

Perioperative Management of Neurological Conditions

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ABSTRACT: Perioperative care of the patients with neurological diseases can be challenging. Most important consideration is the management and understanding of pathophysiology of these disorders and evaluation of new neurological changes that occur perioperatively. Perioperative generally refers to 3 phases of surgery: preoperative, intraoperative, and postoperative. We have tried to address few commonly encountered neurological conditions in clinical practice, such as delirium, stroke, epilepsy, myasthenia gravis, and Parkinson disease. In this article, we emphasize on early diagnosis and management strategies of neurological disorders in the perioperative period to minimize morbidity and mortality of patients.

KEYWORDS: Preoperative, intraoperative, postoperative, delirium, stroke, epilepsy, myasthenia gravis, Parkinson disease

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Introduction

Many patients with neurological disease undergo surgery; it can relate to their neurological disease or an unrelated condition. Perioperative management of these patients can be challenging due to the diverse nature of neurological disease, resulting in diverse clinical manifestations. Perioperative generally refers to 3 phases of surgery: preoperative, intraoperative, and postoperative. Preoperative phase includes attempts to limit anxiety, medical tests, and preoperative fasting. Intraoperative is a time period when the patient is transferred to operating room and subsequently to postanesthetic care unit. Postoperative is a time period between postanesthetic care units and resolution of surgical sequel. This time frame can be short for emergent surgeries and lengthy for elective procedures. In this review, we discuss management of some of the commonly encountered neurological conditions, such as delirium, stroke, epilepsy, myasthenia gravis (MG), and Parkinson disease, in the perioperative phase. Most important consideration is the management and understanding of pathophysiology of these disorders and evaluation of new neurological changes that occur preoperatively.¹ We have emphasized on early diagnosis and management strategies of neurological disorders in the perioperative period to minimize morbidity and mortality of patients.

Delirium

Delirium is an acute change in mental status with a fluctuating change from baseline mental status, with features of inattention and altered thinking.^{2,3} Delirium is a common and important postoperative complication to recognize as it has an incidence of 10% to 18% following general surgery, 53% following orthopedic surgery, and 74% after cardiac surgery.⁴

Postoperative delirium has high associated morbidity and mortality, which may extend up to a decade after surgery.⁵

Postoperative delirium is a marker of brain vulnerability, and its occurrence suggests the possibility of underlying neurological disease such as baseline cognitive impairment and early or preclinical dementia.^{6–9} It is still frequently undiagnosed because the majority of postoperative delirium patients may appear normal or perhaps slightly lethargic.^{10,11} The confusion assessment method for general population versus intensive care unit patients who are unable to speak have been most widely used to diagnose delirium.^{12–14}

Delirium is difficult to prevent or treat because it has several pathological pathways, including neurotransmitter imbalance, neuroinflammation, endothelial dysfunction, and impaired oxidative metabolic and altered availability of large neutral amino acids.^{7,15,16} With such complexity, no single intervention is likely to prevent delirium. But still there are important risk factors for delirium that should be prevented. These include acute medical conditions: sleep disturbance, sensory impairment, pain, social isolation, daylight depression, infections, withdrawal syndrome, dehydration, anemia, blood transfusion, electrolyte abnormalities, acid-base abnormalities, hypoxemia, temperature derangements, seizures, and endocrine dysfunction.^{17–20}

As postoperative delirium is so common, its prevention will have major clinical impact. Recent randomized controlled trials with intraoperative electroencephalogram (EEG) monitoring guiding clinical IV anesthesia and volatile-based general anesthesia administration has shown that it might decrease the incidence of postoperative delirium.^{21–23} Intraoperative EEG



monitoring likely prevents excessive anesthetic administration to vulnerable patients and thus prevention of postoperative delirium associated with deeper anesthesia. It is also expected that regional anesthesia is associated with lower incidence of postoperative delirium than general anesthesia. But meta-analysis of small trials showed that randomized surgical patients to regional anesthesia with light sedation or general anesthesia surprisingly found no increased risk for delirium with general anesthesia.²⁴ This further needs to be evaluated through a large randomized clinical trial.

