Postoperative Care

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Introduction

The intricacies of neurosurgical intervention require cognizant and specialized postoperative care to optimize surgical outcome. Ideal postoperative care leads to optimal recovery of function and minimizes complications from anesthesia and the surgical procedure itself. Multiple etiologies of nervous system malfunction are possible; therefore, postoperative neurosurgical patients must be considered systemically and not only in the context of their nervous system. A multidisciplinary approach is often needed to best prepare the body for nervous system recovery.

Appropriately recognizing abnormal physical examination signs in the immediate postoperative period enables early diagnosis and management of potential complications. Attaining this skill requires appropriate training, technique, and knowledge, which are discussed in this chapter. This chapter also reviews general management principles for patients who have undergone neurosurgery. The majority of the discussion is devoted to elective neurosurgical intervention.

Immediate Postoperative Management

Most postsurgical complications present during the first hours after completion of the procedure. This fact makes the immediate postoperative management of a neurosurgical patient the most critical for an optimal outcome. These steps usually take place in the postanesthesia care unit (PACU) or neurosurgical intensive care unit (ICU).

The first postoperative assessment is generally the clinical evaluation. Before significant emergence from anesthesia, the patient’s clinical evaluation can be limited to an assessment of vital signs. Full emergence from anesthesia enables a basic neurologic evaluation and can be a useful time for identifying changes in the nervous system after surgical intervention.

An interval protocoled neurologic examination is a critical component of vigilant observation. The clinical assessment must also include a multisystem physical examination to ensure appropriate resuscitation after surgery.

In most cases, extubation can be performed immediately after surgery, and it will permit a thorough patient

evaluation. During the patient's emergence from anesthesia, it is important to remain vigilant for early signs of postoperative complications such as impaired consciousness, seizure, or stroke or hematomas that prompt focal neurologic signs. For some patients, postoperative extubation might not be an option; therefore, the postoperative neurologic evaluation can be performed after a temporary hold on sedation administration.

Further postoperative evaluation for a patient undergoing cranial surgery can include an immediate postoperative computed tomography (CT) scan. However, the routine use of CT has been questioned, given the associated cost relative to the minimal incurred benefit in the quality of care.[1]

Postoperative management in common clinical scenarios is discussed below, including details on appropriate patient disposition from the PACU and indications for ICU admission.

General Principles of Postoperative Care

Pain Control

Pain after a neurosurgical intervention is expected to be experienced by approximately 80% of patients. Regimens for pain control vary depending on the site of surgery, anticipated pain and narcotic tolerance of the patient, and preferences of the practitioner.

Multimodal pain control is the treatment of choice given the better pain control and reduced dosage-dependent adverse effects that it provides.[2] General categories to consider include the following:

1. Patient-controlled narcotics (morphine, fentanyl, or hydromorphone) (rarely needed for cranial surgery)
2. Intravenous (IV) narcotics (morphine, 1–2 mg every 2–4 hours as needed [PRN]; fentanyl, 12.5–50 µg every 1–2 hours PRN; hydromorphone, 0.5–1 mg every 1–4 hours PRN)
3. Nonsteroidal anti-inflammatory drugs (ibuprofen, 600–800 mg per os [PO] every 8 hours PRN; ketorolac, 15 mg IV every 6 hours PRN or 10 mg PO every 6 hours PRN)
4. Oral narcotics (oxycodone, 5–20 mg every 3–6 hours PRN; hydrocodone/acetaminophen 5 mg/325 mg every 6–8 hours PRN)
5. Acetaminophen (500–1000 mg every 4–6 hours PRN, not to exceed 4000 mg per day)
6. Muscle relaxants (methocarbamol, 500–1500 mg PO or IV every 6–8 hours PRN; diazepam, 5–10 mg PO or IV every 6–8 hours PRN; baclofen, 5–10 mg PO 3 times/day, or tizanidine, 2–8 mg PO, every 6–8 hours PRN)
7. Steroids (dexamethasone, 4 mg PO every 6 hours or Medrol dose pack)

