Society for Neuroscience in Anesthesiology and Critical Care Expert Consensus Statement: Anesthetic Management of Endovascular Treatment for Acute Ischemic Stroke*

Endorsed by the Society of NeuroInterventional Surgery and the Neurocritical Care Society

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Abstract: Literature on the anesthetic management of endovascular treatment of acute ischemic stroke (AIS) is limited. Anesthetic management during these procedures is still mostly dependent on individual or institutional preferences. Thus, the Society of Neuroscience in Anesthesiology and Critical Care (SNACC) created a task force to provide expert consensus recommendations on anesthetic management of endovascular treatment of AIS. The task force conducted a systematic literature review (up to August 2012). Because of the limited number of research articles relating to this subject, the task force solicited opinions from experts in this area. The task force created a draft consensus statement based on the available data. Classes of recommendations and levels of evidence were assigned to articles specifically addressing anesthetic management during endovascular treatment of stroke using the standard American Heart Association evidence rating scheme. The draft consensus statement was reviewed by the Task Force, SNACC Executive Committee and representatives of Society of NeuroInterventional Surgery (SNIS) and Neurocritical Care Society (NCS) reaching consensus on the final document. For this consensus statement the anesthetic management of endovascular treatment of AIS was subdivided into 12 topics. Each topic includes a summary of available data followed by recommendations. This consensus statement is intended for use by individuals involved in the care of patients with acute ischemic stroke, such as anesthesiologists, interventional neuroradiologists, neurologists, neurointensivists, and neurosurgeons.

Key Words: anesthetic management, ischemic stroke, endovascular treatment

(*J Neurosurg Anesthesiol* 2014;26:95–108)

Endovascular treatment of acute ischemic stroke (AIS) provides a supplement or alternative to systemic intravenous thrombolysis in carefully selected patients. Several studies have shown intra-arterial thrombolysis or mechanical clot-removing devices to be efficacious for recanalization and restoration of cerebral blood flow, which has been correlated with better neurological outcome.[1–4] However, recent data from randomized clinical trials suggest that endovascular therapy was not superior to intravenous tissue plasminogen activator (tPA).[5–7] All patients who present within 3 hours of symptom onset and have no contraindications to therapy are treated with IV tPA. Patients who present between 3 and 4.5 hours after stroke onset and have no contraindications may be considered for treatment with IV tPA. Patients who are not eligible for IV tPA (due to delayed time to presentation or contraindications to tPA therapy such as recent surgery or coagulopathy) can be considered for endovascular therapy.

**Society Consensus Statements published in the Journal of Neurosurgical Anesthesiology have been reviewed by the JNA Affiliate Societies that submit them for publication. They have not undergone review by the Editorial Board of the Journal of Neurosurgical Anesthesiology.*

Received for publication December 17, 2013; accepted December 17, 2013.

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All the authors are supported by the University and Departmental funds.

The authors have no conflicts of interest to disclose.

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Patients with AIS are often elderly with multiple comorbidities. Their neurological status at time of ictus may vary from almost normal to comatose. An anesthesia team is frequently involved in patient care during endovascular treatment of AIS. During endovascular procedures, anesthesiologists are intimately involved in sedating, anesthetizing and monitoring the patient, managing hemodynamics, oxygenation, ventilation, glycemic control, and periprocedure complications, all of which may have a significant effect on the patient's long-term outcome. Despite the significance of the anesthetic management of these patients, evidence supporting specific practices is limited.

Although endovascular treatment of AIS has been available for 2 decades, the anesthetic management during these procedures is still mostly dependent on individual or institutional preferences. Despite the large body of literature on endovascular treatment of stroke, the literature rarely mentions the anesthetic or hemodynamic management during these procedures. Guidelines for management of endovascular ischemic stroke therapy represent a multidisciplinary effort to reduce death and disability from stroke. Thus, the Society for Neuroscience in Anesthesiology and Critical Care (SNACC) created a task force to provide expert consensus recommendations on anesthetic management of endovascular treatment of AIS.

METHODS

After an open search for experts in anesthetic management of endovascular treatment of AIS, the SNACC Executive Board appointed a 4-member task force. All task force members are members of SNACC and practicing neuroanesthesiologists at large university-based medical centers in the United States. None of the task force members declared conflicts of interest relating to this topic.

This consensus statement was developed using the following steps. (1) The task force defined the scope of the consensus statement to focus on anesthetic management of endovascular treatment of AIS during the periprocedure time period. For the purposes of this document, anesthetic management is defined as action or decision that involves the anesthesia care team. Periprocedural is defined as the preprocedure, intraprocedure and postprocedure (until the patient is admitted to the stroke unit or intensive care unit [ICU]) time period in which the anesthesia care team is involved. This consensus statement will not focus on criteria for selection of specific types of endovascular therapies or techniques. (2) The task force divided the scope of work into subcategories; each member was assigned responsibility for 3 or 4 subcategories. (3) A systematic literature review was conducted by each task force member using a computerized search of the National Library of Medicine database of literature (PubMed) to identify relevant literature published up to August 2012. Keyword phrases *acute ischemic stroke, stroke, endovascular treatment, intervention, anesthetic management, and anesthesia* were used. The number of original research articles relating to areas of anesthetic management of this subject matter was extremely limited. Thus, the literature review was expanded to include original articles, case reports, and case series relating to endovascular treatment of patients with AIS and these articles were reviewed for any data relating to periprocedure anesthetic management. Available information up until August 2012 was used to write a draft consensus statement. Classes of recommendations and levels of evidence were assigned to articles specifically addressing anesthetic management during endovascular treatment of stroke using the standard American Heart Association evidence rating scheme.[8] (4) Summaries of the subcategories were circulated among the task force members for comments and after reaching consensus a draft document was written. Expert consensus was used for recommendations if there was a lack of sufficient evidence base. (5) This draft was distributed to the SNACC Executive Board members for their review and opinion. (6) Additional input on the draft recommendations was solicited from Society of Neurointerventional Surgery, and Neurocritical Care Society. (7) The Consensus Statement draft was placed on the SNACC website for 1 month for public review and comments (April 2013). (8) All comments were considered in writing the final document. (9) This Consensus Statement is a result of the Task Force, SNACC Executive Committee, and representatives of SNIS, and NCS reaching consensus on the final document.

