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A. INTRODUCTION

The Society for Vascular Surgery® (SVS) is committed to advancing excellence and innovation in vascular health through education, advocacy, research, and public awareness. To that end, the SVS is proud to release its *Management Guide on the Perioperative Care of Patients with Vascular Disease*, which provides a multidisciplinary resource for the perioperative care of patients with vascular disease who require an intervention.

The *Management Guide* is designed to inform physicians and health care providers about the medical management of patients with vascular disease in the perioperative horizon—30-90 days before intervention, during the intervention, and 30-90 days post-intervention.

The *Management Guide* addresses the medical and nonmedical management of patients with vascular disease in the perioperative period. The content includes information and recommendations about the perioperative care for the following conditions and/or procedures, which encompass the most common vascular disorders:

I. Abdominal aortic aneurysms
II. Abdominal non-aortic pathology
III. Thoracic aortic disease
IV. Peripheral arterial disease, including the diabetic foot
V. Carotid/cerebrovascular
VI. Lower extremity venous disease
VII. Venous thromboembolic disease
VIII. Amputation
IX. Thoracic outlet syndrome
X. Dialysis access

In order to develop this *Guide*, the SVS brought together a panel of experts who represent key members of the perioperative team. The panel included vascular surgeons (Rabih Chaer, MD, MS, who served as the chair of the authoring group; Cassius Iyad Ochoa Chaar, MD, MS; Theodore Yuo, MD); anesthesiologists (Marek Brzezinski, MD, PhD; Martin Zammert, MD); vascular medicine specialists (Yogendra M. Kanthi, MD, FAHA, FSVM; Gaurav Parmar, MD, MPH, FACC, FAAFP, RPVI, CPH); vascular nursing (Christine Owen MS, BSN, ACNP-BC, RNFA); and physician assistants (Ken Bush, PA; Erin Hanlon, PA-C). Special thanks to Katharine McGinigle, MD, MPH and Leila Mureebe, MD for their assistance with the conclusion of the guide, and Lisa Cohen, CHCP and Susan K. Flinn, MA, for staffing support.

These experts analyzed existing guidelines, evidence, and protocols from the SVS as well as consensus documents from other stakeholder groups, including the European Society for Vascular Surgery (ESVS), the Society for Vascular Medicine (SVM), the American Society of Anesthesiologists (ASA), the American Heart Association (AHA), the American Diabetes Association (ADA), and the Society for Vascular Nursing (SVN). This analysis informed the development of the *Management Guide.* (Please see Section C for Resources.)

The *Guide* is intended to supplement these documents and existing local practices, not to replace them. It provides guidance that can be used by individual institutions to build their own perioperative management protocols and design educational programming and complements the Enhanced Recovery After Surgery (ERAS) guidelines that the SVS is developing. The document will help facilities address comorbidities and other risk factors that can affect postoperative outcomes and reduce the use of redundant and/or unnecessary tests.

I. Abdominal Aortic Aneurysms

The following types of procedures are used to treat Abdominal Aortic Aneurysm (AAA):

- Endovascular repair: Abdominal Endovascular Aneurysm Repair (EVAR), Iliac branch devices, chimney endovascular aortic repair (ChEVAR), and Fenestrated Endovascular aneurysm repair (FEVAR).
- Open AAA repair: infrarenal, juxtarenal, and paravisceral aneurysm repair (Type IV thoracoabdominal aortic repair).

Preoperative

The steps are mostly similar for endovascular and open AAA repair.

Patient History

The evaluation of a patient with AAA involves a thorough medical, family, and social history to determine the risk factors for expansion and rupture. Careful review of the surgical history is also essential for accurate and timely recognition of AAA disease. Cholecystitis, appendicitis, or pancreatitis may mimic the presentation of a symptomatic aneurysm. In addition, the nature and extent of previous abdominal surgery may influence the operative approach.

The association between cigarette smoking and AAA disease deserves special emphasis. More than 90% of patients with AAA have smoked cigarettes at some point in their lifetime, and AAA is second only to lung cancer in epidemiologic association to cigarette smoking—more closely associated than either cerebrovascular or coronary artery disease. A history of smoking can also potentially impact outcomes post repair.[1]

Physical Examination

Physical examination has only a moderate sensitivity for detecting AAA, depending on the extent of abdominal girth and aneurysm size. The common iliac arteries may also become aneurysmal and palpable in the lower abdominal quadrants. Palpation does not precipitate rupture, and the concern for a symptomatic aneurysm should not preclude thorough examination. An abdominal aneurysm is common (37 - 40%) in patients with popliteal artery aneurysms, as are concurrent distal arterial aneurysms in patients with an AAA.[2] In patients with a suspected or known AAA, the SVS' AAA guidelines recommend the performance of a physical examination that includes an assessment of femoral and popliteal arteries.[3]

Imaging

The diagnosis of AAA is based on imaging and the choice of imaging modality should be based on the patient's condition and optimal institutional protocols.

Computerized tomography (CT) scan imaging is recommended when repair is contemplated based on aneurysm size, rate of growth, or patient symptoms.[3, 4]

CTA offers a detailed visualization of the entire aorta and its surrounding structures. It can distinguish different aortic pathologies and is quick and widely available. CTA is the current "gold standard" for aortic imaging.

Important disadvantages of CTA include the use of nephrotoxic contrast agents and the exposure of patients to ionizing radiation. In patients at increased risk of contrast induced nephropathy, circulating volume expansion with either isotonic sodium chloride or sodium bicarbonate solutions is recommended.

Alternative imaging modalities such as Magnetic Resonance Imaging/Magnetic Resonance Angiography (MRI/MRA) and rarely intravascular ultrasound (IVUS) can be considered prior to EVAR based on the patient's comorbidities, anatomy, and urgency.

The SVS' AAA guidelines recommend using ultrasound, when feasible, as the preferred imaging modality for aneurysm screening and surveillance.[3]

Medical Management and Lifestyle Changes

During AAA surveillance, the SVS guidelines recommend smoking cessation to reduce the risk of AAA growth and rupture. Hypertension should be treated but the guidelines suggest not administering beta blockers, statins, doxycycline, roxithromycin, angiotensin converting enzyme inhibitors, or angiotensin receptor blockers for the sole purpose of reducing the risk of AAA expansion and rupture.[3]

Risk Stratification for Surgery (both cardiac and pulmonary)

Cardiovascular and pulmonary disease remain the leading causes of early and late death after open surgical repair (OSR) or EVAR. Given the risk associated with either OSR or EVAR, it is essential to evaluate the overall operative risk associated with either method of repair. The first step should be to determine whether an active cardiovascular condition exists, which would mandate further assessment and management before planned aneurysm repair. In the absence of an active cardiovascular condition, further testing, as dictated by functional capacity and cardiovascular risk factors, is indicated only if the results will change the planned treatment approach.

The SVS AAA guidelines state that, in patients with active cardiac conditions, including unstable angina, decompensated heart failure, severe valvular disease, and significant arrhythmia, a cardiology consultation is recommended before EVAR or OSR. In patients with significant clinical risk factors, such as coronary artery disease, congestive heart failure, cerebrovascular disease, diabetes mellitus, chronic renal insufficiency, and unknown or poor functional capacity (MET < 4), who are to undergo OSR or EVAR, the guidelines suggest noninvasive stress testing and echocardiography. In addition, the guidelines recommend a preoperative resting 12-lead electrocardiography (ECG) in all patients undergoing EVAR or OSR within 30 days of planned treatment.[3]

Risk Assessment

A multidisciplinary approach to care can improve outcomes. Medical specialists and team members can assist patients with risk factor modification, such as smoking cessation, maintaining glycemic control, normalizing blood pressure and lipid levels, maintaining antiplatelet therapy and fostering participation in exercise programs, thereby promoting a positive patient experience. Discharge planning should be considered at time of surgical planning.[5-9]

a. Cardiac

The SVS AAA guidelines suggest coronary revascularization before aneurysm repair in patients with acute ST-segment or non-ST-segment elevation myocardial infarction (MI), unstable angina, or stable angina with left main coronary artery or three-vessel disease.[3] The same applies in patients with stable angina and two-vessel disease that includes the proximal left descending artery and either ischemia on noninvasive stress testing or reduced left ventricular function (ejection fraction < 50%). In patients who may need aneurysm repair in the subsequent 12 months and in whom percutaneous coronary intervention is indicated, the guidelines suggest a strategy of balloon angioplasty or bare-metal stent placement, followed by 4 to 6 weeks of dual antiplatelet therapy.[7] In summary, a recommendation for percutaneous or surgical intervention for coronary artery disease should follow established clinical practice guidelines, regardless of the need for aneurysm repair. In order to minimize the risk of perioperative coronary stent thrombosis for both bare-metal stents and drug-eluting stents, surgery should be delayed for 14 days after coronary angioplasty and 30 days after a bare-metal stent if dual antiplatelet therapy cannot be continued through the perioperative period. Likewise, open repair should not be performed within 6 months after implantation of a drug-eluting stent if cessation of dual antiplatelet therapy is required.[10]
The guidelines also recommend perioperative transfusion of packed red blood cells if the hemoglobin level is <7 g/dL.[3]

b. Pulmonary

EVAR is better tolerated than OSR, particularly if EVAR is performed under local anesthesia (LA). However, patients with severe chronic obstructive lung disease (COPD) exhibit increased in-hospital mortality, pulmonary complications, major adverse events, and decreased five-year survival whether they are treated with open repair or EVAR.[11]

Smoking cessation is recommended for at least two weeks prior to aneurysm repair. In addition, preoperative pulmonary function studies, including room air arterial blood gas determinations, are suggested in patients with a history of symptomatic COPD, long-standing tobacco use, or inability to climb one flight of stairs.

Administration of pulmonary bronchodilators for at least two weeks before aneurysm repair is suggested in patients with a history of COPD or abnormal results of pulmonary function testing.

c. Renal

Preoperative renal insufficiency is an established risk factor for poor outcome after aneurysm repair. Among patients with moderate renal dysfunction (eGFR of 30-60 mL/min), mortality and

cardiovascular events are more likely for patients treated by OSR than by EVAR.[12] However, outcomes are uniformly poor in the presence of severe renal dysfunction (eGFR < 30 mL/min), regardless of the type of repair. Outcomes are equally poor after EVAR or OSR for the patient requiring dialysis, with a 30-day mortality of 11%.

Several strategies have been recommended to minimize renal injury after EVAR or open repair. Current guidelines recommend pre-procedure and post procedure hydration with normal saline or 5% dextrose for patients at increased risk of contrast induced nephropathy undergoing EVAR, and preoperative hydration in all non-dialysis-dependent patients with renal insufficiency before aneurysm repair.[13, 14]

d. Diabetes Mellitus

Diabetic patients have increased operative mortality after AAA repair, with reduced survival two to five years after surgery, consistent with an increased burden of cardiovascular disease. Whether diabetes is a distinct risk factor for major adverse events or death after OSR or EVAR is not well-defined, however.[15]

Preoperative Labs

Standard complete blood count (CBC), chemistry profile, and coagulation profile are recommended preoperatively. See above for additional recommendations related to renal abnormalities. From a completion standpoint, obtaining a hemoglobin A1C (HgA1c) measure is a good indicator of how controlled the patient's diabetes is.

Genetic Counseling and Screening

Genetic influences in AAA disease have been demonstrated by twin studies and by formal segregation analyses. Genetic predisposition likely represents small contributions from a large number of risk alleles, with the effect dependent on the population under consideration as well as relevant environmental considerations, such as cigarette smoking.[16]

There are no specific genetic testing guidelines for patients with AAA, but the SVS AAA guidelines suggest ultrasound screening for AAA in first-degree relatives of patients who present with an AAA.[3] Screening should be performed in first-degree relatives who are between 65 and 75 years of age or in those older than 75 years and in good health.

Nutrition Evaluation and Optimization

The SVS AAA guidelines recommend optimization of preoperative nutritional status before elective open aneurysm repair if repair will not be unduly delayed. In addition, parenteral nutrition is recommended if a patient is unable to tolerate enteral support seven days after aneurysm repair.

Recommended Preoperative Consultations

The SVS AAA guidelines recommend multimodality treatment for pain management, including epidural analgesia, for postoperative pain control after OSR of an AAA.

Preoperative Medication Adjustment

The SVS AAA guidelines recommend intravenous administration of a first-generation cephalosporin or, in the event of penicillin allergy, vancomycin within 30 minutes before OSR or EVAR. Prophylactic antibiotics should be continued for no more than 24 hours.

In addition, thromboprophylaxis with unfractionated or low-molecular-weight heparin is suggested for patients undergoing aneurysm repair at moderate to high risk for venous thromboembolism and low risk for bleeding.

- *ACE Inhibitors*: given the association of ACE inhibitors and angiotensin receptor antagonists with hypotension on induction of anesthesia, these medications should be held the morning of surgery and restarted after the patient is euvolemic. The SVS AAA guidelines suggest holding angiotensin-converting enzyme (ACE) inhibitors and angiotensin receptor antagonists on the morning of surgery and restarting these agents after the procedure, once euvolemia has been achieved.

- *Beta Blockers*. The SVS AAA guidelines suggest continuation of beta blocker therapy during the perioperative period if it is part of an established medical regimen. If a decision is made to start beta blocker therapy (because of the presence of multiple risk factors, such as hypertension, coronary artery disease, renal insufficiency, and diabetes), initiation should be well in advance (weeks to months) of surgery to allow sufficient time to assess safety and tolerability.

- *Anticoagulation and its reversal*: oral anticoagulation should be discontinued preoperatively to minimize bleeding complication. Direct oral anticoagulants (DOACs) should be held for 48-72 hours before procedure. Warfarin should be discontinued 3-5 days in advance. Consider bridging with parenteral anticoagulation (unfractionated heparin [UFH] or LMWH) in appropriate patients with high thrombosis risk.[17]

- *Diabetes*: The SVS guidelines recommend holding metformin at the time of administration of contrast material among patients with an Estimated Glomerular Filtration Rate (eGFR) of <60 mL/min or up to 48 hours before administration of contrast material if the eGFR is <45 mL/min and restarting no sooner than 48 hours after administration of contrast material as long as renal function has remained stable. This is recommended to prevent metformin-associated lactic acidosis (MALA). Diabetic patients who receive intermediate or long-acting insulin should receive half the scheduled dose when nil per os (NPO) in preparation for surgery. Glycemic control should be considered per the current guidelines of the American Diabetes Association (ADA).[18]

Intraoperative

Anesthesia Management

a. Optimization and Risk Assessment

Patients presenting with abdominal aortic aneurysm often have multiple significant comorbidities such as poorly controlled hypertension, coronary artery disease (CAD) or chronic obstructive lung disease (COPD) due to long standing smoking. These comorbidities may significantly impact the anesthesia plan.

Patients with significant CAD and congestive heart failure may benefit from intraoperative transesophageal echocardiogram (TEE) to evaluate for regional wall motion abnormalities and left heart strain during cross clamping.

Acute blood loss may precipitate intraoperative myocardial ischemia (MI) in patients with significant CAD. Moderate to severe COPD predisposes patients to postoperative respiratory complications after open AAA repair.

b. Anesthesia Management for Open AAA Repair

i) Anesthesia Techniques for Open AAA Repair

Open aortic aneurysm repair is performed under general endotracheal anesthesia.

Preoperative placement of an epidural catheter allows for intraoperative sparing of opioids as well as postoperative pain control and may help improve outcome.[19-21]

Maintenance of anesthesia can be accomplished using volatile anesthetics such as sevoflurane and desflurane or with a propofol drip. Opioids like fentanyl or sufentanil can be used for intraoperative pain control. Non-steroidal drugs such as ketorolac or ibuprofen may need to be avoided depending on the risk of kidney injury and bleeding

Most patients can be extubated in the operating room (OR) after open AAA repair.

If an epidural catheter could not have been placed preoperatively, bilateral transversus abdominal plane blocks (TAP blocks) can be placed in the operating room prior to emerging from anesthesia to facilitate postoperative pain management.

ii) Monitoring and Access

Standard monitoring of oxygen saturation (SaO2), EKG, non-invasive blood pressure (BP), and temperature.

- *Invasive Arterial Blood Pressure Monitoring*: Placement of an arterial catheter pre-induction allows for tight blood pressure and impulse control in particular during induction of anesthesia and endotracheal intubation. Arterial access also allows for intraoperative blood draws for Activated Clotting Time (ACT) measurements.

- *Central Venous Catheter (CVL)*: The use of vasoactive drugs for tight blood pressure control may require the placement of a CVL after induction of anesthesia.

- *Large Bore Intravenous (IV) Access*: the possibility of acute intraoperative blood loss requires large bore intravenous access for volume resuscitation.

iii) Intraoperative Concerns

Renal protection during suprarenal aortic cross-clamping remains a controversial topic and thus no recommendations have been included in recent guidelines.[3, 21] Renal cooling techniques or the use of fenoldopam or mannitol have been considered nephroprotective to some degree in smaller studies.[22, 23]

Prior to release of the cross clamp, the administration of an intravenous fluid bolus (500ml crystalloid or colloid infusion) can mitigate the effects of central hypovolemia caused by aortic cross clamping and the subsequent release of the clamp. Close communication between the surgery and anesthesia teams is crucial to avoid wide fluctuations in blood pressure during reperfusion. The surgeon may have to manually clamp the aorta and slowly release pressure if the patient develops profound hypotension to allow the anesthesiologist to catch up with resuscitation.

c. Anesthesia Management for Endovascular AAA Repair

i) Anesthesia Techniques for Endovascular AAA Repair

The endovascular approach to AAA can be performed under a variety of anesthesia techniques. General endotracheal anesthesia may be best suited to better control respiration and improve imaging quality.

Maintenance of anesthesia can be accomplished using volatile anesthetics, such as sevoflurane and desflurane, or with a propofol drip. Opioids like fentanyl or sufentanil can be used for intraoperative pain control. Non-steroidal drugs, such as ketorolac or ibuprofen, may need to be avoided depending on the risk of kidney injury and bleeding.

Depending on the femoral access approach (percutaneous or cut down), EVAR can be performed under local anesthesia, regional anesthesia (RA) with a nerve plexus block such as ilioinguinal plexus block, or neuraxial anesthesia in the form of epidural or spinal anesthesia. In patients with contained ruptured AAA, the use of regional or local anesthesia may improve outcomes (IMPROVE trial).[24, 25]

The ilioinguinal nerve plexus block can be performed by the surgeon in the sterile field.[26]

Both the iliohypogastric and the ilioinguinal nerves originate from the nerve root of L1 and perforate the transverse abdominis muscle near the anterior part of the iliac crest. In the anterior abdominal wall, the nerves travel between the transverse abdominis and the internal oblique muscles. The nerve bundle can be visualized using ultrasounds and the injection of 10-20 ml of local anesthetic (e.g., mepivacaine, ropivacaine or bupivacaine) will anesthetize the groin area, as well as the lower portion of the abdominal wall and the upper thigh.

Local anesthesia or regional anesthesia technique can be supplemented with mild to moderate sedation with a propofol or dexmedetomidine drip for patient comfort.

ii) Monitoring and Access

Invasive arterial blood pressure monitoring pressure is performed by placing an arterial catheter pre-induction allows for tight blood pressure and hemodynamic impulse control, especially during induction of anesthesia and endotracheal intubation.

The need for vasoactive drugs as well as significant blood loss is rare during EVAR, hence the placement of central venous catheters is rarely needed. Large bore intravenous access should be adequate to the anticipated blood loss.

iii) Intraoperative Concerns

The need for holding respiration during intraprocedural imaging may make neuromuscular blockade necessary.

d. General and Procedure-Specific Concerns

General intra-operative concerns: Skin preparation (Chlorhexidine [CHG] wipe timeout for three minutes to dry), Foley placed by trained staff, shaving performed with clippers, maintenance of normothermia.

Techniques to minimize contrast nephropathy for endovascular procedures in patients with chronic kidney disease (CKD) include perioperative hydration, the use of carbon dioxide (CO2) imaging as needed, minimizing the use of contrast agent, and the possible use of intravascular ultrasound for imaging.

Techniques to minimize paralysis following endovascular repair include lumbar drain insertion for high risk thoracoabdominal aneurysm repair, as well as Electroencephalography/somatosensory-evoked potentials (EEK/SSEP) monitoring in patients who are at-risk for spinal cord ischemia.

Postoperative

Steps Prior to Discharge

- *General steps include:*
  - Foley removal as soon as possible (ASAP)
  - Pulmonary toilet
  - Perioperative glycemic control as indicated
  - Ambulation instruction, physical therapy as needed
- *Wound Care: I*f applicable (e.g., incisional negative pressure dressing, dry dressing, steps to prevent wound breakdown)
- *Medication:* Resumption of home medications and antithrombotic medications, as indicated.

Steps After Discharge

- *Follow-up:* Follow up call within the first week after surgery.
- *Office / Telehealth Visit*: Follow-up within one month postoperative, unless indicated sooner.
- *Medication:* The use of long-term medications and smoking cessation efforts can be coordinated with the patient's primary care provider and can include the use of statins or a proprotein convertase subtilisin/kexin type 9 (PCSK9) inhibitor in order to achieve optimal low-density lipoprotein (LDL) control. In addition, anti-platelet agents, anti-hypertensive agents, and agents for glycemic control should be prescribed, as indicated.
- *Imaging:* Most patients especially after endovascular repair receive a CT angiogram and or duplex ultrasound to assess for endoleak at one month after surgery.

II. Abdominal Non-Aortic Pathology

These pathologies include chronic mesenteric disease , acute mesenteric ischemia, and renovascular disease.

A. Preoperative

Patient History

The patient history should include any previous history of smoking, hypertension (HTN), hyperlipidemia, and presence of other atherosclerotic diseases. In addition, it is important to assess nutritional status preoperatively, and assess for symptomatic vs. asymptomatic status to determine the need for revascularization, and for acute vs. chronic vs. sub-acute onset.

Mesenteric occlusive disease
In patients with mesenteric ischemia, assessment of the presence of other more common causes of abdominal pain should be included (peptic ulcer disease, cholelithiasis, diverticular disease, etc.).

Specific elements of the history should be assessed for certain conditions:

- *Chronic Mesenteric Disease:* Symptomatic patients should undergo timely revascularization for symptom relief (i.e., post-prandial pain, unexplained weight loss, food fear, etc.), to prevent bowel infarction, or to prevent further weight-loss. Asymptomatic patients may be considered for revascularization if they have severe multi vessel disease or if they require aortic surgery for other indications.

- *Acute Mesenteric Ischemia (AMI):* Differentiate between Acute Superior Mesenteric Artery (SMA) embolism vs. SMA thrombosis vs. Non-Occlusive Mesenteric Ischemia (NOMI).