The opioid epidemic within the United States has encouraged healthcare providers to devise pain management regimens that are judicious with opioid agents. Therefore, investigators embarked on a detailed analysis of nonopioid analgesics. This meta-analysis of 27 randomized clinical trials revealed no difference in postoperative bleeding among patients provided ketorolac and that in control patients.[2]

The University of Pennsylvania Department of Neurosurgery conducted a prospective analysis of an enhanced recovery after surgery (ERAS) protocol.[3] This protocol includes multiple preoperative, perioperative, and postoperative interventions to expedite patient recovery and optimization (Figure 1).

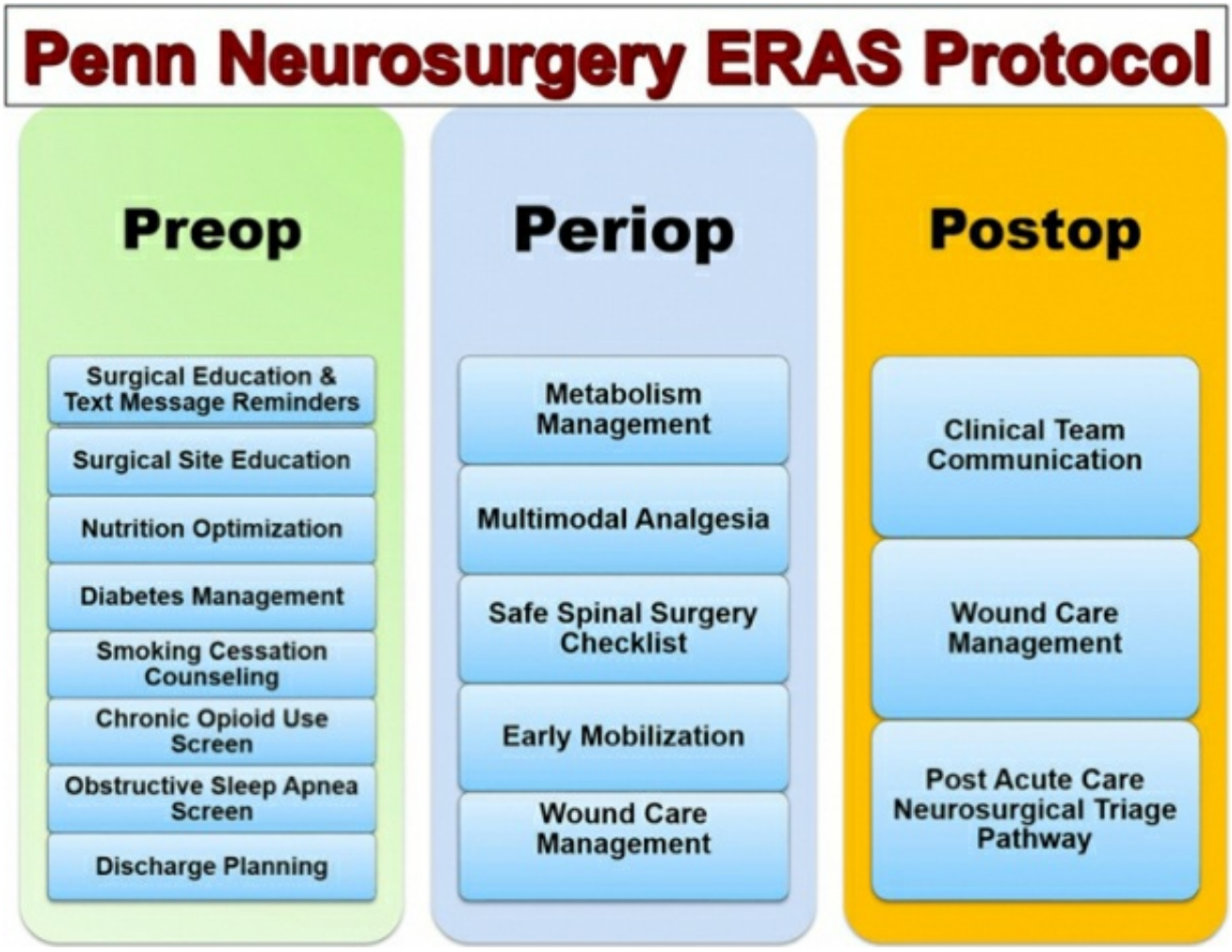

Figure 1: ERAS Protocol. Originally published in reference 3.