The purpose of this consensus statement is to advise on anesthetic management of endovascular treatment of AIS. This consensus statement is intended for use by individuals involved in care of patients with AIS, such as anesthesiologists, interventional neuroradiologists, neurologists, neurointensivists, and neurosurgeons. Because the literature is limited in data pertaining to this topic, this document is based to some degree on the experience and opinion of experts in this area. The recommendations of this consensus statement are not intended as standards or guidelines and should not be used for competency purposes or performance measurements, as most suggestions are not evidence based. Because of the limited amount of data relating to anesthetic management of endovascular treatment of AIS, one of the purposes of this document is to generate guidance in designing and analyzing future clinical studies.

SUMMARIES AND RECOMMENDATIONS

Preprocedure Evaluation

The literature is devoid of data specific to preanesthetic evaluation of patients undergoing interventional treatment of AIS.

Patients with AIS have several diagnostic tests and evaluations in preparation for endovascular treatment of AIS; information commonly acquired is listed below. Thus, these data should be available to the anesthesia care team before the endovascular treatment is begun. Because of the potential for altered mental status, some data

relating to patients' past medical history may be lacking or inaccurate (marked with asterisk).

Time patient was last seen normal
Computed tomography/magnetic resonance imaging findings, particularly arterial territory involved
Chest x-ray
ECG
Neurological status including National Institute of Health Stroke Scale (NIHSS) score
Sex, ethnicity
Serum glucose
Blood pressure, heart rate
Complete blood count, platelet count
International normalized ratio (INR), prothrombin time, partial thromboplastin time
Electrolytes
Creatinine
Weight*
Age*
Allergies to iodinated contrast medium*
Contraindications to magnetic resonance imaging*
History of comorbidities including diabetes, hypertension*
History of medications including oral anticoagulant use*
Administration of intravenous tPA

There are no data specific to preanesthetic evaluation of patients scheduled for endovascular treatment of AIS. However, time is of essence and delays have been shown to have detrimental effects on patient outcome; for example, it is estimated that a 30-minute delay may reduce favorable 3-month outcome (modified Rankin score 0-1) by 10%.[9] Intra-arterial thrombolysis must be performed within 6 hours and thrombectomy up to 8 hours (in exceptional, emergent cases) of the time the patient was last seen normal.

Recommendations

We recommend that, due to the limited time window to perform endovascular treatment of AIS, preprocedure evaluation for anesthesia should be done as quickly as possible with the understanding that the risk benefit ratio of proceeding with a limited preoperative anesthetic evaluation for these urgent procedures is not known (class IIb, level of evidence B). We recommend that anesthesiologists follow American Society of Anesthesiologists (ASA) standards for emergency procedures (Appendix A). Time is of the essence.

Anesthetic Technique for Endovascular Treatment of AIS

There are no randomized controlled clinical trials and no prospectively collected data specific to anesthetic management of endovascular treatment of AIS. Only retrospective studies and surveys are available. Unfortunately, they provide a limited description of anesthetic technique and pharmacologic details for endovascular treatment of AIS.[9–16]

The published studies examining the impact of anesthetic/sedation techniques on the outcomes of ischemic stroke have numerous limitations including but not limited to the variable and inconsistent definitions of levels of sedation, use of various pharmacological agents, and providers of sedation. In all these studies patients receiving general anesthesia (GA) had worse NIHSS scores.

According to the results of a survey of anesthesia and sedation practices during endovascular therapy for AIS the most frequent type of anesthesia preferred by *neurointerventionalists* is GA.[10] In a retrospective study involving 980 patients from 12 stroke centers, 44% of the patients received GA for endovascular stroke intervention.[13] One study reports a 2.7% incidence of conversion from sedation to GA due to agitation/emesis and altered level of consciousness.[11]

Patients who were intubated or received heavy sedation, pharmacological paralysis, or GA have been reported to have higher mortality than those receiving sedation.[11–14,16] Neurological outcome is more likely to be good (modified Rankin score ≤ 2) in patients who are not intubated or do not receive heavy sedation, pharmacological paralysis, or GA.[11–14,16] Patients not intubated for endovascular treatment of AIS have been reported to have a lower final infarct volume on diffusion-weighted magnetic resonance imaging studies or noncontrast head computed tomography and shorter length of stay in the ICU.[11] Patients receiving no sedation or light sedation had higher successful angiographic reperfusion rates than those who received heavy sedation or pharmacological paralysis in 1 study[11] but not in another.[3] However, none of these data come from randomized studies, and when interpreting these data one must consider that the choice between sedation and GA is frequently driven by institutional preferences or patient condition, and that patients with the best preprocedure neurological status are most likely to have the intervention performed awake.

There is no difference in the incidence of intraprocedural complications attributable to microcatheter or microwire perforation[11,14] or hemorrhagic complications[11,13–15] between intubated and nonintubated patients or between patients who received light or deep sedation. The risk of pneumonia and/or sepsis has been reported to be higher in the intubated patients and in those receiving heavy sedation or pharmacologic paralysis.[11–14] Blood pressure is likely to be lower in patients receiving GA compared with those receiving local anesthesia.[16]

Although it is conceivable that induction of GA would delay the endovascular treatment of AIS, no delays or objective difference in time to treatment has been found to be attributable to institution of GA in comparison with sedation.[11,13–15]

The use of variety of anesthetic/analgesic agents including ketamine, propofol, fentanyl, midazolam, and dexmedetomidine has been reported albeit without much detail.[11,12] Available human data do not support the selection of any 1 anesthetic agent over the others based on their neuroprotective properties.[17] Choice of anesthetic

agents should be based on patient condition, pharmacodynamic and pharmacokinetic properties of the drugs, potential adverse effects, and cost.