Renovascular disease
A history of early onset, resistant, accelerated, or malignant hypertension should be obtained. In addition, inquire about unexplained renal insufficiency, ischemic nephropathy, renal atrophy, flash pulmonary edema, or cardiac perturbation syndromes.[27]

Physical Examination

Abdominal bruit may be noted in approximately 50% of patients with visceral occlusive disease, but it is non-specific and a marker of systemic atherosclerosis.[28]

A classic finding of "pain out of proportion to physical exam" is absent in about one-quarter of patients with Acute Mesenteric Ischemia (AMI). A high level of clinical suspicion is needed to establish the diagnosis.

In patients with renovascular disease, peripheral edema can be noted, in addition to an abdominal bruit or diminished lower-extremity pulses.

Imaging

While a detailed discussion of the imaging studies to appropriately diagnose the pathology is beyond the scope of this project, duplex ultrasound and computed tomography angiography (CTA) are the two most commonly used imaging studies to confirm the diagnosis.
While there are established ultrasound criteria for renovascular and visceral occlusive disease, this is limited by operator dependence, patient body habitus and fasting status, and a high negative predictive value.[29] CTA is more accurate but can be detrimental in patients with baseline renal insufficiency and can also be limited by the presence of heavy calcifications.

Diagnostic angiogram is typically done at the time of a planned endovascular intervention.

Medical Management and Lifestyle Changes

Patients typically have systemic vascular disease and associated comorbidities. Accordingly, patients undergoing invasive treatment should undergo an expedited preoperative evaluation designed to optimize their underlying medical conditions and management of their atherosclerotic risk factors. Patients with mesenteric ischemia may benefit from enteral or parenteral nutritional supplements, although this should not delay or prolong the preoperative evaluation before definitive revascularization.

The associated comorbidities and risk factors, including smoking cessation, should be managed optimally before revascularization, similar to patients undergoing any major vascular surgical procedures.[7, 30]

The use of long-term medications can be coordinated with the patient's primary care physician and can include the use of statins or a PCSK9 inhibitor in order to achieve optimal LDL control. In addition, anti-platelet agents, anti-hypertensive agents, and agents for glycemic control should be prescribed, as indicated. Dual antiplatelet therapy (DAPT) should be considered if stenting is anticipated.

Risk Stratification for Surgery

The associated comorbidities and risk factors should be managed optimally before any revascularization for Chronic Mesenteric Ischemia (CMI), similar to patients undergoing any major vascular surgical procedures. There are well-accepted, published guidelines from most of the medical subspecialties to guide the preoperative evaluation, including those from the American Heart Association (AHA) and the American College of Cardiology (ACC) for the optimal preoperative cardiac evaluation for patients undergoing major noncardiac surgery.[31, 32]

Patients with active cardiac conditions, including unstable angina, recent myocardial infarction, significant arrhythmias, poorly compensated congestive heart failure, and/or significant valvular disease should be seen in consultation with a cardiologist and may benefit from preoperative cardiac intervention. Patients should be counseled about the importance of smoking cessation and should be treated with an antiplatelet agent and a cholesterol-lowering agent, preferentially a statin, unless there are specific contraindications.

Patients with imaging consistent with mesenteric occlusive disease and atypical symptoms should undergo a gastrointestinal evaluation to rule out non-vascular causes of their symptoms.

Risk Assessment

A multidisciplinary approach to care will provide best outcomes. Team members (nurses, physician extenders) must be familiar with the disease process to efficiently counsel and educate patients and families. Team members and specialty consultants can assist patients with risk factor modification, such as smoking cessation, maintaining glycemic control, normalizing blood pressure and lipid levels, maintaining antiplatelet therapy and fostering participation in exercise programs, thereby promoting a positive patient experience. Discharge planning should be considered at time of surgical planning.[5-9]

Acute Care Surgery consultation should be considered for patients with Acute Mesenteric Ischemia (AMI) if bowel resection is anticipated.

Preoperative Labs

Recommended preoperative labs include:

- Standard CBC, chemistry profile and coagulation profile
- Albumin/pre-albumin for nutritional status
- 12-lead electrocardiogram (EKG)
- Lipid panel and HbA1c.

In addition, if applicable, consider testing for Clopidogrel resistance, as indicated.

For AMI, preoperative labs include Lactic acid, Anion gap, and D-dimers.

It should be noted, with respect to AMI, that the following have no evidence of use yet: Serum intestinal fatty acid-binding protein (iFABP) and Urinary ileal bile acid-binding protein (I-BABP).

Preoperative Medication Adjustment

- *Medication Adjustment:*
    - Start Acetylsalicylic Acid (ASA, Aspirin) 75-100 mg/day
    - Start high-intensity statins: Atrovastatin 40-80 mg/day or Rosuvastatin 20-40 mg/day
    - Antibiotics: Broad spectrum coverage in cases of bowel infarction/contaminated cases.

- *Renovascular Disease*: strategies to minimize nephropathy include:[13, 14]
    - Ensuring adequate IV hydration.
    -

- *ACE Inhibitors*: If significant volume depletion is anticipated, it is suggested to hold ACE

inhibitors and angiotensin receptor antagonists on the morning of surgery and restarting these agents after the procedure, once euvolemia has been achieved.

- *Diabetes Mellitus:* It is suggested to hold metformin at the time of administration of contrast material among patients with an eGFR of <60 mL/min or up to 48 hours before administration of contrast material if the eGFR is <45 mL/min and restarting no sooner than 48 hours after administration of contrast material as long as renal function has remained stable. Diabetic patients who receive intermediate or long-acting insulin should receive half the scheduled dose when nil per os (NPO) in preparation for surgery. Glycemic control should be considered per the current guidelines of the American Diabetes Association.[18]

B. Intraoperative

Anesthesia Management

a. Optimization and Risk Assessment

Patients who present with chronic or acute mesenteric ischemia or renovascular disease often present with multiple significant comorbidities such as poorly controlled hypertension, CAD or COPD due to long standing smoking. These comorbidities may significantly impact the anesthesia plan.

Patients with significant CAD and congestive heart failure may benefit from intraoperative TEE to evaluate for regional wall motion abnormalities and left heart strain during cross clamping.

Acute blood loss may precipitate intraoperative myocardial ischemia in patients with significant CAD. Moderate to severe COPD predisposes patients to postoperative respiratory complications after open abdominal surgery.

Gastric emptying may be delayed increasing the risk of aspiration upon induction of anesthesia.

b. Anesthesia Management for Open Procedures

i) Anesthesia Techniques for Open Procedures

Open abdominal procedures are usually performed under general endotracheal anesthesia. Maintenance of anesthesia can be accomplished using volatile anesthetics, such as sevoflurane and desflurane, or with a propofol drip. Opioids (i.e., fentanyl or sufentanil) can be used for intraoperative pain control. Non-steroidal drugs, such as ketorolac or ibuprofen, may need to be avoided depending on the risk of kidney injury.

Preoperative placement of an epidural catheter allows for intraoperative sparing of opioids as well as postoperative pain control.

Most patients can be extubated in the operating room after open abdominal vascular surgery.

If an epidural catheter could not have been placed preoperatively, bilateral TAP blocks can be placed in the operating room prior to emerging from anesthesia to facilitate postoperative pain management.[33]

ii) Monitoring and Access (Open)

Standard monitoring of SaO_2, EKG, non-invasive BP, and temperature.

- *Invasive Arterial blood pressure monitoring pressure*: Placement of an arterial catheter may be necessary due to cardiac comorbidities. Arterial access also allows for intraoperative blood draws for ACT measurements.

- *Central venous catheter*: The use of vasoactive drugs for tight blood pressure control may require the placement of a CVL after induction of anesthesia.

- *Large bore IV access*: The possibility of acute intraoperative blood loss requires large bore intravenous access for volume resuscitation.

iii) Intraoperative Concerns (Open)

- Patients should be well-hydrated and administered prophylactic antibiotics, typically against skin and also enteric organisms in contaminated cases. Bowel preparations should likely be avoided owing to the theoretical risk of dehydration.

- Aortic cross clamping usually has less effects on blood pressure in occlusive aortic disease than in non-occlusive disease.

- Renal protection during suprarenal aortic cross-clamping remains a controversial topic and thus no recommendations have been included in recent guidelines.[3, 21] Renal cooling techniques or the use of fenoldopam or mannitol have been considered nephroprotective to some degree in smaller studies.[22, 23]

- In addition, intraoperative TEE may be indicated to assess left ventricular function during aortic cross-clamping and monitor for wall motion abnormalities indicative of myocardial ischemia, depending on the patient's comorbidities.[34, 35]

Prior to release of the cross clamp, the administration of an intravenous fluid bolus (500ml crystalloid or colloid infusion) can mitigate the effects of central hypovolemia caused by the various physiological of aortic cross clamping and the subsequent release of the clamp. Intraoperative duplex U.S. surveillance for open procedures (mesenteric or renal) can be considered.

Intraoperative papaverine or glucagon is not recommended yet for splanchnic vasodilatation but can be used on a case-by-case basis.

Consider hybrid approaches—such as retrograde open mesenteric stenting (ROMS)—in patients requiring bowel resection for ischemic bowel given the contaminated field.

c. Anesthesia Management for Endovascular Procedures

i) Anesthesia Techniques for Endovascular Procedures

Endovascular approach can be performed under a variety of anesthesia techniques. General endotracheal anesthesia may be best-suited if holding respiration to improve imaging quality is warranted. Depending on the percutaneous or cut-down approach, endovascular procedures can be performed under local anesthesia; regional anesthesia with a nerve plexus block, such as ilioinguinal plexus block; or neuraxial anesthesia in the form of epidural or spinal anesthesia.

The ilioinguinal nerve plexus block can be performed by the surgeon in the sterile field.

Both the iliohypogastric and the ilioinguinal nerves originate from the nerve root of L1 and perforate the transverse abdominis muscle near the anterior part of the iliac crest. In the anterior abdominal wall, the nerves travel between the transverse abdominis and the internal oblique muscles. The nerve bundle can be visualized using ultrasounds and the injection of 10-20 ml of local anesthetic (e.g., mepivacaine, ropivacaine or bupivacaine) will anesthetize the groin area, as well as the lower portion of the abdominal wall and the upper thigh.

Local anesthesia or regional anesthesia technique can be supplemented with mild to moderate sedation with a propofol or dexmedetomidine drip for patient comfort.

ii) Monitoring and Access

Standard monitoring of SaO_2, EKG, non-invasive blood pressure and temperature.

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- *Central venous catheter*: The use of vasoactive drugs for tight blood pressure control may require the placement of a CVL after induction of anesthesia.

- *Large bore IV access*: The possibility of acute intraoperative blood loss requires large bore intravenous access for volume resuscitation.

d. General and Procedure-Specific Concerns

General intraoperative concerns: Skin preparation (CHG wipe timeout for three minutes to dry), Foley placed by trained staff, shaving performed with clippers, maintenance of normothermia.

Postoperative

Steps Prior to Discharge

a. Open Procedures

- Patients might require a stay in the intensive care unit (ICU) in order to be monitored for cardiopulmonary and gastroenterological complications.
- Suspicion for graft failure and bowel ischemia should prompt immediate CT, abdominal re-exploration for mesenteric ischemia, or flexible sigmoidoscopy for colonic ischemia.
- Post-procedure ileus may be prolonged in some patients (~10%), who will require Total Parenteral Nutrition (TPN) support.

b. Endovascular Procedures

- Those procedures can be done on an outpatient basis, or with overnight observation, depending on the patient's need for hydration and the type of access or need for access site observation.

Steps After Discharge

- *Follow-up:* Follow up call within the first week after surgery.
- *Office / Telehealth Visit*: Follow-up within a month postoperative, unless indicated sooner.
- *Medication:*
  - The use of long-term medications can be coordinated with the patient's primary care provider and can include the use of statins or a PCSK9 inhibitor in order to achieve optimal LDL control. In addition, anti-platelet agents, anti-hypertensive agents, and agents for glycemic control should be prescribed, as indicated.
  - For patients treated with endovascular intervention, DAPT should be considered with ASA+Clopidogrel for 6-8 weeks, or longer if a covered stent was used. Use an alternative agent such as Ticagrelor (Brilinta) in patients who have a resistance to Clopidogrel.
- *Imaging*: Most patients receive ultrasound surveillance of the treated artery at one month.

III. Diseases of the Descending Thoracic Aorta

These diseases include thoracic aortic aneurysm (TAA), aortic dissection (AD), penetrating aortic ulcer (PAU) traumatic aortic injury, and intramural hematoma.

Preoperative

Patient History

Thoracic aortic aneurysms (TAA), are more common in elderly males with peak incidence in the sixth decade of life.[36-41] AD, and intramural hematoma (IMH) are also more common in males aged 40-70 years, with a peak in the range of 50-65 years. Patients commonly present with chest pain or interscapular back pain, in the setting of severe hypertension. Some patients with AD could have symptoms of abdominal pain, flank pain, or acute lower limb ischemia suggestive of malperfusion.

A comprehensive medical and family history, focusing on cardiac disease and, as well as a history of uncontrolled hypertension, trauma, or aneurysm disease can help establish the diagnosis.

A history of drug use, particularly methamphetamine in young patients with thoracic aortic dissections, should be elicited.

A history of prior open or endovascular abdominal aortic repair is particularly important to note as it increases the risk of spinal cord ischemia during TAA repair.

Patients with fever, chills and night sweats should raise the suspicion for mycotic aneurysm or aortitis. Alternatively, some vasculitis such as Takayasu and giant cell arteritis have been reported to affect the aorta and its main branches causing stenosis, aneurysms, and dissections.

Patients presenting with hemoptysis or hematemesis could have an aortobronchial or aortoesophageal fistula, respectively. A Kommerell diverticulum is a rare aortic dilatation affecting the origin of an aberrant right subclavian artery that can cross posterior to the esophagus and cause dysphagia (dysphagia lusoria) or recurrent laryngeal nerve palsy. Hoarseness has been also reported with large descending thoracic aneurysms.

Physical Examination

A careful physical examination including pulse (upper and lower) symmetry, malperfusion (abdomen), signs of stroke (ascending dissection) and blood pressure measurement in both arms, is required in all patients suspected of thoracic aortic disease. Patients should be examined for clinical signs of cardiac compromise, such as aortic regurgitation, cardiac murmur, pericardial rub, signs of tamponade, as well as abdominal aortic expansion. Synchronous aneurysms tend to occur in other anatomic locations; thus, palpation of the abdomen and popliteal fossa for aneurysms should be a routine part of the physical examination.

All patients should undergo a detailed physical examination designed to detect the presence of a

genetic syndrome associated with AD or TAA (e.g., Marfan, Loeys-Dietz, Ehlers-Danlos, or Turner syndrome). Physical examination should include special attention to the presence of palpable femoral pulses and other potential access sites to deliver the endovascular repair (TEVAR).

Imaging

The diagnosis of thoracic aortic disease is based on imaging and the choice of imaging modality should be based on the patient's condition and optimal institutional protocols.

CTA offers a detailed visualization of the entire aorta and its surrounding structures. It can distinguish different aortic pathologies and is quick and widely available. CTA has replaced digital subtraction aortography (DSA) as the "gold standard" for aortic imaging.[40, 41] The CTA should include the chest abdomen and pelvis and to assess the access vessels (iliac and femoral arteries). Current guidelines recommend that all patients with clinical suspicion of thoracic aortic disease and abnormal chest radiograph should undergo CTA for diagnosis confirmation.[36]

Important disadvantages of CTA include the use of nephrotoxic contrast agents and the exposure of patients to ionizing radiation. In patients at increased risk of contrast induced nephropathy, circulating volume expansion with either isotonic sodium chloride or sodium bicarbonate solutions is recommended.

Postero-anterior and lateral chest radiographs can be used to diagnose calcification within atheromatous lesions, left pleural effusions, aortic enlargement, and anomalous aortic contours in asymptomatic or symptomatic patients. A left pleural effusion can indicate a frank rupture, an exudate from inflammation of the adventitia or, less commonly, inflammatory aortic disease.

Although chest X-rays might be used in very low-risk patients to exclude thoracic aortic diseases, these potentially lethal diseases require a conclusive diagnosis with the use of multiplanar imaging techniques such as computed tomographic angiography (CTA).

The use of Transthoracic echocardiography to assess the descending thoracic aorta (DTA) is limited by structures in the thorax that weaken or distort the ultrasound signal and compromise image quality. Transesophageal echocardiography can visualize the DTA from the left subclavian artery to the celiac artery. This diagnostic test is generally used as a second line imaging modality and is useful to differentiate between AD, IMH, and penetrating aortic ulcer (PAU).

The semi-invasive nature of transesophageal echocardiogram (TEE) has rare procedure related risks, but it can cause patient discomfort, requires sedation, and is contraindicated in the presence of esophageal pathologies. In the majority of cases, CTA scanning is performed as the first imaging modality, providing all required information. TEE may be used in specific circumstances as a second line option.

Alternative imaging modalities such as Magnetic Resonance Imaging/Magnetic Resonance Angiography (MRI/MRA) and rarely intravascular ultrasound (IVUS) can be considered based on the patient's comorbidities, anatomy, and urgency.

Medical Management and Lifestyle Changes

Medical management of patients with thoracic aortic disease includes control of hypertension and heart rate to control cardiac impulse statin therapy/lipid optimization, and smoking cessation, and investigation of the underlying cause of disease (aortitis, penetrating aortic ulcer/intramural hematoma, connective tissue disorder, genetic etiology, etc.).

Medical therapy with antihypertensive agents is widely used as a first-line treatment in patients with aortic disease. Blood pressure control is based on anti-impulse therapy to limit the ventricular ejection force and the aortic wall stress and is eespecially important in cases of symptomatic aneurysms or acute aortic syndromes. Beta blockers such esmolol or labetalol are considered first line therapy. The goal of therapy is to reduce the systolic blood pressure to <120 mm Hg and the heart rate to <60 beats/min, when possible, prior to surgery. This is usually achieved with intravenous beta blockers (or alpha/beta blockers) as first-line therapy. For patients who do not respond to, or are intolerant of beta blockers, calcium channel blockers or angiotensin-converting enzyme inhibitors or blockers can be used as alternatives or adjuncts.

For patients with dyslipidemia, treatment with a statin to achieve a target low-density lipoprotein cholesterol level of <70 mg/dL is reasonable and may be helpful in controlling the progression of aneurysms. Counseling for smoking cessation, reduction of environmental tobacco exposure, referral to special programs for cognitive-behavioral therapy, initiation of pharmacotherapy, or, preferably, multimodal management to achieve complete tobacco abstinence is strongly recommended for patients who have active tobacco use or exposure.[7, 40, 41] Tobacco exposure cessation and abstinence is imperative to reduce progression of aortic aneurysmal disease.

Risk Stratification for Surgery (cardiac and pulmonary)

Preoperative workup in patients undergoing open surgical (OSR) and endovascular repair (TEVAR). The preoperative cardiac assessments should follow the general recommendation of the American College of Cardiology/American Heart Association (ACC/AHA) guidelines.[31]

Cardiovascular and pulmonary disease remain the leading causes of early and late death after OSR or TEVAR. Given the risk associated with either OSR or EVAR, it is essential to evaluate the overall operative risk associated with either method of repair.[31] The first step should be to determine whether an active cardiovascular condition exists, which would mandate further assessment and management before planned aneurysm repair. In the absence of an active cardiovascular condition, further testing, as dictated by functional capacity and cardiovascular risk factors, is indicated only if the results will change the planned treatment approach.

Current guidelines state that in patients with active cardiac conditions, including unstable angina, decompensated heart failure, severe valvular disease, and significant arrhythmia, a cardiology consultation is recommended before TEVAR or OSR.[41] In patients with significant clinical risk factors, such as coronary artery disease, congestive heart failure, cerebrovascular disease, diabetes mellitus, chronic renal insufficiency, and unknown or poor functional capacity (MET < 4), who are to undergo OSR or TEVAR, the guidelines suggest noninvasive stress testing. In addition, the guidelines recommend a preoperative resting 12-lead ECG in all patients undergoing TEVAR or OSR within 30 days of planned treatment.

Risk Assessment

A multidisciplinary approach to care can improve outcomes. Medical specialists and team members can assist patients with risk factor modification, such as smoking cessation, maintaining glycemic control, normalizing blood pressure and lipid levels, maintaining antiplatelet therapy and fostering participation in exercise programs, thereby promoting a positive patient experience. Discharge planning should be considered at time of surgical planning. (Fleisher LA, Fleischmann KE)

a. Cardiac

Current guidelines suggest continuation of beta blocker therapy during the perioperative period if it is part of an established medical regimen.[41] If a decision is made to start beta blocker therapy (because of the presence of multiple risk factors, such as coronary artery disease, renal insufficiency, and diabetes), initiation should be well in advance of surgery to allow sufficient time to assess safety and tolerability.

The SVS guidelines suggest coronary revascularization before aneurysm repair in patients with acute ST-segment or non-ST-segment elevation MI, unstable angina, or stable angina with left main coronary artery or three-vessel disease.[41] The same applies in patients with stable angina and two-vessel disease that includes the proximal left descending artery and either ischemia on noninvasive stress testing or reduced left ventricular function (ejection fraction < 50%).

In patients who may need aneurysm repair in the subsequent 12 months and in whom percutaneous coronary intervention is indicated, the guidelines suggest a strategy of balloon angioplasty or bare-metal stent placement, followed by 4 to 6 weeks of dual antiplatelet therapy.

b. Pulmonary

TEVAR is better tolerated than OSR, particularly if TEVAR is performed under local anesthesia. However, patients with severe COPD exhibit increased in-hospital mortality, pulmonary complications, major adverse events, and decreased five-year survival whether they are treated with open repair or TEVAR.

Smoking cessation is recommended for at least two weeks prior to aneurysm repair. In addition, preoperative pulmonary function studies, including room air arterial blood gas determinations, are suggested in patients with a history of symptomatic COPD, long-standing tobacco use, or inability to climb one flight of stairs. Administration of pulmonary bronchodilators for at least 2 weeks before aneurysm repair is suggested in patients with a history of COPD or abnormal results of pulmonary function testing.

Although there are few supporting data, in trying to determine whether a patient with severe COPD is a candidate for open TAA repair or TEVAR, the SVS guidelines recommend considering pulmonary function testing preoperatively in an attempt to determine baseline pulmonary function, if general endotracheal anesthesia is being considered, to determine risk of ventilator dependency postoperatively and ultimately to guide the choice of anesthesia.[41]

c. Renal

Preoperative renal insufficiency is an established risk factor for poor outcome after aneurysm repair.[13, 14]
Current guidelines recommend pre-procedure and post-procedure hydration with normal saline or 5% dextrose for patients at increased risk of contrast induced nephropathy undergoing TEVAR, and preoperative hydration in all non-dialysis-dependent patients with renal insufficiency before aneurysm repair.[41]

d. Diabetes Mellitus

Diabetic patients have increased operative mortality after TAA repair, with reduced survival two to five years after surgery, consistent with an increased burden of cardiovascular disease. Whether diabetes is a distinct risk factor for major adverse events or death after OSR or TEVAR is not well-defined, however.