The protocol also includes tiered pain management that starts with preoperative administration of multiple agents to ensure appropriate coverage of analgesia before the procedure.[3] This protocol highlights the importance of multimodal pain control, and results of its use have indicated that patients cared for under the protocol had lower opioid requirements both during surgery and in the 1

month afterward. The protocol also improved ambulatory capabilities of the patients.

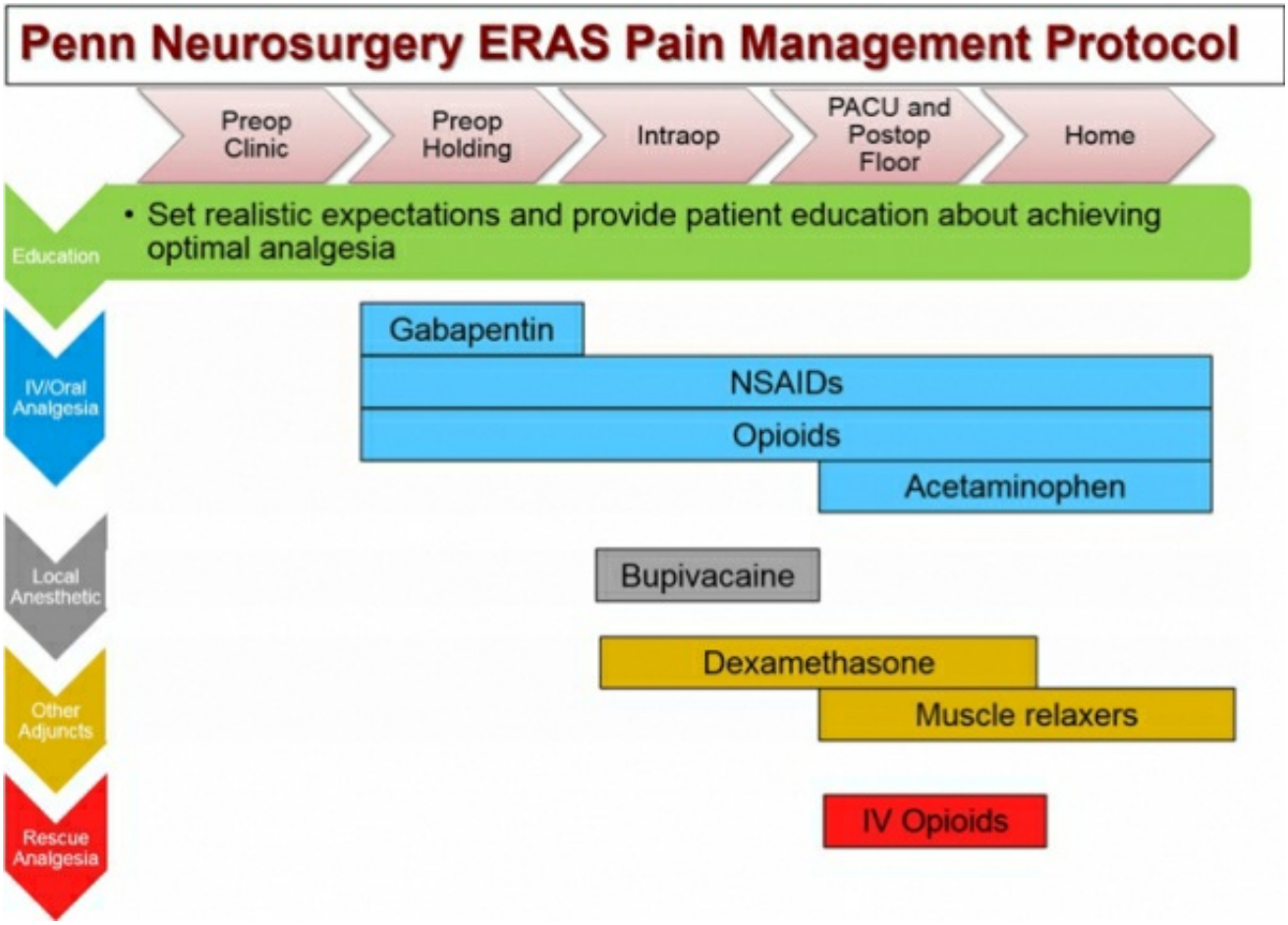

Figure 2: Pain management included in the ERAS protocol. Originally published in reference 3.

Not all modalities of multimodal management are indicated or even safe to combine, but the selection of appropriate agents should be standardized on the basis of the neurosurgeon's preference.

Hypertension

Postoperative hypertension is a frequently observed phenomenon after neurosurgical intervention. The management of this clinical entity is arguably one of the most critical factors for successful postoperative recovery, especially in cases of arteriovenous malformation (AVM) and incompletely secured aneurysm and after tumor resection.

Management must include preventing rapid fluctuations in blood pressure and often should accommodate a tight range of systolic blood pressure. Medications that are particularly helpful in achieving this task include labetalol (10- to 20-mg IV push every 30 minutes to 1 hour), hydralazine (10-mg IV push every 30 minutes to 1 hour), or a titratable nicardipine infusion.

Continuous feedback on systolic blood pressure (arterial line) in patients who need tight blood pressure control can be extremely useful because of the immediate feedback provided after the administration of an IV push or continuous infusion.

Nausea and Vomiting

Postoperative nausea and vomiting occur in approximately 50% of patients after neurosurgical intervention. The management of this condition is relatively standard throughout neurosurgical practice.

