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SUMMARY OF RECOMMENDATIONS

Renal artery aneurysms

1.1: In patients who are suspected to have RAA, we recommend computed tomographic angiography (CTA) as the diagnostic tool of choice (Grade 1B).

1.2: In patients who are suspected to have RAA and have increased radiation exposure risks or renal insufficiency, we recommend non-contrast MRA (NC-MRA) to establish the diagnosis (Grade 1B).

Technical remark: NC-MRA is best suited to children and women of childbearing potential or those who have contraindications to CT or MR contrast materials (i.e. pregnancy, renal insufficiency, or gadolinium contrast material allergy).

1.3: We recommend the use of catheter-based angiography for both preoperative planning and to better delineate distal renal artery branches that may be inadequately assessed on conventional cross sectional imaging (Grade 1C).

2.1: In patients with non-complicated RAA of acceptable risk, we suggest treatment for aneurysm size >3cm (Grade 2C).

2.2: We recommend emergent intervention for any size renal artery aneurysm resulting in patient symptoms or rupture (Grade 1B)

2.3: In patients of child-bearing potential with non-complicated RAA of acceptable risk, we suggest treatment for aneurysm size <3cm (Grade 2B).

2.4: In patient with medically-refractory hypertension and functionally important renal artery stenosis, we suggest treatment for size <3cm (Grade 2C).
3.1: We suggest daily anti-platelet therapy (ie: Aspirin, 81mg) for patients with renal artery aneurysm (Grade 2C).

3.2: We suggest open surgical reconstructive techniques for the elective repair of most renal artery aneurysms (Grade 2B).

3.3: We suggest ex vivo repair and auto-transplantation for complex distal branch aneurysms over nephrectomy when technically feasible (Grade 2B).

3.4: We suggest endovascular techniques for the elective repair of anatomically appropriate RAAs to include stent graft exclusion of main renal artery aneurysms and embolization of distal and parenchymal aneurysms (Grade 2B).

3.5: We suggest consideration of laparoscopic and robotic techniques as an interventional alternative based on institutional resources and surgeon experience with minimally invasive techniques (Grade 2C).

4.1: We suggest screening female patients for fibromuscular dysplasia with a focused history and one-time axial imaging study (ie: CTA or MRA) to assess for cerebrovascular, mesenteric and iliac arterial dysplasia (Grade 2C).

5.1: We suggest completion imaging following open surgical reconstruction for renal artery aneurysm, prior to hospital discharge, by way of arteriogram or ultrasound and long-term follow-up with surveillance imaging (Grade 2C)

5.2: For patients managed non-operatively, we suggest annual surveillance imaging until two consecutive studies are stable; thereafter surveillance imaging may be extended to every 2-3 years (Grade 2B).
Splenic Artery Aneurysms

1.1: We recommend computerized tomographic angiography (CTA) as the initial diagnostic tool of choice for splenic artery aneurysms. (Grade 1C)

1.2: In patients with suspected splenic artery aneurysms and pre-existing renal insufficiency limiting the use of iodinated contrast material, we suggest magnetic resonance angiography (MRA) to establish diagnosis. (Grade 1C)

1.3: We recommend using arteriography when non-invasive studies have not sufficiently demonstrated the status of relevant collateral blood flow and when endovascular intervention is planned. (Grade 1B)

2.1: We recommend emergent intervention for ruptured splenic artery aneurysms. (Grade 1A)

2.2: We recommend treatment of non-ruptured splenic artery pseudoaneurysms of any size in patients of acceptable risk due to the possibility of rupture. (Grade 1B)

2.3: We recommend treating non-ruptured splenic artery true aneurysms of any size in women of child-bearing age due to the risk of rupture. (Grade 1B)

2.4: We recommend treating non-ruptured splenic artery true aneurysms more than 2 cm in size, with a demonstrable increase in size, or with associated symptoms in patients of acceptable risk due to the risk of rupture. (Grade 1C)

2.5: We suggest observation over repair for small (< 2 cm), stable asymptomatic splenic artery true aneurysms, or those in patients with significant medical comorbidities or limited life expectancies. (Grade 2C)
3.1: In patients with ruptured SAA discovered at laparotomy, we suggest treatment with ligation with or without splenectomy depending on the aneurysm location. (Grade 2B)

3.2: In patients with ruptured SAA diagnosed on preoperative imaging studies, we suggest treatment with open surgical or appropriate endovascular techniques based upon the patient’s anatomy and underlying clinical condition. (Grade 2B)