Preoperative Labs

Standard CBC, chemistry profile and coagulation profile are recommended preoperatively.

Serial troponins in patients presenting with chest pain to rule out myocardial infarction.

The SVS guidelines also recommend perioperative transfusion of packed red blood cells if the hemoglobin level is <7 g/dL.[41]

Preoperative Medication Adjustment

- Current guidelines recommend intravenous administration of a first-generation cephalosporin or, in the event of penicillin allergy, vancomycin within 30 minutes before OSR or TEVAR.[41] Prophylactic antibiotics should be continued for no more than 24 hours.

- In addition, thromboprophylaxis with unfractionated or low-molecular-weight heparin is suggested for patients undergoing aneurysm repair who are moderate- to high-risk for venous thromboembolism and low-risk for bleeding.

- *ACE Inhibitors*: If significant volume depletion is anticipated, it is suggested to hold ACE inhibitors and angiotensin receptor antagonists on the morning of surgery and restarting these agents after the procedure, once euvolemia has been achieved.

- *Diabetes Mellitus:* It is suggested to hold metformin at the time of administration of contrast material among patients with an eGFR of <60 mL/min or up to 48 hours before administration of contrast material if the eGFR is <45 mL/min and restarting no sooner than 48 hours after administration of contrast material as long as renal function has remained stable. This is recommended to prevent metformin-associated lactic acidosis (MALA). Diabetic patients who receive intermediate or long-acting insulin should receive

half the scheduled dose when nil per os (NPO) in preparation for surgery. Glycemic control should be considered per the current guidelines of the American Diabetes Association.[18]

Genetic Counseling and Screening

Genetic predisposition in descending thoracic aortic aneurysm disease likely represents small contributions from a large number of risks alleles but is important to consider in certain populations (i.e., age <60, signs suggestive of connective tissue disorder, family history of aneurysm or sudden death, etc.).

It is important to note that classical physical exam findings of connective tissue disorder are only seen in a minority of patients with genetic thoracic aortic aneurysm and dissection (TAAD).[42] Referral to a genetic counselor or medical geneticist should be routinely incorporated into the care plans for patients with clinical or historic features of genetic TAAD.

Specific screening and surveillance recommendations should be followed for patients with a personal or family history of genetic syndromes, such as Marfan syndrome, Ehlers-Danlos syndrome, Loeys-Dietz syndrome, Familial Thoracic Aortic disease, or Turner syndrome.

Nutrition Evaluation and Optimization

Current guidelines recommend optimization of preoperative nutritional status before elective open aneurysm repair if repair will not be unduly delayed.[41]

In addition, parenteral nutrition is recommended if a patient is unable to tolerate enteral support seven days after aneurysm repair.

Recommended Consultations (pain management, GMT, tobacco)

Current guidelines recommend multimodality treatment for pain management, including epidural analgesia, for postoperative pain control after OSR of an TAA.[41]

Intraoperative

General:

- Shaving performed with clippers
- Skin preparation: CHG wipe timeout for three minutes to dry
- Perioperative antibiotics are weight based and initial dose should be administered prior to incision.
- Foley is placed by trained staff
- The placement of large bore IV access and arterial line for hemodynamic monitoring is recommended.
- A number of prevention strategies have been employed to mitigate risk of spinal cord injury (SCI), including preservation of the left subclavian artery and hypogastric patency, staging strategies for long-segment aortic coverage, prophylactic Cerebrospinal Fluid (CSF) drainage, anemia prevention, permissive hypertension, steroid and naloxone therapy, burst suppression, permissive hypothermia, and hyperoxygenation therapy.
- The SVS guidelines recommend increasing perfusion pressure through controlled hypertension (mean arterial pressure >90 mm Hg) as a component of a spinal cord protection protocol in patients at high risk of SCI because of extensive coverage length (>15 cm), poor hypogastric perfusion (occluded or significantly stenosed hypogastric arteries), or coverage of important collaterals (subclavian/hypogastric arteries).[41]
- Somatosensory and motor evoked potentials permit continuous monitoring of the spinal cord's function, assist in the early detection of SCI, and are popular techniques used in high-risk cases but are rarely used in the setting of simple TEVAR.
- Full dose anticoagulation is administered prior to introducing large sheath and when advancing catheters and wires into the arch; ACT is maintained above 200s.
- Normothermia should be maintained intra-operatively.

Anesthesia Management

a. Optimization and Risk Assessment

Patients presenting with thoracic aortic aneurysm disease often have multiple significant comorbidities such as poorly controlled hypertension, coronary artery disease (CAD), and/or chronic obstructive lung disease (COPD) due to long-standing smoking. These comorbidities may significantly impact the anesthesia plan.

Patients with significant CAD and congestive heart failure may benefit from intraoperative TEE to evaluate for regional wall motion abnormalities and left heart strain during cross clamping.

Acute blood loss may precipitate intraoperative myocardial ischemia in patients.

b. Anesthesia Management for Open Procedures

i) Anesthesia Techniques for Open Procedures

Open thoracic aortic aneurysm repair is performed under general endotracheal anesthesia.

Lung isolation and single lung ventilation may be necessary during the procedure. This can be achieved by the placement of a double lumen endotracheal tube (ETT) or the placement of a bronchial blocker. Correct placement of either device and successful lung isolation need to be confirmed by bronchoscopy prior to incision.

Preoperative placement of an epidural catheter allows for intraoperative sparing of opioids as well as postoperative pain control.

Maintenance of anesthesia can be accomplished using volatile anesthetics such as sevoflurane and desflurane or with a propofol drip. Opioids like fentanyl or sufentanil can be used for intraoperative pain control. Non-steroidal drugs such as ketorolac or ibuprofen may need to be avoided depending on the risk of kidney injury.

Most patients are transferred to the Intensive Care Unit intubated after open thoracic aortic repair for further management and weaning of ventilation.

If an epidural catheter could not have been placed preoperatively, intercostal nerve block in the surgical field may be an option to optimize postoperative pain control.

ii) Monitoring and Access

- *Invasive Arterial Blood Pressure Monitoring Pressure*: Placement of an arterial catheter pre-induction allows for tight blood pressure and impulse control particularly during induction. Of anesthesia and endotracheal intubation. Arterial access also allows for intraoperative blood draws for ACT measurements.

- *Central venous catheter*: The use of vasoactive drugs for tight blood pressure control may require the placement of a CVL after induction of anesthesia.

- *Large bore IV access*: The possibility of acute intraoperative blood loss requires large bore intravenous access for volume resuscitation.

iii) Intraoperative Concerns

During aortic cross clamping, the blood pressure should be kept high, above the patient's baseline, in order to promote collateral blood flow to the kidneys. This may not be needed in patients who undergo an atrio-femoral bypass to maintain visceral perfusion.

Renal protection during suprarenal aortic cross-clamping remains a controversial topic and thus no recommendations have been included in recent guidelines.[3, 21] ischemia can be reduced by using bypass modalities such as axillo-femoral bypass or partial cardiopulmonary bypass,

Prior to release of the cross clamp the administration of an intravenous fluid bolus (500ml crystalloid or colloid infusion) can mitigate the effects of central hypovolemia caused by aortic cross clamping and the subsequent release of the clamp if no bypass technique was used.

Acute hypoxemia during single-lung ventilation may require for intermittent inflation of the operative lung, and the need for holding respiration during intraprocedural imaging may make neuromuscular blockade necessary.

c. Anesthesia Management for Endovascular Procedures (TEVAR)

i. Anesthesia Techniques for Endovascular Procedures

TEVAR can be performed under a variety of anesthesia techniques. General endotracheal anesthesia may be best suited if prolonged episodes of apnea to improve imaging quality are warranted. Maintenance of anesthesia can be accomplished using volatile anesthetics such as sevoflurane and desflurane or with a propofol drip. Opioids like fentanyl or sufentanil can be used for intraoperative pian control. Non-steroidal drugs such as ketorolac or ibuprofen may need to be avoided depending on the risk of kidney injury.

Depending on the percutaneous or cut-down approach, TEVAR can be performed under local anesthesia, regional anesthesia with a nerve plexus block such as ilioinguinal plexus block, or neuraxial anesthesia in the form of epidural or spinal anesthesia.

The ilioinguinal nerve plexus block can be performed by the surgeon in the sterile field.

Both the iliohypogastric and the ilioinguinal nerves originate from the nerve root of L1 and perforate the transverse abdominis muscle near the anterior part of the iliac crest. In the anterior abdominal wall, the nerves travel between the transverse abdominis and the internal oblique muscles. The nerve bundle can be visualized using ultrasounds and the injection of 10-20 ml of local anesthetic (e.g., mepivacaine, ropivacaine or bupivacaine) will anesthetize the groin area, as well as the lower portion of the abdominal wall and the upper thigh.

Local anesthesia or regional anesthesia technique can be supplemented with mild to moderate sedation with a propofol or dexmedetomidine drip for patient comfort.

ii) Monitoring and Access

Placement of an arterial catheter pre-induction allows for tight blood pressure and impulse control in particular during induction of anesthesia and endotracheal intubation.

The need for vasoactive drugs as well as significant blood loss is rare during TEVAR procedure, hence the placement of central venous catheters is rarely needed. Intravenous access should be adequate to the anticipated blood loss.

d. General & Procedure-Specific Concerns

General intraoperative concerns: Skin preparation (CHG wipe timeout for three minutes to dry), Foley placed by trained staff, shaving performed with clippers, maintenance of normothermia.

Techniques to minimize contrast nephropathy for endovascular procedures in patients with CKD include perioperative hydration, the use of CO2 imaging as needed, minimizing the use of contrast agent, and the possible use of intravascular ultrasound for imaging. One has to be

cognizant of the risk of neurotoxicity related to inadvertent C02 injection into the cerebral circulation. Avoidance of CO2 injection above the diaphragm can minimize the potential complications.

Techniques to minimize paralysis following endovascular repair include lumbar drain insertion for TAA/AAA, as well as EEG/SSEP monitoring in patients who are at-risk for spinal cord ischemia.

Placement of prophylactic CSF drainage catheter placement during TEVAR is controversial, and CSF drains should be used as only one part of a multimodal protocol to reduce the risk of SCI. Some authors recommend selective CSF drain placement for only high-risk patients, whereas others perform CSF drain placement preoperatively routinely. The drain is placed below the level of the termination of the cord (L2-L3 or below) and connected to a manometer which should be set at 10cm/H2O, measured from the lumbar drain insertion site.

High-risk features that warrant prophylactic CSF drainage for SCI protection in TEVAR cases include:[38, 39]

- Covering extensive length of descending aorta (more than 15cm);
- Previous aortic coverage, including EVAR and open AAA repair;
- Compromised pelvic perfusion with diseased or occluded common or internal iliac arteries;
- Diseased or occluded vertebral arteries
- Planned left subclavian artery (LSA) coverage; or
- The patient is deemed to be high-risk by the operating surgeon.

Postoperative

Steps Prior to Discharge

- Patients might require a stay in the intensive care unit (ICU) in order to be monitored for cardiopulmonary complications and in order to achieve optimal blood pressure control.
- Prophylactic lumbar drains can be monitored for up to 72 hours and are removed by the anesthesia team after any coagulopathy is corrected.

- *General steps include:*
  - Foley removal ASAP
  - Pulmonary toilet
  - Perioperative glycemic control as indicated
  - Ambulation instruction, physical therapy as needed
- *Wound Care:* If applicable (e.g., incisional negative pressure dressing, dry dressing, steps to prevent wound breakdown)
- *Medication:* Resumption of home medications and antithrombotic medications as indicated.

Steps After Discharge

- *Follow-up:* Follow up call within the first week after surgery.
- *Office / Telehealth Visit*: Follow-up within one month postoperative, unless indicated sooner.
    - SVS guidelines recommend contrast enhanced CT scanning at 1 and 12 months after TEVAR and then yearly for life, with consideration of more frequent imaging if an endoleak or other abnormality of concern is detected at 1 month.[41]
    - All patients with thoracic aortic disease require aggressive management of hypertension, secondary prevention of cardiovascular diseases, and close follow up to monitor the evolution of the diseased aorta. In particular, conservatively treated patients are prone to develop progression of disease and patients treated with open repair can develop anastomotic pseudoaneurysm, new para-anastomotic aneurysms, graft infection or graft occlusion. TEVAR may result in stent graft related complications such as endoleak, stent graft migration, or stent graft collapse. The primary importance of the surveillance protocols is to prevent these complications.
    - CTA is the modality most often used for follow-up in DTA disease. However, cumulative lifetime radiation exposure caused by multiple CTA examinations must be taken into account during planning of follow up. In addition, iodinated intravenous contrast agents are associated with nephrotoxic effects. MRI can be used to avoid radiation and iodinated contrast media. MRI compatible stent grafts are a prerequisite, as the presence of stainless-steel implants causes artifacts.
- *Medication:* The use of long-term medications can be coordinated with the patient's primary care provider and can include the use of statins or a PCSK9 inhibitor in order to achieve optimal LDL control. In addition, anti-platelet agents, anti-hypertensive agents, and agents for glycemic control should be prescribed, as indicated.

IV. Peripheral Arterial Disease (PAD), Including the Diabetic Foot

Treatment for peripheral arterial disease (PAD) include angiography, with or without intervention; hybrid procedures (endarterectomy, with endovascular intervention); and open revascularization (bypass or endarterectomy with autogenous, prosthetic or bioprosthetic material).

Preoperative

Patient History & Physical Examination

The SVS clinical practice guidelines recommends against invasive treatments for peripheral arterial disease (PAD) in the absence of symptoms.[43] Conducting a complete history and physical examination of patients with PAD is important, and focusing on the legs, as well as systemic risk factors and comorbidities, is essential. The manifestations of chronic lower extremity ischemia often include pain produced by varying degrees of ischemia, ranging from no or atypical leg symptoms to typical exertional muscular pain (intermittent claudication [IC]) to ischemic rest pain.[43]

The target population of patients includes adults with claudication or critical limb threatening ischemia (CLTI), defined as a patient with objectively documented and any of the following clinical symptoms or signs: Ischemic rest pain with confirmatory hemodynamic studies, diabetic foot ulcer (DFU) or any lower limb ulceration present for at least two weeks and gangrene involving any portion of the lower limb or foot.[43] For patients with CLTI, the one year risk of requiring major amputation is 30% and 1-year mortality risk is 25%.[44]

Imaging

The SVS guidelines recommend using the ankle brachial index (ABI) as the first-line noninvasive test to establish diagnosis.[43]
For patients who are being considered for revascularization, physiologic noninvasive studies, such as segmental pressures and pulse volume recordings, aid in the quantification of arterial insufficiency and help localize the level of obstruction.[43]

The SVS also recommends obtaining high-quality angiographic imaging with dedicated views of the ankle and foot arteries to permit anatomic staging and procedural planning in all CLTI patients who are candidates for revascularization.[43] The use of an integrated limb-based staging system (Global Limb Anatomical Staging System) to define the anatomic pattern of disease and preferred target artery path in all CLTI can be considered.[43] Another commonly used risk stratification scoring system to rate the need for revascularization or potential need for amputation is the Wound, Ischemia and Foot Infection (WIFI).[45]

Other studies that should be considered for planning revascularization, and not for routine screening, are arterial duplex ultrasound, CTA, magnetic resonance angiography (MRA), and contrast arteriography. The SVS guidelines recommend either axial imaging (e.g., CTA, MRA) or catheter-based angiography.[43]

In high-volume expert centers and especially for patients with recurrent disease the arterial duplex US is considered in place of axial imaging.

Medical Management and Lifestyle Changes

- *Smoking cessation*: A multidisciplinary comprehensive smoking cessation approach should be utilized until tobacco use has been stopped.

Exercise: Supervised exercise therapy[46], now reimbursed by Centers for Medicare and Medicaid Services (CMS), is a first-line indication for patients with claudication; it includes walking a minimum of 3 times per week (30-60 min/session) for at least 12 weeks. Home-based exercise[47] can be done when a supervised program is unavailable.[43]

- *Diabetes*: For patients with PAD, it is important to optimize diabetes control (hemoglobin A1c goal of <7.0) without hypoglycemia.

- The SVS recommends therapy with aspirin (75-325 mg daily). Clopidogrel is recommended (75 mg daily) as an alternative to aspirin for antiplatelet therapy.[48] Dual antiplatelet therapy, with aspirin and Plavix, is not better than aspirin alone.[48, 49]

- In patients with claudication without heart failure, a 3-month trial of cilostazol (100 mg twice daily) is recommended, with dose reduction to 50 mg twice daily for patients with side effects. Those who cannot tolerate or are ineligible for cilostazol can try pentoxifylline (400 mg, 3 times daily). Clinicians should consider using reduced dose Rivaroxaban for those patients with PAD and low bleeding risk.[43, 50]

- *Hypertension*: Anti-hypertensive control should be focused on a goal blood pressure of less than 140/90, with ACE inhibitors[51] and ARB[52] recommended as first line. The use of beta blockers (hypertension, cardiac indications), should be considered if symptoms are due to atherosclerosis

- *Dyslipidemia:* For patients with dyslipidemia, treatment with a statin to achieve a target low-density lipoprotein cholesterol (LDL-C) level of <70 mg/dL is recommended.[53] If LDL-C goal is not achieved by statin therapy, then PCSK9i should be considered. Even if LDL-C is at goal, statin therapy should be initiated and continued due to its overall pleiotropic beneficial effects.

Risk Stratification

Because cardiac disease is so prevalent among patients with peripheral vascular disease, ECG should be performed in all patients. Chest radiography may be helpful in some patients if undiagnosed underlying disease is suspected on the basis of the history and physical examination. In select patients, more advanced testing may be appropriate, such as cardiac stress testing or pulmonary function evaluation when cardiac or pulmonary disease is suspected. The associated comorbidities and risk factors, including smoking cessation, should be managed optimally before revascularization, similar to patients undergoing any major vascular surgical procedures. There are well-accepted, published guidelines from most of the medical subspecialties to guide the

preoperative evaluation, including those from the American Heart Association and the American College of Cardiology for the optimal preoperative cardiac evaluation for patients undergoing major noncardiac surgery.[31]

A multidisciplinary approach to care can optimize outcomes. Medical specialists and team members can assist patients with risk factor modification, such as smoking cessation, maintaining glycemic control, normalizing blood pressure and lipid levels, maintaining antiplatelet therapy and fostering participation in exercise programs, thereby promoting a positive patient experience. Discharge planning should also be considered at time of surgical planning.[54]

Preoperative Labs

A complete blood count should be obtained to screen for the presence of infection, to ensure an adequate red blood cell volume, and to rule out a serious hematologic abnormality. Serum electrolyte concentrations should be evaluated and corrected when abnormalities exist. Of special importance are serum potassium, calcium, and magnesium levels because if they are abnormal and not corrected, they can lead to deleterious cardiac effects.[17]

Furthermore, because renal disease is prevalent in patients with vascular disease and some vascular interventions may compromise renal function, a baseline creatinine level should be obtained. All patients should also have serum glucose concentration measured, and in diabetic patients, glucose levels and HbA1c should be controlled before, during, and after intervention.

Measures of coagulation, such as the prothrombin time and international normalized ratio, should be determined to identify coagulation abnormalities, and in patients taking warfarin or other anticoagulants, an appropriate anticoagulation scheme should be decided on before surgery.

Preoperative Medication Adjustment

It is important to take into consideration medications due the administration of radiocontrast material that may lead to acute kidney injury.

- *Perioperative antibiotics*: Prophylactic antibiotics for open procedure should be considered perioperatively as for any other surgery, and for endovascular interventions on a case-by-case basis.[17]

- *Anticoagulation and its reversal*: oral anticoagulation should be discontinued preoperatively to minimize bleeding complication. Direct oral anticoagulants (DOACs) should be held for 48-72 hours before procedure. Warfarin should be discontinued 3-5 days in advance. Consider bridging with parenteral anticoagulation (unfractionated heparin [UFH] or LMWH) in appropriate patients with high thrombosis risk.[17]

- *Nephropathy*: Techniques to minimize contrast nephropathy for endovascular procedures in patients with CKD should be utilized. While many different agents have been studied with varying success, only fluid loading has been consistently reported to be associated with better renal outcomes. If there is no contraindication fluid administration pre, intra and post operatively is recommended. The issue to hold ACEs and ARBs is still not

resolved and more research is needed. CO2 digital angiography should also be considered in patient with CKD. The advantages include no allergic potentiation and no renal metabolism of CO2, because CO2 is cleared by the lungs and does not recirculate.[17]

- *ACE Inhibitors*: If significant volume depletion is anticipated, it is suggested to hold ACE inhibitors and angiotensin receptor antagonists on the morning of surgery and restarting these agents after the procedure, once euvolemia has been achieved.[17]

- *Diabetes Mellitus:* It is suggested to hold metformin at the time of administration of contrast material among patients with an eGFR of <60 mL/min or up to 48 hours before administration of contrast material if the eGFR is <45 mL/min and restarting no sooner than 48 hours after administration of contrast material as long as renal function has remained stable. Diabetic patients who receive intermediate or long-acting insulin should receive half the scheduled dose when nil per os (NPO) in preparation for surgery. Glycemic control should be considered per the current guidelines of the American Diabetes Association.[18, 31]

Intraoperative

Anesthesia Management

a) Anesthesia Techniques

PAD procedures can be safely performed under local, regional, neuraxial, and general anesthesia, or a combination of the three, depending on the local clinical practice as well as patient preferences.[55-58] The question regarding safest anesthetic modality for PAD surgery remains controversial, with inconsistent results regarding the incidence of perioperative complications.[59-61] Having said this, studies reported a decreased incidence of postoperative pneumonia, myocardial infarction, and graft failure with neuroaxial (NA) compared to general anesthesia (GA).[61-66] Currently, the choice of anesthetic technique reflects patient-specific factors as well as procedure-specific factors (e.g., anticipated duration).

i) Open Procedures

Lower extremity bypass may need to be performed under general endotracheal anesthesia. Maintenance of anesthesia can be accomplished using volatile anesthetics, such as sevoflurane and desflurane, or with a propofol drip. Opioids (i.e., fentanyl or sufentanil) can be used for intraoperative pain control. Non-steroidal drugs, such as ketorolac or ibuprofen, may need to be avoided depending on the risk of kidney injury.

ii) Endovascular Procedures

The majority of lower extremity endovascular interventions can be performed under local anesthesia and sedation.

Other approaches can be considered on a case-by-case basis. General endotracheal anesthesia may be best-suited if prolonged episodes of apnea to improve imaging quality are warranted. Depending on the percutaneous or cut-down approach, endovascular procedures can be performed

under local anesthesia; regional anesthesia with a nerve plexus block, such as ilioinguinal plexus block; or neuraxial anesthesia in the form of epidural or spinal anesthesia.[55-58, 61]

The ilioinguinal nerve plexus block can be performed by the surgeon in the sterile field.