For supratentorial surgery, the use of ondansetron (4–8 mg every 6 hours PRN) and/or promethazine (6.25–25 mg every 6–8 hours PRN) is generally standard. Ondansetron can contribute to serotonin syndrome and lead to significant sedation imparted by promethazine. Other alternatives include prochlorperazine (25 mg every 12 hours PRN), metoclopramide (10 mg IV every 6 hours PRN), haloperidol (1–2 mg IV every 2 hours PRN), and diphenhydramine (25–50 mg IV/PO/per rectal every 4 hours PRN).

Nausea and vomiting after infratentorial surgery, especially after manipulation of the vestibular nerves, can be counteracted by meclizine (6.25–12.5 mg PO every 4 hours

PRN), diazepam (5 mg PO/IV every 6 hours PRN), or a scopolamine patch (1.5 mg 3 times/per day every 3 days).

Shivering

Approximately 30% of patients are expected to experience shivering after neurosurgical intervention. Restoration and maintenance of normothermia are important considerations for a patient's hemodynamics and comfort.

The occurrence of shivering in the setting of hypothermia has been reported to induce a 200% to 400% increase in oxygen consumption. The ideal management of shivering includes warming the body to normal body temperature through the use of either warm blankets or forced-air warming devices. Medication options include meperidine (25 mg every 3–4 hours PRN). For patients who are intubated, low-dose propofol can be used to reduce shivering.

Gastrointestinal Prophylaxis

The prevalence of stress ulceration within the gastric mucosa after neurosurgical intervention or in neurocritically ill patients has been well demonstrated. Therefore, efforts to reduce the risk of ulceration have been undertaken through the routine administration of chemoprophylactic agents. Brophy et al[4] evaluated famotidine (20 mg IV/PO 2 times/day) versus pantoprazole (20 mg PO 1 time/day) and found them to be equal in their efficacy for reducing gastric acid production and to result in no statistically significant difference in the incidences of thrombocytopenia or microscopic/macroscopic enteral bleeding.