Summary

The use of local anesthesia with conscious sedation for endovascular treatment of AIS is associated with lower mortality and better neurological outcomes compared with GA.[11–14,16] However, existing literature is limited by selection bias and the quality of existing data is not sufficient to influence clinical practice. Local anesthesia with sedation offers the advantages of allowing neurological monitoring during the procedure and does not delay intervention due to anesthetic induction but may expose the patient to the risk of aspiration, respiratory depression, undesirable movement and possibly increased procedure duration.[9–15] GA offers the advantages of airway control with avoidance of intraprocedure aspiration, patient immobility, and possibly reduced procedural duration, but may expose patients to the risk of blood pressure fluctuations, restricts neurological monitoring during intervention, and requires qualified anesthesia providers; GA may also be associated with pneumonia and sepsis.[9–16]

Recommendations

We recommend that the choice of anesthetic technique and pharmacological agents should be individualized based on clinical characteristics of each patient, in close communication with the neurointerventionalist. GA may be preferable in uncooperative or agitated patients or patients with elevated neurological severity who cannot protect their airway (most patients with posterior circulation stroke, depressed level of consciousness, respiratory compromise) (class IIa, level of evidence B). Local anesthesia with sedation and GA are feasible options for patients with anterior circulation stroke who can protect their airway and are cooperative (class IIa, level of evidence B). In all patients receiving local anesthesia with sedation, the anesthesia provider should be prepared to rapidly convert to GA if needed (class IIa, level of evidence C). If GA is chosen, standardized protocols for early postprocedural neurological assessment and extubation should be used to minimize the postextubation risks. There is no recommendation on a specific pharmacologic agent or combination for the provision of sedation or GA. Anesthesia-related procedures should be done as quickly as possible to avoid delay in endovascular treatment.

Management of Oxygenation and Ventilation during Endovascular Treatment of AIS

Hypoxia may adversely affect clinical outcome after stroke. Unfortunately, there are no data specific to hypoxia under GA or procedural sedation for endovascular treatment of AIS.[18,19] Patients with acute stroke may become hypoxemic because of altered central regulation of respiration, sleep apnea, weakness of the respiratory muscles, and aspiration.[20–26] Sleep-related breathing disorders may be present in 44% to 95% of stroke patients[21,27–30] and may contribute to hypoxia during pharmacologically induced sedation. In a randomized controlled trial of sedation for neurointerventional procedures (not including AIS) a 25% incidence of respiratory complications (snoring, airway obstruction, $SpO_2 < 90\%$ or respiratory rate < 8/min) was reported despite administration of supplemental oxygen.[31]

Hyperoxia has been suggested as a neuroprotective strategy to salvage acutely ischemic brain tissue and to extend the time window for the administration of thrombolytic drugs.[32] Cerebral blood volume and blood flow within ischemic regions have been shown to improve with high-flow oxygen therapy[33] and the regional cerebral vasoconstrictor responsiveness to 100% oxygen inhalation may be lost or paradoxically reversed in patients with acute hemispheric infarction.[34] Yet, conflicting results have been reported with prolonged administration of supplemental oxygen routinely to stroke patients (for 24 to 72 h). No benefit, decreased survival, better neurological recovery as well as transient improvement of clinical function have all been reported to be associated with administration of supplemental oxygen.[35–37]

There are no data specific to management of ventilation and end-tidal CO_2 under GA for endovascular treatment of AIS. Existing data in stroke patients suggest that hypocapnia is associated with poor prognosis in stroke.[38–40] There are no data to support the use of hypocapnia as a therapeutic measure to redistribute cerebral blood flow during focal cerebral ischemia. However, hypocapnia may be used temporarily to treat increases in intracranial pressure due to stroke or hemorrhagic conversion thereof.

Hypercapnia increases cerebral perfusion,[41] and may be neuroprotective after transient global cerebral injury in rats.[42] However, regional cerebral vasodilatory response to hypercapnia may be impaired in patients with symptomatic cerebral ischemia.[43] There are currently no clinical data relating the use of therapeutic hypercapnia to improve outcomes of ischemic stroke.

Recommendations

Tracheal intubation is not required if adequate oxygenation and ventilation can be maintained with/without supplemental oxygen and adequate cooperation can be achieved under procedural sedation. However, patients with decreased consciousness or signs of brainstem dysfunction with compromised protective airway reflexes, those having active nausea/vomiting before endovascular treatment, those who develop agitation or inability to communicate and those who develop airway obstruction under sedation may require tracheal intubation (class IIa, level of evidence C).

Benefits of hyperoxia are unclear and some side effects may be undesirable. According to the recommendations of ASA, supplemental oxygen should be considered for moderate sedation and should be administered during deep sedation (class IIa, level of evidence C).[44] Overzealous oxygenation is not recommended

before the procedure. We recommend that all patients undergoing endovascular treatment of AIS should be monitored by continuous pulse oximetry and capnography (class IIa, level of evidence C). Monitoring of PaO_2 and $PaCO_2$ may be performed intermittently by sampling from the intra-arterial cannula or the endovascular access port. The optimal ranges of SpO_2 and PaO_2 specific to AIS are unknown. We recommend that FiO_2 should be titrated to maintain $SpO_2 > 92\%$ and $PaO_2 > 60$ mm Hg (class IIa, level of evidence C). Ventilation should be adjusted to maintain normocapnia ($PaCO_2$, 35 to 45 mm Hg) under GA (class IIa, level of evidence C). Respiratory depression-induced hypercarbia should be avoided during procedural sedation (class IIa, level of evidence C).

Periprocedural Hemodynamic Management

There are no prospective trials on periprocedural (pre, intra, and post) hemodynamic management of patients having endovascular treatment of AIS caused by thromboembolic events. However, there are retrospective studies that relate to the issue of anesthetic management.[13,16,45–52]

Because of the lack of prospective trials on hemodynamic management of patients having endovascular treatment of AIS, we are left to infer targets using data from patients with AIS caused by thromboembolic events. The conclusions are by and large straightforward: avoid hypotension, unclear about induced hypertension.