Both the iliohypogastric and the ilioinguinal nerves originate from the nerve root of L1 and perforate the transverse abdominis muscle near the anterior part of the iliac crest. In the anterior abdominal wall, the nerves travel between the transverse abdominis and the internal oblique muscles. The nerve bundle can be visualized using ultrasounds and the injection of 10-20 ml of local anesthetic (e.g., mepivacaine, ropivacaine or bupivacaine) will anesthetize the groin area, as well as the lower portion of the abdominal wall and the upper thigh.[61]

Local anesthesia or regional anesthesia technique can be supplemented with mild to moderate sedation with a propofol or dexmedetomidine drip for patient comfort.

b) Monitoring and Access

Standard monitoring of SaO_2, EKG, non-invasive blood pressure and temperature.[67]

- *Invasive Arterial blood pressure monitoring* : Placement of an arterial catheter may be necessary due to cardiac comorbidities. Arterial access also allows for intraoperative blood draws for ACT measurements.

- *Central venous catheter*: The use of vasoactive drugs for tight blood pressure control may require the placement of a central venous catheter after induction of anesthesia.

- *Large bore* intravenous *access*: The possibility of acute intraoperative blood loss requires large bore IV access for volume resuscitation.

c) Intraoperative Concerns

Notably, up to 55% of patients with PAD were found to display severe, asymptomatic CAD.[68] Consequently, blood pressure should be maintained within 20% of the preoperative baseline value (with mean arterial pressure >65 mmHg). Severe hypertension or hypotension should be avoided as it may result in myocardial ischemia. Thermoregulation becomes impaired with aging.[69, 70]

Thus, temperature regulation should be aggressively managed using different modalities such as heated mattresses, bear huggers, warm intravenous fluid infusion, and warm ambient room temperature.[7]

<u>d. General & Procedure-Specific Concerns</u>

General intraoperative concerns: Skin preparation (CHG wipe timeout for three minutes to dry), Foley placed by trained staff, shaving performed with clippers, normothermia.[71]

Postoperative

Steps Prior to Discharge

Open Procedures

- Patients might require a stay in the ICU or telemetry unit in order to be monitored for cardiopulmonary complications.
- Monitoring for patency of the revascularization should be continued throughout the hospital stay.
- Wound care should be continued in patients with tissue loss.
- Physical therapy and pain control should be initiated.

Endovascular Procedures

- These procedures can be done on an outpatient basis, or with overnight observation, depending on the patient's need for hydration and the type of access or need for site observation.

Steps After Discharge

- *Follow-up:* Follow up call within the first week after surgery.
- *Office / Telehealth Visit*: Follow-up within a month postoperative, unless indicated sooner.
  - For endovascular lower extremity procedures, the SVS recommends clinical examination, ABI, and DUS within the first month to provide a post-treatment baseline and evaluate for residual stenosis. For open lower extremity procedures, the SVS recommends clinical exam and ABI, with or without the addition of duplex ultrasound, in the early postoperative period to provide a baseline for further follow up. This is usually within a month from discharge.
  - Clinical exam and ABI/ pulse volume recording (PVR) with or without the additions of DUS should be performed at 6 and 12 months and then annually as long as there are no new signs or symptoms.[43] Specific duplex US velocity criteria should be used to diagnose a hemodynamically significant stenosis post stenting as well as for graft stenosis following bypass.
- *Medications:*
  - The use of long-term medications can be coordinated with the patient's primary care physician and can include the use of statins or a PCSK9 inhibitor in order to achieve optimal LDL control.[61] In addition, anti-platelet agents, anti-hypertensive agents, and agents for glycemic control should be prescribed, as indicated.
  - In patients undergoing infrainguinal endovascular intervention , it is recommended to treat with aspirin and clopidogrel for at least 30 days.[48] Options for antiplatelet treatment include ASA 81 mg/day or Clopidogrel 75 mg/day or DAPT w ASA + Clopidogrel for at least 30 days in some patients with stenting (MIRROR trial).[72] The combination of aspirin with low-dose Rivaroxaban has shown some benefit following endovascular intervention and can be be considered if not contraindicated(VOYAGER trial).[73] In patients with resistance to Clopidogrel, the use of an alternative agent such as Ticagrelor (Brilinta) is indicated.[31]

V. Carotid/Cerebrovascular

Carotid/Cerebrovascular procedures include:

- Carotid Endarterectomy (CEA)
- Transcarotid Artery Revascularization (TCAR)
- Trans-femoral carotid stent (TFCAS)
- Subclavian artery stent (trans-femoral or trans-brachial/radial)
- Carotid subclavian artery bypass or transposition
- Carotid–carotid bypass
- Vertebral artery interventions or bypass
- Carotid body tumor.

A. Preoperative

Patient History

Carotid disease
Carotid artery atherosclerotic disease is a major cause of ischemic stroke, being an underlying cause in 10% to 20% of cases.[74] It is important to assess symptom status to determine the need for intervention as well as the type of intervention. Symptoms could be permanent (stroke), or transient (TIA and amaurosis fugax). A transient ischemic attack (TIA) or mini stroke lasts less than 24 hours, and amaurosis fugax involves the transient loss of vision in one or both eyes. Patients with innominate artery disease can also present with anterior cerebral ischemic symptoms due to reversal of flow in the carotid artery.

It is important to assess for comorbidities to confirm the patient's life expectancy of at least five years at the time of planned intervention in asymptomatic patients.[48]

Vertebrobasilar disease
The diagnosis of vertebrobasilar disease is challenging due to conditions that mimic posterior circulation ischemia such as cardiac arrhythmias or orthostatic hypotension. Two main mechanisms are low-flow or embolic: low-flow presents with vertigo drop attacks, diplopia, tinnitus, dysphagia, dysarthria, and ataxia. Similar positional symptoms can also occur due to vertebral artery compression. Significant bilateral vertebral artery stenosis is necessary to produce low-flow symptoms.

In addition, patients with proximal subclavian artery stenosis may present with vertebrobasilar insufficiency due to reversal of flow in the vertebral artery. Patients with subclavian stenosis may also present with arm claudication, rest pain, digital embolization, or coronary-subclavian steal

Physical Examination

A complete physical exam should be performed, with special attention paid to the neurologic exam, documenting existing deficits. Evaluation of the neck to determine prior surgical history is important to determine if surgical re-operation may be challenging (i.e., anatomic high risk).

Elicitation of other physical exam findings that suggest high medical risk is also important (e.g., oxygen dependence, lower extremity edema, elevated Jugular Venous Pressure [JVP], and irregular heart rhythm).

A carotid bruit detected on auscultation is associated with an increased risk of cardiovascular mortality by 2-3-fold, but the positive predictive value for a greater than 50% Internal Carotid Artery (ICA) stenosis is poor (less than 40%).[75, 76]

Imaging

- *Duplex Ultrasound (DUS)* is the first-line imaging modality for carotid occlusive disease and is associated with high sensitivity and specificity. In asymptomatic patients with high-grade carotid stenosis, DUS findings of echolucent, homogenous, ulcerated plaque can predict increased stroke risk and may benefit from intervention. In some expert centers, DUS alone is adequate for planning prior to carotid endarterectomy.

- *Computed Tomography Angiography (CTA)*: CTA of the chest, neck, and head is appropriate prior to intervention in order to assess the anatomy of the vasculature, especially if carotid stenting is performed. Magnetic resonance angiography (MRA) can also be performed but is prone to overestimation of the degree of stenosis.

- *Diagnostic Digital Subtraction Angiography (DSA)*: DSA is rarely indicated for diagnostic purposes only but can be performed if there is a discrepancy between different diagnostic modalities when assessing the degree of stenosis. In patients with chronic kidney disease and equivocal DUS imaging, DSA is preferred over CTA and MRA (by minimizing contrast load). DSA is also preferred in patients for whom CTA or MRA are technically inadequate or difficult (e.g., obesity, or indwelling ferromagnetic material).

Medical Management and Lifestyle Changes

In patients with carotid artery stenosis, treatment of hypertension, hypercholesterolemia, and efforts at smoking cessation are recommended to reduce overall cardiovascular risk and risk of stroke regardless of whether intervention is planned. Smoking cessation, antiplatelet/ anticoagulation therapy, blood pressure control, cholesterol and diabetes management can all impact the risk of stroke and should be aggressively managed.

- *Smoking*: Smoking increases stroke risk up to 50%; cessation is particularly advised for all patients with cerebrovascular disease.

- *The use of Antiplatelets/Anticoagulation for stroke reduction should be considered based on published data:*
  Aspirin or Plavix is the mainstay of antiplatelet therapy:
  - ASA 75-100 mg/day reduces relative risk by ~25% compared to placebo.
  - Clopidogrel did not reduce stroke risk compared to ASA in CAPRIE trial.[48]
  - DAPT did not reduce stroke risk compared to ASA alone in the CHARISMA trial.[49]
  - DAPT did not reduce stroke risk compared to Clopidogrel alone in the MATCH

trial.[77]
    - Adding Dipyridamole to ASA may provide only marginal benefit in the European Stroke Prevention Study 2.[78]
    - ASA+Dipyridamole had similar effect compared to Clopidogrel for noncardioembolic ischemic stroke in PRoFESS trial.[79]
    - Vitamin-K Antagonist (VKA, Warfarin) reduces stroke risk only in patients with atrial fibrillation.
- *Antihypertensive management:*
    - ~6 mmHg reduction in DBP reduces nonfatal stroke risk by 43%
    - Particular antihypertensive agent has not been shown to be associated with reduction of stroke risk in HOPE[80] (ACEI), PROGRESS[81] (ACEI), LIFE[82] (ARB), and ALLHAT[83] (Diuretics) studies.
    - It is prudent to be cautious with BP reduction in patients with stroke, as J-shaped relationship with BP and Stroke risk and hypotension may lead to cerebral hypo-perfusion and worsen stroke clinically.

- *Cholesterol management:* Statin use reduced relative risk of stroke by 25-30% in 4S,[84] CARE,[85] HPS,[86] and SPARCL[87] studies.

- *Diabetes management*: Diabetes increases stroke risk by about three-fold. There are conflicting randomized controlled trial (RCT) results for intensive glycemic control and stroke risk. Glycemic control should be considered per the current guidelines of the American Diabetes Association.[18]

Risk Stratification for Surgery (both physiologic and anatomic)

A multidisciplinary approach to care can optimize outcomes. Medical specialists and team members can assist patients with risk factor modification, such as smoking cessation, maintaining glycemic control, normalizing blood pressure and lipid levels, maintaining antiplatelet therapy and fostering participation in exercise programs, thereby promoting a positive patient experience. Discharge planning should also be considered at time of surgical planning.

Risk stratification for surgery is critical in patients with carotid stenosis, as it affects the decision making to treat with revascularization vs medical therapy alone, and also impacts the choice of intervention in patients being considered for revascularization.[88] For patients being considered for CEA, the 30-day perioperative CEA stroke and death rate should not exceed 6% for symptomatic patients and 3% for asymptomatic patients.

The cardiac assessments should follow the general recommendation of the American College of Cardiology/American Heart Association (ACC/AHA) guidelines.[31]

Cardiovascular and pulmonary disease remain the leading causes of early and late death in patients with peripheral vascular disease, and the first step should be to determine whether an active cardiovascular condition exists, which would mandate further assessment and management before planned intervention.[88] There are well-accepted, published guidelines from most of the medical subspecialties to guide the preoperative evaluation, including those from the American

Heart Association and the American College of Cardiology for the optimal preoperative cardiac evaluation for patients undergoing major or moderate risk noncardiac surgery.[31]

Factors that may increase the risk of CEA include:

- Medical comorbidities like advanced CHF, severe coronary artery disease (e.g., left main or severe multivessel CAD, recent MI in last 6 weeks), and severe COPD
- Anatomical features (such as high cervical or intrathoracic lesion)
- History of neck surgery or radiation, contralateral ICA occlusion, ipsilateral CEA, tracheal stoma, immobilized neck (e.g., from arthritis)

Asymptomatic patients at high risk of complications after CEA and CAS may be managed medically. Patients should be on aspirin (75-100 mg daily). The addition of rivaroxaban 2.5 mg twice daily to aspirin monotherapy may improve cardiovascular outcomes (COMPASS trial).[89]

Preoperative Labs

Standard CBC, chemistry profile and coagulation profile are recommended preoperatively.

Preoperative Medication Adjustment

It is reasonable to individualize the management of perioperative clopidogrel therapy. There is no clear information regarding the risks or benefits of continued clopidogrel monotherapy in the periprocedural period for CEA.

Preoperatively:

- *ASA*: Start ASA 75-100 mg/day. Clopidogrel can be used as an alternative in patients already on it prior to CEA. While DAPT with aspirin and clopidogrel may slightly reduce the risk of perioperative stroke, the incidence of perioperative bleeding events is significantly higher compared to monotherapy.

- *Statins*: Start high-intensity statins: Atrovastatin 40-80 mg/day or Rosuvastatin 20-40 mg/day

- *Perioperative antibiotics*: Prophylactic antibiotics for open procedure should be considered perioperatively as for any other surgery, and for endovascular interventions on a case-by-case basis.

- *Anticoagulation and its reversal*: If patient is on oral anticoagulation preoperatively, then discontinue them before the procedure to minimize bleeding complication. DOACs should be held for 48-72 hours before procedure. Warfarin should be discontinued 3-5 days in advance. Please consider bridging with parenteral anticoagulation (UFH or LMWH) in appropriate patients with high thrombosis risk.

- *Nephropathy*: Techniques to minimize contrast nephropathy for endovascular procedures in patients with CKD should be utilized. While many different agents have been studied with varying success, only fluid loading has been consistently reported to be associated with better renal outcomes. If there is no contraindication fluid administration pre, intra

and post operatively is recommended. The issue to hold ACEs and ARBs is still not resolved and more research is needed.

- *Allergy*: Patients with allergy to intravenous iodinated contrast and scheduled for angiography should get premedication with prednisone 50 mg in 3 oral doses at 13 hours, 7 hours, and one hour prior to procedure, and Diphenhydramine 50 mg one hour prior to procedure
- *ACE Inhibitors*: If significant volume depletion is anticipated, it is suggested to hold ACE inhibitors and angiotensin receptor antagonists on the morning of surgery and restarting these agents after the procedure, once euvolemia has been achieved.

- *Diabetes Mellitus:* It is suggested to hold metformin at the time of administration of contrast material among patients with an eGFR of <60 mL/min or up to 48 hours before administration of contrast material if the eGFR is <45 mL/min and restarting no sooner than 48 hours after administration of contrast material as long as renal function has remained stable. Diabetic patients who receive intermediate or long-acting insulin should receive half the scheduled dose when nil per os (NPO) in preparation for surgery. Glycemic control should be considered per the current guidelines of the American Diabetes Association.[18]

Intraoperative

General

- Anesthetic technique: General anesthetic, regional or local per surgeon preference.

- Hair is removed with clippers if needed.
- Skin preparation with chlorhexidine gluconate/alcohol antiseptic.
- Perioperative antibiotics are routinely used (cefazolin or vancomycin).

a. Optimization and Risk Assessment

The perioperative anesthesia process should include identifying potential perioperative risks, since patients scheduled for carotid surgery are at high-risk for neurological and/or cardiovascular complications.[90, 91] They are commonly older and have significant comorbid burden, including peripheral arterial disease, coronary artery disease, history of TIA or stroke, hypertension, diabetes mellitus, chronic kidney disease, with poor functional status and extensive smoking history.[91]

b. Anesthesia Management

i) Anesthesia Techniques

Most carotid procedures can be safely performed under general anesthesia (GA), regional anesthesia (RA), sedation, or a combination of the three, depending on the local clinical practice as well as patient preferences.[92-94]

Despite theoretical advantages of RA and a plethora of well-designed clinical studies, the question regarding safest anesthetic modality for carotid surgery remains controversial, though

some more recent reports found GA to represent an independent risk factor for perioperative MI and to be associated with higher mortality compared with RA.[95]

The lack of clear and consistent evidence supporting one particular anesthetic approach has led to development of a wide range of individual views on what constitutes "optimal anesthesia."

- *General Anesthesia*: The majority of carotid procedures in the US are performed under general endotracheal anesthesia.[92] It offers airway protection, cerebral protection (volatile anesthetic agents), and arterial carbon dioxide control (cerebral perfusion). Endotracheal tube (ETT, "tube") provides better protection from aspiration and thus may be preferred over Laryngeal Mask Airway (LMA) (high co-morbid burden may increase the risk of aspiration). GA can be maintained using either: (1) inhalational agent ("gas"): Sevoflurane, with a "sweet" smell, is commonly used compared to Desflurane as the latter has a more pungent smell/taste (i.e., avoid in patients with irritable airway). Desflurane was however reported to be associated with a faster emergence;[96, 97] (2) TIVA (total intravenous anesthesia; commonly consisting of a combination of infusions, e.g., propofol, opioid, lidocaine, ketamine) offers another approach to maintain general anesthesia. TIVA was found to reduce nausea/anesthesia (propofol).[98]

- *Regional Anesthesia:* This offers intact cerebral autoregulation with easy assessment of neurological function during carotid cross-clamping, lower shunt insertion rate, reduced blood loss, lower risk of thromboembolic events, less hemodynamic instability with a reduction of cardiac- and respiratory-related morbidity, shorter hospital stay, and lower cost compared with GA.[99-102] Most carotid procedures require a blockade of C1-4 dermatomes using either (1) superficial cervical plexus block, (2) deep cervical plexus block, or, (3) local infiltration by the surgeon (alone or in combination).[103-105] Of note, up to half of the patients with deep cervical block present with an unintended phrenic nerve block.[106] All anesthetic nerve blockades can be done safely under ultrasound guidance. Choice of local anesthetic drug will depend on expected duration of surgical procedure. Mepivacaine is suitable for procedures of up to 2 hours, Ropivacaine or Bupivacaine may be preferred for procedures expected to take longer than 2 hours.[104]

- *Sedation:* All local or regional anesthetic techniques can be supplemented with light to moderate sedation such as propofol or dexmedetomidine drips for patient comfort.[107-109] On the other hand, avoidance of perioperative benzodiazepines has been recommended to reduce the risk of postoperative delirium.[110] Opioids may be added for analgesia/sedation as well. Sedation should be adjusted during cross-clamping to allow neurological assessment and should be minimized in patients undergoing TCAR or TFCAS.

ii) Monitoring and Access

All patients require the standard mandated by the American Society of Anesthesiologists including oxygenation (peripheral oxygen saturation [SpO2]), ventilation (CO2 monitor), circulation (ECG and BP), and temperature monitoring.[67]

In addition, all patients need adequate IV access and continuous oxygen supply.

Several techniques have been introduced to monitoring cerebral perfusion including internal carotid artery stump pressure, EEG, transcranial Doppler, somatosensory-evoked potentials (SSEP), Bispectral index (BIS) monitoring, or cerebral oximetry, with none showing consistently improved outcome.[111-115] As such, many surgeons choose to routinely shunt all patients under GA during cross-clamping. Of note, even patients undergoing carotid surgery under regional or local anesthesia who display a significant drop in brain regional oxygen saturation as measured with a cerebral oximeter after cross-clamping, may fail to present immediate neurologic symptoms.[116]

Indwelling arterial catheter may be considered in patient with cardiac, pulmonary, renal, or metabolic conditions requiring continuous hemodynamic monitoring and/or blood sampling.

Intra- and postoperative use of vasoactive drips may require the placement of a central venous line.

iii) Intraoperative Concerns

- *Neurological deficit after cross-clamping:* (1) Presentation: contralateral motor weakness, loss or altered consciousness, agitation, confusion, dysphasia, and/or seizures; (2) Prevention: While the commonly applied augmentation of arterial pressure to > 20% above preoperative baseline after cross-clamping has been shown to reduce the incidence of postoperative cognitive dysfunction, it may trigger myocardial ischemia; (3) Treatment: (a) augmentation of arterial pressure to > 20% above preoperative baseline; (b) Administration of high concentrations of oxygen, (c) release of the carotid cross-clamp followed by shunt placement (4) Post-unclamping: Avoidance of hypertension (hyperperfusion syndrome).[58, 99, 117]

- *Myocardial infarction*: Recent evidence reported higher incidence of MI in patients undergoing CEA under general anesthesia.[95]

d. General and Procedure-Specific Concerns

General interoperative concerns: Skin preparation (CHG wipe timeout for three minutes to dry), Foley placed by trained staff, shaving performed with clippers, normothermia intra op.

Postoperative

Steps Prior to Discharge

- *General:* Avoid hypotension or hypertension, which may precipitate a neurologic event or bleeding.
- *Monitoring:*
    - Perform close physical examination and frequent neurologic checks in the immediate postoperative period in order to evaluate for new neurologic deficits or cranial nerve injuries.
    - Conduct strict blood pressure monitoring in order to detect and treat cerebral hyperperfusion syndrome, which may lead to intracranial hemorrhage. This can also manifest initially as ipsilateral headache. Particular care should be taken in patients with high-grade or bilateral high-grade carotid artery stenosis.

- *Medication:*
  - Administer aspirin monotherapy after CEA (typically performed)
  - Administer dual antiplatelet therapy (e.g., aspirin plus clopidogrel) after CAS (standard treatment)
  - Narcotics are typically avoided for pain control as they can lead to mental status changes, and pain control is often adequate with over-the-counter agents.
- *Discharge*: Most asymptomatic patients can be discharged safely on the first postoperative day after carotid revascularization.

Steps After Discharge

- *General:*
  - Instruct patients to contact the surgeon if swelling develops at the operative site, there are signs of infection (e.g., erythema, purulence), worsening pain at the surgical site or if ipsilateral headaches develop. Hyperperfusion syndrome can occur several days after CEA and can manifest as new onset headache.
  - Factors associated with restenosis include continued smoking, small ICA diameter, operative defect detected at intraoperative assessment, and primary closure after CEA.
  - Smoking cessation and abstinence
- *Follow-up*: Conduct a one-month follow-up visit with carotid duplex ultrasound to assess for patency.
- *Office / Telehealth Visit*:
  - Follow-up within a month with a postoperative, unless indicated sooner.
  - Surveillance carotid duplex ultrasound at 1 month, at 6 months (if >50% stenosis), and then yearly after CEA
  - Surveillance carotid duplex ultrasound at 1 month, 6 months, and yearly after carotid stenting to assess stent patency and for to assess for development of new or contralateral lesions
  - Specific carotid duplex US velocity criteria must be used post CAS to detect a hemodynamically significant stenosis post CAS, per local interpretation criteria.
- *Medication:* The use of long-term medications can be coordinated with the patient's primary care physician and can include the use of statins or a PCSK9 inhibitor in order to achieve optimal LDL control. In addition, anti-platelet agents, anti-hypertensive agents, and agents for glycemic control should be prescribed, as indicated.
  - Reasonable antiplatelet regimens:
    - ASA 81 mg/day or
    - Clopidogrel 75 mg/day or
    - ASA+Dipyridamole (25-200 mg) twice a day (BID)
    - DAPT w ASA+Clopidogrel for at least 30 days in patients who underwent carotid stenting
  - Statin – high intensity if tolerated
    - Atrovastatin 40-80 mg/day or
    - Rosuvastatin 20-40 mg/day
    - PCSK9 inhibitor if LDL-C is not at goal <70 with maximum therapy with a high potency statin.
    - Anti-hypertensive management is similar to that for the normal

population with cardiovascular disease. Strict control is especially recommended in patients at high risk for hyperperfusion syndrome.

