway concerns
- Signs of CSF leak to monitor

Key Learning Points

1. Endocrine management is critical, particularly steroid coverage and DI detection
2. Base of skull considerations prohibit bag-mask ventilation after extubation
3. Airway management might be challenging, especially in acromegaly
4. Sodium and fluid balance monitoring extends into the postoperative period

Clinical Connection: The endocrine management principles in pituitary surgery can be applied to other neurosurgical procedures that risk hypothalamic-pituitary axis disruption.

8. Laser Interstitial Thermal Therapy (LITT)

Overview and Indications

Laser Interstitial Thermal Therapy (LITT) using the NeuroBlate system is a minimally invasive procedure for treating intracranial lesions through MRI-guided thermal ablation. This procedure has unique logistical challenges, requiring movement between the OR and MRI suite.

Primary Indications:

- Intracranial tumors (gliomas, metastases, radiation necrosis)
- Focal epilepsy (mesial temporal sclerosis)
- Deep-seated lesions difficult to access with open surgery

Preoperative Assessment

- Standard neuroanesthesia evaluation
- MRI safety screening (implants, devices)
- Assessment for claustrophobia (relevant for prolonged MRI)
- Review for pressure sore risk due to prolonged immobility

Anesthetic Technique

LITT requires a general anesthesia technique compatible with:

1. Patient transport between OR and MRI suite
2. MRI environment safety
3. Prolonged procedure duration

Equipment Preparation ("The Packlist")

- **Airway Equipment:**
    - HME filter for transport
    - Straight connector and accordion extension for circuit
    - MRI-compatible circuit extensions in scanner
- **IV and TIVA Setup:**
    - Six microbore tubings in series ("seaweed bundle")
    - Total tubing volume ~10.2 mL (4-minute delay for medication changes)
    - TIVA carrier at 150 mL/hr via pump

- **Medications:**
    - Propofol, remifentanil, dexmedetomidine in MRI Pyxis
    - Standard antibiotics (cefazolin 2 g IV)
    - Dexamethasone (10 mg IV) for cerebral edema
    - Emergency drugs for transport

Resident Action: Verify your "seaweed bundle" setup and confirm all medications are available in both locations before induction.

Initial Setup

- Induction on gurney with table at 180°
- Secure oral ETT taped midline
- Transfer to OR bed with MRI-compatible board
- IVs placed ipsilateral to surgical site
- Foot IV for TIVA (visible during transfers)
- EKG stickers high on chest for access
- BP cuff cable routed toward feet

Intraoperative Management

Transport to MRI Suite

- TIVA maintenance: propofol (75-150 mcg/kg/min) + remifentanil (0.05-0.2 mcg/kg/min)
- Coordinate with respiratory therapy for transfer ventilator
- Remove patient gown before transport
- Transfer to gurney with MRI board
- Take drip stand with TIVA pumps to MRI Zone 3
- Use ED elevator for transport

MRI Suite Management

- Replace OR EKG with MRI-compatible pads
- Patient fully inserted into scanner
- Secure microbore extensions to prevent trip hazards
- BP monitoring may show "0/0" during ablation (artifact)
- Monitor for hypothermia during prolonged scan
- Reduce propofol to 75 mcg/kg/min during final scan

Resident Tip: Tape microbore extensions securely to the floor or cover with blankets to avoid trip hazards. Label them with red tags for visibility.

Return to OR

- Reduce propofol to 50 mcg/kg/min when leaving MRI
- Apply warm blankets during transport
- Return via ED elevator
- Closure typically on gurney with MRI board
- Turn off propofol upon OR arrival
- Apply Bair Hugger immediately for temperature support

Postoperative Considerations

- Minimal pain expected (acetaminophen sufficient)
- Monitor for signs of intracranial hemorrhage or edema
- Most patients can go to regular floor after standard PACU stay
- Document temperature trends and pressure points
- Gather feedback for process improvement

Resident Action: Create a thorough PACU handoff emphasizing temperature management and neurological monitoring. Check skin integrity at pressure points after this prolonged procedure.

Key Learning Points

1. Transport logistics require meticulous planning
2. MRI safety principles must be strictly followed
3. Temperature management is critical throughout
4. IV medication adjustments must account for tubing delay
5. Team coordination between OR, MRI, and RT staff is essential

Clinical Connection: The MRI-compatibility considerations for LITT apply to any neurosurgical procedure requiring intraoperative MRI imaging.

Self-Assessment: What aspects of TIVA management differ in the MRI environment compared to the standard OR? How would you handle a hemodynamic emergency in the MRI suite?

PART III: FUNCTIONAL AND EPILEPSY PROCEDURES

9. Deep Brain Stimulation (DBS)

Overview and Indications

Deep brain stimulation involves the surgical placement of electrodes in specific brain regions to deliver electrical stimulation for treating movement disorders and other neurological conditions. The procedure may be performed in stages (electrode placement followed by generator implantation) or as a single procedure.

Primary Indications:

- Parkinson's disease (PD)
- Essential tremor
- Dystonia
- Medication-refractory epilepsy

Emerging Indications:

- Obsessive-compulsive disorder (OCD)
- Tourette syndrome
- Treatment-resistant depression

Preoperative Assessment

Disease-Specific Considerations

- **Parkinson's Disease:**
  - Off medications for microelectrode recordings (MER)
  - Screen for autonomic dysfunction (orthostatic hypotension)
  - Assess airway for rigidity and risk of aspiration
- **Dystonia:**
  - Evaluate for cervical involvement (difficult airway)
  - Consider contractures that might affect positioning
- **Essential Tremor:**
  - Usually less systemic involvement than PD

Medication Review

- MAO-I interactions with vasopressors (may cause hypertensive crisis)
- Anti-parkinsonian medications may be held preoperatively
- Screen for medications that affect neuromonitoring quality

Airway Evaluation

- Limited access due to stereotactic headframe
- Consider high-flow nasal oxygenation for MAC cases
- Formalize airway management plan (MAC vs GA)

Resident Action: Review the patient's medication list with special attention to MAO-Is and anti-parkinsonian drugs. Discuss MAO-I management with your attending.

Anesthetic Technique

Stage 1: Electrode Placement

Can be performed under:

- **Monitored Anesthesia Care (MAC)** - preferred for MER quality
- **General Anesthesia (GA)** - for patients unable to tolerate awake procedure

MAC Technique

- **Pre-medication:** Midazolam (1-2 mg IV) for headframe placement only
- **Sedation:**
    - Propofol (25–50 mcg/kg/min)
    - Dexmedetomidine (0.2–0.7 mcg/kg/hr)
    - Maintain SBP <130 mmHg
    - **Critical:** Pause sedation during macrostimulation

GA Technique

- **Airway:** Video laryngoscopy if headframe in place
- **Maintenance:** Light TIVA to optimize MER quality
    - Propofol (50-100 mcg/kg/min)
    - Remifentanil (0.05-0.1 mcg/kg/min)

- Avoid volatile agents (interfere with MER)

Equipment and Monitoring

- Position in semi-sitting (beach chair) position
- Noninvasive continuous BP monitoring preferred
- For MAC: Nasal cannula with EtCO2, humidified O2, rescue devices

Resident Tip: Communicate clearly with the patient about the need to be awake and cooperative during macrostimulation, even if they received sedation earlier.