Continuous hemodynamic monitoring and close attention to hemodynamic management during endovascular treatment of AIS, which occurs at a minimum of 1 to 2 hours after the onset of the stroke, may not be sufficient to provide optimal patient outcomes. Untreated hypotension before endovascular treatment of AIS may have adverse effects on patient outcome. Significant decreases in blood pressure after acute stroke have been associated with poor outcome[53] and induced hypertension may result in short-term neurological improvement.[54] However, precise blood pressure targets have not been determined. Guidelines from the American Heart Association and the American Stroke Association are that "[b]oth elevated and low blood pressure … [is] associated with poor outcome after stroke."[55] The authors in another paper analyzed 17,398 patients from the International Stroke Trial to explore the relationship between systolic blood pressure and subsequent clinical events over 2 weeks and functional outcome at 6 months in patients with acute stroke.[56] There is a U-shaped relationship between baseline systolic blood pressure and both early and late death or late dependency.[55,57] Treatment of acute stroke induced-hypertension with antihypertensive medications does not significantly improve patient outcome.[58]

Recommendations

We recommend that hemodynamic monitoring and management, as outlined below, should be started as soon as diagnosis of AIS has been made (class IIa, level of evidence C). Heart rate and cardiac rhythm should be monitored continuously and blood pressure should be monitored continuously or measured at least once every 3 minutes. We recommend that systolic blood pressure should be maintained >140 mm Hg (fluids and vasopressors) and <180 mm Hg (with or without IV tPA), and diastolic blood pressure <105 mm Hg (class IIa, level of evidence B). Cause of hypotension should be investigated (volume depletion, myocardial infarction, cardiac arrhythmia, blood loss, retroperitoneal hemorrhage, and aortic dissection) and treated if possible. We also recommend that blood pressure targets may be adjusted (lowered) in communication with the neurointerventionalists and neurologists following successful recanalization of occluded vessel(s) (class IIb, level of evidence C), as reperfused brain often lacks autoregulation leading to high risk of hyperperfusion leading potentially to hemorrhagic conversion.

Fluid Management During Endovascular Treatment of AIS

There are no published data on perioperative management of fluids in patients undergoing endovascular treatment of AIS. Because of the lack of published data, it is reasonable to focus on medical management of patients with acute stroke caused by thromboembolic events given that the management of this population of patients will likely be similar to what is required for patients having endovascular treatment. Euvolemia should reduce the incidence of significant decreases in blood pressure after AIS.

While patients experiencing acute stroke may have increased whole-blood viscosity, intentional hemodilution does not reduce case fatality and may lead to reduced oxygen carrying capacity.[59]

Recommendations

Extrapolating from acute stroke patient data, we recommend to maintain euvolemia (class III, level of evidence C), and to avoid glucose containing fluids unless treating serum glucose values <50 mg/dL (class IIb, level of evidence C).

Temperature Management During Endovascular Treatment of AIS

There are no published data on perioperative management of temperature in patients undergoing endovascular treatment of AIS. Because of the lack of published data, it is reasonable to focus on medical management of patients with acute stroke caused by thromboembolic events given that the management of this population of patients will likely be similar to what is required for patients having endovascular treatment.

Although systemic cooling may provide neuroprotection in some patient populations, definitive evidence is lacking in patients with AIS.[60] Available data does not support routine use of hypothermia in these patients.[60] If hypothermia therapy is used, there is a short window of time for the therapies to reperfuse the penumbra.

Approximately a third of the patients with AIS are febrile. Increased body temperature in the setting of AIS is associated with poor neurological outcome. This may be due to increased metabolic demands, enhanced release of neurotransmitters, inflammatory response, and increased free radical production.[59,61,62] Treatment includes antipyretic medications and cooling devices. Only small studies have been performed with no major improvements.[61,62]

Recommendations

Extrapolating from acute stroke patient data, we recommend maintaining target temperature between 35°C and 37°C during endovascular treatment of AIS and to treat the patients with antipyretics and cooling devices if febrile (class IIb, level of evidence B). Shivering should be treated with meperidine.

Intraprocedural Monitoring

There are no data specific to management of intraprocedure monitoring of patients undergoing interventional treatment of AIS. However, in view of the critical condition of this patient population, minimum monitoring should include monitoring of blood pressure, heart rate, and cardiac rhythm (ECG), temperature, noninvasive oxygen saturation (SpO_2), respiratory rate and end-tidal CO_2, and level of neuromuscular blockade during GA (ASA standard monitoring). An intra-arterial cannula is useful if it can be placed without delaying the procedure.

Recommendations

We recommend continuous invasive intra-arterial pressure measurement for periprocedural management of endovascular management of AIS, as long as cannulation of the artery can be done without delaying endovascular therapy. If an arterial cannula has not been placed, we recommend noninvasive blood pressure measurements at least every 3 minutes. We recommend that once an artery has been cannulated by the neurointerventional team, it should be used for continuous arterial blood pressure monitoring if an arterial line has not been previously placed. Significant hemodynamic aberrations (increase in blood pressure, decrease in heart rate) should be communicated immediately with the team taking care of the patient, as this may be an indication of an intracerebral hemorrhage (ICH). We recommend that ECG, SpO_2, ET CO_2, and respiratory rate monitoring be continuous (class I, level of evidence B).

Periprocedure Management of Anticoagulation

The goals and concerns of periprocedural anticoagulation and administration of antiplatelet drugs during endovascular treatment of AIS are to reduce catheter-related, stent-related, and thrombus-related embolic and thrombotic events while minimizing the incidence of hemorrhagic events.

The literature is void of anesthesia management specific information on anticoagulation during interventional treatment of AIS. Available data are based on expert opinion and case studies. Most publications with anticoagulation-related data during interventional treatment of AIS do not include doses for anticoagulants. Optimal level for anticoagulation for this patient population has not been determined.