- Diabetes medications – optimal glucose control recommended

VI. Lower Extremity Venous Disease and Treatment of Post-Thrombotic Syndrome

Treatment for lower extremity venous disease (including varicose veins and ulcers) includes:

- Venous ablation for reflux (thermal, non-thermal)
- Phlebectomy / high ligation and stripping
- Sclerotherapy
- Venography and intervention (iliocaval stenting, renal vein stenting, ovarian vein embolization)
- Open venous bypass / endophlebectomy.

A. Preoperative

Patient History

Chronic Venous Insufficiency (CVI) manifests as leg swelling, varicose veins, and in more advanced stages skin changes and ulceration. Patients complain of various degrees of pain, aching, heaviness, itching, burning, swelling, and bleeding affecting the lower extremities. The symptoms are exacerbated by prolonged standing, activity, and heat and are more pronounced at the end of the day compared to the morning. Leg elevation and compression bandages may alleviate symptoms.

A history of venous thromboembolism (VTE), May-Thurner syndrome (MTS)/Non-thrombotic iliac vein lesion (NIVL), pelvic radiation, or pelvic malignancy should be sought.

Patients complaining of pelvic pain, especially premenopausal women with irregular menses, pelvic heaviness, or dyspareunia could have pelvic congestion syndrome or nutcracker syndrome. The differentiation of pain related to venous disease from other common causes of lower extremity pain such as arterial, musculoskeletal, and neurogenic etiologies is essential.[118] In addition, inquiring about the impact of symptoms on quality of life (QOL) and addressing cosmetic concerns is crucial to set the expectations of any therapy.

Physical Examination

A thorough exam of the lower extremities should focus on the presence of edema around the ankles, the pattern of varicose veins or spider veins, and skin changes (lipodermatosclerosis). Varicose veins in the inguinal, perineal, or lower abdominal area should raise suspicion of outflow obstruction or pelvic congestion syndrome.[119] Palpating a thrill or auscultation of a bruit can be related to arteriovenous malformation or arteriovenous fistula. On the other hand, non-pitting edema affecting the dorsum of the foot, squaring of the toes, and skin thickening are suggestive of chronic lymphedema.

Venous ulcers typically affect the malleolar area. Tenderness and erythema can be a sign of acute infection or thrombophlebitis. Examination of the pedal pulses is important to rule out concomitant peripheral arterial disease (PAD) prior to prescribing compression therapy. The clinical staging can be done using the CEAP classification (clinical class, etiology, anatomy, and

pathophysiology) and severity of disease can be assessed using the revised Venous Clinical Severity Score (VCSS).[120]

Imaging

Duplex scanning of the lower extremities is recommended as a first line diagnostic test in all patients with CVI.

Ultrasound can detect acute and chronic deep vein thrombosis (DVT).[121]
It can also provide a detailed map of the superficial and perforator veins with size and degree of valvular reflux when present. Reflux time ≥ 0.5 second is considered abnormal in the superficial veins and ≥ 1 second is abnormal in the deep veins. A pathological perforator is defined by a diameter of ≥ 3.5 mm and reflux ≥ 0.5 second located beneath an active or healed ulcer. Blunting of respiratory variation in the common femoral vein is suggestive of venous outflow obstruction. In thin patients, ultrasound can also be used to evaluate the iliac veins and the inferior vena cava (IVC) for obstruction, as well as ovarian vein reflux in patients with pelvic venous congestion.[122]

Alternatively, cross-sectional imaging using computed tomography venogram (CTV) or magnetic resonance venogram (MRV) can characterize the relationship of the veins and arteries and define the anatomy of other clinically relevant processes (e.g., tumor, lymphadenopathy, retroperitoneal fibrosis, arteriovenous fistula, non-thrombotic iliac vein occlusion, etc.).

Medical Management and Lifestyle Changes

The first-line treatment for patients with CVI is compression therapy in the form of elastic stockings, wraps, or paste gauze boots (Unna boots).[121]
In patients with no significant arterial insufficiency, a grade of 20-30 mmHg is recommended for patients with varicose veins and edema while a higher grade of 30-40 mmHg is recommended for patients with venous ulcers and wounds.[119] Stockings are typically put on in the morning and removed at the end of the day prior to going to sleep. Pneumatic compression devices (intermittent compression pumps) can be used also to decrease the fluid in the lower extremities and decrease venous hypertension.[123]

In patients with venous ulcers, local wound care with debridement under local anesthesia and systematic antibiotics as needed is essential to promote wound healing. Ulcers that do not improve after 4-6 weeks of wound care and compression therapy or that have atypical features should be biopsied. Intermittent leg elevation, exercise, and weight loss in obese patients have been suggested as lifestyle modifications to alleviate symptoms.

Horse chestnut seed extract (i.e., aescin) can decrease edema, pain, and itching in patients with CVI.[119-120] Pentoxifylline, flavonoid drugs (e.g., diosmin and hesperidin) and other venotonic agents have been associated with healing of venous ulcers and improvement of CVI symptoms.[119,120]

Risk Stratification for Surgery

Saphenous vein ablation, phlebectomy, and high ligation with stripping constitute the common procedures for superficial venous reflux associated with large varicosities. Sclerotherapy is typically performed in an office setting without anesthetic. Venous ablation can be performed in an office setting using tumescent or local anesthesia. Patients are awake and the procedure is generally very well-tolerated.

More extensive varicose vein surgery can be performed with anesthesia in an outpatient surgery center or hospital.[119]

Patients with very large or tortuous superficial veins, or large subcutaneous varicosities are better suited for high ligation with stripping and / or phlebectomy. Similarly, venography and endovascular venous interventions are performed percutaneously as outpatient procedures under local anesthesia and conscious sedation.

Open venous reconstruction in the form of bypass or endophlebectomy is reserved for patients with advanced CVI and unsuccessful endovascular therapy. These should be reserved to patients with advanced CVI who are considered fit for major surgery.[124]

Risk Assessment

A comprehensive cardiac and medical risk stratification should be performed for patients prior to open venous reconstructive surgery. A multidisciplinary approach to care can optimize outcomes. Medical specialists and team members can assist patients with risk factor modification, such as smoking cessation, maintaining glycemic control, normalizing blood pressure and lipid levels, maintaining antiplatelet therapy and fostering participation in exercise programs, thereby promoting a positive patient experience. Discharge planning should also be considered at time of surgical planning.[7]

Venous ablation in the office setting is well-tolerated and no additional evaluation prior to the procedure is required. Patients who are receiving anticoagulation do not need to stop this prior to their intervention. Patients undergoing more extensive varicose veins surgery with the use of general anesthesia could benefit from medical risk assessment and optimization prior to surgery especially if they have significant comorbidities, are on dialysis, or have high American Society of Anesthesiologist (ASA) scores.[119, 125]

Similarly, patients undergoing venography with local anesthesia and conscious sedation generally do not require additional evaluation. Patients who have significant comorbidities may need risk stratification prior to venography, especially if general anesthesia is considered. Hydration with normal saline or 5% dextrose/sodium bicarbonate before and after the procedure should be considered in patients who are at risk of postcontrast acute kidney injury.

Preoperative Labs

No labs are recommended prior to vein ablation.

Standard CBC, chemistry profile and coagulation profile are recommended before varicose vein surgery involving monitored or general anesthesia, venography, and open venous reconstructive surgery.[119] A normal international normalized ratio (INR) should be documented prior to surgery and attention is made to renal function in patients undergoing venography with iodinated contrast material.

Preoperative Medication Adjustment

No medication adjustment is needed prior to vein ablation. Patients on anticoagulation can continue their regular regimen as the risk of bleeding is extremely low.[126]

Patients undergoing more extensive phlebectomy, high ligation with stripping, or venography should hold anticoagulation prior to surgery.

- *Perioperative antibiotics*: Prophylactic antibiotics for open procedures should be considered perioperatively as for any other surgery, and for endovascular interventions on a case-by-case basis.

- *Anticoagulation and its reversal*: If patient is on oral anticoagulation preoperatively, then discontinue them as needed before the procedure to minimize bleeding complication. DOACs should be held for 48-72 hours before procedure. Warfarin should be discontinued 3-5 days in advance. Please consider bridging with parenteral anticoagulation (UFH or LMWH) in appropriate patients with high thrombosis risk.

- *Nephropathy*: Techniques to minimize contrast nephropathy for endovascular procedures in patients with CKD should be utilized. While many different agents have been studied with varying success, only fluid loading has been consistently reported to be associated with better renal outcomes. If there is no contraindication fluid administration pre, intra and post operatively is recommended. The issue to hold ACEs and ARBs is still not resolved and more research is needed.

- *Allergy:* Patients with allergy to intravenous iodinated contrast and scheduled for angiography should get premedication with prednisone 50 mg in 3 oral doses at 13 hours, 7 hours, and one hour prior to procedure, and Diphenhydramine 50 mg one hour prior to procedure. Rescue dosing with IV solumedrol or Decadron can be used as needed. CO2 venography can also be considered as indicated

- *ACE Inhibitors*: If significant volume depletion is anticipated, it is suggested to hold ACE inhibitors and angiotensin receptor antagonists on the morning of surgery and restarting these agents after the procedure, once euvolemia has been achieved.

- *Diabetes Mellitus:* It is suggested to hold metformin at the time of administration of contrast material among patients with an eGFR of <60 mL/min or up to 48 hours before

administration of contrast material if the eGFR is <45 mL/min and restarting no sooner than 48 hours after administration of contrast material as long as renal function has remained stable. Diabetic patients who receive intermediate or long-acting insulin should receive half the scheduled dose when nil per os (NPO) in preparation for surgery. Glycemic control should be considered per the current guidelines of the American Diabetes Association.[18]

Nutrition Evaluation and Optimization

Optimization of preoperative nutritional status before any intervention is warranted especially in patients with open wounds and ulcers to promote healing.

Recommended Preoperative Consultations

Patients with family history of VTE or recurrent episodes of VTE should get a hematology evaluation to identify hypercoagulable conditions and better determine long-term anticoagulation plan.

Patients undergoing open venous reconstructive surgery should get a formal medical and cardiac risk assessment. There are well-accepted, published guidelines from most of the medical subspecialties to guide the preoperative evaluation, including those from the American Heart Association and the American College of Cardiology for the optimal preoperative cardiac evaluation for patients undergoing major and moderate noncardiac surgery.[31]

Intraoperative

General: Some lower extremity venous procedures can be safely performed without anesthesia involvement.

The perioperative anesthesia process should include identifying risk factors and potential intraoperative challenges, with particular attention to h/o hypercoagulable state, including h/o DVT, PE, pulmonary HTN and/or RV dysfunction due to perhaps chronic embolic disease, edema/infection of the lower extremity, anticoagulation etc.

No standardized criteria define patients who may benefit from anesthesia care team involvement; however, commonly used criteria include:

- *Patient factors*: High ASA classification due to co-morbid conditions, risk for respiratory or hemodynamic decompensation, inability to tolerate awake procedure (e.g., anxiety, post-traumatic stress disorder [PTSD]) or lying supine for a prolonged period of time (e.g., back pain).
- *Surgical factors*: Complex surgery or anatomy likely associated with increased nociceptive stimulation, duration of the procedure, or fluid shifts; concerns for ineffective local analgesia.

a. Optimization and Risk Assessment

Patient expectations should be managed and optimized as well. For example, with limited or no sedation, it is prudent to communicate to the patient that, while he/she will feel surgeon's touch

and may hear OR chatter/noise, the benefits of the sparing use of sedatives (e.g., reduced incidence of delirium, better neurocognitive outcomes, decreased risk of intraoperative disinhibition, confusion or restlessness) may outweigh these inconveniences.

While general anesthesia (GA) may be more desirable to the patient or may be indicated in certain situations (for instance, extensive or long surgeries, need for advanced monitoring, TEE etc.), it can be associated with higher risk of perioperative complications, especially in the elderly.

b. Anesthesia Management

i) Anesthesia Techniques

Local anesthesia (LA) +/- sedation is the technique most commonly used for venous procedures.

- *Tumescent anesthesia:* The most popular form of LA. It involves infusion of a solution of normal saline and lidocaine with addition of epinephrine and sodium bicarbonate to provide analgesia. Other preparations can be considered without the use of epinephrine.

- *Sedation:* Commonly provided with benzodiazepine, propofol, and/or dexmedetomidine infusion. Notably, avoidance of perioperative benzodiazepines has been recommended to reduce the risk of postoperative delirium.[110] Dexmedetomidine, on the other hand, with its lack of respiratory depression may be an attractive alternative. However, when used in high doses, hypotension and/or bradycardia resulting from Dexmedetomidine may outlast its sedative effects leading to prolonged stay in the post-anesthesia care unit (PACU).

- *Opioids:* May be added for analgesia/sedation.

General anesthesia may be required in select patients who are unable to tolerate sedation, be supine for prolonged period of time, or who require a complex surgical intervention. In such patients, LMA, an inflatable supra-glottic device positioned above the vocal cords, is most commonly used. Since LMA does not enter the trachea, it is less stimulating. However, it does not protect against aspiration. Consequently, it should not be used in patients at risk for aspiration (e.g., Gastroesophageal reflux disease [GERD], obesity, diabetes, etc.) or in longer cases.

Endotracheal tube (ETT, "tube") on the other hand, does provide better protection from aspiration but typically requires deeper levels of anesthesia (+/- muscle relaxation) for placement and subsequent anesthesia maintenance.

General anesthesia can be maintained using either: (1) Inhalational Agent ("gas"): Sevoflurane, with a "sweet" smell, is commonly used compared to Desflurane as the latter has a more pungent smell/taste (i.e., avoid in patients with irritable airway). Desflurane was, however, reported to be associated with a faster emergence;[96, 97] or (2) TIVA (total intravenous anesthesia; commonly consisting of a combination of infusions, e.g., propofol, opioid, lidocaine, ketamine). TIVA has recently become popular because it may be part of intraoperative multimodal analgesia (when ketamine and/or lidocaine infusions are included). TIVA was also found to reduce nausea/anesthesia (propofol).[98]

ii) Monitoring and Access

Lower extremity venous procedures are generally less invasive, and these patients tend to have lower co-morbid burden than other vascular conditions/procedures. Consequently, most patients will need only the standard mandated by the American Society of Anesthesiologists including oxygenation (SpO_2), ventilation (CO_2 monitor), circulation (ECG and BP) and temperature monitoring. In addition, all patients need an adequate IV-access and continuous oxygen supply.

- *Indwelling arterial catheter:* May be considered in patients with cardiac, pulmonary, renal, or metabolic conditions requiring continuous hemodynamic monitoring and/or blood sampling.

- *Depth of Anesthesia Monitor (EEG, or EEG-based device):* may be considered in elderly patients at risk, as increased anesthesia depth has been linked with postoperative cognitive decline and delirium.[127, 128]

- *Brain Oxygenation:* Monitoring using cerebral oximetry (similar principle as peripheral pulse oximetry) may be considered in patients with history of or at risk for stroke.[129]

iii) Intraoperative Concerns

The intraoperative course is commonly uneventful, though three potential issues should be mentioned:

- *Hypotension*: The cardiovascular changes associated with aging are largely the result of stiffening of the heart and the vascular system, leading to systemic hypertension, left ventricular hypertrophy, and to a decreased range of acceptable left atrial filling pressures. As such, intraoperative hypotension should be treated primarily with peripheral vasoconstrictors (e.g., phenylephrine, an alpha-1 adrenergic receptor agonist) and judicious volume administration.[130] Notably, fluids should be administered based on clinical evidence of hypovolemia, *not* simply on the basis of hypotension alone.

- *Kidney Injury:* While many different agents have been studied with varying success, only fluid loading (while avoiding overt volume overload) has been consistently reported to be associated with better renal outcomes.

- *Hypothermia in the elderly:* Thermoregulation becomes impaired with aging.[69, 70] Thus, temperature regulation should be aggressively managed.[7]

Postoperative pain after lower extremity venous procedures is commonly well-controlled with the intraoperatively administered local anesthetic and over-the-counter non-opioid analgesics, such as Acetaminophen or Non-steroidal anti-inflammatory drugs (NSAIDS).

Nontraditional drugs that have been found to reduce postoperative pain and deserve consideration on an individual basis include gabapentin, ketamine, clonidine, and dexmedetomidine.

Some patients may, however, require supplemental opioids in the PACU:

- *Patients with Renal Impairment:*[131, 132]
    - Fentanyl seems to be safe
    - Dose adjustments are required when using morphine (active metabolites accumulate in renal failure), oxycodone (80% metabolized in the liver, 20% excreted unchanged in the urine), or hydromorphone (metabolized in liver, but 3-glucuronide metabolite can accumulate and produce neuroexcitatory effects)
    - Codeine (accumulation of toxic metabolites) and meperidine (accumulation of normeperidine, which may cause seizures) should not be used.

- *Patients with Hepatic Dysfunction:*[131-133]
    - Fentanyl seems to be safe
    - Morphine, hydromorphone, and oxycodone may not be readily converted to active metabolites
    - Codeine (reduced pain control as codeine is a prodrug hepatically converted to morphine), methadone (reduced clearance), and meperidine (reduced clearance and prolonged half-life; risk of seizures) should not be used.

c. General and Procedure-Specific Concerns

General intra-operative concerns: Skin preparation (CHG wipe timeout for three minutes to dry), Foley placed by trained staff, shaving performed with clippers, normothermia.

- *Sclerotherapy*:
    - No anesthetic technique required.
    - Shaving typically not required.
    - Skin prep: Alcohol wipes are typically the only requirement.
    - Patients at high risk of thrombosis could be treated with a single prophylactic dose of low molecular weight heparin (LMWH) prior to procedure.
    - Ultrasound guided access of the superficial vein can be utilized and sclerosant injected into the target vessels. This can also be used to massage the sclerosant into distant target vessels.
    - Ultrasound assessment of the deep vein to rule out DVT and the superficial vein to ensure adequate treatment is performed at the end of the procedure.

- *Vein ablation:*
    - Tumescent anesthesia (500ml solution of 445 ml of 0.9N saline, 50 mL of 1% Lidocaine with 1:100,000 epinephrine, and 5 mL of 8.4% sodium bicarbonate) is infiltrated under ultrasound guidance in the saphenous sheath for thermal ablations to provide analgesia and to act as heat sink during cauterization of the vein and prevent damage to surrounding structures. Non-thermal ablations can be performed with only local anesthesia at the access site. Additional sedation can be provided at the discretion of the treating physician.
    - Perioperative antibiotics and venous thromboprophylaxis are not routinely used.
    - Patients at high risk of thrombosis could be treated with a single prophylactic

dose of LMWH prior to procedure.
    - Ultrasound guided access of the superficial vein is gained. Also, ultrasound is used to position the catheter relative to the junction with deep venous system.
    - Ultrasound assessment of the deep vein to rule out DVT and the superficial vein to ensure adequate treatment is performed at the end of the procedure.

- *Phlebectomy, high ligation with stripping:*
    - Anesthetic technique: General anesthesia, monitored anesthesia care (MAC), conscious sedation with local or tumescent anesthesia.
    - Perioperative antibiotics are weight-based, and the initial dose should be administered prior to incision.
    - Venous thromboprophylaxis could be administered to patients at high risk for thrombosis.
    - Mapping of varicose veins: The veins to be removed during surgery are typically marked while the patient is standing preoperatively.
    - Alternatively, intraoperative ultrasound can be used to map the location of the target veins.

- *Venography*:
    - General anesthesia, MAC, or conscious sedation
    - Perioperative antibiotics are not routinely administered.
    - Venous thromboprophylaxis not routinely administered.
    - Full dose anticoagulation is administered prior to intervention (balloon angioplasty/stenting) and ACT is maintained above 200 seconds.
    - Venous access should be performed under ultrasound guidance regardless of access site (femoral, popliteal, jugular or other)
    - Contrast volume should be minimized in patients with renal insufficiency by using dilute contrast or CO_2 angiography to avoid contrast-associated acute kidney injury. Intravascular ultrasound can further decrease use of contrast agents and is the preferred modality for identifying venous outflow obstruction and sizing of venous stents.

- *Open venous reconstructive surgery:*
    - General anesthesia, MAC
    - Perioperative antibiotics are weight based and initial dose should be administered prior to incision.
    - The placement of central intravenous lines and arterial line for hemodynamic monitoring is determined on a case-by-case basis depending on patient comorbidities and expected blood loss.
    - Full dose anticoagulation is administered prior to clamping the vessels and ACT is maintained above 200 seconds.

Postoperative

Steps Prior to Discharge

Venography:

- *Medication:* After stent placement, patients are started on antiplatelets (aspirin or clopidogrel) if they do not receive any antithrombotic therapy prior to procedure. Patients on chronic anticoagulation can resume medications the next day after the procedure. Anticoagulation is recommended following deep venous intervention/stenting for chronic ilio-caval obstruction although the duration is still in evolution and is not well established and can vary from 4-6 weeks to a year based on local protocols and different clinical trial protocols.
- *Discharge*: Patients remain supine for three hours after the procedure and are typically discharged the same day.

Open Venous Reconstructive Surgery:

- *General:*
  - Patients are admitted to a monitored unit and are assessed for patency of flow and bleeding.
  - Perioperative antibiotics are discontinued in 24 hours.
  - Incentive spirometer use is encouraged immediately after surgery and should be performed every hour.
  - Foley catheter is discontinued in 24-48 hours after surgery when accurate assessment of urine output is no longer necessary.
  - Mobilization out of bed is initiated in 24-48 hours after surgery with gradual increase in ambulation as tolerated.
  - Diet can be resumed within 24 hours when patient is awake and there is no concern for aspiration.
  - Glucose control
- *Monitoring:* Central intravenous lines and arterial lines are removed when hemodynamic stability is established, and invasive monitoring is no longer warranted.
- *Wound Care:* Sterile occlusive intraoperative wound dressings are changed on postoperative day two. Alternatively, negative pressure dressings can be left in situ for longer period (typically five to seven days).
- *Medication:* Antithrombotic therapy is resumed as soon as safe, from a bleeding standpoint. Patients at high-risk for thrombosis can be maintained on low dose subtherapeutic anticoagulation started immediately in the operating room.
- *Pain Control*: Pain medications consists of intravenously narcotics initially and transitioned to oral narcotics as soon as patient is tolerating diet.
- Physical therapy and pain control should be initiated.