Several perioperative pharmacological agents have also been investigated for the prevention of delirium, such as low-dose haloperidol subanesthetic dose of ketamine and perioperative dexmedetomidine.^{25–27} Of these agents, dexmedetomidine has been more thoroughly investigated and it may be superior to benzodiazepines and morphine in terms of the duration of delirium.^{27–30} But it might be associated with increased hemodynamic side effects when compared with agents such as propofol.³¹ Currently, switching to dexmedetomidine from alternative analgesic or sedative agents cannot be recommended as it needs further evaluation.

Postoperatively, early discontinuation of limb restraints, bladder catheters, tracheal tubes, invasive lines, surgical drains, and internal tubes may help in preventing delirium as these may cause unnecessary discomfort and agitation in patient.³² Antipsychotic medications are frequently administered postoperatively to delirious patients to treat agitation, but their impact on outcome is still unknown.^{33–35} Postoperative pain control is another challenge faced by clinicians, as pain and many analgesic medications can precipitate delirium. Nonsedating analgesics and regional anesthetics should be considered in patients vulnerable to delirium. However, in patients with severe postoperative pain, opioid (sedating) medications have been shown to alleviate both pain and delirium.

In summary, delirium is common and possibly preventable in an estimated 30% to 40% of cases with preoperative monitoring and evaluation. Medical conditions that may precipitate postoperative delirium should be recognized and treated preoperatively. Intraoperative EEG monitoring and EEG-monitored administration of anesthesia may further decrease the incidence of postoperative delirium. Early identification of patients at risk for delirium, early recognition of delirium, and instituting non-pharmacological and pharmacological interventions are key to decreasing the incidence of perioperative delirium.

Stroke

Perioperative stroke is defined as cerebral infarction of ischemic or hemorrhagic origin occurring during or after surgery with the postoperative time period sometimes defined as up to 30 days. Although rare, occurring at a rate of 0.3% to 3.5% depending on the age of the patient and other complicating factors,³⁶ it is still a feared surgical complication with a mortality rate of up to 26%.³⁷ The majority of perioperative strokes are embolic in nature,^{38–41} and hypoperfusion is an uncommon mechanism of

perioperative stroke, even in patients with carotid artery stenosis.^{42,43} Other less common mechanisms of perioperative stroke include hemorrhagic infarction; air, fat, and paradoxical embolism; and arterial dissection due to neck manipulation.^{38–44} Cardiac surgeries and carotid endarterectomy pose higher risk for perioperative strokes, with an incidence reaching 8% for combined procedures (eg, combined coronary artery bypass grafting [CABG] and valve surgeries)^{38,45,46} and 13% in patients with prior stroke or transient ischemic attack (TIA),⁴² whereas stroke following noncardiac, nonvascular, and nonneurological surgeries has significantly lower incidence.⁴⁷

Given the increase in mortality and permanent disability, prevention of perioperative stroke is of utmost importance. All surgical patients should have detailed neurological evaluation preoperatively, including meaningful history and risk factor stratification. Risk factors can be modifiable or nonmodifiable. Advanced age and history of cerebrovascular diseases are nonmodifiable risk factors. History of cerebrovascular disease is a strong protector of perioperative stroke.^{39–42,47–49} Detailed history with specific questions on any previous unreported, unrecognized, or inadequately evaluated cerebrovascular symptoms within the past 6-month period must be asked. Medical management of other preoperative risk factors, such as hypertension, diabetes mellitus, and hypercholesterolemia, must also be optimized.

Important modifiable preoperative risk factors include carotid artery stenosis, atheromatous aortic disease, and perioperative discontinuation of antithrombotic therapy. Patients with symptomatic carotid artery stenosis (carotid stenosis with stroke or TIA in the preceding 6 months) have a high risk of perioperative stroke^{42,50} and may benefit from revascularization before or during major cardiac or vascular surgeries.⁵¹ Perioperative stroke risk in a patient with carotid artery stenosis, undergoing cardiac surgery, is summarized in Table 1.