3.3: We suggest elective treatment of SAA using an endovascular approach if anatomically feasible. However, elective treatment may appropriately involve open surgical, endovascular or laparoscopic methods of intervention depending on the patient’s anatomy and underlying clinical condition. (Grade 2B)

3.4: When treating SAA, we suggest that the splenic artery does not routinely require preservation or revascularization. (Grade 2C)

3.5: When treating distal SAA adjacent to the hilum of the spleen, we suggest open surgical techniques including possible splenectomy as opposed to endovascular methods given concern regarding the possibility of end organ ischemia, including splenic infarction and/or pancreatitis. (Grade 2B)

3.6: In pregnant women with SAA, we recommend that treatment decisions be individualized and consider the potential morbidity to both the mother and fetus. (Ungraded best practice statement)

4.1: We suggest screening of patients with splenic artery aneurysms for other arterial aneurysms. (Grade 2B)
5.1: In patients in whom a splenic artery aneurysm is being followed with a non-operative / non-interventional approach, we suggest annual surveillance with CT scans to assess for growth in size. (Grade 2B)

5.2: Following endovascular intervention for splenic artery aneurysms, we suggest periodic surveillance with appropriate imaging studies to assess for the possibility of endoleak or other continued aneurysm perfusion which could lead to a continued risk of aneurysm growth or rupture. (Grade 2B)

Celiac artery aneurysms

1.1 We suggest computerized tomographic angiography (CTA) as the initial diagnostic tool of choice for celiac artery aneurysms. (Grade 2B)

1.2 We suggest magnetic resonance angiography (MRA) in patients with suspected celiac AA and pre-existing renal insufficiency limiting the use of iodinated contrast material. (Grade 2B)

1.3 We suggest arteriography when non-invasive studies have not sufficiently demonstrated the status of relevant collateral blood flow or when endovascular intervention is planned. (Grade 2C)

2.1 We recommend emergent intervention for ruptured celiac artery aneurysms. (Grade 1A)

2.2 We recommend treatment of non-ruptured celiac artery pseudoaneurysms of any size in patients of acceptable risk due to the possibility of rupture. (Grade 1B)
2.3 We recommend treatment of non-ruptured celiac artery true aneurysms more than 2 cm in size, with a demonstrable increase in size, or with associated symptoms in patients of acceptable risk due to the risk of rupture. (Grade 1C)

2.4 We suggest observation over intervention for small (< 2 cm), stable asymptomatic celiac artery aneurysms, or those in patients with significant medical comorbidities or limited life expectancy (Grade 2C)

3.1 In patients with ruptured CAA discovered at laparotomy, we suggest ligation if sufficient collateral circulation to the liver can be documented. (Grade 2C)

3.2 In patients with ruptured CAA diagnosed on preoperative imaging studies who are stable, we suggest treatment with open surgical or appropriate endovascular methods based upon the patient’s anatomy and underlying clinical condition. (Grade 1B)

3.3 For the elective treatment of CAA, we suggest using an endovascular intervention if anatomically feasible. However, elective treatment may appropriately involve open surgical, endovascular or laparoscopic methods of intervention depending on the patient’s anatomy and underlying clinical condition. (Grade 2B)

3.4 To determine the need for revascularization of the celiac artery and its branches when treating CAA, we suggest evaluating the status of the superior mesenteric artery, gastroduodenal artery, and other relevant collateral circulation which must be carefully documented on preoperative imaging studies. (Grade 2B)
4.1 We suggest screening patients with celiac artery aneurysms for other arterial aneurysms. (Grade 2B)

5.1 In patients in whom a celiac artery aneurysm is being followed with a non-operative / non-interventional approach, we suggest annual surveillance with CT scans to assess for growth in size. (Grade 2B)

5.2 Following endovascular intervention for celiac artery aneurysms, we suggest periodic surveillance with appropriate imaging studies to assess for the possibility of endoleak or other continued aneurysm perfusion which could lead to a continued risk of aneurysm growth or rupture. (Grade 2B)

Gastric and Gastroepiploic Artery Aneurysms

1.1: In patients who are suspected to have GA/GEA, we recommend computed tomographic angiography (CTA) as the diagnostic tool of choice (Grade 1B).