Intraoperative Management

Neuromonitoring Considerations

- Unplug nonessential devices causing electrical interference
- Avoid medications altering MER quality
- Coordinate with neurophysiologist for testing phases

Analgesia

- Local anesthetic infiltration at pin sites
- IV acetaminophen (1000 mg)
- Low-dose remifentanil for breakthrough pain

Hypertension Management

- Target SBP <130 mmHg to reduce hemorrhage risk
- Short-acting agents preferred (clevidipine, esmolol)
- Avoid agents that alter cerebral blood flow or consciousness

Stage 2: Generator Placement

Anesthetic Considerations

- Typically performed 1-2 weeks after Stage 1
- GA with ETT due to head/neck manipulation
- Video laryngoscopy if headframe remnants present
- Position supine with head turned 90° ("clock" position)
- Consider processed EEG monitoring (SedLine) in PD patients

Key Considerations

- High infection risk at generator pocket site
- Timely antibiotic administration
- Medtronic representative must be present

Generator Replacement

Anesthetic Options

- GA or MAC based on patient/surgeon preference
- Similar infection considerations to Stage 2
- Generally shorter procedure with minimal stimulation

Combined Stage 1 and 2 Procedures

Special Considerations

- Requires GA due to prolonged duration
- Longer case duration (4-6 hours)
- Plan fluid management for PD patients with autonomic dysfunction
- Prepare for extended OR time with adequate monitoring

Resident Action: For combined procedures, discuss with the attending how to manage anesthetic depth during the various phases of surgery to optimize both comfort and neuromonitoring.

Postoperative Considerations

- Minimal analgesia required (acetaminophen sufficient)
- Resume antiparkinsonian medications promptly
- Monitor for intracranial hemorrhage, new neurological deficits
- Provide thorough PACU handoff emphasizing medication resumption

Key Learning Points

1. Medication Safety: Understand MAO-I interactions
2. Airway Management: Master headframe intubation techniques
3. Neuromonitoring: Optimize conditions for MER and macrostimulation
4. Blood Pressure Control: Maintain SBP <130 mmHg

5. Team Communication: Coordinate with all involved specialists

Clinical Connection: The neuromonitoring considerations for DBS electrode placement parallel those used in epilepsy surgery with ECoG.

10. Responsive Neurostimulation System (RNS)

Overview and Indications

Responsive Neurostimulation (RNS) is a closed-loop neurostimulation system that detects and aborts seizure activity in patients with refractory focal epilepsy. The system continuously monitors brain electrical activity and delivers stimulation when seizure patterns are detected.

Primary Indication:

- Medically refractory focal epilepsy with 1-2 well-localized seizure foci not amenable to resection (e.g., foci in eloquent cortex)

Secondary Indications:

- Investigational use for generalized epilepsy or behavioral disorders

Preoperative Assessment

Seizure History

- Document seizure type, frequency, duration, triggers, and auras
- Assess perioperative seizure risk
- Consider premedication for patients with low seizure threshold
- Review AED regimen and timing of last dose

Comorbidities

- Many epilepsy patients have psychiatric comorbidities (depression, anxiety)
- Evaluate cognitive status and ability to cooperate with postoperative care
- Screen for sleep disorders (common in epilepsy patients)

Airway and Positioning

- Standard airway assessment
- Anticipate limited head movement due to stereotactic headframe
- Discuss positioning challenges with the surgical team

Resident Action: Document detailed seizure history in the EMR for PACU handoff. Discuss any recent seizure activity with the neurology team during preoperative huddle.

Anesthetic Technique

RNS placement involves two stages:

Stage 1: Electrode & Neurostimulator Placement

Preoperative Medication

- Minimal sedation to avoid interference with intraoperative testing
- Avoid benzodiazepines unless necessary
- Ensure morning administration of AEDs

Induction and Maintenance

- GA standard for Stage 1
- Smooth induction with propofol and remifentanil
- TIVA maintenance:
    - Propofol (50-150 mcg/kg/min)
    - Remifentanil (0.05-0.2 mcg/kg/min)
- Avoid deep inhalational anesthesia if neuromonitoring planned
- Consider processed EEG (SedLine) for depth monitoring

Resident Tip: Prepare for video laryngoscopy in case the headframe restricts standard laryngoscopy access. Have backup airway equipment readily available.

Intraoperative Management

Patient Positioning

- Minimize movement to prevent lead dislodgement
- Ensure proper headframe fixation and padding
- Support extremities to prevent nerve compression

Ventilation

- Maintain normocapnia ($PaCO_2$ 35-40 mmHg)
- Avoid hyperventilation which may lower seizure threshold
- Send ABG if arterial line placed to confirm ventilation parameters

Neuromonitoring

- EEG or ECoG may be used for focus localization
- Avoid agents that suppress cortical activity during monitoring
- Unplug nonessential devices during ECoG to reduce interference
- Coordinate with neurophysiologist for testing phases

Seizure Management

- Develop a plan with the surgical team:
    - First-line: Propofol (10-30 mg IV)
    - Second-line: Lorazepam (1-2 mg IV)
    - Cold saline available for surgical irrigation
- Document any intraoperative seizures for postoperative management

Intraoperative Imaging

- CT or O-arm may be used for lead localization
- Ensure adequate ventilator circuit length for patient movement
- Coordinate with radiology technicians for timing

Postoperative Considerations

Emergence

- Smooth wake-up to avoid lead dislodgement
- Use IV lidocaine or remifentanil to blunt airway reflexes
- Monitor for seizures, which may occur during emergence

Pain Management

- Typically mild; IV acetaminophen (1000 mg)
- Avoid opioids if possible due to potential respiratory depression
- Local anesthetic infiltration by surgeon at incision sites

Seizure Risk

- Highest in first 24-48 hours post-implantation
- Ensure prompt resumption of AEDs
- Have rescue medications readily available

- Document baseline exam for comparison if seizures occur

Imaging

- Postoperative head CT to confirm placement and rule out hemorrhage
- Review results before PACU discharge if possible

Resident Action: Provide thorough PACU handoff emphasizing:

- Seizure history and AED resumption
- Any intraoperative seizure activity
- Head CT requirements
- Neurological monitoring plan

Stage 2: Programming & Follow-Up

- Outpatient procedure for device activation and titration
- No anesthesiology involvement typically required

Generator Replacement

- Consider MAC or GA based on patient factors
- High infection risk; prophylactic antibiotics within 60 minutes of incision
- Ensure AED continuity perioperatively

Key Learning Points

1. Seizure Preparedness: Document history and have management plan ready
2. Anesthetic Optimization: Use TIVA to minimize neuromonitoring interference
3. Lead Stability: Ensure minimal movement during procedure
4. Hemodynamic Control: Maintain stable MAP to reduce bleeding risk
5. Team Coordination: Collaborate for effective testing and monitoring

Clinical Connection: The neuromonitoring needs during RNS placement share similarities with DBS electrode placement, though the target brain regions differ.