Heparin

Heparin is used during the procedure to reduce catheter-induced embolic and thrombotic events. Heparin dosing may be initiated after the decision to treat an intra-arterial thrombus by endovascular treatment has been made. Heparin administration (repeat boluses or infusion) is typically stopped at the end of the procedure, without reversing the heparin with protamine.

None of the articles describing periprocedural ICHs (with or without previous administration of IV tPA) discuss subsequent management of anticoagulation. However, in the event of catheter-induced ICH, immediate reversal of heparin effect by protamine (typically 50 mg IV) is indicated. Thus, protamine should always be immediately available when heparin is used during endovascular treatment of AIS. Subsequent protamine dosing should be based on ACT values.

Warfarin (Coumadin)

Many of the patients having an AIS are taking aspirin and/or clopidogrel and/or coumadin. Most of the earlier studies using IV recombinant prourokinase *arbitrarily* excluded patients with INR > 1.7 or partial thromboplastin time > 45 seconds.[1,63–65] Thus, many of the patients taking coumadin and having a therapeutic INR did not receive IV prourokinase. Instead, interventional endovascular treatment has been suggested for selected patients. A retrospective analysis of Mechanical Embolus Removal in Cerebral Ischemia (MERCI) and Multi MERCI data (enrolled patients with INR < 3.0)[66] and few case reports suggest that patients with abnormal hemostasis are not at an increased risk of symptomatic ICH.[67,68] Similarly, another retrospective study suggests that patients taking oral anticoagulants are not at an increased risk of symptomatic ICH.[69] In contrast, 1 retrospective study found a 10× higher incidence of ICH in patients taking oral coumadin (INR > 1.7).[70] Anesthesiologists may be asked to reverse the effect of coumadin. No AIS-specific data are available regarding reversal of coumadin.

Aspirin/Clopidogrel (Plavix)

Administration of aspirin is typically withheld for 24 hours after procedure in patients with AIS if thrombolytic therapy was performed. Clopidogrel and/or aspirin need to be administered during endovascular treatment of AIS if an endovascular stent will be used.[71,72]

Abciximab (ReoPro)

Some interventionalists have used Abciximax in attempt to prevent rethrombosis.[73] No AIS treatment–specific data are available for use of abciximab.

Dabigatran

Use of newer oral anticoagulants is increasing. Patients with atrial fibrillation may be taking dabigatran, a direct thrombin inhibitor. Thrombin time may be needed to measure the anticoagulation effect of dabigatran.

Recommendations

Optimal level of anticoagulation during endovascular treatment of AIS has not been determined. Heparin is frequently administered during these procedures and we recommend that anesthesiologists be prepared to administer heparin throughout the procedure as requested by the neurointerventional team (class I, level of evidence B). Anesthesiologists should also be prepared to administer protamine (typically 50 mg IV) immediately to a patient who has received heparin in case of an ICH (class IIa, level of evidence C).

Glycemic Management During Endovascular Treatment of AIS

Hyperglycemia (HG) is common in patients with AIS and independently predicts a larger infarct size, poor clinical outcome, and a higher risk of mortality particularly in patients with cortical infarction.[74–82] However, HG may not be associated with poor outcome in patients with lacunar stroke.[82–84] The association between HG and poor clinical outcome is more pronounced in patients treated with thrombolytic therapy than in patients not treated with tPA.[81,82,85,86] It has been suggested that the impact of intra-arterial thrombolysis-induced recanalization on clinical improvement may not be apparent without strict glucose control[86] and that HG in patients with AIS can cause a worse clinical outcome despite recanalization.[77] HG has been implicated in the increased risk of symptomatic ICH after intra-arterial thrombolysis.[87] Unfortunately, there are no data on glycemic management during endovascular treatment of AIS.

The majority of the published data indicate an association of glucose levels of >140 mg/dL with greater final infarct size, failure of recanalization despite tPA, worse functional outcome despite tPA-induced recanalization, lack of improvement 24 hours after thrombolytic therapy, increased risk of mortality, and risk of parenchymal hemorrhage.[79,80,85–88] The association between admission serum glucose and Rankin score at 12 months has been described by a J-shaped curve with a nadir of 90 mg/dL and long-term (12 mo after stroke) favorable outcome with glucose values between 67 and 131 mg/dL.[89]

In contrast, 1 large prospective clinical trial (the UK Glucose Insulin in Stroke Trial, GIST-UK) has specifically investigated the effect of glycemic control on stroke outcome and failed to show a clinical benefit.[90] While some investigators have reported reduced mortality with insulin treatment to decrease blood glucose to <130 mg/dL,[91,92] others found no effect of tight glucose control.[93] Yet, the current guidelines from the American Heart Association/American Stroke Association recommend insulin treatment of blood glucose concentrations >140 to 185 mg/dL.[59] The European Stroke Organization guidelines for management of ischemic stroke and TIA recommend treatment of serum glucose levels of >180 mg/dL with insulin.[94]

Intensive insulin therapy for tight glucose control has been associated with increased risk of hypoglycemia and poor clinical outcomes in the neurocritical care setting.[95,96] The anesthetic period is physiologically distinct from critical care environment and the blood glucose levels increase under anesthesia even in nondiabetic patients[97] with new-onset HG under anesthesia and wide variability of glucose values[98] indicating the need for frequent glucose monitoring and careful titration of insulin.

As symptoms and signs of hypoglycemia may mimic AIS and because hypoglycemia may lead to brain injury, rapid correction of low glucose level is important.[59] European Stroke Organization guidelines recommend that blood glucose of <50 mg/dL should be treated with intravenous dextrose or infusion of 10% to 20% glucose.[94] Importantly, in patients under anesthesia and sedation, the symptoms of hypoglycemia may not be recognizable. A variety of blood glucose measurement techniques are currently in use. However, it is unclear if they are equivalent.[99,100]

While subcutaneous insulin is frequently used for glucose management, most experts recommend protocol-driven intravenous insulin infusion rather than subcutaneous insulin in patients with AIS.[101] In the UK Glucose Insulin in Stroke Trial, a continuous intravenous GKI infusion (500 mL of 10% dextrose and 20 mmol potassium chloride with 16 U of insulin) was used effectively to achieve the glucose target.[90]

Recommendations

Patients arriving for endovascular treatment of AIS already should have serum glucose measured. If not, we recommend that the anesthesia provider should obtain a serum glucose value (class I, level of evidence C). There is no preferable method of glucose sampling and capillary/venous/arterial blood may be sampled with point of care glucometer or blood gas analyzer. We recommend that glucose should be sampled at least once every hour during endovascular treatment of AIS (class IIa, level of evidence C).