Therefore, patients with high-grade and hemodynamically significant asymptomatic carotid artery stenosis may benefit from revascularization, especially if bilateral. The preoperative evaluation in these patients should include brain imaging to rule out silent ipsilateral strokes, which may strengthen the argument for revascularization prior to surgery. In cases of urgent cardiac surgery, combined or divorce stage approach may be used, although the combined approach has higher morbidity associated with it.⁵²

The perioperative discontinuation of antithrombotic therapy increases stroke risk, especially in patients with coronary artery disease, but this must be weighed against the risk of surgical bleeding complications.^{53,54} As per current evidence, antiplatelet agents can be discontinued at least 5 days prior to CABG and can be reinitiated as early as 6 hours postoperatively,^{55–60} whereas antiplatelet therapy may be safely continued in the perioperative period for patients undergoing carotid endarterectomy without any increased risk of bleeding/complications, and in fact it is associated with lower cardiac and neurological events.⁶¹

Table 1. Carotid artery disease and stroke during coronary artery bypass.⁴²

CAROTID ARTERY STENOSIS PERCENTAGE	PERIOPERATIVE STROKE RISK IN A PATIENT UNDERGOING CARDIAC SURGERY
Carotid artery stenosis <50%	2%
Carotid artery stenosis 50%-99%	3%
Bilateral carotid artery stenosis	5%
Carotid artery occlusion	7%

Anticoagulation is considered safe in patients undergoing dental procedures, cataract surgery, arthrocentesis, and diagnostic endoscopy with or without biopsy.⁶² Patients undergoing knee or hip replacement surgery may be continued on warfarin maintaining low therapeutic international normalized ratio safely.⁶³ For more invasive procedures, bridging therapy using intravenous heparin is advised, stopped 6 hours prior to surgery and to be resumed as early as possible in the postoperative period.⁶⁴⁻⁶⁶

Intraoperative risk factors have not been studied extensively, but in one study of cardiac surgery patients, 20% of patients had impaired cerebral autoregulation during cardiopulmonary bypass, which would make them dependent on higher-than-normal mean arterial pressure for adequate cerebral blood flow.⁶⁷ In this study, patients with compromised cerebral autoregulation had a higher incidence of perioperative strokes (12.8%) compared with those who did not (2.7%). Intraoperative hypotension has been associated with perioperative stroke in surgical patients, but the clinical significance is yet to be determined.⁶⁸

Important elements in early management of stroke are identifying patients at risk and early diagnosis.⁶⁹ Emergency non-contrast computed tomographic scanning of the brain is the primary diagnostic brain imaging study for evaluation of patients with suspected stroke. Given the benefit to be gained, on a case-by-case basis, patients who suffer a preoperative ischemic stroke may be eligible for intravenous thrombolysis. Intra-arterial thrombolysis is another option for treatment, either alone or in conjunction with intravenous thrombolysis, and may be safely administered to patients within 6 hours of symptom onset. They may also be candidate for mechanical thrombectomy within 8 hours of symptom onset if National Institutes of Health Stroke Scale is more than 7 or if there is a contraindication for thrombolytic therapy. Unfortunately, much of the emergency advanced treatment of acute stroke, such as pharmacologic thrombolysis, mechanical recanalization of occluded arteries, and heparin administration, are not suitable for patients after major surgery. The current American Heart Association guidelines consider major surgery within 14 days of stroke a contraindication to intravenous thrombolysis. Patients with minor surgeries, surgeries other than neurological surgeries, and surgeries done at a site where bleeding can be controlled with compression may still be considered for thrombolytic treatments and mechanical thrombectomy postoperatively.

In summary, perioperative stroke is a rare but serious complication. Patients at risk need preoperative screening, close intraoperative hemodynamic monitoring, and rapid neurological assessment postoperatively for diagnosis and instituting proper treatment for stroke. Patients with postoperative stroke may still be a candidate for thrombolytic therapy and mechanical thrombectomy as surgeries other than intracranial or spinal, and minor surgeries done at a site where bleeding can be controlled with mechanical pressure are not an absolute contraindication to these treatment options.