11. Vagal Nerve Stimulator (VNS) Implantation

Overview and Indications

Vagal nerve stimulator implantation is a surgical procedure to treat refractory epilepsy by placing a device on the left vagus nerve to deliver electrical stimulation. This approach provides seizure control without directly targeting brain tissue.

Primary Indication:

- Refractory epilepsy unresponsive to antiepileptic drugs (AEDs)

Secondary Indications:

- Treatment-resistant depression (investigational)
- Certain pain syndromes (investigational)

Preoperative Assessment

Seizure History

- Document seizure type, frequency, duration, triggers, and auras
- Assess for service dogs (permitted in preoperative and PACU areas with family management)
- Review video EEG monitoring results if available

Medication Review

- Confirm AED regimen and ensure morning administration
- Note AED side effects and interactions:
    - Phenytoin: Gingival hyperplasia may affect airway
    - AEDs may prolong neuromuscular blockade
- Consider IV levetiracetam (1000 mg) if AEDs missed

Physical Examination

- Thorough airway exam, noting gingival hyperplasia from phenytoin
- Evaluate carotid pulses and neck anatomy
- Assess for autonomic dysfunction (may affect hemodynamic stability)

Resident Tip: Patients with epilepsy often have significant anxiety about procedures. Take extra time during your preoperative visit to establish rapport and address concerns.

Anesthetic Technique

Preoperative Medication

- Midazolam (1-2 mg IV) may increase seizure threshold; use cautiously
- Continue scheduled AEDs without interruption

Induction

- One large-bore IV (≥18-gauge) typically sufficient
- Consider second IV if vascular access challenging
- Oral ETT, taped to the right (away from surgical field)
- Standard induction unless difficult airway anticipated

Maintenance

- TIVA preferred to minimize seizure risk:
    - Propofol (50-150 mcg/kg/min)
    - Remifentanil (0.05-0.2 mcg/kg/min)
- Sevoflurane (<0.5 MAC) possible but potentially more epileptogenic

Resident Action: Secure ETT on the right side of the mouth and confirm IV patency. Set up TIVA pumps to minimize seizure risk during the procedure.

Intraoperative Management

Positioning

- Supine with slight extension of the neck
- Arms tucked at sides
- Ensure padding at pressure points
- Surgical field includes left anterior neck and left upper chest

Ventilation

- Avoid hyperventilation (lowers seizure threshold)
- Target normocarbia ($PaCO_2$ 35-40 mmHg)

- Consider end-tidal CO2 monitoring if available

Hemodynamic Considerations

- **Key Challenge: Bradycardia Risk**
    - Left vagus nerve placement minimizes cardiac effects compared to right
    - Monitor heart rate during nerve stimulation testing
    - Bradycardia typically self-limiting once stimulation ceases
    - Have atropine (0.5 mg IV) or glycopyrrolate (0.2 mg IV) ready
- Maintain normotension throughout the procedure

Surgical Phases

1. **Neck Incision:** Access to left vagus nerve
2. **Chest Incision:** Creation of subcutaneous pocket for generator
3. **Tunneling:** Connection between electrodes and generator
4. **Testing:** Intraoperative device testing with potential bradycardia

Resident Tip: Have atropine drawn up and ready at the bedside before nerve stimulation testing begins. The surgeon should warn you before stimulation starts.

Postoperative Considerations

Pain Management

- Typically minimal; use acetaminophen (1000 mg IV/PO every 6 hours)
- Avoid NSAIDs due to bleeding risk
- Consider fentanyl (0.5-1 mcg/kg IV) for breakthrough pain

Antiepileptic Drugs

- Resume oral AEDs as soon as possible
- Maintain consistent AED levels to prevent withdrawal seizures

Specific Complications

- **Paratracheal Hematoma:** Monitor for neck swelling, respiratory distress
- **Vagus Nerve Damage:** Assess vocal cord function (hoarseness)
- **Obstructive Sleep Apnea:** May worsen with VNS activation

- **Dyspnea:** Can occur due to nerve irritation or hematoma

Device Activation

- Usually performed 2-4 weeks postoperatively by neurologist
- Initial settings are conservative and gradually titrated

Resident Action: Perform thorough PACU handoff emphasizing:

- Need for AED resumption
- Monitoring for airway compromise from hematoma
- Assessment of vocal cord function (hoarseness)
- Continuation of seizure precautions

Key Learning Points

1. Seizure History Assessment: Document details to guide perioperative care
2. Anesthetic Choice: Use TIVA to minimize epileptogenic risk
3. Bradycardia Management: Anticipate and treat during nerve stimulation
4. Airway Vigilance: Monitor for postoperative vocal cord issues and neck hematoma
5. Team Coordination: Communicate with surgical team during device testing

Clinical Connection: The device implantation aspects of VNS are similar to DBS generator placement, though the anatomical location and physiological effects differ.

12. IEA Recording and Cortical Mapping

Overview and Indications

Intraoperative recording of interictal epileptiform activities (IEAs), electrocorticography (ECoG), and cortical mapping are crucial techniques in epilepsy surgery and tumor resection near functional areas. These procedures help delineate epileptogenic zones from eloquent cortex, guiding surgical resection.

Primary Indications:

- Epilepsy surgery (e.g., temporal lobectomy, lesionectomy)
- Tumor resection near eloquent cortex (e.g., speech, motor areas)

Purpose:

- Localize epileptogenic zones via IEAs and ECoG
- Map functional cortical areas to avoid postoperative deficits
- Guide electrode placement for postoperative monitoring

Preoperative Assessment

Procedure Classification

Different surgical scenarios require specific anesthetic approaches:

1. **Intraoperative IEA/ECoG Recording:**
    - Requires "neutral anesthesia regimen" to avoid suppression or activation of epileptiform activity
    - Anesthetic drugs can significantly affect recording quality
2. **Strip/Grid/Depth Electrode Placement:**
    - Less stringent anesthetic requirements than IEA recording
    - Focus on electrode-brain contact for postoperative mapping
3. **Functional Cortical Mapping:**
    - Direct brain stimulation to map eloquent areas
    - May trigger seizures during mapping
    - Propofol readily available for seizure management

Seizure History

- Document seizure type, frequency, triggers, and auras
- Review prior EEG findings to identify seizure focus
- Assess perioperative seizure risk

Awake vs. Asleep Decision

- **Awake:** Required for language mapping
- **Asleep:** Suitable for motor mapping and IEA/ECoG recording

Resident Action: Clarify with the surgical team which specific procedure type is planned to tailor your anesthetic approach appropriately. Document the procedure type in your anesthesia plan.