Thrombocytopenia was experienced by 17% of the patients

in the famotidine group and 4% of patients in the proton pump inhibitor group, which has led some neurosurgeons to use proton pump inhibitors for patients who have clinically significant thrombocytopenia at the time of admission or after surgery.[4]

Thromboembolism Prophylaxis

Evidence shows that providing neurosurgical patients with compression stockings and prophylactic-dose anticoagulation, when clinically appropriate, is critical. Agnelli et al[5] published evidence supporting 40 mg of enoxaparin daily as a standard dose for reducing the incidence of thromboembolism in neurosurgical patients compared to that in those who used compression stockings alone.

The timing of chemoprophylaxis has been debated and most likely should be considered on a case-by-case basis, given that each patient has a different risk for thromboembolism and intracranial hemorrhage based on the type of microsurgical intervention, location of surgery, and comorbid medical conditions.

For most patients, chemoprophylaxis within 24 hours after surgery is considered standard practice. For those with a subtotally resected tumor (eg, schwannoma or glioma), those who have undergone a posterior fossa operation, or those with a high-volume blood loss (eg, during deformity-correction spinal surgery), chemoprophylaxis can be delayed until postoperative day 2 or later. **For further details, please download this Venous Thromboembolism Prevention Protocol.**

Postoperative Monitoring in the ICU

Common practice after most intracranial procedures is to admit the patient to the ICU for appropriate blood pressure control and close observation. However, a retrospective analysis of 400 elective intradural operations discovered that diabetes and older age were predictive factors for the need for ICU admission.[6] The following factors might prompt admission to the ICU from the PACU: the extent of intraoperative bleeding, duration of surgery, and administration of blood products. In general, patients who undergo the following neurosurgical interventions warrant postoperative ICU admission:

1. Most types of craniotomy for resection of a lesion
2. Craniotomy for aneurysm clipping
3. Revascularization procedures
4. Craniofacial surgery
5. Transsphenoidal procedures
6. Carotid endarterectomy
7. Major spine surgery involving a long duration or high-volume blood loss
8. Endovascular interventions
9. Any procedure in a patient with a complicating medical comorbidity or who experienced intraoperative complications

Many additional indications for ICU admission exist, and each case should be considered uniquely for qualification. A stepwise approach to determining the need for regular-ward or ICU admission can be considered for each patient. Delayed ICU admission is not associated with postoperative complications or a longer duration of ICU admission.[7,8]

The analysis of physiologic processes relevant to neurocritical care and patient recovery in the postoperative phase should include[9]:

- Clinical evaluation
- Systemic hemodynamics
- Cerebrovascular autoregulation
- Intracranial pressure
- Cerebral perfusion pressure
- Cerebral blood flow
- Cerebral metabolism
- Nutrition and glucose use
- Electrophysiology
- Hemostasis parameters
- Temperature and inflammation

For an excellent summary discussion of these topics, please refer to the Consensus Summary Statement of the International Multidisciplinary Consensus Conference on Multimodality Monitoring in Neurocritical Care.[9]

Special Considerations

There are many nuances to postoperative management that are innate to the specific pathology addressed during the surgical intervention. A select few procedures are discussed below, but more detailed reviews of postoperative management strategies are provided in the dedicated chapters throughout the *Neurosurgical Atlas* volumes.

Aneurysm Clipping

Patients who have undergone elective aneurysm clipping are observed in the ICU overnight. Although vasospasm

most frequently occurs in the setting of aneurysmal subarachnoid hemorrhage, this phenomenon also rarely occurs after manipulation of the cerebrovasculature after elective aneurysm surgery.

Postoperative systolic blood pressure control can generally be liberal, given that the patient does not have an unsecured aneurysm. In most cases, systolic blood pressure is controlled to less than 160 mm Hg, although if the patient has a higher risk of vasospasm, an even more liberal goal is reasonable, often up to less than 200 mm Hg.