Steps After Discharge

Vein Ablation:

- *General:*
  - Patients are encouraged to ambulate after vein ablation and can resume most activities the same day.

    - Compression stockings are placed at the end of the procedure after thermal vein ablation and are recommended for at least 1-2 weeks after procedure. Non-thermal vein ablation does not require compression therapy after the procedure.
- *Follow-up:* Follow up call within the first week after surgery.
- *Office / Telehealth Visit*:
    - A visit to assess clinical improvement and check for complications (phlebitis, hematoma formation, infection, nerve injury) should take place within a month. Patient should be assessed also for the need of additional procedures (e.g., phlebectomy, sclerotherapy).
    - Patients should receive follow-up ultrasound to document closure (thrombosis) of the vein treated and to rule out endothermal heat induced thrombosis (EHIT) within 1-2 weeks of the procedure.[134]
    - Follow up beyond the first visit can be done as needed.
- *Medication*: Patients can use Acetaminophen or NSAIDs over-the-counter pain medications as needed.

Phlebectomy, High Ligation with Stripping:

- *General:* Compression therapy typically in the form of an ACE wrap covering the lower extremity from the foot to the thigh is placed at the end of the procedure after phlebectomy and high ligation with stripping. The compression helps tamponade any venous bleeding in the soft tissue caused by avulsion of the veins and prevents hematoma formation and should be applied for one week.
- *Follow-up:* Follow-up call within the first week after surgery.
- *Office / Telehealth Visit*: Follow-up to assess clinical improvement and check for complications (wound infection, hematoma formation) within a month postoperative, unless indicated sooner.
- *Medication*: Patients can use Acetaminophen or NSAIDs over-the-counter pain medications as needed.

Venography:

- *Follow-up:* Follow-up call within the first week after surgery.
- *Office / Telehealth Visit*:
    - Follow up office visit with ultrasound in a month after the procedure to assess clinical improvement and stent patency.
    - Long-term follow up consists of yearly office visits for clinical assessment and ultrasound if a stent is placed.[135]
    - *Medication*: Patients can use Acetaminophen or NSAIDs over-the-counter pain medications as needed.

Open Venous Reconstructive Surgery:

- *General:*
    - Incisions at high risk for wound break down (e.g., inguinal) should be covered with an incisional negative pressure dressing or dry gauze dressing on daily basis for 2-4 weeks after surgery.
- *Follow-up:* Follow-up call within the first week after surgery.
- *Office / Telehealth Visit*:

    - Follow up office visit with ultrasound in a month after the procedure should be scheduled to assess clinical improvement and stent patency.
    - Patients with venous ulcer or wounds should continue with periodic monthly follow up until wounds are completely healed.
    - Long-term follow up consists of yearly office visits for clinical assessment and ultrasound to document patency of the venous reconstruction.
- *Medication*:
    - Upon discharge, patients should be stable on oral antithrombotic therapy. Alternatively, outpatient therapy with low molecular weight heparin with transition to an oral anticoagulant is an acceptable option.
    - Narcotic medications are prescribed for pain control with goal to transition to over-the-counter pain medications (Acetaminophen or NSAIDs) as soon as tolerated.

VII. Venous Thromboembolic Disease

Venous thromboembolic disease is treated with the following procedures:

- Catheter-directed thrombolysis/thrombectomy for deep vein thrombosis
- Catheter-directed thrombolysis/thrombectomy for pulmonary embolism
- Inferior vena cava (IVC) filter placement or retrieval

Preoperative

Patient History

Venous thromboembolism (VTE) consists of deep vein thrombosis (DVT) and pulmonary embolism (PE). While only 25% of patients with DVT have clinical evidence of PE, up to 80% can have clinically silent embolization to the lungs.[136] Patients with DVT typically present with acute onset of lower extremity pain, swelling, and erythema. Chest pain, dyspnea, and sometimes hemoptysis are symptoms of PE.

Occasionally, patients can present with paradoxical arterial embolization (stroke, limb ischemia) in the setting of a patent foramen ovale.

Patients should be assessed for provoking factors such as recent surgery, hospitalization, immobilization, and long travel. Patients with active cancer, hypercoagulable disorders, and personal history of VTE are particularly at increased risk.

Physical Examination

Physical exam of the lower extremities reveals edema, erythema, and calf or thigh pain upon palpation. Cyanosis and decreased pulses on exam especially if the limb is tense or exhibits neurological changes should raise concern for phlegmasia and constitutes a vascular emergency.

Patients with PE can present with tachycardia and low oxygenation on pulse oximetry. Distended neck veins and signs of right sided heart failure can be noted in intermediate risk PE. Patients with high-risk PE present with hypotension and can progress to hemodynamic collapse.

Imaging

Duplex scanning of the lower extremities is the imaging modality of choice to diagnose acute DVT. The affected veins are non-compressible, dilated, and show no flow on doppler interrogation in the presence of occlusive thrombus.

Computed tomography angiography (CTA) provides fast and accurate imaging for the diagnosis of PE and the extent of embolization to the lungs, as well as the presence of right heart strain. Echocardiography is indicated for patients with submassive and massive PE to look for right heart strain (McConnell sign). Cross sectional imaging of the abdomen and pelvis with CTA or Magnetic Resonance Venography (MRV) is sometimes warranted to diagnose occult DVT and rule out extrinsic compression or to assess the proximal extent of the thrombus in patients with extensive iliofemoral DVT. Cross sectional imaging can also be used to assess thrombus burden

in the IVC, the size of the IVC, and any associated anatomical abnormalities if IVC filter placement is considered.

Medical Management and Lifestyle Changes

Anticoagulation is the mainstay treatment for VTE.[137] Patients can receive heparin drip in the inpatient setting as a bridge to oral therapy. Alternatively, direct oral anticoagulants (DOACs) can be used for outpatient therapy without hospitalization. Dabigatran, rivaroxaban, apixaban, and edoxaban (DOACs) are the anticoagulants of choice for outpatient VTE treatment over vitamin K antagonists, or LMWH.[137]

Patients with PE and hypotension (high-risk PE) should be evaluated by the PE response team (PERT) if available and treated with systemic thrombolytic therapy, suction thrombectomy or pulmonary embolectomy as indicated.[138]

A selective group of patients are considered at low risk of VTE recurrence or propagation and can be managed without anticoagulation. Patients with subsegmental PE and no proximal DVT can undergo clinical surveillance and patients with provoked isolated tibial vein DVT (unless symptomatic) can undergo serial ultrasounds to rule out proximal extension. Compression stockings should be offered to patients with DVT and significant swelling for symptomatic relief as needed. Leg elevation can also alleviate symptoms in patients with DVT.[137]

Risk Stratification for Surgery

Patients with iliofemoral DVT who have moderate-to-severe symptoms despite anticoagulation and compression therapy can be treated with catheter directed thrombolysis or thrombectomy. Early thrombus removal can be offered to patients with acute iliofemoral DVT, who are at low risk of bleeding and are ambulatory with good functional capacity and an acceptable life expectancy.[139]

Patients with extensive DVT and limb threatening venous ischemia (phlegmasia) should be treated with emergent thrombus removal. Patients with PE and signs of right heart strain (intermediate and high-risk PE) could be treated with catheter-directed thrombolysis, suction thrombectomy or surgical thrombectomy in consultation with the PERT.

Patients with contraindication to anticoagulation and documented VTE should be considered for IVC filter placement in the setting of ongoing significant clinical risk for PE. IVC filter placement can be selectively placed in patients undergoing catheter directed interventions for DVT or PE with a defined plan for filter retrieval.[140]

Risk Assessment

A multidisciplinary approach to care can optimize outcomes. Medical specialists and team members can assist patients with risk factor modification, such as smoking cessation, maintaining glycemic control, normalizing blood pressure and lipid levels, maintaining antiplatelet therapy and fostering participation in exercise programs, thereby promoting a positive patient experience. Discharge planning should also be considered at time of surgical planning.[7]

Preoperative Labs

Standard CBC, chemistry profile and coagulation profile are recommended before all interventions. D-dimer levels can help in diagnosing VTE. Patients with PE should have biomarker levels of troponin and Brain Natriuretic Peptide (BNP) checked as markers of myocardial injury. Baseline fibrinogen levels can be considered for patients undergoing thrombolytic therapy.

Preoperative Medication Adjustment

Patients who plan to undergo catheter directed intervention are typically hospitalized and should be stable on anticoagulation without evidence of bleeding. Hydration with normal saline or 5% dextrose/sodium bicarbonate before and after the procedure should be considered in patients at risk of postcontrast acute kidney injury, and if pharmacomechanical intervention with the is considered given the risk of hemolysis and renal insult (specifically with the Angiojet device (Boston Scientific)).[141]

Preoperative anticoagulation with heparin infusion can be usually continued but should be held prior to procedure if the perceived risk of bleeding is high..

- *Perioperative antibiotics*: Prophylactic antibiotics for open procedures should be considered perioperatively as for any other surgery, and for endovascular interventions on a case-by-case basis.

- *Anticoagulation and its reversal*: If patient is on oral anticoagulation preoperatively, then discontinue them as needed before the procedure to minimize bleeding complication. DOAC should be held for 48-72 hours before procedure. Warfarin should be discontinued 3-5 days in advance. Bridging with parenteral anticoagulation (UFH or LMWH) in appropriate patients with high thrombosis risk should be considered.

- *Nephropathy*: Techniques to minimize contrast nephropathy for endovascular procedures in patients with CKD should be utilized. While many different agents have been studied with varying success, only fluid loading has been consistently reported to be associated with better renal outcomes. If there is no contraindication fluid administration pre, intra and post operatively is recommended. The issue to hold ACEs and ARBs is still not resolved and more research is needed.

- *Allergy*: Patients with allergy to intravenous iodinated contrast and scheduled for angiography should get premedication with prednisone 50 mg in 3 oral doses at 13 hours, 7 hours, and one hour prior to procedure, and Diphenhydramine 50mg one hour prior to procedure. Rescue dosing with IV solumedrol or Decadron can be used as needed. CO2 venography can also be considered as indicated.

- *ACE Inhibitors*: If significant volume depletion is anticipated, it is suggested to hold ACE inhibitors and angiotensin receptor antagonists on the morning of surgery and restarting these agents after the procedure, once euvolemia has been achieved.

- *Diabetes Mellitus:* It is suggested to hold metformin at the time of administration of contrast material among patients with an eGFR of <60 mL/min or up to 48 hours before administration of contrast material if the eGFR is <45 mL/min and restarting no sooner than 48 hours after administration of contrast material as long as renal function has remained stable. Diabetic patients who receive intermediate or long-acting insulin should receive half the scheduled dose when nil per os (NPO) in preparation for surgery. Glycemic control should be considered per the current guidelines of the American Diabetes Association.[18]

Recommended Perioperative Consultations

Patients with family history of VTE or recurrent episodes of VTE should get a vascular medicine or hematology evaluation to identify hypercoagulable conditions and help to define a long-term anticoagulation plan.

The decision to intervene on PE is preferably made by a pulmonary embolism response team (PERT) which can include vascular surgery, vascular medicine, cardiology, pulmonology, interventional radiology, cardiac surgery, or other specialists depending on the local expertise.

Intraoperative

General: Some procedures for venous thromboembolic disease, such as IVC filter placement, can be safely performed without anesthesia involvement.

Patients who may benefit from anesthesia care team involvement, include patients:
- With high ASA classification.
- At-risk for respiratory or hemodynamic decompensation.
- Who are unable to tolerate awake procedure or supine position for a prolonged period of time.
- With procedures that are anticipated to be technically complex.

Postoperative pain for venous thromboembolic disease is commonly well-controlled with the intraoperatively administered local anesthetic and over the counter non-opioid analgesics, such as Acetaminophen.

a. Optimization and Risk Assessment

The acuity with which a venous thromboembolic disease presents can range from a stable patient awaiting a "semi-elective" procedure to a highly unstable patient requiring hemodynamic support and mechanical ventilation.

Consequently, the perioperative anesthesia process should be meticulous and include identifying potential risk factors, with particular attention paid to h/o hypercoagulable state, including h/o DVT, PE, pulmonary HTN due to potential chronic embolic burden (RV function), and anticoagulation.

b. Anesthesia Management

i) Anesthesia Techniques

MAC is preferred.

LA +/- sedation is the technique most commonly used for venous thromboembolic disease interventions.

Sedation is commonly provided with benzodiazepine, propofol, and/or dexmedetomidine infusion. Notably, avoidance of perioperative benzodiazepines has been recommended to reduce the risk of postoperative delirium.[110] Dexmedetomidine, with its lack of respiratory depression, may be an attractive alternative. When used in high doses, however, hypotension and/or bradycardia resulting from Dexmedetomidine may outlast its sedative effects leading to prolonged stay in the PACU.
Opioids may be added for analgesia/sedation as well.

General anesthesia may be required in select patients who are unable to tolerate sedation, be supine for prolonged period of time, or who require a complex surgical intervention. Patients with high acuity (e.g., hypoxia or hypercarbia) and/or co-morbid burden may need endotracheal tube placement for mechanical ventilation. However, general anesthesia (or even deep sedation with propofol) can lead to hemodynamic collapse in unstable patients with PE. Therefore, in unstable patients with PE general anesthesia induction should either be avoided or conducted with great caution, with ECMO stand-by, if available.

ii) Monitoring and Access

All patients require the standard mandated by the American Society of Anesthesiologists including oxygenation (peripheral O2S), ventilation (CO2 monitor), circulation (ECG and BP) and temperature monitoring.[67]

In addition, all patients need an adequate IV-access and continuous oxygen supply.

- *Indwelling Arterial Catheter*: May be considered in patient with cardiac, pulmonary, renal, or metabolic conditions requiring continuous hemodynamic monitoring and/or blood sampling.

- *Depth of Anesthesia Monitor (EEG, or EEG-based device):* May be considered in elderly patients at risk, as increased anesthesia depth has been linked with postoperative cognitive decline and delirium.[127, 128]

- *Brain Oxygenation:* Monitoring using cerebral oximetry (similar principle as peripheral pulse oximetry) may be considered in patients with history of or at risk for stroke.[129]

- *Cardiac Output Monitor*: May be considered in those with tenuous cardio-pulmonary status or at risk of hemodynamic decompensation.

iii) Intraoperative Concerns

In most patients the intraoperative course is uneventful. However, hypotension, kidney injury, and/or hypothermia may ensue.

- *Patients with Pulmonary Hypertension:* For example, due to thromboembolic burden, should be identified in effort to prevent acute intraoperative right heart failure/ischemia (e.g., due to acute embolus or intraoperative hypercarbia leading to increase in right heart pressures). The differential diagnosis of an intraoperative hemodynamic collapse (code blue) should include acute RV ischemia/failure. Notably, the reverse Trendelenburg and not the Trendelenburg position may help unload right heart chamber. In patients with pronounced hypotension refractory to other therapies, emergent use of VA-ECMO should be considered.[142] Bradycardia can also occur with rheolytic thrombectomy using the Angiojet device. Although often asymptomatic and self-resolving, it can lead to cardiac compromise in elderly patients with existing coronary disease and should be treated accordingly.

- *Kidney Injury:* While many different agents have been studied with varying success, only fluid loading (while avoiding overt volume overload) has been consistently reported to be associated with better renal outcomes. This is particularly important when rheolytic thrombectomy with the Angiojet device is performed, given the risk of heme pigment nephropathy from intravascular hemolysis.

- *Hypothermia:* In the elderly, hypothermia could be detrimental. Thermoregulation becomes impaired with aging.[69, 70] Thus, proactive methods for temperature regulation should be aggressively utilized.[7]

c. General and Procedure-Specific Concerns

General intraoperative concerns: Skin preparation (CHG wipe timeout for three minutes to dry), Foley placed by trained staff, shaving performed with clippers, normothermia.

General:

- Perioperative antibiotics are not routinely administered unless intravenous/intraarterial catheters are left in place for lytic infusion.
- Venous access should be performed under ultrasound guidance regardless of site (femoral, popliteal, jugular or other)
- Contrast volume should be minimized in patients with renal insufficiency by using dilute contrast or CO2 angiography to avoid Postcontrast acute kidney injury. Intravascular ultrasound can further decrease use of contrast and is the preferred modality for identifying venous outflow obstruction and sizing of venous stents.
- Full dose anticoagulation is administered prior to intervention (balloon angioplasty/stenting/mechanical thrombectomy) and ACT is maintained above 200s.
- For initiation/continuation of catheter-directed thrombolysis, the sheaths and catheters should be secured to the patient to prevent dislodgement during transportation.
- For initiation/continuation of catheter-directed thrombolysis, all the infusion lines should be clearly labeled with the respective medication for continuation of care.

- *Patients Undergoing Catheter-directed Thrombolysis*
- *General:*
    - Administer low-dose heparin through the access sheaths and avoid full anticoagulation during the infusion of thrombolytic agent to minimize the risk of bleeding.
    - Patients are on bed rest and should not ambulate.
    - Patients can resume diet after the procedure but should be kept NPO subsequently for enough time in preparation for follow up procedure.
- *Monitoring:*
    - Patient should be admitted to a monitored unit or intensive care unit per hospital protocol.
    - Patients should be assessed at least every 2-3 hours for bleeding at the access site and remotely, extremity perfusion, and change in mental status.
    - Patients should have labs (CBC, prothrombin time [PT], partial thromboplastin time [PTT], INR, and fibrinogen) checked periodically during the day per local protocol.

Postoperative

Steps Prior to Discharge

- *General:*
    - Mobilization out of bed is initiated within 24 hours after termination of catheter directed thrombolysis and removal of procedural sheath (s)
    - Full anticoagulation should be resumed within 24 hours of termination of catheter directed thrombolysis and removal of procedural sheath (s) when deemed safe from a bleeding standpoint.
    - IVC filter placement can be performed on an inpatient or outpatient basis and requires immobilization for 2-3 hours after procedure only.
- *Medication:* Perioperative antibiotics are discontinued in 24 hours.
- *Pain Control*: Pain medications can be administered orally or intravenously.

Steps After Discharge

- *General:*
  - Patients with IVC filters should be periodically evaluated for retrieval within the recommended device instructions for use, when the risk of PE resolves or when they can resume anticoagulation.[143]
  - The use of compression stockings is recommended for edema management.
- *Follow-up*: Follow up call within the first week after surgery.
- *Office / Telehealth Visit*:
  - Follow-up in a month after the procedure to assess clinical improvement and related imaging (venous duplex of the lower extremities for patients with DVT, Echo for patients with PE)
  - Follow-up office visit with ultrasound after one year to assess clinical status, recurrence of VTE, and development of post-thrombotic syndrome or post-thrombotic pulmonary hypertension.
  - Proper follow-up with consulting services (such as hematology, nephrology, or the pulmonary hypertension clinic) should be established, as needed.
- *Medication*:
  - Patients are typically kept on oral antithrombotic therapy
  - Anticoagulation is recommended following deep venous intervention/stenting for chronic ilio-caval obstruction although the duration is still in evolution and is not well established and can vary from 4-6 weeks to a year based on local protocols and different clinical trial protocols.
  - Patients can use Acetaminophen or NSAID over-the-counter pain medications, as needed.
  - The use of long-term medications can be coordinated with the patient's primary care provider and can include the use of statins or a PCSK9 inhibitor in order to achieve optimal LDL control. In addition, anti-platelet agents, anti-hypertensive agents, and agents for glycemic control should be prescribed, as indicated.

VIII. Amputations

A. Preoperative

Patient History

Lower extremity major amputations are often complications of peripheral arterial disease (PAD), neuropathy, and sepsis due to soft tissue infection. Peripheral arterial disease alone, or in combination with diabetes mellitus, contributes to more than half of all amputations. Other risk factors to elucidate in the patient's history include chronic kidney disease, coronary artery disease, functional status, smoking history, and history of TIA or stroke.

Indications for lower extremity major amputation includePAD after revascularization attempts have been made and failed; foot sepsis; and trauma. Primary amputation is the most effective therapy for non-ambulatory patients with advanced chronic limb-threatening ischemia especially in the presence of limb contraction. This should be documented in the patient's medical record.[43]

Physical Examination

A thorough exam is required prior to a major amputation, with a special focus on the level of arterial perfusion present at possible amputation levels. Further, the amputation margin should be proximal to existing wounds or non-viable lower extremity tissue.

Pulse examination can assist in determining the level of amputation. For example, lack of easily palpable femoral pulses may predict poor healing of a below knee amputation, and palpable popliteal pulse is more likely to predict healing of a below knee amputation (BKA).

To further determine type and level of amputation, the limb should be evaluated for nonviable tissue (dry gangrene, wet gangrene, fixed mottling in acute limb ischemia), spreading infections compromising survival (necrotizing fasciitis, chronic ulceration, and osteomyelitis), and disabling conditions (non-functional/ limited limb function, intractable pain, or nonhealing diabetic wounds).

Imaging

Imaging of the lower extremity prior to amputation is important in determining the level of amputation. Arterial duplex, Doppler, and thigh pressures can be used to assist in determining the arterial perfusion that is available to support a particular level of amputation. Transcutaneous oxygen level measurement can provide guidance regarding adequacy of perfusion at a proposed amputation level, with a measurement of greater than 40 mm Hg being associated with successful healing.[144]

CT angiography can be employed to assess arterial anatomy if other non-invasive testing is inconclusive.

Plain X-ray can assess for infection, and prior orthopedic intervention or hardware that may interfere with amputation. In these cases, specialized saws may be necessary to cut through the metal, or orthopedic surgery consultation may be required to remove the hardware prior to amputation. MRI can be used to assess for infection with bony involvement. The amputation margin should be proximal to any infected regions.

Medical Management and Lifestyle Changes

- *Smoking cessation*: A multidisciplinary comprehensive smoking cessation approach should be utilized until tobacco use has been stopped.

- *Diabetes mellitus*: For patients with PAD, it is important to optimize diabetes control (hemoglobin A1c goal of <7.0) without hypoglycemia.

- The SVS recommends therapy with aspirin (75-325 mg daily). Clopidogrel is recommended (75 mg daily) as an alternative to aspirin for antiplatelet therapy. Dual antiplatelet therapy, with aspirin and Plavix, is not better than aspirin alone.

- *Hypertension*: Anti-hypertensive control should be focused on a goal blood pressure of less than 140/90, with ACE inhibitors and ARB recommended as first line. The use of beta blockers (hypertension, cardiac indications) should be considered if symptoms are due to atherosclerosis.