Anesthetic Technique

Preoperative Medication

- Avoid benzodiazepines if IEA/ECoG recordings planned
- Continue scheduled AEDs unless directed otherwise
- Consider levetiracetam (1000 mg IV) for seizure prophylaxis

Anesthetic Management

- **Depth of Anesthesia:**
    - Maintain stable, light anesthetic depth to preserve signals
    - Use processed EEG monitoring (SedLine) to target PSI 25-50
    - Monitor spectral edge frequency (SEF) at 95% if available
- **Anesthetic Agent Selection:**
    - **Propofol:** Variable effect on IEAs; may need to stop/reduce 15-20 minutes before recording
    - **Dexmedetomidine:** Minimal effect at low doses (0.3-0.5 mcg/kg/hr)
    - **Sevoflurane:** Keep <0.5 MAC if used; can cause nonspecific spike activity
    - **Opioids:** Low-dose remifentanil (0.05-0.1 mcg/kg/min) usually acceptable
    - **Nitrous Oxide:** Avoid unless specifically requested
- **Neuromuscular Blockade:**
    - Use minimal or no blockade during mapping
    - Low-dose rocuronium can be used for patient safety if movement is a concern

Resident Tip: If using propofol, inform the neurophysiologist about dosing changes at least 15 minutes before recording to account for context-sensitive half-time effects on EEG.

Intraoperative Management

Electrical Interference Reduction

- Unplug nonessential electrical equipment (SCDs, Bair Hugger)
- Position monitoring cables away from recording equipment
- Notify neurophysiologist of any medication boluses

Ventilation Management

- Maintain normocapnia (PaCO2 35-40 mmHg)
- Avoid hypocapnia, which may trigger seizures
- Use arterial line for ABG sampling if available

Seizure Management

- **Intraoperative Seizure Protocol:**
  - Notify surgical team immediately
  - First-line treatment: Cold saline irrigation by surgeon
  - Second-line: Small propofol bolus (10-30 mg IV)
  - Avoid benzodiazepines if further recordings needed
  - Follow SNACC visual aids on anesthesia machine

Special Procedures

- **Corpus Callosotomy:**
  - Higher bleeding risk due to proximity to sagittal sinus
  - Ensure large-bore IV access
  - Anticipate postoperative lethargy and somnolence
- **Wada Test:**
  - Performed before some epilepsy surgeries
  - Involves selective hemisphere anesthesia
  - Requires careful coordination with neurology

Resident Action: Prepare propofol boluses in 10 mg increments for potential seizure management. Develop a clear communication plan with the surgical team for seizure recognition and treatment.

Postoperative Considerations

PACU Handoff

- Communicate all intraoperative events (especially seizures)
- Ensure continuation of AEDs
- Report any ECoG findings relevant to postoperative care

Airway Monitoring

- Watch for potential airway obstruction in patients with postoperative lethargy
- Position with head elevated to reduce cerebral edema

Seizure Vigilance

- Higher seizure risk in immediate postoperative period
- Have rescue medications readily available
- Document baseline neurological status for comparison

Key Learning Points

1. Anesthetic Selection: Different epilepsy procedures require tailored approaches
2. Depth Control: Maintain light, stable anesthesia for accurate recordings
3. Interference Management: Minimize electrical noise during recordings
4. Seizure Preparedness: Have clear protocols for intraoperative seizures
5. Team Communication: Coordinate with neurophysiology for optimal recordings

Clinical Connection: The neuromonitoring techniques in epilepsy surgery share principles with those used during DBS electrode placement, particularly regarding depth of anesthesia and electrical interference.

Self-Assessment: How would you adjust your anesthetic technique if the neurosurgeon wanted to transition from ECoG recording to cortical stimulation mapping during the same procedure?

PART IV: SPINE PROCEDURES

13. Complex Spine Surgery

Overview and Classification

Complex spine surgeries encompass procedures with heightened risk of spinal cord injury, significant blood loss potential, or challenging patient comorbidities. These cases demand meticulous anesthetic planning and multidisciplinary collaboration.

Definition of Complexity:

- Cases flagged by surgeons on the electronic scheduling board for increased complexity
- Multilevel instrumentation (typically >3 levels)
- Anticipated blood loss >1000 mL
- Revision procedures
- Patients with significant comorbidities

Common Complex Spine Procedures:

- Multilevel fusion with instrumentation
- Scoliosis correction
- Spinal tumor resection
- Revision surgery with hardware removal/replacement

Preoperative Planning

Team Huddle

The anesthesia resident and attending should participate in the preoperative huddle with surgical and nursing teams to discuss:

1. **Estimated Blood Loss (EBL):**
    - Anticipate EBL based on procedure complexity
    - Consider cell saver for cases with expected EBL >1000 mL
    - Discuss tranexamic acid (TXA) dosing (typically 10 mg/kg bolus followed by 1 mg/kg/hr)
    - Ensure blood availability (type and screen vs. crossmatch)

    - Plan for point-of-care coagulation testing (TEG)
2. **Positioning:**
    - Confirm prone vs. lateral approach
    - Discuss arm positioning for access
    - Determine if Mayfield pins will be used
    - Plan pressure point protection strategy
3. **Blood Pressure Goals:**
    - Target MAP ≥80-85 mmHg for cases with spinal cord manipulation
    - Discuss permissive hypotension phases if blood conservation needed
4. **Neuromonitoring:**
    - Confirm which modalities will be used (MEPs, SSEPs, EMG)
    - Determine need for "pre-flip" baseline signals
    - Anticipate poor baseline signals in myelopathy patients

Resident Action: Document the huddle outcomes in your anesthesia plan and ensure blood product availability based on the discussion.

Anesthetic Technique

Positioning

- Start in supine position for line placement and induction
- For prone positioning:
    - Ensure all pressure points padded (eyes, nose, breasts, genitalia, knees)
    - Use Mepilex wafers on face to prevent pressure sores
    - Check abdomen is free (to minimize IVC compression)
    - Confirm all limbs secured and peripheral nerves protected
    - Perform final "time out" after positioning

Vascular Access and Monitoring

- Two large-bore IVs (≥18G)
- Arterial line for continuous BP monitoring and sampling
- Consider central line for very extensive cases
- Foley catheter with temperature monitoring
- SedLine for anesthetic depth monitoring with TIVA

Neuromuscular Blockade

- Single dose for intubation; avoid maintenance doses for MEP monitoring
- If "pre-flip" MEP baselines needed, ensure full reversal before positioning
- Have sugammadex available for rapid reversal if needed

Resident Tip: Set a timer to remind you to check the face hourly during prone cases. Document these checks in your anesthesia record.