Epilepsy

Epilepsy affects at least 1 million people in the United States, and most of these patients are managed with antiepileptic drugs.⁷⁰ Significant numbers of patients with epilepsy undergo surgery and are at significant risk of perioperative and postoperative complications.⁷¹ Although mortality rate in patients with epilepsy undergoing surgery is similar to patients without epilepsy, postoperative complications in patients with epilepsy are far more. Stroke is a common and significant postoperative complication in patients with epilepsy; other possible complications are pneumonia, septicemia, and acute renal failure.⁷¹

The risk of perioperative seizures is dependent on baseline control of patients with seizures and epilepsy.⁷² Anesthesia, metabolic derangements, drug and alcohol withdrawal, intracranial surgery, and baseline control of seizures are the factors causing seizures in perioperative patients. Seizures puckering intraoperatively may be anesthetic related, but postoperative seizures are generally not related to the effects of anesthesia, which warrants investigation in patients without unknown underlying epilepsy.

Patients with epilepsy undergoing surgery should be maintained on their antiepileptic medications as close to baseline as possible. They should be instructed to take their morning dose of antiepileptic medications with a sip of water before surgery. Antiepileptic medications should be reinstated as soon as possible after the surgery. If enteral options are not possible, intravenous equivalents of these agents should be started in the postoperative period. A number of intravenous formulations are available: phenytoin, valproic acid, levetiracetam, phenobarbital, and lacosamide.

Types of anesthesia may be pro- and anticonvulsions, which may influence the threshold for seizures.^{73,74} Anesthetics such

Table 2. Medications used to manage myasthenia gravis.⁸⁵

ANTICHOLINESTERASE MEDICATIONS	PYRIDOSTIGMINE (SHORT- AND LONG-ACTING PREPARATIONS)
Chronic immunosuppressive Agents	Azathioprine, cyclosporine, cyclophosphamide, methotrexate, and corticosteroids

as etomidate are proconvulsive at a lower dose and anticonvulsant at a higher dose.^{75,76} Opioids are proconvulsive. Agents such as enflurane may cause seizures during inhalational induction or during the postoperative period. In contrast, isoflurane and halothane are potent anticonvulsants.⁷⁶ It is also to be noted that sometimes recovery from anesthesia may lead to transient shivers and myoclonus, which could sometimes be misjudged as seizure activity.

Most of the patients without underlying epilepsy who experienced perioperative seizures have a metabolic disorder. Patients should be screened for electrolyte abnormality such as hyponatremia following transurethral surgery and hypercalcemia following thyroid or parathyroid surgery. Sepsis can also cause seizures and should be evaluated in any patient with trauma with an obvious source of infection. Patients with seizures in the setting of metabolic derangements generally do not require antiepileptic drug treatment, and correction of causative metabolic abnormality mostly suffices.

Patients can also experience seizures following withdrawal from any sedative-hypnotic medications; alcohol and barbiturate withdrawals are common.⁷⁷ Alcohol withdrawal seizures are mainly seen in patients with long history of alcoholism. They are typically generalized tonic-clonic convulsions within 48 hours after the last drink. These patients do not require antiepileptic medications; these seizures can be aborted with benzodiazepines.

Seizure occurrence following intracranial surgery depends on location of intracranial surgery, underlying pathological conditions, and degree of brain manipulation required to perform the procedure.^{78,79} Conditions such as subarachnoid hemorrhage, intracranial brain tumors, subdural hematoma, empyema, and intracerebral abscesses increase the risk of seizures. The type of brain tumors may also affect the risk of seizures.^{78,79} Although a common medical practice, prophylactic use of antiepileptic medications in patients undergoing craniotomy is debatable; there is literature for^{80,81} and against the use of prophylaxis in these patients.^{82,83}

In summary, perioperative seizure is a serious but treatable complication. Patients with epilepsy have more perioperative complications compared with those without a history of seizures. Patients with epilepsy undergoing surgery should be kept on antiepileptic medications. The type of anesthesia used in patients with epilepsy may also cause perioperative seizures and needs close monitoring. Patients should be checked for Metabolic derangements and toxicology screen. The type, location, and degree of brain manipulation during intracranial surgery also pose a risk of seizures, but prophylactic use of antiepileptic medications in these patients is debatable.