We recommend that insulin treatment of HG should be initiated for glucose values of >140 mg/dL (class IIb, level of evidence C). Protocol-driven intravenous insulin infusion should be used to control HG rather than subcutaneous insulin. We recommend that glucose concentration is maintained in the range of 70 to 140 mg/dL with treatment for hypoglycemia being initiated for glucose values of <50 mg/dL (class IIa, level

of evidence C). Fluids containing dextrose should be avoided during endovascular treatment of AIS unless hypoglycemia is present (class IIb, level of evidence C). The goal of treatment of hypoglycemia should be to achieve glucose levels of >70 mg/dL.

Provider of Care for Anesthesia/Sedation for Endovascular Treatment of AIS

In AIS patients, institution of stroke unit with a dedicated neurological care team has been associated with a reduction of resource utilization and improved clinical outcomes.[102,103] In addition, the presence of experienced intensive care teams in the neurocritical care unit might be associated with improved clinical outcomes in patients with AIS.[104] There are no data relating anesthesia/sedation provider (anesthesiologist/nurse anesthetist/non-anesthesia personnel) for endovascular treatment of AIS to outcomes. Given the emergent and complex nature of the interventional procedures for AIS, frequent association of multiple comorbidities in stroke patients, the need for strict hemodynamic management and ensuring homeostasis, anesthesiologist/anesthesia team should be present to provide sedation and hemodynamic monitoring. For procedures requiring GA, an anesthesiologist/anesthesia team must be physically present with the patient.

Acute stroke interventions, even when performed on patients in the awake state, should be carried out in the presence of or with immediate availability of experienced anesthesia or critical care trained providers who can rapidly manage untoward events, including securing the airway.[11] This is important because of the risk of hypoxia/hypercarbia, because of acute airway obstruction resulting from sedation, and the possible need to convert into GA. Although it is conceivable that induction of GA would delay the endovascular treatment of AIS, no delays or objective difference in time to treatment has been found to be attributable to institution of GA in comparison with sedation.[11,13–15]

Endovascular treatment of AIS is a multidisciplinary team approach involving providers from various specialties including but not limited to emergency medicine, neurology, anesthesiology, interventional neuroradiology, and neurocritical care. Moreover, the care of patients undergoing endovascular treatment may be handed-off multiple times from one team to another in the first few hours of hospital treatment. Specifically, the patients are often managed initially by the emergency medicine physicians followed by involvement of the neurologists. Subsequently, the care is handed-off to the anesthesiologist who then hands off the care after endovascular treatment to the neurointensivist. It is therefore, vital that adequate communication be ensured among members of all teams involved to maintain continuity of care targeted towards common goals. Such communications should be timely and succinct and targeted at avoiding any delays in definitive treatment as well as collective decision of important treatment strategies. The issues particularly relevant to anesthesia care include choice of anesthetic technique and pharmacological agents, blood pressure, and glycemic goals. The choice of anesthetic technique (GA vs. sedation) and pharmacological agents should be made based on clinical characteristics of each patient, following close communication between the anesthesiologist, neurointerventionalist, and neurologist. The importance of continued communication between providers during various stages of endovascular intervention cannot be overemphasized. The anesthesia provider also should ensure clear communication with the patient, especially if local anesthesia/sedation is planned. The patient may need to be informed about procedural details and reassured to achieve cooperation.

Team communication also may facilitate early interventions for hemodynamic and glycemic management as the patient is transported from the emergency department to the interventional neuroradiology suite for endovascular treatment. Moreover, in-hospital delays in intervention may be reduced by creation of rapid response teams or Computerized Physician Order Entry (CPOE)-based stroke code and by establishing multidisciplinary care pathways.[105,106]

Recommendations

Medical centers providing endovascular treatments for AIS should be able to provide the services in a timely manner. Thus, institutional systems should be in place to notify and involve the anesthesia care team for stroke treatment in a timely manner. Because of the importance of hemodynamic monitoring in addition to sedation/analgesia, we recommend that an anesthesiologist with expertise in management of critically ill neurology patients be available to provide care and that policies, statements, and recommendations of the ASA pertaining to sedation and anesthesia provider for general purposes be followed (class I, level of evidence C).[44,107–110] According to the ASA guidelines, "sedation and analgesia" comprise a continuum of states ranging from minimal sedation (anxiolysis) to moderate sedation/analgesia (conscious sedation), deep sedation/analgesia, and GA.[108] Although an anesthesiologist must be involved for all procedures performed under GA, other qualified personnel, including registered nurses may provide sedation (class I, level of evidence C). However, while a patient is sedated, the responsible physician must be physically present in the procedure suite and should be responsible for leading any acute resuscitation needs, including emergency airway management.[107]

Complications and Management of Endovascular Treatment of Stroke

Although intravenous and/or intra-arterial thrombolytic treatment with tissue plasminogen activator, and mechanical thrombectomy are effective therapies for AIS; major complications may occur following these interventions.[111–113]

Endovascular treatment of AIS has a significant risk of ICH. ICH occurs in both IV and IA treatment, however, may not be clinically evident or symptomatic. ICH

can occur due to hemorrhagic transformation of an infarct or be iatrogenic through direct vessel trauma (microwires, microcatheters, or mechanical thrombectomy devices). Early IV and IA thrombolysis trials reported 6% and 10% rate of symptomatic ICH, respectively.[63,114–117] More recent trials using newer endovascular devices (stent retrievers) have reported symptomatic ICH rates between 1.5% and 15%.[118–120] Symptomatic subarachnoid hemorrhage may require urgent ventriculostomy and intracranial pressure management. Guidelines for blood pressure management, surgical management, and management of anticoagulation (with or without use of tPA) for post-thrombolytic ICH are lacking. Heparin effect should be reversed immediately with protamine in case of an intraprocedural ICH. Patients who have received tPA may require administration of fresh frozen plasma, cryoprecipitate, and platelets.