1.2: In patients suspected to have GA/GEA and have high radiation exposure risks or renal insufficiency, we recommend non-contrast MRA (NC-MRA) for diagnosis (Grade 1B). Technical remarks: NC-MRA is best suited to children and women of childbearing potential or those who have contraindications to CT or MR contrast materials (i.e. pregnancy, renal insufficiency, or gadolinium contrast material allergy).

1.3: We recommend the use of catheter-based angiography for all emergent cases presenting with rupture (Grade 1B) and electively for preoperative planning (Grade 1C).
2.1: We recommend treatment of all gastric and gastroepiploic aneurysms of any size (Grade 1B).

3.1: We recommend endovascular embolization first-line for gastric and gastroepiploic aneurysms (Grade 1B).

4.1: We suggest abdominal axial imaging to screen for concomitant abdominal aneurysms (Grade 2B).

4.2: We suggest a one-time screening CTA (or MRA) of the head, neck and chest for those patients with segmental arterial mediolysis (Grade 2C).

5.1: We suggest interval surveillance (ie: every 12-24 months) with axial imaging (ie: CTA or MRA) in cases of segmental medial arteriolysis in light of reported cases of rapid arterial transformation (Grade 2B).

5.2: We suggest post-embolization surveillance at every 1-2 years with axial imaging to assess for vascular remodeling and evidence of aneurysm reperfusion (Grade 2B).

Hepatic Artery Aneurysm

1.1: In patients who are suspected to have hepatic artery aneurysm (HAA), we recommend computed tomographic angiography (CTA) as the diagnostic tool of choice (Grade 1B).

1.2: In patients with HAA who are considered for intervention, we recommend mesenteric angiography for preoperative planning (Grade 1B).
2.1: Given the high propensity of rupture and significant antecedent mortality, we recommend that *all* hepatic artery pseudoaneurysms, regardless of cause, be repaired as soon as the diagnosis is made (Grade 1A).

2.2.a: We recommend repair of all symptomatic hepatic artery aneurysm regardless of size (Grade 1A).

2.2.b: In Asymptomatic patients without significant comorbidity, we recommend repair if (true) hepatic artery aneurysm is larger than 2 cm (Grade 1A) or if aneurysm enlarges >0.5 cm/year (Grade 1C). In patients with significant comorbidities, we recommend repair if HAA is larger than 5.0 cm (Grade 1B).

2.3: We recommend repair of HAA in patients with vasculopathy or vasculitis, regardless of size (Grade 1C). Strong consideration should also be given in HAA patients with positive blood cultures (Grade 1C).

3.1: We recommend endovascular first approach to all HAA (Grade 1A).

3.2: In patients with extrahepatic aneurysms, we recommend open and endovascular techniques to maintain liver circulation (Grade 1A).

3.3: In patients with intraportal aneurysms, we recommend coil embolization of the affected artery (Grade 1B). In patients with large intraportal artery aneurysm, we recommend resection of the involved lobe of liver to avoid significant liver necrosis (Grade 1C).

4.1: We suggest abdominal axial imaging to screen for concomitant intra-abdominal aneurysms in patients who did not have CTA at the time of HAA diagnosis (Grade 2B).
4.2: We suggest a one-time screening CTA or MRA of the head, neck and chest for those patients with non-atherosclerotic causes of hepatic artery aneurysm (Grade 2B).

5.1: We suggest annual follow-up with CTA or non-contrast CT to follow patients with asymptomatic hepatic artery aneurysm (Grade 2B).

**Superior Mesenteric Artery Aneurysms (SMAA)**

1.1: In patients with SMAA, we recommend computed tomographic angiography (CTA) as the diagnostic tool of choice (Grade 1B).

1.2: We recommend mesenteric angiography to delineate anatomy in preoperative planning for SMAA repair (Grade 1B).

2.1: We recommend repair of all SMA aneurysms and pseudoaneurysms as soon as the diagnosis is made regardless of size (Grade 1A)

2.2: We suggest careful observation of SMAA due to dissection unless the patient becomes symptomatic (Grade 2B)

3.1: We recommend endovascular first approach to all SMAA if anatomically feasible (Grade 1A)

4.1: We suggest abdominal axial imaging to screen for concomitant intra-abdominal aneurysms in patients who did not have CTA at the time of diagnosis (Grade 2B).

5.1: We suggest annual CTA to follow postsurgical patients (Grade 2B)

**Jejunal, Ileal and Colic Artery Aneurysms**
1.1: In patients who are suspected to have JA/IA/CA, we recommend computed tomographic angiography (CTA) as the diagnostic tool of choice (Grade 1B).