Intraoperative Management

TIVA Management

For cases with neuromonitoring (especially MEPs):

- Propofol (75-150 mcg/kg/min)
- Remifentanil (0.05-0.2 mcg/kg/min)
- Consider dexmedetomidine (0.3-0.7 mcg/kg/hr) for hemodynamic stability
- Target PSI 25-50 on SedLine to facilitate monitoring
- Ensure adequate analgesia with multimodal approach

Blood Pressure Control

- Maintain MAP ≥80-85 mmHg during spinal cord manipulation
- Use phenylephrine (50-100 mcg bolus or 0.5-1 mcg/kg/min infusion) or norepinephrine for ongoing support
- Have vasopressors prepared before positioning (prone position often causes hypotension)

Transfusion and Hemostasis

- Target hemoglobin 8-9 g/dL (higher for patients with cardiac disease)
- Monitor coagulation with TEG in cases with substantial blood loss
- TXA administration as discussed preoperatively
- Special considerations for cell saver blood:
    - Lacks platelets and clotting factors
    - May need FFP/platelet supplementation if >3000 mL returned

Temperature Management

- Maintain normothermia (36-37°C)
- Active warming with forced-air warming device
- Warm IV fluids for large-volume resuscitation
- Temperature affects coagulation and neuromonitoring quality

Signal Loss Management

If neuromonitoring signals deteriorate:

1. Notify the attending anesthesiologist and surgical team immediately
2. Increase MAP to ≥85-90 mmHg
3. Check hemoglobin, oxygenation, and electrolytes via ABG
4. Verify normothermia
5. Consider reducing anesthesia depth slightly if hemodynamically stable
6. Rule out technical issues with neuromonitoring team

Resident Action: Create a systematic checklist for signal loss management and keep it visible on your workstation.

Postoperative Considerations

Emergence

- Plan for smooth emergence with minimal coughing/bucking
- Consider deep extubation if appropriate
- Have vasopressors available (position change may cause hypotension)
- Perform detailed neurological assessment immediately post-extubation

Pain Management

- Implement multimodal analgesia:
    - IV acetaminophen (1000 mg)
    - Ketorolac (15-30 mg) if no bleeding concerns
    - Patient-controlled analgesia for major procedures
- Collaborate with acute pain service for complex cases

Postoperative Monitoring

- Close neurological surveillance for new deficits
- Monitor for epidural hematoma (severe pain, new weakness)
- Serial hemoglobin checks after major blood loss
- Vigilance for respiratory complications after prone positioning

Key Learning Points

1. Hemodynamic Management: Balance adequate spinal cord perfusion against bleeding risk
2. Blood Conservation: Employ pharmacological and technical strategies to minimize transfusion
3. Positioning Safety: Prevent complications from prolonged prone positioning
4. Neuromonitoring Integration: Adjust anesthetic technique to preserve signal quality
5. Team Communication: Coordinate with surgical, nursing, and neuromonitoring teams

Clinical Connection: The neuromonitoring principles used in complex spine surgery parallel those used in functional neurosurgery procedures like DBS.

14. Spine ERAS Protocol

Overview

Enhanced Recovery After Surgery (ERAS) for spine procedures aims to optimize outcomes through evidence-based perioperative interventions. The protocol focuses on multimodal analgesia, minimizing opioid use, reducing complications, and facilitating early mobilization.

Protocol Structure

The UC Davis Spine Surgery ERAS Protocol divides interventions into distinct perioperative phases:

Prior to Surgery

Anesthesia Responsibilities:

- Comprehensive assessment in Pre-Anesthesia Clinic
- Clear explanation of anesthetic plan and ERAS expectations

- Identification of risk factors for delayed recovery
- Documentation of baseline pain management requirements

Patient Education:

- Fasting guidelines (clear liquids up to 2 hours pre-surgery)
- Carbohydrate loading benefits and protocol
- Expectations for early mobilization
- Multimodal pain management approach

Resident Action: Review patient's chart for chronic pain issues or opioid tolerance that might impact ERAS protocol effectiveness.

Preoperative (Day of Surgery)

Medication Administration:

- **Gabapentin:** 600 mg PO if <65 years; 300 mg PO if ≥65 years
- **Acetaminophen:** 1000 mg IV or PO
- **Celecoxib:** 400 mg PO (if no contraindications)
- **Antiemetics:** Ondansetron 4 mg IV
- **Scopolamine Patch:** 1.5 mg (for high PONV risk patients <65 years)

Regional Anesthesia Considerations:

- Consider spinal analgesia for lumbar procedures
- Discuss regional options with attending and surgical team
- Document plan in anesthesia record

Resident Tip: Set up a medication checklist to ensure all ERAS components are administered in the holding area. Document administration times in the EMR.

Intraoperative Phase

Anesthetic Technique:

- TIVA preferred for IONM cases:
    - Propofol (50-150 mcg/kg/min)

    - Remifentanil (0.05-0.2 mcg/kg/min)
- Consider ketamine (0.5 mg/kg bolus or 5-10 mcg/kg/min) for opioid-sparing effect
- Maintain normothermia with forced-air warming

Fluid Management:

- Goal-directed therapy using SVV (<12%)
- Avoid fluid overload which can worsen tissue edema
- Use balanced crystalloids (Plasmalyte preferred)

Hemostasis:

- TXA administration for complex cases
- Cell salvage for cases with anticipated high blood loss
- Maintain normothermia to support coagulation

Antimicrobial Prophylaxis:

- Administer antibiotics within 60 minutes of incision
- Redose for cases >4 hours or significant blood loss

PACU Management

Lidocaine Infusion:

- Continue at 1.5 mg/kg/hr for maximum 4 hours
- Monitor for toxicity signs:
    - Cardiac: Dysrhythmias
    - Neurological: Perioral numbness, tinnitus, visual disturbances
    - Severe: Seizures, altered consciousness
- Discontinue immediately if toxicity suspected
- Restart after anesthesia sign-out if appropriate

Multimodal Analgesia:

- Scheduled acetaminophen (1000 mg IV/PO every 6 hours)
- NSAIDs if no contraindications
- Minimize opioid usage
- Consider ketamine for opioid-resistant pain

Patient Mobilization:

- Encourage early mobilization (within 4-6 hours if stable)
- Collaborate with physical therapy for assessment
- Document mobility achievements

Resident Action: Create a thorough PACU handoff emphasizing:

- ERAS protocol adherence
- Lidocaine infusion management
- Multimodal analgesia plan
- Mobilization goals

Outcome Monitoring

Key Metrics:

- Opioid consumption (morphine milligram equivalents)
- Time to ambulation
- Length of stay
- Pain scores
- Patient satisfaction
- Readmission rates

Quality Improvement:

- Document protocol deviations and reasons
- Participate in ERAS team meetings
- Suggest protocol refinements based on clinical experience

Key Learning Points

1. Multimodal Analgesia: Combines pharmacological and regional techniques
2. Opioid Minimization: Reduces side effects and facilitates recovery
3. Early Mobilization: Prevents complications and reduces length of stay
4. Team Approach: Requires coordination across disciplines
5. Continuous Improvement: Protocol evolves based on outcomes data

Clinical Connection: Many ERAS principles for spine surgery can be applied to cranial neurosurgical procedures, particularly the multimodal analgesia approach.