Other acute complications of endovascular approaches include catheter-induced blood vessel dissections and vasospasm, puncture site hematomas, limb ischemia, thromboembolism, and retroperitoneal hematoma.[117] Puncture of the femoral arteries is associated with severe hemorrhage in 1% to 3% of all patients.[114] Arteriotomy closure devices have shown to be safe and effective at stopping access site bleeding and are used frequently after endovascular procedures. These devices can be helpful in patients who are on antiplatelets, anticoagulants, or were treated with IV thrombolysis before the intra-arterial procedure.[121] Pseudoaneurysm formation and artery dissection requiring surgery are rare, but are potential complications of closure devices. In cases of a retroperitoneal hemorrhage, a computed tomography scan can be considered to determine the extent and severity of the hemorrhage. Vasovagal reactions may occur after sheath removal and this can be treated with atropine and intravenous fluids.[117]

Other endovascular treatment–related complications include arterial reocclusion, distal embolization, vasospasm, and vessel dissection.[117,122] Anesthesia-related/sedation-related complications include patient movement, blood pressure lability, aspiration, and upper airway obstruction.

Recommendations

We recommend that anesthesiologists caring for patients with AIS are familiar with and be prepared to manage endovascular treatment–related acute complications. In case of ICH, heparin effect should be reversed immediately with protamine. We recommend that after ICH systolic blood pressure should be maintained >140 mm Hg (class IIa, level of evidence B). Given the potential for neurological insult with arterial hypertension, emergent management of elevated blood pressure is necessary to prevent further complications. However, there is a general consensus that the rapid lowering of blood pressure during ischemic stroke may be harmful and is not recommended (class IIa, level of evidence B). Labetalol and/or nicardipine is recommended for patients with ICH to maintain systolic blood pressure of <180 mm Hg or mean blood pressure of <130 mm Hg (class IIb, level of evidence B). Conversion from sedation to GA may be necessary to protect the airway, provide adequate oxygenation and ventilation, and, in the event of procedural complication, help manage intracranial pressure.[123–130]

Postprocedure Care

There are no data specific to management of patients immediately after endovascular treatment of AIS. Patients should go to a dedicated ICU specializing in neurovascular care or a stroke unit after the procedure, and be taken care of by person(s) with expertise in management of critically ill neurology patients. Decision to extubate should be made in communication with the neurointerventionalist. In general, patients who were not intubated before neurointervention should be extubatable at the end of the endovascular procedure if they meet standard extubation criteria. Because of the critical condition of this patient population, hemodynamic and neurological monitoring should be continued in the intensive care setting. Postprocedure blood pressure management should be discussed within the team taking care of the patient with consideration of the results of the endovascular treatment. Anesthetics/sedatives should be discontinued to allow for neurological examination. Monitoring of oxygenation and ventilation should be continued in the immediate postanesthetic period.[131]

Recommendations

We recommend that patients should go to a dedicated ICU specializing in neurovascular care or a stroke unit after the procedure. We also recommend that continuous hemodynamic monitoring should be continued in the ICU or stroke unit (class I, level of evidence B). Patients who meet standard extubation criteria after the procedure should be extubated.

CONCLUSIONS

We reviewed the literature and made recommendations. Because of the limited available data, most recommendations are based on current expert opinion. As more data become available, our recommendations need to be revised accordingly. Future studies in this area should have improved documentation of hemodynamic and anesthetic management, and should use this document to guide their study design and subsequent data collection.

Anesthesia technique and hemodynamic data were not the main focus of hardly any studies. Thus, high-quality data on these variables are lacking. All that is available are retrospective studies and associations from mixed stroke patient populations. This is especially noticeable and important in the currently ongoing debate between GA and sedation for these procedures. By default, most of the studies have a significant selection bias. Because this topic is keenly important in delivering anesthesia for this patient population, controlled, randomized studies in this area are needed in a timely manner.

Another important focus of the anesthesiologists is hemodynamic management. Although anesthesiologists pay significant attention to hemodynamic management during the procedures, improved patient outcomes may depend on other variables. Unmeasured/untreated hypotension is known to have effects on patient outcome independently of whether endovascular therapy is undertaken. Brain-directed hemodynamic management should begin as soon the diagnosis of AIS has been made.

Summary of Recommendations for Anesthetic Management of Endovascular Treatment of AIS

Recommendations for Preprocedure Evaluation

(1) Preprocedure evaluation for anesthesia should be done as quickly as possible to avoid a delay in endovascular therapy (class IIb, level of evidence B).
(2) Anesthesiologists should follow ASA standards for emergency procedures.

Recommendations for Anesthetic Management

(1) GA is recommended in patients who are already intubated for medical reasons (class IIa, level of evidence B).
(2) GA is recommended for uncooperative patients and most patients with posterior circulation strokes (class IIa, level of evidence B).
(3) Local anesthesia with sedation and GA are feasible options for cooperative patients who can protect their airway (class IIa, level of evidence B). Anesthesia-related procedures should be done as quickly as possible to avoid delay in endovascular treatment.
(4) In all patients receiving local anesthesia with sedation, the anesthesia provider should be prepared to rapidly convert to GA if needed (class IIa, level of evidence C).
(5) Anesthetic technique and pharmacological agents should be individualized based on clinical characteristics of each patient, in close communication with the neurointerventionalist.