1.2: In patients with high radiation exposure risks or renal insufficiency, we recommend non-contrast MRA (NC-MRA) for diagnosis (Grade 1B). Technical remarks: NC-MRA is best suited to children and women of childbearing potential or those who have contraindications to CT or MR contrast materials (i.e. pregnancy, renal insufficiency, or gadolinium contrast material allergy).

1.3: We recommend the use of catheter-based angiography for all emergent cases presenting with rupture (Grade 1B) and electively for preoperative planning (Grade 1C).

1.4: We suggest screening all patients with JA, IA and CA aneurysms for vasculitis with routine inflammatory markers (Grade 2C).

2.1 We recommend elective intervention for jejunal and ileal aneurysms >2cm in maximal diameter and for all colic aneurysms, any size (Grade 1B).

2.2 We recommend emergent intervention for any jejunal, ileal or colic aneurysm, any size, resulting in patient symptoms or rupture and all mesenteric branch vessel pseudoaneurysms (Grade 1A).

3.1: We suggest open surgical ligation or aneurysm excision for cases of jejunal, ileal and colic aneurysms when laparotomy is being considered for hematoma evacuation or bowel assessment for viability (Grade 2B).

3.2: We suggest endovascular embolization for cases of jejunal, ileal, and colic aneurysm (Grade 2B)
3.3: We suggest medical treatment of non-ruptured, asymptomatic ileal, jejunal and colic aneurysms associated with PAN (Grade 2B).

4.1: We suggest abdominal axial imaging to screen for concomitant abdominal aneurysms (Grade 2B).

4.2: We suggest a one-time screening CTA (or MRA) of the head, neck and chest for those patients with segmental arterial mediolysis (Grade 2B).

5.1: We suggest interval surveillance (ie: every 12-24 months) with axial imaging (ie: CTA or MRA), for cases of segmental medial arteriolysis in light of reported cases of rapid arterial transformation and to monitor regression in cases of PAN (Grade 2B).

5.2: We suggest post-embolization surveillance at every 1-2 years with axial imaging to assess for vascular remodeling and evidence of aneurysm reperfusion (Grade 2B).

Pancreaticoduodenal and Gastroduodenal Artery Aneurysms

1.1: In patients who are suspected to have GDAA and PDAA, we recommend computed tomographic angiography (CTA) as the diagnostic tool of choice (Grade 1B).

1.3: In patients with high radiation exposure risks or renal insufficiency, we suggest non-contrast MRA (NC-MRA) for diagnosis (Grade 2C). Technical remarks: NC-MRA is best suited to children and women of childbearing potential or
those who have contraindications to CT or MR contrast materials (i.e. pregnancy, renal insufficiency, or gadolinium contrast material allergy).

2.1: In patients with non-complicated GDAA and PDAA of acceptable risk, we recommend treatment no matter what the size of the aneurysm due to the risk of rupture (Grade 1B).

3.1: In patients with intact and ruptured aneurysms, we recommend coil embolization as the treatment of choice (Grade 1B).

3.2: In patients where coil embolization is not feasible, we suggest covered stenting or stent-assisted coil embolization as a treatment option in select cases of GDAA and PDAA (Grade 2C).

3.3: In patients with appropriate anatomy, we suggest transcatheter embolization with liquid embolic agents as a treatment option for both GDAA and PDAA (Grade 2C).

3.4: In patients with suitable anatomy, we suggest flow-diverting, multilayered stents as a treatment option for GDAA and PDAA, although these have not been adequately studied to recommend as a primary treatment modality (Grade 2C).

3.5: In patients with non-ruptured aneurysms, we suggest open surgical reconstruction if needed to preserve flow (Grade 2B).

3.6: In patients with concomitant stenosis or occlusion, we suggest celiac reconstruction (Grade 2B).