Myasthenia Gravis

Myasthenia gravis is an autoimmune disorder affecting the neuromuscular junction at the postsynaptic membrane. The prevalence of MG in the United States is estimated at 14 to 20 per 100 000.⁸⁴ It is a condition that still remains underdiagnosed, and the prevalence is likely higher. Myasthenia gravis may present at any age, although it is more common in younger and middle-aged adults. Women are slightly more affected among younger patients, but more men are affected among middle-aged and older patients. Patient with MG present with muscle weakness and fatigue. It can affect the extraocular muscles, bulbar muscles, proximal limb muscles, or a combination of these. Acetylcholine receptor antibodies are detected in more than 85% of patients with generalized MG and about 50% of cases with restricted ocular MG.

Patients with MG are commonly treated with anticholinesterase agents, prednisone, and immunosuppressive agents (Table 2). Some patients may require plasma exchange or intravenous immunoglobulin therapies in acute crisis and rapid deterioration of symptoms. Several drugs are well known to exacerbate MG (Table 3), and some of these agents may have a potential use perioperatively. Patients with MG can experience potentially life-threatening complications in the perioperative period. These patients are at risk of the possibility of myasthenia crisis and/or prolonged ventilator support postoperatively.

Preoperative preparation is essential in patients with MG. Pulmonary function studies must be performed because chronic respiratory disease and a preoperative vital capacity of <2.9L are 2 predictive criteria for postoperative respiratory support.⁸⁷ Patients with MG may have little respiratory reserve, and drugs which may depress respiratory functions should be used with caution and avoided in patients with bulbar symptoms. Patients with MG can be premedicated with atropine, and diazepam may be used for sedation. It is a common practice to hold pyridostigmine on the morning of surgery in patients with MG to avoid muscarinic side effects and need for muscle relaxant, but the value of holding pyridostigmine is questionable due to the potential respiratory complications it poses.⁸⁸ Patients taking long-acting preparations of pyridostigmine can be given a short-acting formulation the night before surgery. These medications should be started as soon as the patient is hemodynamically stable after surgery. Postoperatively, if oral administration is not possible, parenteral substitution should be considered, but dose may need to be adjusted. When given intramuscularly, 1/10th of the usual dose is given, and when used intravenously, 1/30th of the usual dose is given.

Patients taking oral steroids, a boosting dose of intravenous methylprednisolone, can be considered prior to extubating and

Table 3. Medications that may worsen myasthenia gravis.⁸⁶

Antibiotics	Aminoglycoside, fluoroquinolones, tetracycline, macrolides, sulfonamides, penicillin, vancomycin, clindamycin, ketolides such as telithromycin
Nondepolarizing neuromuscular-blocking agents	Pancuronium, vecuronium, atracurium.
Cardiovascular Drugs	β -blockers, calcium channel blockers, procainamide, quinidine, beryllium
Anesthetic agents	Local: procaine, lidocaine, bupivacaine Inhalation: halothane, isoflurane Neuromuscular blockers
Anticonvulsant	Carbamazepine, gabapentin, phenobarbital, phenytoin, ethosuximide
Other drugs	Botulinum toxin, chloroquine, hydroxychloroquine, magnesium, penicillamine, quinine, iodinated contrast agents, cisplatin, riluzole, interferon- α , interleukin-2

normal dose resumed once the patient starts oral intake. As other immunosuppressive agents such as azathioprine and cyclosporine have slow onset and long duration of action, these agents can be held on the morning of surgery and resumed when the patient starts taking oral medication.

Intraoperative monitoring with electrocardiogram, arterial blood pressure monitoring, pulse oximetry, end-tidal CO₂ and expiratory gas analysis are warranted in patients with MG. Neuromuscular transmission may be monitored during surgery by peripheral nerve stimulation to titrate the necessary dose of muscle relaxants and to ensure adequate reversal of neuromuscular block at the end of surgery.^{89,90} The use of regional or local anesthesia seems warranted whenever possible.⁸⁷ General anesthesia may be performed safely in patients who are optimally prepared and neuromuscular transmission is adequately monitored during and after surgery.⁸⁷

All patients with MG should be closely monitored postoperatively in the postanesthesia care unit or the surgical intensive care unit, where respiratory support can be immediately reinstated. Adequate postoperative pain control, pulmonary toilet, and avoidance of drugs that interfere with neuromuscular transmission will facilitate early tracheal extubation.