Self-Assessment: How would you modify the ERAS protocol for a patient with chronic opioid use or a history of adverse reactions to NSAIDs?

PART V: SPECIAL CONSIDERATIONS

15. Traumatic Brain Injury Management

Overview and Core Principles

Traumatic brain injury (TBI) management focuses on preventing secondary brain injuries through meticulous control of intracranial pressure (ICP), cerebral perfusion pressure (CPP), and oxygenation. The anesthesiologist's role is critical in maintaining physiologic parameters that optimize recovery.

Prevention of Secondary Brain Injury: Secondary brain injuries result from:

- Hypotension (leading to cerebral ischemia)
- Hypoxemia (oxygen delivery failure)
- Hypercapnia or severe hypocapnia (cerebral blood flow dysregulation)
- Hyperglycemia or hypoglycemia (metabolic derangement)
- Hyperthermia (increased metabolic demand)
- Seizures (increased metabolic demand and excitotoxicity)

Blood Pressure Management

Age-Based SBP Goals

- Age 15–49 years: Maintain SBP >110 mmHg
- Age 50–69 years: Maintain SBP >100 mmHg
- Age >70 years: Maintain SBP >110 mmHg

CPP Targets

- Aim for CPP 60–70 mmHg (CPP = MAP – ICP)
- Requires ICP monitoring (external ventricular drain or parenchymal monitor)
- Individualize based on autoregulation status

Intraoperative Considerations

- Dural opening can cause rapid BP drop due to sudden ICP release
- Prepare volume bolus (500 mL crystalloid) and vasopressors

- Monitor for cardiac dysfunction secondary to TBI (neurogenic stunned myocardium)

Resident Action: Set up phenylephrine infusion (0.5-1 mcg/kg/min) before craniotomy and have push-dose vasopressors immediately available.

Fluid Management

Fluid Selection

- Use isotonic fluids (0.9% NaCl or Plasmalyte)
- Target serum sodium 140-150 mmol/L
- Avoid hypotonic fluids (e.g., D5W, 0.45% NaCl)
- Avoid albumin based on historical evidence (SAFE trial)
- Monitor for hyperchloremic metabolic acidosis with excessive saline

Volume Status

- Maintain euvolemia (avoid both hypo- and hypervolemia)
- Use dynamic parameters (SVV <12%) to guide fluid administration
- Consider closed-loop systems for precise volume management

Hemoglobin Targets

- Aim for Hgb 7-9 g/dL in most cases
- Consider higher thresholds (>9 g/dL) for patients with active hemorrhage or cerebral ischemia

Coagulopathy Management

- TBI-associated coagulopathy is common and multifactorial
- Send early coagulation studies (TEG preferred over conventional tests)
- Correct coagulopathy aggressively to prevent hematoma expansion

Resident Tip: Monitor serum sodium every 4-6 hours during TBI management. Rising sodium may indicate cerebral salt wasting or diabetes insipidus.

ICP Management

Osmotherapy

- **Mannitol:** 0.25-1 g/kg IV as needed for ICP reduction
- **Hypertonic Saline:** 3% NaCl bolus (100-250 mL) or continuous infusion
- Ensure adequate intravascular volume before administration
- Monitor serum osmolality and electrolytes

Ventilation Strategies

- Maintain PaCO2 35-40 mmHg (normocapnia)
- Avoid prophylactic hyperventilation in first 24 hours
- Brief hyperventilation (PaCO2 30-32 mmHg) only for acute herniation
- Target PaO2 100-150 mmHg (avoid both hypoxemia and hyperoxia)

Anesthetic Choices

- Propofol preferred for ICP control (50-150 mcg/kg/min)
- Consider burst suppression for refractory ICP elevation
- Avoid volatile agents in patients with severely elevated ICP
- Maintain normothermia (36-37°C)

Positioning

- Elevate head 30° to promote venous drainage
- Maintain head in neutral position (avoid neck flexion/extension)
- Ensure ETT and ventilator tubing don't compress jugular veins

Endocrine and Electrolyte Monitoring

Glucose Management

- Maintain glucose 80-180 mg/dL
- Avoid both hyper- and hypoglycemia
- Implement insulin protocol for persistent hyperglycemia

Fluid and Electrolyte Disorders

- **Cerebral Salt Wasting (CSW):**

    - Hyponatremia with hypovolemia
    - Treat with sodium replacement and volume repletion
    - Consider fludrocortisone for severe cases
- **Diabetes Insipidus (DI):**
    - Polyuria (>300 mL/hr) with hypernatremia
    - Check urine specific gravity (<1.005 suggests DI)
    - Treat with desmopressin (DDAVP) and fluid replacement
- **SIADH:**
    - Hyponatremia with euvolemia
    - Treat with fluid restriction
    - Consider hypertonic saline for severe symptomatic cases

Resident Action: Use a Foley catheter with hourly output monitoring to detect DI early. Document fluid balance meticulously.

Seizure Management

Prophylaxis

- Levetiracetam (1000 mg IV loading, then 500-1000 mg BID)
- Consider prophylaxis for 7 days in all moderate-severe TBI
- Extended prophylaxis for patients with:
    - Cortical contusion
    - Subdural hematoma
    - Intracerebral hemorrhage
    - Penetrating injury

Active Seizure Management

- Propofol (50-100 mg IV) for immediate control
- Levetiracetam (1000-3000 mg IV) or phenytoin (20 mg/kg) for ongoing control
- Consider continuous EEG monitoring for patients with:
    - GCS <8
    - Prior seizure activity
    - Penetrating injury
    - Suspected non-convulsive status epilepticus

Key Learning Points

1. Secondary Injury Prevention: Focus on maintaining physiologic parameters
2. CPP Optimization: Balance adequate cerebral perfusion against ICP
3. Fluid Selection: Use isotonic solutions and maintain euvolemia
4. Ventilation Strategy: Normocapnia with brief hyperventilation only for herniation
5. Metabolic Management: Control glucose, temperature, and electrolytes

Clinical Connection: The principles of ICP management in TBI apply to other neurosurgical procedures with risk of cerebral edema, such as large tumor resections.