Recommendations for Management of Oxygenation and Ventilation

(1) Tracheal intubation is recommended for patients with decreased level of consciousness or signs of brainstem dysfunction with compromised protective airway reflexes, those having active nausea/vomiting before endovascular treatment, those who are hypoxic or hypercarbic, and those who develop airway obstruction under sedation (class IIa, level of evidence C).
(2) Supplemental oxygen administration is recommended during moderate and deep sedation (class IIa, level of evidence C).
(3) All patients undergoing endovascular treatment of AIS should be monitored by continuous pulse oximetry and capnography (class IIa, level of evidence C).
(4) FiO_2 should be titrated to maintain $SpO_2 > 92\%$ and $PaO_2 > 60$ mm Hg (class IIa, level of evidence C). Ventilation should be adjusted to maintain normocapnia ($PaCO_2$, 35 to 45 mm Hg) under GA (class IIa, level of evidence C).
(5) Respiratory depression-induced hypercarbia should be avoided during procedural sedation (class IIa, level of evidence C).

Recommendations for Periprocedural Hemodynamic Management

(1) Hemodynamic monitoring and management should be started as soon as diagnosis of AIS has been made (class IIa, level of evidence C).
(2) Systolic blood pressure should be maintained >140 mm Hg (fluids and vasopressors) and <180 mm Hg and diastolic blood pressure <105 mm Hg (class IIa, level of evidence B). Acutely decreasing blood pressure <140 mm Hg during induction of anesthesia is not permissible.
(3) There are insufficient data to recommend a specific vasopressor to support blood pressure. Vasopressor choice should be based on individual patient characteristics.
(4) Blood pressure targets may be adjusted in communication with the neurointerventionalists and neurologists following successful recanalization of occluded vessel(s) (class IIb, level of evidence C).

Recommendations for Fluid Management

(1) Maintaining euvolemia is recommended during endovascular treatment of AIS (class III, level of evidence C).
(2) Glucose containing fluids should be avoided unless treating serum glucose values of <50 mg/dL (class IIb, level of evidence C).

Recommendations for Temperature Management

(1) Maintaining target temperature between 35°C and 37°C is recommended during endovascular treatment of AIS (class IIb, level of evidence B).
(2) Treating patients with antipyretics if febrile is recommended during endovascular treatment of AIS (class IIb, level of evidence B).

Recommendations for Intraprocedural Monitoring

(1) Continuous ECG, SpO_2, ET CO_2, and respiratory rate monitoring is recommended (class I, level of evidence B).
(2) Blood pressure should be monitored continuously or measured noninvasively at least once every 3 minutes. Continuous invasive intra-arterial pressure monitoring is recommended during the procedure, as long as cannulation of the artery will not cause a delay in endovascular therapy. If feasible, the femoral artery cannulated by the neurointerventional team, may be used for continuous arterial blood pressure monitoring.

Recommendations for Periprocedure Management of Anticoagulation

(1) Anesthesiologists should be prepared to administer heparin throughout the procedure as requested by the neurointerventional team (class I, level of evidence B).
(2) Anesthesiologists should be prepared to administer protamine immediately to a patient who has received

heparin in case of an ICH or iatrogenic SAH (class IIa, level of evidence C).

Recommendations for Glycemic Management

(1) The anesthesia provider should obtain a serum glucose value in the beginning of the procedure if it is not already available (class I, level of evidence C). Serum glucose should be sampled at least once every hour during endovascular treatment of AIS (class IIa, level of evidence C).
(2) We recommend that insulin treatment of HG should be initiated for glucose values of >140 mg/dL (class IIb, level of evidence C). Protocol-driven intravenous insulin infusion is recommended to be used to control HG rather than subcutaneous insulin.
(3) Serum glucose concentration should be maintained in the range of 70 to 140 mg/dL with treatment for hypoglycemia being initiated for glucose values of <50 mg/dL (class IIa, level of evidence C).

Recommendations for Provider of Care for Anesthesia/Sedation

(1) Policies, statements, and recommendations of the ASA pertaining to sedation should be followed (class I, level of evidence C).
(2) Although an anesthesiologist must be involved for all procedures performed under GA, other qualified personnel with expertise in management of critically ill neurology patients, including registered nurses may provide sedation (class I, level of evidence C).
(3) While a patient is sedated, the responsible doctor must be physically present in the procedure suite and is be responsible for leading acute resuscitation needs, including emergency airway management.

Recommendations for Management of Complications During Endovascular Treatment of Stroke

(1) In case of ICH, heparin effect may have to be reversed immediately with protamine.
(2) After ICH systolic blood pressure is recommended to be maintained >140 mm Hg (class IIa, level of evidence B).
(3) In case of arterial hypertension rapid lowering of blood pressure during stroke is not recommended (class IIa, level of evidence B).
(4) Labetalol and/or nicardipine is recommended for patients with ICH to maintain systolic blood pressure of <180 mm Hg or mean blood pressure of <130 mm Hg (class IIb, level of evidence B).

Recommendations for Postprocedure Care

(1) Patients should be admitted to an ICU specializing in neurovascular care or a stroke unit after the procedure.
(2) Continuous hemodynamic monitoring should be continued in the ICU or stroke unit (class I, level of evidence B).

APPENDIX A

Basic Standards for Preanesthesia Care (ASA 2005)

These standards apply to all patients who receive anesthesia care. In exceptional circumstances, these standards may be modified. When such is the case, the circumstances shall be documents in the patient's record. An anesthesiologist shall be responsible for determining the medical status of the patient and developing a plan of anesthesia care.

The anesthesiologist, before the delivery of anesthesia care, is responsible for the following:

(1) Reviewing the available medical record.
(2) Interviewing and performing a focused examination of the patient to:
   (a) Discuss the medical history, including previous anesthetic experiences and medical therapy.
   (b) Asses aspects of the patient's physical condition that might affect decisions regarding perioperative risk and management.
(3) Ordering and reviewing pertinent available tests and consultations as necessary for the delivery of anesthesia care.
(4) Ordering appropriate preoperative medications.
(5) Ensuring that consent has been obtained for the anesthesia care.
(6) Documenting in the chart that the above has been performed.

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