- For patients with dyslipidemia, treatment with a statin to achieve a target low-density lipoprotein cholesterol (LDL-C) level of <70 mg/dL is recommended. If LDL-C goal is not achieved by statin therapy, then PCSK9i should be considered. Even if LDL-C is at goal, statin therapy should be initiated and continued due to its overall pleiotropic beneficial effects.

Risk Stratification for Surgery

Because cardiac disease is so prevalent among patients with peripheral vascular disease, an ECG should be performed in all patients and if time allows, cardiac risk stratification should be obtained.

Chest radiography may be helpful in some patients if undiagnosed underlying disease is suspected on the basis of the history and physical examination. In select patients, more advanced testing may be appropriate, such as cardiac stress testing or pulmonary function evaluation when cardiac or pulmonary disease is suspected. The associated comorbidities and risk factors, including smoking cessation, should be managed optimally before surgery, similar to patients undergoing any major vascular surgical procedures. There are well-accepted, published guidelines from most of the medical subspecialties to guide the preoperative evaluation, including those from the American Heart Association and the American College of Cardiology for the optimal preoperative cardiac evaluation for patients undergoing major noncardiac surgery.[31]

A multidisciplinary approach to care can optimize outcomes. Medical specialists and team members can assist patients with risk factor modification, such as smoking cessation, maintaining

glycemic control, normalizing blood pressure and lipid levels, maintaining antiplatelet therapy, thereby promoting a positive patient experience. Discharge planning should also be considered at the time of surgical planning.

When a patient presents with a limb that is life-threatening (e.g., necrotizing fasciitis, sepsis, acute limb ischemia) the patient may require a staged amputation approach. An open (guillotine) amputation can be performed first in order to obtain source control. The planned second stage involves delayed closure and can be scheduled when the patient is medically stable. This two-stage approach may lead to decreased residual limb infections and need for revision.[145]

Risk Assessment

When assessing patients who need a major amputation, it is important to understand the risk of postoperative morbidity and mortality.[7] Myocardial infarction, pulmonary complications, and renal failure are frequent after lower extremity amputations.

By the time a patient is being assessed for a major lower extremity amputation, most other management techniques have been tried and failed. It is still important to optimize patients' comorbid conditions (smoking cessation, high-density lipoproteins (HDL), HTN, Type 2 diabetes mellitus [T2DM] optimization) and optimize arterial perfusion as much as possible.

In many cases, the patient presents with a severely infected extremity that cannot be managed with aggressive debridement and antibiotics. This represents a surgical emergency, and the patient should undergo amputation expeditiously without further testing or optimization. However, prior to elective or semi-elective amputationsmedical optimization of peripheral arterial disease (including possible inflow revascularization), diabetes management, smoking cessation, and optimization of comorbid conditions including CKD and CAD should be pursued.

Given the high risk of coronary disease, all patients should be on aspirin (75-100 mg daily). The addition of rivaroxaban 2.5 mg twice daily to aspirin monotherapy may improve cardiovascular outcomes (COMPASS trial).[89] Aggressive statin therapy should also be employed.

Perioperative transfusion of packed red blood cells should be performed if the hemoglobin level is less than 7 g/dL. Recent EKG should be obtained for all patients. In some patients, and in consultation with cardiology, an echocardiogram, cardiac stress test, or cardiac catheterization may be helpful.

a. Diabetes Mellitus

Glycemic control should be considered per the current guidelines of the American Diabetes Association.[18]

Preoperative Labs

Standard preoperative labs should be ordered and reviewed prior to surgery. This includes complete blood count (CBC), basic metabolic panel (BMP), PT/INR, hemoglobin A1C, albumin, and pre-albumin.

Preoperative Medication Adjustment

- *Anticoagulation*: Anticoagulation should be held in the periprocedural period. Heparin bridging may be required, especially for mechanical mitral valve replacement.

- *Antiplatelet and anti-hypertensive medications*: Aspirin and other antiplatelet medications and anti-hypertensives should be continued through the procedure.

- *Preoperative antibiotics:*

  - Recommended within one hour of skin incision
  - Intravenous antibiotics that are appropriate for skin flora are adequate for amputations that are not complicated by soft tissue infection or wound infection
  - In patients with active wounds, wound cultures should be obtained in order to tailor antibiotic treatment.
  - Anaerobic coverage should be used in diabetic patients.
  - Continued use of antibiotics post operatively can be considered.

- *Thromboprophylaxis*: Patients undergoing major amputations are at high-risk for thromboembolism due to the nature of surgery; therefore, LMWH or heparin subcutaneous should be administered.

- *ACE Inhibitors*: If significant volume depletion is anticipated, it is suggested to hold ACE inhibitors and angiotensin receptor antagonists on the morning of surgery and restarting these agents after the procedure, once euvolemia has been achieved.

- *Diabetes Mellitus:* It is suggested to hold metformin at the time of administration of contrast material among patients with an eGFR of <60 mL/min or up to 48 hours before administration of contrast material if the eGFR is <45 mL/min and restarting no sooner than 48 hours after administration of contrast material as long as renal function has remained stable. Diabetic patients who receive intermediate or long-acting insulin should receive half the scheduled dose when nil per os (NPO) in preparation for surgery. Glycemic control should be considered per the current guidelines of the American Diabetes Association.[18]

Recommended Preoperative Consultations

Some patients with chronic wounds and rest pain requiring amputation may benefit from proper counseling on the subject prior to elective amputation. Preoperative teaching and evaluation for postoperative needs can be addressed with discharge planning, which include coordination with a prosthetist and amputee advocate. Unfortunately, since many amputations are performed in the urgent and emergency setting,counseling, medical management, and stumpcare are provided in the postoperative period.

Intraoperative

Anesthesia Management

General: While some minor amputation procedures, such as toe amputation, can be safely performed without anesthesia involvement, most patients will benefit from anesthesia care team involvement, as patients frequently:

- Are older with high ASA classification.
- Display significant comorbidities, including peripheral arterial disease, diabetes mellitus, hypertension, chronic kidney disease, coronary artery disease, poor functional status, smoking history, and history of TIA or stroke.
- Are at risk for respiratory or hemodynamic decompensation.
- Are unable to tolerate awake procedure or supine position for a prolonged period of time (e.g., due to back pain).

The acuity of illness underlying the need for amputation, can range from a stable (i.e., "semi-elective") procedure, to a highly unstable clinical presentation with the patient requiring hemodynamic support and mechanical ventilation (e.g., sepsis and/or unstable coronary artery disease).

The reported perioperative mortality rates range from 0.9% to 14.1% for BKA, and 2.8% to 35% for AKA.[146, 147] Consequently, the perioperative anesthesia process should be meticulous and identify potential risk factors—with particular attention to cardiovascular risk factors, anticoagulation, diabetes, and sepsis.

a. Anesthesia Management

i) Anesthesia Techniques

Interestingly, retrospective analysis of the American College of Surgeons National Surgical Quality Improvement Project (ACS-NSQIP) database did not identify any significant effects of the mode of anesthesia on perioperative outcomes after major lower extremity amputation in the geriatric population.[148] Anesthesia type was not an independent risk factor for wound, cardiac, pulmonary, renal, stroke complications, or postoperative mortality.[148] Of note, general anesthesia was more likely to be used by general and orthopedic surgeons than by vascular surgeons.[148] The operative time was not affected by anesthesia technique, though general anesthesia was associated with a lower time from anesthesia to the operation.

- *General anesthesia:* May be required in select patients (1) with contraindications to neuraxial anesthesia or peripheral nerve blocks, (2) unable to be supine for prolonged periods of time, or (3), requiring a complex surgical intervention. Endotracheal tube (ETT, "tube") provides better protection from aspiration and thus may be preferred over LMA (high co-morbid burden may increase the risk of aspiration).

  General anesthesia can be maintained using either: (1) inhalational agent ("gas"): Sevoflurane, with a "sweet" smell, is commonly used compared to Desflurane as the latter has a more pungent smell/taste (i.e., avoid in patients with irritable airway). Desflurane was, however, reported to be associated with a faster emergence;[96, 97] (2) total intravenous anesthesia [TIVA]; commonly consisting of a combination of infusions (e.g., propofol, opioid, lidocaine, ketamine) offers another approach to maintain general anesthesia. TIVA was also found to reduce nausea/anesthesia (propofol).[98]

- *Neuraxial technique (spinal and/or epidural anesthesia) +/- sedation:* May provide adequate analgesia while avoiding the risk of general anesthesia. Notably, an epidural catheter allows for postoperative pain control. Choice of local anesthetic drug will depend on expected duration of the surgical procedure.

- *Regional anesthetic techniques (e.g., combination of single shot femoral and sciatic nerve blockade):* Represents safe, although less commonly utilized alternatives, especially if the use of lower extremity tourniquet is considered. All anesthetic nerve blockades can be done safely under ultrasound guidance. The choice of local anesthetic drug will depend on

expected duration of surgical procedure. Mepivacaine is suitable for procedures of up to two hours, Ropivacaine or Bupivacaine may be preferred for procedures expected to take longer than two hours.

- *Sedation:* All local, neuraxial or regional anesthetic techniques can be supplemented with light to moderate sedation such as propofol or dexmedetomidine drips for patient comfort. Opioids may be added for analgesia/sedation as well.

ii) Monitoring and Access

All patients require the standard mandated by the American Society of Anesthesiologists including oxygenation (peripheral SpO2), ventilation (CO2 monitor), circulation (ECG and BP) and temperature monitoring.[67] In addition, all patients need an adequate IV-access and continuous oxygen supply.

- *Indwelling Arterial Catheter:* may be considered in patient with cardiac, pulmonary, renal, or metabolic conditions requiring continuous hemodynamic monitoring and/or blood sampling.

- *Central Venous Line:* Intra- and postoperative use of vasoactive drips or large fluid shifts may require the placement of a central venous line.

- *Brain Oxygenation*: Monitoring using cerebral oximetry (similar principle as peripheral pulse oximetry) may be considered in patients who have a history of or who are at-risk for stroke.[129]

iii) Intraoperative Concerns

- *Hypotension*: The cardiovascular changes associated with aging are largely the result of stiffening of the heart and the vascular system, leading to systemic hypertension, left ventricular hypertrophy, and to a decreased range of acceptable left atrial filling pressures. Consequently, intraoperative hypotension should be treated primarily with peripheral vasoconstrictors (e.g., phenylephrine, an alpha-1 adrenergic receptor agonist) and judicious volume administration.[130] Notably, fluids should be administered based on clinical evidence of hypovolemia, not simply on the basis of hypotension alone.

- *Hypothermia*: In the elderly, hypothermia could be detrimental, as thermoregulation becomes impaired with aging.[69, 70] proactive methods for temperature regulation should be aggressively utilized.[7]

d. General & Procedure-Specific Concerns

General intraoperative concerns: Skin preparation (CHG wipe timeout for three minutes to dry), Foley placed by trained staff, shaving performed with clippers, normothermia.

Postoperative

Postoperative care of patients who have undergone major amputation requires a multidisciplinary approach including team members (nurses, physician extenders) , case managers, nutrition, pain management, physical therapy, occupational therapy, psychotherapy, medical care of comorbid conditions, and wound care. One third of postoperative mortality occurs after discharge from acute inpatient care, so therefore close post discharge follow up is recommended. Discharge to a rehabilitation facility may be appropriate. To prevent thromboembolic events, patients should continue DVT prophylaxis while hospitalized.

Steps Prior to Discharge

- *General:* The most common mechanical complication after transtibial amputation is knee contracture. To prevent this, surgeons may use a soft knee immobilizer or rigid stump dressings including casting, or a stump protector.
- *Wound Care:* Immediate postoperative wound care is tailored to the indication for amputation. In the case of transtibial amputations, preventing knee contractures is of paramount importance. The postoperative dressing should stay in place until postoperative day three if the wound bed was clean, the skin was closed, and if the postoperative dressing is not saturated. Otherwise, the dressing should be removed earlier, and the incision line evaluated for signs of bleeding or infection. It is also important to keep transfemoral amputations clean, as they are at higher risk of contamination from urine or stool due to proximity to the trunk.
- *Pain Control*: Acute pain following amputation is expected. Narcotic analgesia in the form of intravenous and oral medications are commonly used. If the patient had a nerve block as operative anesthesia, it may still be effective for hours following the procedure. Reduction in pain allows for patients to initiate mobility and rehabilitation services sooner in their postoperative course. Phantom limb pain is common after amputation, and is experienced by approximately 25% of patients. Mirror therapy has been used as an effective treatment. Gabapentin (Neurontin) or Pregabalin (Lyrica) pharmacotherapy can also be considered.

Physical Therapy: Mobilization is the priority after any major amputation. This includes mobility in the bed and strengthening the upper limbs and remaining limb. Physical therapy and occupational therapy can be initiated postoperative day one if appropriate pain management is achieved and appropriate based on the patient's previous level of mobility. **Steps After Discharge**

- *Follow-up:* Follow up call within the first week after surgery.
- *Office / Telehealth Visit*:
  - Follow-up in clinic within a month after surgery unless indicated sooner.
- Fitting should be performed once the skin has fully healed, at least 8 weeks after amputation. First fitting should be with a firm stocking to help shape and form the residual limb for a prosthesis. Rehabilitation and prosthesis training is necessary during this time. Early introduction to a certified prosthetist, and the use of amputation support groups can also expedite the post op rehabilitation process.

- *Medication:* The use of long-term medications can be coordinated with the patient's primary care provider and can include the use of statins or a PCSK9 inhibitor in order to

achieve optimal LDL control. In addition, anti-platelet agents, anti-hypertensive agents, and agents for glycemic control should be prescribed, as indicated.

IX. Thoracic Outlet Syndrome

This section addresses interventions for neurogenic, venous and arterial thoracic outlet syndrome.

A. Preoperative

Patient History

Thoracic outlet syndrome (TOS) has been classified as neurogenic (95% of cases), venous (3-5%), or arterial (1%). Patients commonly complain of arm pain. Presenting symptoms and predisposing conditions should be elucidated in the preop evaluation.

- *Neurogenic TOS (nTOS):* Patients have associated occipital headache, tension and tightness in the shoulders and interscapular area. Even though discomfort, numbness, and paresthesia can affect the forearm and the hand, they are unlikely to be confined to a single peripheral nerve distribution.

- *Venous TOS (vTOS):* Patients complain of swelling, heaviness, venous congestion, and sometimes cyanosis of the hand. These symptoms can develop acutely when associated with deep vein thrombosis (DVT) of the subclavian vein (in the setting of "effort thrombosis") and occasionally can lead to pulmonary embolism (PE)

- *Arterial TOS (aTOS):* Patients present with hand ischemia related to distal microembolization, acute limb ischemia, or fullness in the supraclavicular area related to subclavian artery aneurysm formation. Hand coolness and discoloration has been also reported with nTOS because of compression of sympathetic nerve fibers causing Raynaud's phenomenon.

A history of trauma to the area is common either as an accident (whiplash injury, clavicular fracture) or repetitive strain (computer typing for nTOS, baseball pitching for vTOS).

Activities involving abduction of the arm typically increase compression and exacerbate symptoms. TOS can also develop secondary to other diseases such as tumor compression or indwelling venous devices (tunneled catheters for dialysis, pacemaker leads) affecting typically an older group of patients.

Physical Examination

A thorough exam of the upper extremities should focus on the presence of edema, discoloration, or coolness of the hand. Dilated superficial veins on anterior chest and shoulder regions may be present on the affected side of vTOS (Urschel sign). VTOS can very rarely present with venous gangrene (phlegmasia).

Neurological exam assesses the motor and sensory functions of the hand as well as any hypersensitivity in the arm. The neck, shoulders, and the area of the scalene triangle should be evaluated for spasm, stiffness, and trigger points that can reproduce the symptoms. The EAST (elevated arm stress test) test involves elevating the arms above the head and opening and closing the fists for 3 minutes. This maneuver compresses the neurovascular bundle and reproduces

symptoms within 60 seconds in most patients especially with nTOS. The radial pulse is palpated, and intensity compared in both arms.

The Adson maneuver involves feeling the radial pulse in adduction and then raising the arm in 90 degrees abduction with rotating the head to the contralateral side and taking a deep breath. Loss of the pulse suggests compression of the artery in the thoracic outlet but is not sufficient to make the diagnosis as it can be anormal finding in patients without TOS.

Imaging

Plain radiographs of the chest and neck can demonstrate bony anomalies associated with TOS such as cervical ribs. Venous and arterial duplex ultrasound with provocative maneuvers can demonstrate vascular compression and reproduce the pathophysiology. In patients with venous TOS, duplex ultrasound can also establish the diagnosis of acute axillosubclavian vein thrombosis.

Cross-sectional imaging with CTA or MRA should be performed with the arms at the sides and then in hyperabduction above the head to demonstrate vascular entrapment and define the relationship of the neurovascular structures and bony elements of the thoracic outlet. The extent of vascular thrombosis or aneurysmal degeneration can be assessed as well as the potential targets for reconstruction. Cross-sectional imaging can also rule out tumors or masses compressing the area and evaluate the cervical spine for degenerative disease. Although various ligamentous bands can contribute to the development of TOS, they are beyond the resolution of the current imaging modalities.

Catheter-based Angiography is used selectively in vascular TOS to assess arterial damage, embolization to the small arteries of the hand, or confirm diagnosis in conjunction with venous thrombolysis.

While advanced imaging is often enough for confirmation of diagnosis and operative planning in vascular TOS, the evaluation of patients with nTOS requires additional testing. Electromyography and nerve conduction studies are performed to rule out radiculopathy, peripheral nerve syndrome, or generalized myopathy. Several neurogenic and musculoskeletal conditions can mimic the symptoms of nTOS or simultaneously affect the patient. A scalene block is used to predict the potential response to surgical decompression. Relief of symptoms after injection of local anesthetic into the anterior scalene muscle can help select the patients that will benefit most from surgery.[149]

Medical Management and Lifestyle Changes

Physical therapy is recommended as first line treatment for patients with nTOS. A course of 4-8 weeks focused on stretching and relaxing the anterior scalene muscle can alleviate symptoms. Patients with mild nTOS could get sufficient relief with physical therapy combined with lifestyle changes minimizing activities that exacerbate symptoms.[150] Patients presenting with arterial or venous thrombosis or embolization should be started on anticoagulation unless contraindicated. Patients with profound and limb-threatening ischemia to the upper extremity should undergo urgent revascularization.

Risk Stratification for Surgery

Most patients with TOS are relatively young, have limited comorbidities, and are considered good surgical candidates. Patients with more significant comorbidities may require a cardiac evaluation.

Some patients with end stage renal disease may require decompression for venous TOS, and will need a careful preoperative evaluation of comorbidities, and coordination of care with their nephrologist.

vTOS that is associated with subclavian vein thrombosis in patients with tunneled dialysis catheters or pacemaker leads typically affects an older group of patients who suffer from end stage renal disease or advanced cardiac disease. The risks of surgery may outweigh the benefits in this group of patients.

Careful evaluation of the severity of patients' symptom, goals of treatment, and alternative options should be considered.

Preoperative Labs

Standard CBC, chemistry profile and coagulation profile are recommended before TOS surgery.

Preoperative Medication Adjustment

Patients on anticoagulation with heparin infusion should have the infusion held prior to procedure.

- *Perioperative antibiotics*: Prophylactic antibiotics for open procedures should be considered perioperatively as for any other surgery.

- *Anticoagulation and its reversal*: If patient is on oral anticoagulation preoperatively, then discontinue them as needed before the procedure to minimize bleeding complication. DOAC should be held for 48-72 hours before procedure. Warfarin should be discontinued 3-5 days in advance. Please consider bridging with parenteral anticoagulation (UFH or LMWH) in appropriate patients with high thrombosis risk.

- *Nephropathy*: Techniques to minimize contrast nephropathy for endovascular procedures in patients with CKD should be utilized. While many different agents have been studied with varying success, only fluid loading has been consistently reported to be associated with better renal outcomes. If there is no contraindication fluid administration pre, intra and post operatively is recommended. The issue to hold ACEs and ARBs is still not resolved and more research is needed.

- *Allergy*: Patients with allergy to intravenous iodinated contrast and scheduled for angiography should get premedication with prednisone 50 mg in 3 oral doses at 13 hours, 7 hours, and one hour prior to procedure, and Diphenhydramine 50mg one hour prior to procedure. Rescue dosing with IV solumedrol or Decadron can be used as needed. CO2

venography can also be considered as indicated

- *ACE Inhibitors*: If significant volume depletion is anticipated, it is suggested to hold ACE inhibitors and angiotensin receptor antagonists on the morning of surgery and restarting these agents after the procedure, once euvolemia has been achieved.

- *Diabetes Mellitus:* It is suggested to hold metformin at the time of administration of contrast material among patients with an eGFR of <60 mL/min or up to 48 hours before administration of contrast material if the eGFR is <45 mL/min and restarting no sooner than 48 hours after administration of contrast material as long as renal function has remained stable. Diabetic patients who receive intermediate or long-acting insulin should receive half the scheduled dose when NPO in preparation for surgery. Glycemic control should be considered per the current guidelines of the American Diabetes Association.[18]

Intraoperative

General:

Patients undergoing corrective surgery for thoracic outlet syndrome are often young and lack significant comorbidities.

The goal of surgery for TOS is to decompress the narrow thoracic outlet and remove all the structures contributing to compression of the neurovascular bundle. It consists of first rib resection with scalenotomy/scalenectomy. Some patients exhibit aberrant anatomy such as a cervical rib, scalenus minimus, and a variety of other fibromuscular bands that contribute to compression and should be removed concomitantly.[151]

a. Anesthesia Management

i) Anesthesia Techniques

- General endotracheal anesthesia is most commonly used. Placement of arterial pressure catheters or central venous catheters for monitoring should be decided on an individual patient basis depending on comorbidities in closed communication between the anesthesia and the surgical team.
- For a younger patient population, total intravenous anesthetic (TIVA) technique with propofol and minimizing opioids may be beneficial to prevent postoperative nausea and vomiting (PONV).
- Muscle relaxation should only be used if necessary and in close communication with the surgical team.
- Low cervical plexus block and intercostal nerve blocks by single shot or continuous infusion via catheter may help with intraoperative opioid minimization and postoperative pain control.

ii) Monitoring and Access

Standard monitoring SaO2, EKG and non-invasive blood pressure and temperature.

Invasive blood pressure monitoring is usually not necessary. Should existing cardiac comorbidities warrant the placement of an invasive arterial catheter, it should be placed on the contralateral side, as blood pressure measurements on the operative side may be interrupted by tourniquets or be inaccurate due to the existing compression.

IV access should be placed on the contralateral arm.

iii) Intraoperative Concerns

Intraoperative pneumothorax may occur.

d. General & Procedure-Specific Concerns

General intraoperative concerns: Skin preparation (CHG wipe timeout for three minutes to dry), Foley placed by trained staff, shaving performed with clippers, normothermia.