4.1: In patients with median arcuate ligament syndrome, we suggest screening for GDAA or PDAA with CT angiography or duplex ultrasound (Grade 2C).
5.1: In patients status post treatment of GDAA and PDAA, we recommend follow-up imaging after endovascular treatment of GDAA and PDAA in order to rule out persistent flow through the aneurysm sac (Grade 1B).
INTRODUCTION

Aneurysms of the visceral arteries are a rare but clinically important vascular condition. Of all intra-abdominal aneurysms, only approximately 5% affect the visceral arteries. Visceral artery aneurysms include both true aneurysms as well as pseudoaneurysms. Many true visceral artery aneurysms are degenerative or atherosclerotic in nature, with histologic specimens demonstrating reduced smooth muscle, disruption of elastic fibers, and deficiency of the arterial media. Other common etiologies associated with visceral artery aneurysms include fibromuscular dysplasia, collagen vascular diseases, inflammatory conditions, and other rare inherited illnesses such as the Ehlers-Danlos syndrome. In contrast to the causes of true aneurysms of the visceral vessels, visceral artery pseudoaneurysms are most commonly related to trauma, iatrogenic injury, local inflammatory processes, or infection.

The clinical significance of visceral artery aneurysms is mainly related to their potential for rupture, and the extreme challenge of emergent diagnosis and treatment of these uncommon aneurysms once rupture has occurred. Nearly one fourth of visceral artery aneurysms reported in the literature have presented with rupture, and the reported mortality rate of these diagnosed ruptures is at least 10% and is likely to be much higher. Reported mortalities following ruptured celiac artery aneurysms and ruptured splenic artery aneurysms in pregnant women approach 100%. Because of the increased use of sophisticated forms of intra-abdominal imaging, including magnetic resonance imaging and angiography (MRI,
MRA) and computerized tomographic scans and angiography (CT, CTA), occult visceral artery aneurysms are being diagnosed with increased frequency. These detailed imaging studies are allowing for an improved ability among vascular surgeons to identify asymptomatic lesions, and an enhanced potential for preoperative or pre-procedural planning and elective treatment of these aneurysms. Improvements in endovascular therapies have also allowed an enhanced ability for treatment of these often anatomically complex lesions with a large variety of individualized and precise catheter based therapies.

However, the natural history of visceral aneurysms and their potential for rupture or other complications is relatively poorly defined due to their overall scarcity. The great majority of the reports in the literature consist of only one or two cases. Larger institutional case series have been reported, but rarely consist of more than a compilation of several dozen cases. The recent increase in the reports of visceral aneurysms in the literature is mainly related to an escalation in the use of novel and varied catheter-based techniques for their treatment. While much valuable information may be gained from reading these individual reports, they may be inherently predisposed towards a representation of unusual presentations and successful outcomes. However, it is clear even from these numerous case reports that a significant proportion of visceral artery aneurysms present with rupture; therefore, an aggressive approach towards their diagnosis and management certainly seems warranted.
It is somewhat difficult to precisely characterize which factors in an individual aneurysm will predispose towards rupture. Splenic artery aneurysms are thought to have a particular tendency towards rupture, especially during the third trimester of pregnancy.\textsuperscript{4} Visceral artery pseudoaneurysms certainly have a higher rupture potential than true aneurysms. Although larger size would certainly seem to imply a higher chance of rupture, very small visceral aneurysms can rupture as well. There is no firm evidence that calcification in a visceral artery aneurysm protects against a risk of rupture. When it occurs, rupture of visceral artery aneurysms can occur into the peritoneal cavity, retroperitoneal space, gastrointestinal tract or biliary tract. Free rupture into the peritoneal cavity resulting in hemoperitoneum is often termed “abdominal apoplexy”. Rupture of visceral artery aneurysms may also manifest with life-threatening gastrointestinal hemorrhage as well.

Although not directed by randomized prospective trials, general principles of management of visceral artery aneurysms do exist. Because of their potential for rupture, most visceral artery pseudoaneurysms, and many larger true aneurysms warrant intervention. Treatment can generally be accomplished by either open surgical or endovascular approaches. The treatment goal is to prevent aneurysm expansion and potential rupture by exclusion from the arterial circulation while maintaining necessary distal or collateral bed perfusion. Depending on the location of the aneurysm, this can be accomplished in a variety of ways. In areas of the visceral circulation with an abundance of collateral flow, for example in the splenic
artery, proximal and distal ligation of the aneurysm segment is a viable surgical option. This can also be accomplished with endovascular isolation of the aneurysmal segment, either by placement of a stent-graft or by coil embolization of the proximal and distal arterial segment. The preferred treatment for an individual patient and aneurysm must be carefully based upon the particular anatomy and any associated clinical conditions, as well as the underlying condition of the patient.