16. Transport and MRI Considerations

Overview

Neurosurgical patients frequently require transport for imaging or procedures, presenting unique challenges in maintaining anesthesia, monitoring, and patient safety. MRI environments add additional complexity due to magnetic field restrictions.

General Transport Principles

Preparation

- Complete pre-transport checklist
- Ensure adequate oxygen supply (calculate needs for entire transport)
- Verify battery power for all essential equipment
- Prepare emergency medications in transport bag
- Create contingency plans for equipment failure
- Communicate with receiving location to confirm readiness

Monitoring During Transport

- Maintain standard ASA monitoring throughout
- Consider using transport-specific monitoring equipment
- Have backup manual BP measurement capability
- Ensure alarm limits are appropriate for transport

Personnel

- Minimum of two providers (anesthesiologist plus assistant)
- Additional personnel for complex patients
- Clearly defined roles for each team member
- Communication plan established before departure

Resident Action: Perform a structured equipment check before transport, including oxygen supply calculation, medication verification, and battery status.

MRI-Specific Considerations

MRI Safety Zones

- **Zone I:** General public access
- **Zone II:** Patient screening and preparation
- **Zone III:** Control room (restricted access)
- **Zone IV:** MRI scanner room (highly restricted)

Equipment Considerations

- All equipment entering Zone IV must be MRI-compatible
- Standard IV pumps and monitoring equipment remain in Zone III
- Extension tubing required to reach from Zone III to patient
- MRI-compatible anesthesia machine in Zone IV

Special Setup Requirements

Airway Management

- Use MRI-compatible circuit with extensions
- HME filter for transport between locations
- MRI-compatible laryngoscope available in scanner
- Emergency airway equipment readily accessible

IV and Medication Administration

- **TIVA Setup for MRI:**
    - Long microbore extension tubing
    - Calculate dead space (typical volume 10-12 mL)
    - Increased carrier rate (150 mL/hr) to ensure flow
    - Account for ~4-minute delay when changing infusion rates
    - Secure extensions to prevent disconnection or tripping

Monitoring

- Remove and replace standard EKG leads with MRI-compatible leads
- Position all cables to prevent loops (reduces burn risk)
- BP readings may be unreliable during scanning
- Temperature monitoring particularly important in MRI

Resident Tip: When working with long extension tubing, adjust medication changes gradually to avoid bolus effects when dead space volume reaches the patient.

Special Transport Scenarios

Transport for LITT Procedures

- **Workflow:**
    1. Induction in OR
    2. Transfer to MRI for ablation
    3. Return to OR for closure
- **Equipment:**
    - "Seaweed bundle" of extension tubing
    - Transport ventilator between locations
    - MRI-compatible board for transfers
    - Warming devices to prevent hypothermia

Transport for Intraoperative MRI During Tumor Resection

- Coordinate with surgical and radiology teams on timing
- Ensure surgical field is properly covered
- Remove all non-MRI-compatible instruments
- Verify airway security before transport
- Maintain sterility throughout transport

Emergency Transport of Neurosurgical Patients

- Stabilize before transport when possible
- Maintain cervical spine precautions if indicated
- ICP monitoring should continue during transport
- Ventilation parameters must remain consistent
- Documentation continues throughout transport

Troubleshooting Common Issues

Hemodynamic Instability During Transport

- Have push-dose pressors readily available
- Position changes may cause significant BP changes
- Maintain access to patient for interventions

- Document interventions even during transport

MRI Compatibility Questions

- When in doubt, assume item is NOT compatible
- Consult MRI safety manual or website
- MRI safety officer available for consultation
- Never bring questionable items into Zone IV

Medication Delivery Through Long Lines

- Bolus medications may take several minutes to reach patient
- IV fluid boluses require calculation of tubing dead space
- Label all extensions clearly to prevent confusion
- Consider dedicated line for emergency medications

Key Learning Points

1. Preparation: Thorough planning prevents most transport complications
2. MRI Safety: Strict adherence to zone protocols prevents catastrophic events
3. Communication: Clear handoffs between care areas maintain continuity
4. Equipment Limitations: Anticipate and mitigate monitoring restrictions
5. Medication Delivery: Account for dead space in extended tubing systems

Clinical Connection: The principles of safe transport apply across neurosurgical subspecialties, from complex spine cases to functional neurosurgery.

Self-Assessment: How would you prepare for the transport of an unstable TBI patient who requires emergency MRI? What equipment and personnel would you arrange?

Concluding Thoughts

This rotation guide is designed to progress your knowledge from fundamental concepts to complex case management. Remember that each patient and procedure presents unique challenges and learning opportunities. The focus on resident actions, clinical connections, and self-assessment questions aims to develop not just your knowledge base but also your clinical reasoning skills.

We encourage you to:

1. Review relevant sections before each case
2. Maintain detailed case logs with reflections
3. Seek feedback regularly from faculty
4. Use the self-assessment tools to identify growth areas
5. Build connections between different procedures and concepts

The field of neuroanesthesiology continues to evolve with new techniques and evidence. This guide provides a foundation, but your commitment to continued learning will define your growth as a neuroanesthesiologist.

Welcome to an exciting and rewarding rotation!

APPENDICES

Appendix 1: Critical Mnemonics

CBF Influences ("CO_2, O_2, Pressure")

- **CO_2:** $PaCO_2$ most potent influencer (1 mmHg change = 2-4% CBF change)
- **O_2:** Hypoxia (PaO_2 < 50 mmHg) ↑CBF
- **Pressure:** CPP drives perfusion (requires adequate MAP and controlled ICP)

Anesthetic Effects on Brain ("VAPID")

- **V**olatile agents: ↑CBF, ↓$CMRO_2$, ↑ICP
- **A**nesthetics (IV: propofol, thiopental): ↓CBF, ↓$CMRO_2$, ↓ICP
- **P**rotection: Burst suppression on EEG (barbs, propofol)
- **I**ncreased ICP: Ketamine caution in high ICP states
- **D**epress neuromonitoring: Volatile agents impair MEPs

Brain Protection ("HEADS")

- **H**yperventilation (judicious use only)
- **E**uvolemia (or slight hyperosmolarity)
- **A**nesthetic management (reduce $CMRO_2$)
- **D**rugs (mannitol, hypertonic saline)
- **S**uppression (EEG burst suppression for severe ischemia)

Signs of VAE ("MACH")

- **M**ill-wheel murmur
- **A**ir aspiration from central line
- **C**ardiovascular collapse
- **H**ypoxia

Neuromonitoring Agents ("MOVE FAST")

- **M**orphine: Minimal effect on SSEPs/MEPs
- **O**pioids: Generally compatible with IONM
- **V**olatiles: Dose-dependent depression of signals