First rib resection:

- General anesthesia
- The placement of central intravenous lines and arterial line for hemodynamic monitoring is determined on a case-by-case basis depending on patient comorbidities and expected blood loss.
- Ipsilateral arm usually prepped sterile in the field to allow manipulation and optimization of exposure while avoiding tension on the brachial plexus for a long period of time.
- Perioperative antibiotics are weight based and initial dose should be administered prior to incision.
- Neuromuscular blocking agents should be avoided to allow intraoperative assessment of the brachial plexus
- If endovascular intervention or open venous reconstruction is performed, full dose anticoagulation is administered, and ACT is maintained above 200.
- A drain should be left in the surgical bed at the end of the operation to monitor for bleeding and lymphatic leak.

Postoperative

Steps Prior to Discharge

Open reconstructive surgery:

- *General:*
  - An upright chest X-Ray is performed postoperatively.
  - Incentive spirometer use is encouraged immediately after surgery and should be performed every hour.
  - Mobilization out of bed is initiated within 24 hours after surgery with gradual increase in ambulation as tolerated.
  - Diet can be resumed within 24 hours when patient is awake and there is no concern for aspiration.

    - Glucose control.
    - Foley catheter, although rarely needed in this patient population, is discontinued in 24-48 hours after surgery when accurate assessment of urine output is not needed any more.
- *Monitoring:*
    - Patients are admitted to a monitored unit and are assessed for hand neurological function, bleeding, and patency of flow when arterial reconstruction is performed.
    - Drain output is monitored daily for early detection of bleeding or lymphatic leak.
    - Central intravenous lines and arterial lines are removed when hemodynamic stability is established, and invasive monitoring is not warranted any more.
- *Wound Care:* Sterile occlusive intraoperative wound dressings are changed on postoperative day two.
- *Medication:*
    - Perioperative antibiotics are discontinued in 24 hours.
    - Anticoagulation for cases with vascular thrombosis should be started within 24-48 hours after surgery and when safe from bleeding standpoint
- *Pain Control*: Pain medications consists of intravenously narcotics initially and transitioned to oral narcotics as soon as patient is tolerating diet. Ketorolac and muscle relaxants are useful adjuncts to minimize discomfort.[152]
- *Physical Therapy:* Should be considered, especially for patients with neurogenic TOS who should continue with TOS therapy.

Steps After Discharge

- *General:* Heavy lifting or strenuous physical activity involving the arm should be avoided early after surgery, but a light range of motion exercises is encouraged as tolerated.
- *Follow-up*: Patients should be called within a week after discharge to ensure adequate recovery.
- *Office / Clinic Visit*:
    - Follow up office visit in 2-4 weeks after the procedure to assess clinical improvement (obtain duplex ultrasound for vTOS and aTOS)[153]
    - Long-term follow up consists of yearly office visits for clinical assessment and ultrasound to document patency of the vascular reconstruction.
- *Exercise*: Supervised, dedicated physical therapy for at least 6-8 weeks can start as soon as adequate wound healing is ensured.
- *Medication*:
    - Narcotic medications are prescribed for pain control with goal to transition to over-the-counter pain medications (Acetaminophen or NSAIDs) as soon as tolerated.
    - Anticoagulation is continued for at least four weeks post-surgery for patients with vascular thrombosis.
    - The use of long-term medications can be coordinated with the patient's primary care physician and can include the use of statins or a PCSK9 inhibitor in order to achieve optimal LDL control. In addition, anti-platelet agents, anti-hypertensive agents, and agents for glycemic control should be prescribed, as indicated.

X. Hemodialysis Access

Functionally patent hemodialysis access is achieved by:

- Open surgical AVF and AVG in the upper extremity
- Open surgical AVF and AVG in the lower extremity
- Fistulogram, with or without intervention
- Revision surgery for dialysis access associated steal syndrome (e.g., DRIL, PAI, RUDI, banding), venous outflow occlusion, or aneurysm.
- Percutaneous AVF creation

Preoperative

Patient History

A thorough history should be obtained, and physical examination performed on all patients before creation of an AVF or AVG or any revision procedures. The evaluation should focus on arterial inflow, possible superficial veins that can be used for cannulation of an AVF, possible recipient outflow veins for an AVG, and central venous outflow.

Review of previous operative reports, chest radiographs, venograms, and CT scans can also assist in characterizing possible impediments like indwelling vascular stents or devices, central venous stenotic lesions, or previous arteriovenous access attempts.

Physical Examination

The nondominant arm is preferred for AVF/AVG placement. Creating the access in the patient's nondominant arm allows the dominant arm to be used during hemodialysis treatments. Furthermore, in the rare event of a disabling complication, the dominant arm would be spared.

Physical exam should focus on an evaluation of distal pulses on the extremity of interest in addition to surgical scars that may be present and that may suggest unfavorable anatomy that can render surgery more challenging.[154] An Allen test should also be performed test to evaluate completeness of the palmar arch.

From the perspective of obtaining a functional AV access, an examination for heart failure is mandatory. Poor cardiac output or ejection fraction may affect the success of the AV access that is created (e.g., low output may increase risk of maturation failure).[155]

Imaging

Preoperative duplex mapping of the upper extremity veins and arteries focusing on vein diameter and artery patency should be performed prior to surgery. Occasionally, venography can be helpful in order to identify central venous lesions that may need to be avoided or that may require treatment.

An ECG and chest X-ray are also typically required.

Medical Management and Lifestyle Changes

Smoking is associated with poorer outcomes in ESRD patients, and it should be discouraged. ESRD patients should be managed aggressively regarding their comorbid conditions to assist in healing of surgical wounds and maturation of access.

The use of adjuvant clopidogrel to enhance AVF maturation after surgery has not been shown to be efficacious and is not encouraged.[156] Similarly, the routine use of fish oil or aspirin to prevent AVF flow dysfunction has not been shown to improve outcomes.[157]

On the other hand, primary AVG patency can be improved with the use of aspirin/dipyridamole as well as fish oil.[158, 159]

Use of anticoagulants in this population should be approached cautiously due to the risk of bleeding potentially compounding the elevated baseline risk that this population carries.[160]

Risk Stratification for Surgery (cardiac and pulmonary)

Risk stratification for surgery is needed if the patient requires general anesthesia. While most AV access surgery can be performed with local or regional anesthetic, general anesthetic is occasionally needed.

Conduct preoperative anesthesia evaluation as per societal guidelines. The timing of the procedure may depend on the preexisting dialysis schedule.

Dialysis immediately preoperatively may be necessary to correct volume status and electrolyte disturbances. Thus, temporary dialysis catheter placement may be necessary. Close coordination with the patient's nephrologist and dialysis unit should be universal.

Regarding percutaneous procedures, a fistulogram is nearly always performed with local anesthetic and sedation and is only minimally invasive. As such, routine pre-procedural risk stratification is not necessary.

Risk Assessment

A multidisciplinary approach to care can optimize outcomes. Medical specialists and team members can assist patients with risk factor modification, such as smoking cessation, maintaining glycemic control, normalizing blood pressure and lipid levels, maintaining antiplatelet therapy, thereby promoting a positive patient experience. Discharge planning should also be considered at the time of surgical planning, with the goal being same day discharge. Coordination of care with the patient's nephrologist and dialysis unit should be an integral part of the care of patients with ESRD.[7]

Preoperative Labs

For all dialysis access surgeries or percutaneous procedures, the most important laboratory value that should be assessed preoperatively is the serum potassium level, which is frequently elevated in patients with chronic or end-stage kidney disease. Hyperkalemia may rise to dangerous levels if a patient requires general anesthesia. Active infection, as reflected by an elevated leukocyte count, should be investigated, and surgery delayed until after the infection has resolved.

A coagulation panel, including an INR should be obtained prior to surgery. Patients who are anticoagulated should hold their anticoagulation and have an INR less than 1.5 prior to surgery. Regarding percutaneous procedures, a fistulogram can be performed safely with INR as high as 2.5. Percutaneous AVF creation should not be performed unless the INR is less than 1.5, due to the possible need for immediate surgical conversion.

Preoperative Medication Adjustment

Optimization of blood pressure may enhance maturation success. Severe hypertension should be addressed in order to achieve normotension. Conversely, overzealous use of anti-hypertensives may lead to hypotension, which in extreme circumstances, can lead to immediate access failure. Midodrine can be used to treat chronic hypotension. Patients on anticoagulation with heparin infusion should have the infusion held prior to procedure.

- *Perioperative antibiotics*: Prophylactic antibiotics for open procedures should be considered perioperatively as for any other surgery.

- *Anticoagulation and its reversal*: If the patient is on oral anticoagulation preoperatively, it should be discontinued before the procedure in order to minimize the risk of bleeding complications. DOAC should be held for 48-72 hours before procedure. Warfarin should be discontinued 3-5 days in advance. Consider bridging with parenteral anticoagulation (UFH) in appropriate patients with high thrombosis risk.

- *Allergy*: Patients with allergy to intravenous iodinated contrast and scheduled for angiography or fistulography should be premedicated with prednisone 50 mg in 3 oral doses at 13 hours, 7 hours, and one hour prior to procedure. Diphenhydramine 50 mg can be given one hour prior to the procedure. Rescue dosing with IV solumedrol or Decadron can be used as needed. CO_2 venography can also be considered.

- *ACE Inhibitors*: If significant volume depletion is anticipated, ACE inhibitors and angiotensin receptor antagonists can be held on the morning of surgery. These agents can be restarted after the procedure, once euvolemia has been achieved.

- *Diabetes Mellitus:* Metformin should be held at the time of administration of contrast material among patients with an eGFR of <60 mL/min or up to 48 hours before administration of contrast material if the eGFR is <45 mL/min and restarting no sooner than 48 hours after administration of contrast material as long as renal function has remained stable. Diabetic patients who receive intermediate or long-acting insulin should receive half the scheduled dose when NPO in preparation for surgery. Glycemic control should be considered per the current guidelines of the American Diabetes Association.[18]

Intraoperative

a. Optimization and Risk Assessment

Patients with ESRD often present with significant comorbidities such as hypertension, diabetes mellitus, coronary artery disease, stroke etc. The dialysis schedule of these patients needs to be taken into consideration in order to avoid operation during a state of volume overload and hyperkalemia.

b. Anesthesia Management

i) Anesthesia Techniques

- *Local Anesthesia +/- Sedation*: This is frequently feasible, depending on the extent of the planned intervention. The choice of local anesthetic drug will depend on expected duration of surgical procedure. Mepivacaine is suitable for procedures of up to 2 hours, Ropivacaine or bupivacaine may be preferred for procedures expected to take longer than 2 hours.

- *Regional Anesthetic Technique*: Regional anesthetic (i.e., brachial plexus blockade with a single shot injection) is associated with venous dilatation, which can be desirable. Depending on the location of the incision, this can be accomplished by axillary plexus nerve block for more distal incision sites. Infra- or supraclavicular plexus nerve blockade will allow for more proximal procedural sites on the upper arm. If tourniquet will be used, additional blockade of the intercostobrachial nerve may be necessary. All brachial plexus nerve blockades can be performed safely under ultrasound guidance.

- *Local or Regional Anesthetic Techniques:* Both local and regional anesthetics can be supplemented with light to moderate sedation such as propofol or dexmedetomidine drips for patient comfort.

- *General Anesthesia*: General anesthetic can also be employed with either endotracheal intubation or supraglottic airway management such as laryngeal mask airways, which are also safe alternatives.

ii) Monitoring and Access

Standard monitoring of SaO_2, EKG, non-invasive blood pressure and temperature.

IV access is typically established on the contralateral upper extremity after confirming that the target side is unlikely to be used for future fistula creation. Occasionally, lower-extremity IV access is required.

iii) Intraoperative Concerns

If supraclavicular brachial plexus block was performed, the phrenic nerve may be affected by the block, leading to respiratory distress if the contralateral phrenic nerve has been injured previously.

c. General and Procedure-Specific Concerns

General intraoperative concerns: Skin preparation (CHG wipe timeout for three minutes to dry), If the patient is not anuric, and the procedure is expected to be very long, a Foley catheter can be placed by trained staff. Hair clipping should be performed, and normothermia maintained.

- *Percutaneous or surgical Arteriovenous Fistula or Arteriovenous Graft or Revision Surgery for Steal syndrome (e.g., DRIL, PAI, RUDI, banding), venous outflow occlusion, or aneurysm.*
    - Local, regional, or general anesthetic as per surgeon preference.
    - Skin preparation with chlorhexidine gluconate/alcohol antiseptic.
    - Perioperative antibiotics are routinely used (cefazolin or vancomycin).
    - Venous thromboprophylaxis is not necessary.

- *Fistulogram +/- angioplasty and stenting +/- coil embolization of competing outflow veins*
    - Local anesthetic with sedation is the standard.
    - Skin preparation with chlorhexidine gluconate/alcohol antiseptic.
    - Perioperative antibiotics are used (cefazolin or vancomycin) if a stent or other prosthetic is deployed.
    - Venous thromboprophylaxis is not necessary.

Postoperative

Steps Prior to Discharge

- *Pain Control*: Acetaminophen or ibuprofen can be used for pain control in patients on dialysis. Pain requiring narcotic pain control is unusual and may require an early clinic evaluation to assess for possible complications.

- *Discharge*: Patients can be commonly discharged the same day, or on the first postoperative day if a basilic vein transposition or complex venous reconstruction was performed.

Steps After Discharge

- *Follow-up*: Patients should be called about a week after surgery to assess for pain and possible complications.

- *Sutures*: Sutures left in situ for hemostasis after percutaneous interventions can be removed by the staff at the dialysis clinic, if appropriately trained clinicians are available.

- *Office / Clinic Visit*: An office visit should be performed at about two weeks and, if the AVF is not maturing as expected, a duplex should be performed to evaluate for possible causes.

- *Medication*: The use of long-term medications can be coordinated with the patient's primary care physician and can include the use of statins or a PCSK9 inhibitor in order to achieve optimal LDL control. In addition, anti-platelet agents, anti-hypertensive agents, and agents for glycemic control should be prescribed, as indicated.

B. CONCLUSION

By some estimates over 100 million people in the USA will be experiencing vascular disease that requires significant medical management and/or procedural treatment in the next 10-15 years. As vascular disease develops over the lifespan of each individual, it is a perfect candidate for a multi-specialty, population health approach. Such a model would bring together the primary and specialty care medical communities to optimize vascular disease prevention, diagnosis, appropriate referral and transition, and a broad spectrum of medical and surgical treatment when indicated and necessary to preserve limbs, lives, and restore quality of life. This is a broad, bold, and compelling vision, that is being explored by the SVS Task Force on Population Health.

This *Practice Management Guide* was designed to focus on a segment of this broader vascular population health model: When vascular disease progresses to a stage where procedural treatment is necessary and indicated. It was developed by a multi-disciplinary team as an easy-reference resource to highlight and integrate key information and suggested best practices to address 10 of the most common vascular disorders faced by medical teams.

Outcome research for vascular patients requiring procedural intervention strongly suggests that optimizing the medical management of patients with vascular disease in the perioperative horizon—30-90 days before intervention, during the intervention, and 30-90 days post-intervention, may have a profound impact on long-term health, and quality of life. Due to the complexity of the medical and surgical management that is often required in common vascular conditions, the perioperative period is an inherently risky time in a patient's life. Vascular conditions requiring surgical/endovascular intervention often develop due to poorly- or uncontrolled medical co-morbidities, and meticulous attention to all facets of peri-operative care from the entire care team can mean the difference between a successful recovery and a life-threatening complication.

The bottom line is that optimizing care of patients throughout this perioperative horizon requires a full team effort, crossing many professions and medical specialties. Working in a coordinated fashion has been proven to reduce care variation, and thereby can improve and hasten the surgical recovery process for patients. An excellent reference and body of literature for further exploration of team-based perioperative care can be found in the Enhanced Recovery After Surgery (ERAS®) model, a multimodal, multidisciplinary approach to the care of surgical patients that aims to reduce the stress of the operation to retain anabolic homeostasis. The importance of patient education and patient engagement in their vascular perioperative care is a key component of both ERAS® Guidelines and the practice suggestions put forth in this *Practice Management Guide*.[161-164]

Vascular surgeons have a clear and essential role in the population health of our patients. As we often experience the end-result of progressive vascular disease process, no medical or surgical specialty has a stronger stake and understanding of the importance of vascular disease prevention, diagnosis and early treatment, and ensuring access to quality vascular care for all of our elderly citizens.

When vascular disease does progress to requiring procedural or surgical intervention, we hope you will find this resource helpful in planning for the entire perioperative horizon of care, and

integrating the perspectives of vascular surgeons, anesthesiologists, vascular medicine, vascular nursing, and vascular physician assistants.

This Guide is a beginning, and we hope it encourages many similar future efforts in the SVS and across Societies, to bring professions and disciplines together to optimize care for our vascular patients, for whom we care deeply.

C. DEFINITIONS

Abdominal Aortic Aneurysm (AAA)	Acetylsalicylic acid (Aspirin) (ASA)
Activated Clotting Time (ACT)	Acute Mesenteric Ischemia (AMI)
Acute Mesenteric Ishemia (AMI)	American College of Cardiology (ACC)
American College of Surgeons National Surgical Quality Improvement Project (ACS-NSQIP)	American Diabetes Association (ADA)
American Heart Association (AHA)	American Society of Anesthesiologist (ASA)
Angiotensin-converting enzyme (ACE) inhibitors	Ankle brachial index (ABI)
Aortic dissection (AD)	As soon as possible (ASAP)
Basic metabolic panel (BMP)	Below knee amputation (BKA)
Bispectral index (BIS)	Blood pressure (BP)
Brain Natriuretic Peptide (BNP)	Carbon Dioxide (CO2)
Carotid Endarterectomy (CEA)	Centers for Medicare and Medicaid Services (CMS)
Central Venous Catheter (CVL)	Cerebrospinal fluid (CSF)
Chimney endovascular aortic repair (ChEVAR)	Chlorhexidine (CHG)
Chronic kidney disease (CKD)	Chronic Mesenteric Ischemia (CMI)
Chronic obstructive lung disease (COPD)	Chronic Venous Insufficiency (CVI)
Complete blood count (CBC)	Computed tomography angiography (CTA)
Computed tomography venogram (CTV)	Computerized tomography (CT)
Coronary artery disease (CAD)	Critical limb threatening ischemia (CLTI)
Deep vein thrombosis (DVT)	Descending thoracic aorta (DTA)
Diabetic foot ulcer (DFU)	Digital Subtraction Angiography (DSA)
Direct oral anticoagulants (DOACs)	Dual antiplatelet therapy (DAPT)
Duplex Ultrasound (DUS)	Electrocardiogram (EKG)
Electrocardiography (ECG)	Electroencephalography (EEG)
Endothermal heat induced thrombosis (EHIT)	Endotracheal tube (ETT)
Endovascular Aneurysm Repair (EVAR)	Endovascular repair (TEVAR)
Estimated Glomerular Filtration Rate (eGFR)	European Society for Vascular Surgery (ESVS)
Extracorporeal membrane oxygenation (ECMO)	Fenestrated Endovacular aneurysm repair (FEVAR)
Gastroesophageal reflux disease (GERD)	General anesthesia (GA)
Hemoglobin A1C (HgA1c)	High-density lipoproteins (HDL)
Hypertension (HTN)	Ileal bile acid-binding protein (I-BABP)
Inferior vena cava (IVC)	Intensive care unit (ICU)
Intermittent claudication (IC)	Internal Carotid Artery (ICA)
International normalized ratio (INR)	Intestinal fatty acid-binding protein (iFABP)
Intramural hematoma (IMH)	Intravascular ultrasound (IVUS)
Intravenous (IV)	Jugular Venous Pressure (JVP)
Laryngeal mask airway (LMA)	Laryngeal Mask Airway (LMA)
Left subclavian artery (LSA)	Local anesthesia (LA)
Low molecular weight heparin (LMWH)	low-density lipoprotein (LDL)
Magnetic resonance angiography (MRA)	Magnetic resonance imaging (MRI)
Magnetic Resonance Venography (MRV)	May-Thurner syndrome (MTS)
	Monitored anesthesia care (MAC)
Myocardial infarction (MI)	Myocardial infarction (MI)
Neuroaxial (NA)	Nil per os (NPO)
Non-Occlusive Mesenteric Ischemia (NOMI)	Non-steroidal anti-inflammatory drugs (NSAIDs)
Non-thrombotic iliac vein lesion (NIVL)	Open surgical repair (OSR)
Operating Room (OR)	Oxygen Saturation (SaO2)
Oxygen saturation (SpO2)	Partial thromboplastin time (PTT)

Penetrating aortic ulcer (PAU)	Peripheral arterial disease (PAD)
Post-anesthesia care unit (PACU)	Post-traumatic stress disorder (PTSD)
Proprotein convertase subtilisin/kexin type 9 (PCSK9)	Prothrombin time (PT)
Pulmonary embolism (PE)	Pulse volume recording (PVR)
Quality of life (QOL)	Randomized controlled trial (RCT)
Regional anesthesia (RA)	Retrograde open mesenteric stenting (ROMS)
Society for Vascular Medicine (SVM)	Society for Vascular Nursing (SVN)
Society for Vascular Surgery (SVS)	Somatosensory-evoked potentials (SSEP)
Spinal cord injury (SCI)	Superior Mesenteric Artery (SMA)
Thoracic aortic aneurysm and dissection (TAAD)	Thoracic aortic aneurysms (TAA)
Total intravenous anesthesia (TIVA)	Total Parenteral Nutrition (TPN)
Trans-femoral carotid stent (TFCAS)	Trans-femoral carotid stent (TFCAS)
Transcarotid Artery Revascularization (TCAR)	Transesophageal echocardiogram (TEE)
Transient ischemic attack (TIA)	Transversus abdominal plane blocks (TAP blocks)
Twice a day (BID)	Type 2 diabetes mellitus (T2DM)
Unfractionated heparin (UH)	Venous Clinical Severity Score (VCSS)
Venous thromboembolism (VTE)	Vitamin-K Antagonist (Warfarin) (VKA)

D. ACKNOWLEDGEMENTS

The Society for Vascular Surgery wishes to thank and acknowledge the following organizations for their support of the development of the *Perioperative Care Practice Management Guide*:

- The American Society of Anesthesiologists
- The Society for Vascular Medicine
- The Society for Vascular Nursing

Additionally, the Society for Vascular Surgery thanks its Education Council (Rabih Chaer, MD, Chair) and Document Oversight Committee (Ruth Bush, MD, Chair) for their diligent work in preparing and reviewing the *Management Guide on the Perioperative Care of Patients with Vascular Disease.* Special thanks to Katharine McGinigle, MD, MPH and Leila Mureebe, MD for their assistance with the conclusion of the guide, and Lisa Cohen, CHCP and Susan K. Flinn, MA, for staffing support.

Finally, the *Management Guide* and residual educational activities are supported through an educational grant provided by Janssen Pharmaceuticals, Inc.

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