The purpose of the current guidelines is to guide the diagnosis, treatment options, screening and follow up of visceral aneurysms based on the available published literature and the GRADE approach.5

METHODS

GUIDELINE FRAMEWORK

The committee used the GRADE approach (Grades of Recommendation Assessment, Development and Evaluation) to rate the quality of evidence (confidence in the estimates) and grade the strength of recommendations. This system, adopted by more than 100 other organizations, categorizes recommendations as strong GRADE 1 or weak (also called conditional) GRADE 2, based on the quality of evidence, the balance between desirable effects and undesirable ones, patient’s values and preferences, and required resources.
GRADE 1 recommendations are meant to identify practices where benefit clearly outweighs risk. These recommendations can be made by clinicians and accepted by patients with a high degree of confidence. GRADE 2 recommendations are made when the benefits and risks are more closely matched and are more dependent on specific clinical scenarios. In general, physician and patient preferences play a more important role in the decision-making process in these latter circumstances.

In GRADE, the level of evidence to support the recommendation is divided into 3 categories: A (high quality), B (moderate quality), and C (low quality). Conclusions based on high-quality evidence are unlikely to change with further investigation; whereas those based on moderate-quality evidence are more likely to be affected by further scrutiny. Those based on low-quality evidence are the least supported by current data and the most likely to be subject to change in the future.

It is important to recognize that occasionally a GRADE 1 recommendation can be made based on low-quality (C) evidence. A full explanation of the GRADE approach has been presented to the vascular surgery community.\{Murad, 2011 #5\} The committee reached consensus about all the recommendations and the level of supporting evidence. These guidelines are likely to be a “living document” that will be modified as techniques are further refined, technology develops, medical therapy improves, and new data emerge.

EVIDENCE SYNTHESIS
The Committee commissioned a systematic review of MEDLINE, EMBASE, Cochrane databases, and Scopus that had wide inclusion criteria. The review included studies with 10 patients or more that reported outcomes of patients with VAA treated with open or endovascular approach. Studies were comparative or noncomparative but had to have longitudinal follow up and evaluate an outcome of interest [mortality, need of re-intervention, myocardial infarction, stroke, end-organ ischemia, end-organ infarction, deep vein thrombosis (DVT), pulmonary embolism (PE), post embolization syndrome (PES), respiratory complications, gastrointestinal complications, post-embolization syndrome, coil migration, post endovascular aortic repair rupture, rupture during intervention or wound complications (e.g. surgical site infection)]. The systematic review eventually summarized data from 80 observational studies that were mostly noncomparative. Data were available on 2,845 aneurysms (1279 renal artery, 775 splenic artery, 359 hepatic artery, 226 pancreaticoduodenal and gastroduodenal arteries, 95 superior mesenteric artery, 87 celiac artery, 15 jejunal, ileal and colic arteries, 9 gastric and gastroepiploic arteries).

A methodology group independently selected and appraised studies and subsequently collaborated with the committee to integrate evidence into recommendations. The Committee provided additional references and monitored the literature for new evidence emerging after the original search.
1. DIAGNOSIS AND EVALUATION

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<tr>
<th>Recommendations for Diagnosis and Evaluation of Renal Artery Aneurysms</th>
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</thead>
<tbody>
<tr>
<td>Supporting studies are summarized in appendix</td>
</tr>
</tbody>
</table>

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<tr>
<th>Recommendation</th>
<th>Strength of Recommendation</th>
<th>Quality of Evidence</th>
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<tr>
<td>1.1 In patients who are suspected to have RAA, we recommend computed tomographic angiography (CTA) as the diagnostic tool of choice</td>
<td>1 (Strong)</td>
<td>B (Moderate)</td>
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<td>1.2 Recommendation 1.2: In patients who are suspected to have RAA and have increased radiation exposure risks or renal insufficiency, we recommend non-contrast MRA (NC-MRA) to establish the diagnosis (Grade 1B).</td>
<td>1 (Strong)</td>
<td>B (Moderate)</td>
</tr>
<tr>
<td>Technical remark: NC-MRA is best suited to children and women of childbearing potential or those who have contraindications to CT or MR contrast materials (i.e. pregnancy, renal insufficiency, or gadolinium contrast material allergy).</td>
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<tr>
<td>1.3 We recommend the use of catheter-based angiography for both preoperative planning and to better delineate distal renal artery branches that may be inadequately assessed on conventional cross sectional imaging</td>
<td>1 (Strong)</td>
<td>C (Low)</td>
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Renal artery aneurysms (RAA) occur in approximately 0.1% of the population, although the absolute incidence is unknown. Autopsy studies likely underestimate renal artery aneurysm incidence at 0.01 to 0.09%, while angiographic studies likely overestimate this at 0.73 to 0.97%. Overall, RAAs
are most commonly identified on imaging obtained for unrelated reasons. In a recent multi-center study, computed tomography angiography (CTA) (58%) was the most commonly used modality for the diagnosis and evaluation of renal artery aneurysms, followed by non-contrast CT (24%), magnetic resonance angiography (MRA) (6%), catheter angiography (5%), and ultrasound (4%). CTA with multiplanar, maximal intensity projection reconstruction, volume rendering and 3-dimensional reconstructions better assess the arterial anatomic details of the renal arteries at all branch levels, including intra-pelvic and intraparenchymal locations. Furthermore, the 3-dimensional reconstructions may give a better representation of the number and relation of all involved branches compared to 2-dimensional catheter angiography or ultrasound.