- **E**tomidates: Can enhance signals
- **F**entanyl: Good for IONM procedures
- **A**ntiepileptics: May alter signals (especially phenytoin)
- **S**uccinylcholine: Brief effect, then compatible with MEPs
- **T**IVA: Preferred for IONM (propofol + remifentanil)

Appendix 2: Equipment Checklists

Standard Neuroanesthesia Setup

- Large-bore IV access (18G or larger)
- Arterial line supplies
- Processed EEG monitor (SedLine)
- Forced-air warmer
- Foley catheter with temperature probe
- Positioning equipment (prone, park bench, sitting)
- Bite blocks (for TcMEP cases)

MRI Transport Packlist

- MRI-compatible ventilator
- Extension breathing circuit
- HME filter
- "Seaweed bundle" of microbore tubing
- 1L bag of carrier fluid
- MRI-compatible monitoring leads
- Emergency medications
- Transfer board

Difficult Airway Cart Additions for Neurosurgery

- Video laryngoscope
- Flexible fiberoptic scope
- Long oral and nasal airways
- Airway exchange catheters
- Intubating LMA
- Surgical airway kit
- Dedicated difficult airway documentation forms

Appendix 3: Drug Reference Tables

Vasopressors in Neuroanesthesia

Agent	Starting Dose	Maintenance Range	Primary Effect	Considerations
Phenylephrine	50-100 mcg bolus	0.5-1 mcg/kg/min	α1-agonist	Minimal cerebral vasculature effect
Norepinephrine	-	0.03-0.1 mcg/kg/min	α1 > β1	Good for septic patients with TBI
Ephedrine	5-10 mg bolus	Not for infusion	Mixed α and β	Tachyphylaxis with repeated doses
Vasopressin	-	0.04 units/min	V1 receptor	May reduce ICP in refractory cases

Hyperosmolar Therapy

Agent	Dosing	Onset	Duration	Monitoring	Considerations
Mannitol	0.25-1 g/kg IV	15-30 min	3-6 hours	Serum osmolality	Diuresis, hypotension risk
3% Saline	100-250 mL bolus	5-10 min	2-4 hours	Serum sodium	Target Na 145-155 mEq/L
23.4% Saline	30 mL IV	5 min	2-4 hours	Serum sodium	Central line administration only

Anesthetic Agents and Neuromonitoring

Agent	SSEPs	MEPs	EEG	ECoG	MER	Considerations
Propofol	↓	↓↓	↓↓↓	↓↓↓	↓↓↓	Dose-dependent suppression
Dexmedetomidine	↔/↓	↔/↓	↓	↓	↓	Minimal effect at low doses
Sevoflurane	↓↓	↓↓↓	↓↓	↓↓	↓↓↓	>0.5 MAC significantly impairs MEPs
Ketamine	↑	↑	↑	↑	↓↓	Can enhance MEPs but disrupt MER
Remifentanil	↔	↔	↔/↓	↔/↓	↔/↓	Minimal effect at standard doses

Appendix 4: Case Logs and Reflection Templates

Neuroanesthesia Case Log Template

Date	Case Type	Key Features	Anesthetic Technique	Challenges	Learning Points
[Date]	[e.g., DBS Stage 1]	[e.g., Parkinson's, on MAO-I]	[e.g., MAC with dexmedetomidine]	[e.g., Hypertension during mapping]	[e.g., MAO-I management]

Appendix 5: Reflection Questions for Neuroanesthesia Cases

After each complex case, consider these questions:

1. What went well in this case? What strategies were effective?
2. What challenges did I encounter? How did I address them?
3. What would I do differently next time?
4. What resources or knowledge would have been helpful?
5. How did I collaborate with the surgical and neuromonitoring teams?
6. What concepts from this case apply to other neuroanesthesia scenarios?

Appendix 5: Self-Assessment Guide

Evaluate your performance in these domains after each week:

- **Technical Skills:** Airway management, line placement, positioning
- **Clinical Decision-Making:** Hemodynamic management, anesthetic choices
- **Crisis Management:** Response to intraoperative events (e.g., VAE, IONM changes)
- **Communication:** Team interactions, handoffs, patient explanations
- **Efficiency:** Room turnover, case preparation, documentation quality

Appendix 6: UC Davis Neuroanesthesiology Protocol Authors and Versions

Topic	Author(s)	Date	Version
Intraoperative Neuromonitoring	Brian Pitts	2025-05	1.0
Complex Spine Surgery	Brian Pitts	2025-05	1.0
Spine ERAS Protocol	Brian Pitts	2025-05	1.0
Responsive Neurostimulation System (RNS)	Brian Pitts	2025-05	1.0
Transport and MRI Considerations	Brian Pitts	2025-05	1.0
Fundamentals of Neurophysiology	Brian Pitts	2025-05	1.0
Awake Craniotomy	Brian Pitts	2025-05	1.0
Asleep Craniotomy	Brian Pitts	2025-05	2.0
Aneurysm Clipping	Christian Bohringer, Brian Pitts	2025-05	2.0
Traumatic Brain Injury	Brian Pitts	2025-05	2.0
IEAs, Cortical Mapping & ECoG	Brian Pitts	2025-05	2.0
LITT "Neuroblate"	Brian Pitts	2025-05	3.0
Vagal Nerve Stimulator	Brian Pitts	2025-05	2.0
DBS Placement	Brian Pitts	2025-05	3.0
Transsphenoidal Pituitary Surgery	Brian Pitts	2025-05	3.0
Intraoperative Neuromonitoring	Brian Pitts	2025-05	1.0
Complex Spine Surgery	Brian Pitts	2025-05	1.0
Spine ERAS Protocol	Christian Bohringer, Brian Pitts	2025-05	1.0
Responsive Neurostimulation System (RNS)	Brian Pitts	2025-05	1.0
Transport and MRI Considerations	Brian Pitts	2025-05	1.0
Fundamentals of Neurophysiology	Brian Pitts	2025-05	1.0
LITT "Neuroblate"	Nina Schloemerkemper, Adam Ferber, Sharyn Babbitt	20220-08	2.0
DBS Placement	Nina Schloemerkemper	2022-04	2.0
IEAs, Cortical Mapping & ECoG	Nina Schloemerkemper	2019-05	1.0
Traumatic Brain Injury	Nina Schloemerkemper	2018-10	1.0
Transsphenoidal Pituitary Surgery	Nina Schloemerkemper	2018-10	1.0
Awake Craniotomy	Sophia Yi	2018-09	1.0
Asleep Craniotomy	Cinthia Tirado	2018-09	1.0
Aneurysm Clipping	Christian Bohringer	2018-09	1.0
Vagal Nerve Stimulator	Nina Schloemerkemper	2018-09	1.0