In summary careful planning is needed for myasthenia patients undergoing surgery. Certain medications used preoperatively may exaggerate and worsen myasthenia symptoms. Anticholinesterase agents may need to be started as soon as possible postoperatively; parenteral substitutions may be used immediately after the surgery. Patients and their family should be informed about possible complications with MG and/or prolonged ventilator support postoperatively.

Parkinson Disease

Parkinson disease is a disabling neurodegenerative disease with symptoms of resting tremor, rigidity, bradykinesia, and impaired postural reflexes. Patients with Parkinson disease may also manifest autonomic dysfunction, such as orthostatic hypotension, poor temperature regulation, abnormal sweating, and sialorrhea.⁹¹ A majority of patients with Parkinson disease are managed on medications such as dopaminergic agents (Levodopa), dopamine agonists such as ropinirole and pramipaxole,

monoamine oxidase B (MAO-B) inhibitors such as selegiline and rasagiline, catechol-O-methyltransferase inhibitors such as entacapone and tolcapone, amantadine, and antioxidants, and some patients in their later stages of Parkinson disease may have deep brain stimulation implants.⁹²

Major perioperative issues in patients with Parkinson disease are swallowing impairment, decline in pulmonary function, timing and administration of antiparkinsonian medications, and maintenance of volume status. Postoperative patients with Parkinson disease are found to have a longer hospital stay and increased risk of aspiration pneumonia, urinary tract infections, and bacterial infections compared with individuals without Parkinson disease.⁹³

Most patients with moderate to severe Parkinson disease have swallowing abnormalities, which may be due to abnormal lingual control, delayed pharyngeal swallowing, and repetitive and involuntary reflux from sinuses into the oral cavity. Patients with moderate to severe Parkinson disease and impaired swallowing should have a barium swallow preoperatively. Patients with impaired swallowing should be taught how to avoid aspiration and enhance swallowing techniques. Such patients postoperatively can have nasogastric administration of Parkinson medications, rotigotine and dopamine agonist transdermal patch application, and parenteral forms of anticholinergic drugs (benztropine and diphenhydramine), and they may also be given a trial of orally disintegrating levodopa (Parcopa). Few centers have institutional review board protocol for intravenous administration of levodopa, but it remains experimental.⁹⁴

It is recommended that patients with Parkinson disease have preoperative pulmonary function tests and arterial blood gas testing to assess the degree of pulmonary dysfunction. Postoperatively, these patients should be subjected to incentive spirometry, postural drainage, percussion, and early reinstatement of antiparkinsonian medications.

Parkinson medication management in perioperative period poses a great challenge related to timing of cessation as abrupt withdrawal of Parkinson medications leads to exacerbation of Parkinson symptoms and sometimes is associated with withdrawal syndrome/neuroleptic malignant-like syndrome, which involves hyperpyrexia, dysautonomia, and elevated muscle

enzymes (creatinine phosphokinase).⁹⁵ Due to the short duration of action, carbidopa/levodopa can be given the night before the surgery and even in early morning on the day of surgery. Dopamine agonists can be administered close to the time of surgery, and these medications should be reinstated as early as possible postoperatively. Other formulations can also be administered postoperatively (as mentioned above) if the patient is not able to tolerate oral formulations. Patients taking MAO inhibitors may lead to serious serotonergic syndrome when combined with medications such as meperidine and dextromethorphan. Due to additional interactions between MAO inhibitors and anesthetic agents, it is advisable to stop all MAO inhibitors at least 3 weeks prior to surgery.⁹⁶

Postoperative symptoms of nausea and vomiting in patients with Parkinson disease may be treated with ondansetron or trimethobenzamide, as other medications such as phenothiazines are centrally acting dopamine antagonists, may exaggerate Parkinson symptoms, and should be avoided. Patients with deep brain stimulation device may undergo surgeries safely once the implanted pulse generator is turned off. It may be turned on soon after the surgery. It is advisable to contact Deep Brain Stimulation device (DBS) manufacturer if the hospital is not equipped with handling such a device.