Cranial dressings are removed on the first postoperative day. If a subgaleal drain was used to reduce postoperative swelling, it also is generally removed on this first postoperative day. At the time of discharge, the patient is instructed to return for suture or staple removal 10 days to 2 weeks after the surgical intervention. I use absorbable sutures for skin closure and typically see each patient 1 month after surgery.

Patients with aneurysmal subarachnoid hemorrhage will have a much longer ICU stay because of their need for close monitoring for vasospasm, electrolyte observation, and systolic blood pressure control. If weaning of the external ventricular drain is not tolerated, the patient might require placement of a ventriculoperitoneal shunt.

For additional details on the management of patients with aneurysmal subarachnoid hemorrhage, please download this protocol.

Arteriovenous Malformation Resection

Special consideration for patients after resection of an AVM should be given. Blood pressure control is particularly important for these patients. Maintenance of normotension or mild-to-moderate hypotension for these patients is important for minimizing the risk for postoperative hemorrhage or perfusion-related dysfunction of the parenchyma affected by the periregional AVM.

The patient is admitted to the ICU after surgery and is observed closely for evidence of postoperative bleeding. After a difficult surgery (eg, in a patient with a large AVM who suffered intraoperative swelling or in any case that causes concern for postoperative hemorrhage), the patient should remain intubated and sedated overnight to prevent the blood pressure spikes that often accompany coughing and gagging during extubation.

The principle of normal perfusion pressure breakthrough refers to postoperative cerebral edema, hyperemia, and possibly hemorrhage within the perinidal region after operative disconnection and nidal resection.[10] Although these findings are controversial, they have been observed after AVM surgery in a subset of patients. This phenomenon is likely to be caused by a loss of autoregulatory tone within the tunica media smooth muscle of the perinidal vasculature caused by the chronic dilation that occurs within these vessels to accommodate the high fistulous flow within the AVM.

Patients who have undergone resection of a giant AVM are usually kept under controlled moderate arterial hypotension (systolic blood pressure less than 110 mm Hg) for a few days. They should remain intubated for 24 to 48 hours after

surgery.

A detailed postoperative angiogram is mandatory for confirming complete resection of the AVM even if an intraoperative angiogram was obtained. Small residual niduses can appear after surgery despite an unremarkable intraoperative angiogram.

For additional details on the management of patients undergoing resection of an AVM, refer to the Nuances in AVM Resection chapter.

Brain Tumor Resection

A neurologic examination should be performed immediately after surgery in the operating room once the patient is awake. If the patient remains difficult to arouse or has an unexpected focal deficit, a CT scan should be performed.

Patients can start with having ice chips and small sips of water and advance their diet as tolerated. Hourly neurologic and vital sign checks should be performed throughout the first night for select patients whose condition might deteriorate. After a period of close monitoring in the PACU, many patients can be observed outside the ICU via neurologic evaluations every 2 to 4 hours.

Patients typically can be transferred out of the ICU or intermediate care unit to the regular ward on the first postoperative day. Antibiotics should be discontinued after 24 hours unless otherwise indicated, and steroids should usually be continued at a dose of 4 mg every 6 hours.

The decision to taper off of steroids should be individualized, and patients can be weaned off over 1 to 2 weeks, starting

on the fourth or fifth postoperative day. Prophylactic anticonvulsant medications also should be terminated 1 week after surgery if the patient has never suffered from a seizure.[11]

Magnetic resonance imaging should be obtained within 48 hours of surgery to assess for residual tumor. Physical and occupational therapists should be consulted to aid with any speech, motor, or sensory deficits. Patients can be discharged safely ~3 days after their craniotomy.

For additional details on the management of patients with a brain tumor, refer to the General Principles chapter in the Brain Tumors subvolume.