In summary Parkinson patients undergoing surgery can have a longer hospital stay and increased risk of pulmonary and urinary tract infections. It is of paramount importance that these patients should have appropriate preoperative assessment and evaluation and planned medicine management as some Parkinson medications need to be continued as close to surgery and other medications should be discontinued in a timely manner to avoid interactions with anesthetics/analgesics. Postoperatively, certain medications should be avoided to prevent low dopaminergic state which may exacerbate Parkinson symptoms.⁹⁷

Conclusions

Patients with neurological conditions undergoing surgical procedures have a higher rate of cardiac, pulmonary, and central nervous system complications in the perioperative period. A thorough preoperative assessment of these patients and instituting proper management during intra- and postoperative period are of utmost importance in controlling morbidity and mortality in these patients. In this article, we have tried to address the management of some of the neurological conditions encountered in the perioperative phase. Some conditions are more common than the others, although the impact of less common conditions, such as stroke, could be more devastating than others.

Delirium is commonly seen in the postoperative phase and could be related to multiple factors. Intraoperative EEG monitoring that guided the use of IV anesthesia has shown to decrease the incidence of postoperative delirium. Surprisingly, regional anesthesia with light sedation compared with general anesthesia did not show any difference in the occurrence of postoperative delirium; this may need to be further evaluated. Nonpharmacological interventions postoperatively have also

shown to decrease the incidence of delirium. Pharmacological interventions, such as pain management, have shown to alleviate both pain and delirium postoperatively. The role of antipsychotic medications to treat agitation/delirium still needs to be further evaluated.

Perioperative stroke, although rare, has a significant impact on patient's morbidity and mortality. Cardiac surgeries and carotid endarterectomy pose higher risk of perioperative strokes compared with noncardiac and nonvascular surgeries. Patients with high-grade and hemodynamically significant carotid artery stenosis may benefit from revascularization surgery before undergoing an elective procedure. Intraoperative factors which may put patients at risk of stroke need to be further evaluated. Postoperative stroke needs early recognition and diagnosis as a subset of these patients may still be candidates of thrombolytic therapy and mechanical thrombectomy.

Patients with epilepsy have more perioperative complications compared with those without any history of seizures. Surprisingly, stroke is a common and significant postoperative complication in patients with epilepsy. Risk of perioperative seizures depends on multiple factors, such as baseline control of seizures, anesthetic agents, metabolic derangement, use of drugs and alcohol prior to surgery, and intracranial versus extracranial surgeries. Patients with epilepsy should be maintained on their antiepileptic medications, but prophylactic use of antiepileptic agents in nonepileptic patients undergoing intracranial surgeries is still debatable.

Patients with MG undergoing surgery may have more postoperative complications, requiring prolonged ventilatory support. These patients may benefit from preoperative aggressive treatment of respiratory diseases and screening of pulmonary functions, using local or regional intraoperative anesthesia whenever possible and adequate postoperative pain control, pulmonary toileting, and avoidance of drugs which may aggravate MG symptoms.

Patients with Parkinson disease usually experience a longer hospital stay and increased risk of pulmonary and urinary tract infections perioperatively. Management of Parkinson medications poses a great challenge as abrupt withdrawal of these medications leads to exacerbation of symptoms as well as withdrawal symptoms/neuroleptic malignant-like syndrome. At times when patient cannot be administered oral medications, other methods of drug delivery should be considered. Some medications can have transdermal administration; others can be administered parenterally. Intravenous administration of levodopa, although approved at a few centers, still remains experimental.

In conclusion, many neurological conditions pose a marked risk of perioperative complications and need aggressive preoperative assessment and intra- and postoperative management to decrease morbidity and mortality. This assessment and treatment should be individualized on the basis of preoperative neurological condition and its related potential complications in perioperative period.

Author Contributions

MSD, AB and MB were involved in study concept and design; MSD, AB and MB did the data analysis and interpretation; MSD, AB and MB wrote the paper; SC and MSD did critical revision of the paper for important intellectual content; all authors read and approved the final paper.

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