Carotid Endarterectomy

Institutional practices regarding the postoperative disposition of patients who have undergone a carotid endarterectomy vary. Some institutions evaluate the patient during the immediate postoperative period in the PACU and, if the patient is hemodynamically stable, transfer him or her to the surgical floor, and they restrict the ICU to patients with hemodynamic instability. However, some institutions universally admit such patients to the ICU for blood pressure monitoring.

Prevention of hyperperfusion injury and subsequent hematoma formation is essential for these patients, so controlling systolic blood pressure to less than 140 mm Hg is recommended.

Neck circumference monitoring is also a critical component of the postoperative evaluation. Surgical drains are often left

in these patients after surgery, and output from these drains can also provide insight into the risk for a compressive hematoma. A postoperative neck hematoma arises most commonly from a venous source but occasionally can result from an inadequate arteriotomy closure. The mass effect from the hematoma can obstruct the patient's airway; the surgeon must be prepared to reopen the wound at the bedside to allow for decompression of the trachea, if necessary. This situation is an emergency and must be handled as such. Re-exploratory surgery often discloses nonspecific venous oozing from the deep tissues and bleeding from inadvertent puncture sites in the jugular vein.

Patients are maintained on antiplatelet agents (usually 81 mg of aspirin once daily for life) and clopidogrel 75 mg once daily for at least 1 month after surgery in select patients. Adherence to a statin regimen is also a component of the standard of care for these patients. Some surgeons perform carotid duplex ultrasonography before patient discharge to rule out arterial occlusion.

For additional details on the care of patients after a carotid endarterectomy, please refer to the Carotid Endarterectomy chapter.

Dural Arteriovenous Fistula Obliteration

Blood pressure management is a component of appropriate postoperative care; systolic blood pressure should be kept to less than 160 mm Hg for 24 hours after surgery. The hemodynamic alteration present after fistula obliteration poses a risk for postoperative hemorrhage.

A thorough postoperative diagnostic evaluation is necessary

to ensure complete obliteration of the lesion. This evaluation involves postoperative diagnostic angiography. For additional discussion of details for the management of patients with a dural arteriovenous fistula, please refer to the Dural Arteriovenous Fistulas subvolume.

Revascularization

Appropriate postoperative management for patients who have undergone a revascularization procedure involves prevention of thromboembolic, hyperperfusion, and graft occlusion complications. To achieve this goal, strict blood pressure control and appropriate use of antiplatelet agents are necessary. A noncompressive head bandage should be applied, and the patient should avoid sleeping on the side of the anastomosis for the first few days after surgery. Careful observation in the ICU for any signs of underlying vasospasm or ischemia during the first 24 to 48 hours after surgery is recommended.

Postoperative angiography shows bypass patency and can serve as a good reference for future imaging. Although not necessary, a CT perfusion scan can also be considered to establish the degree of perfusion to the revascularized parenchyma. This scan can also serve as a reference if the patient experiences neurologic decline and ischemia is suspected.

Blood pressure parameters should be specific to the patient's pathology. Patients who require a revascularization procedure might have a baseline systolic blood pressure higher than those with normal normotensive parameters. Therefore, a universal blood pressure parameter for all patients after a bypass procedure can result in

hypoperfusion and should be considered on a case-by-case basis.

Antiplatelet agents are essential for patients who have undergone a revascularization procedure. Some institutions have reported on the use of clopidogrel in the postoperative period to prevent perforator thrombosis and thromboembolic events. This medication should be considered for patients with a higher risk for thromboembolus, such as those whose procedure included flow reversal. Patients who have undergone a more traditional revascularization procedure should be started on a single 325-mg aspirin per day as soon as 6 hours after surgery or on the morning of postoperative day 1, depending on the caliber of bypass donor and recipient.

Neurologic abnormalities can be observed in patients after a revascularization procedure. Hyperperfusion can result in cortical dysfunction. Similarly, hypoperfusion, especially in patients with minimal hemodynamic reserve, such as those with Moyamoya disease, often prompt temporary worsening of the preoperative neurologic status even in the absence of any findings in imaging studies.

For additional details on the management of patients after a revascularization procedure, please refer to the High Flow Revascularization or Low Flow Revascularization chapters.

Pearls and Pitfalls

- Postoperative care for neurosurgical patients is a diverse process that requires multisystem consideration but a tailored strategy that depends on the procedure and postoperative goals of care.

- The postoperative care plan should be thoroughly discussed before the procedure to ensure that appropriate preparation is made before the end of the surgical intervention.
- Postoperative care plays a paramount role in the results of surgery.

Contributor: Benjamin K. Hendricks, MD

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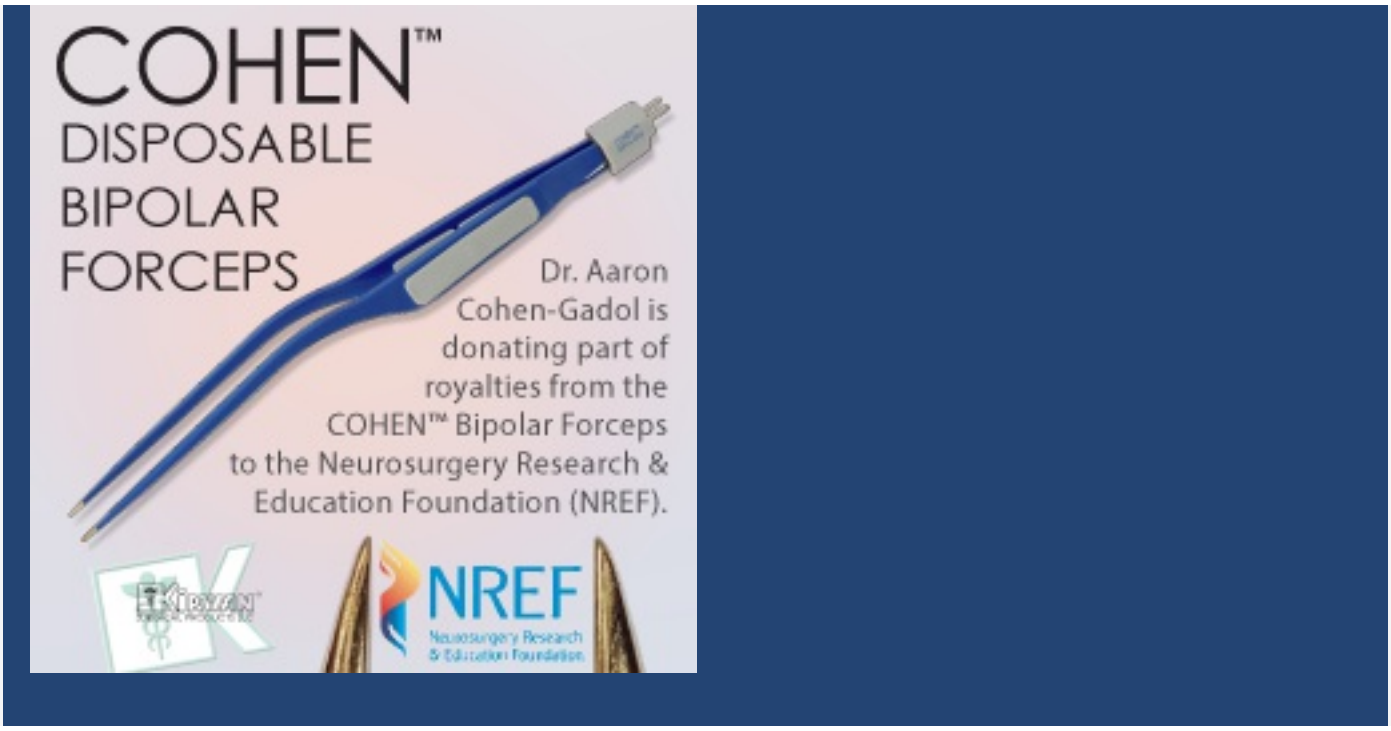
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