In certain patients, compromised renal function puts them at increased risk of contrast-induced nephropathy. In an effort to avoid the nephrotoxic effects of iodinated contrast agents, non-enhanced magnetic resonance angiography (MRA) has been used to assess the renal arteries. MRA can be performed with a “breath-hold” steady-state free-precession (SSFP) sequence or time-spatial labeling inversion pulse (time-SLIP) technique. Studies evaluating SSFP sequences have shown excellent concordance, as well as inter-observer agreement, with contrast-enhanced MR. Furthermore, time-SLIP NC-MRA has also shown promise when compared to contrast-enhanced CTA with 74% sensitivity, 93% specificity, and 90% accuracy. While contrast-enhanced ultrasound has been used in the evaluation of RAAs, this technique has not been compared to other invasive and non-invasive
angiographic techniques and is operator-dependent. MRA may also be considered for those patients at the extremes of youth and for routine surveillance to decrease the risk of radiation-induced malignancy with cumulative exposure.

While 3-dimensional CTA is the diagnostic tool of choice for RAAs, the anatomic association of multiple renal arteries may limit the surgeon’s ability to plan a successful endovascular treatment. In such cases, preoperative 3-dimensional rotational catheter-based angiography may be of great benefit in planning optimal working angles. Furthermore, 3-dimensional rotational catheter-based angiography has been shown advantageous compared to 2-dimensional catheter-based angiography in 75% of cases when evaluating the neck, feeding arteries and relationship between branches of RAA.

The ability of CTA to assess microaneurysms of the distal renal vasculature may also be limited even with comprehensive renal-specific CT protocols. This is due to the rapid background enhancement of the renal parenchyma of the cortex. In such cases, CTA may show parenchymal infarcts or extra-renal hematomas, consistent with distal microaneurysmal disease as seen in cases of polyarteritis nodosa. However, catheter-based angiography is better to directly visualize distal microaneurysms.

### 2. SIZE CRITERIA AND ALTERNATE INDICATIONS FOR INTERVENTION

| Recommendations for Indications for Intervention in Renal Artery Aneurysms |
|-----------------------------|-----------------|-----------------|
| Supporting studies are summarized in appendix |
| Recommendation | Strength of Recommendation | Quality of Evidence |
| 2.1 In patients with non-complicated RAA of | 2 (Weak) | C (Low) |
acceptable risk, we suggest treatment for aneurysm size >3cm

| 2.2 | We recommend emergent intervention for any size renal artery aneurysm resulting in patient symptoms or rupture | 1 (Strong) | B (Moderate) |
| 2.3 | In patients of child-bearing potential with non-complicated RAA of acceptable risk, we suggest treatment for aneurysm size <3cm | 2 (Weak) | B (Moderate) |
| 2.4 | In patient with medically-refractory hypertension and functionally important renal artery stenosis, we suggest treatment for size <3cm | 2 (Weak) | C (Low) |

Previous guidelines have suggested the repair of most visceral arterial aneurysms >2cm in maximum diameter. While no prospective or randomized trial directly compares operative repair of intermediate renal artery aneurysms >2cm to surveillance, the natural history of these aneurysms appears more benign than historic rates have suggested with lower associated risks of rupture, slow to null rates of growth and improved survival following rupture apparent from more contemporary series.

The natural history of RAAs appears to be that of slow to no growth. Contemporary reports do not support historic series that described rupture rates as high as 14-30% with associated mortality of 80%,. Modern-day rupture rates are estimated at 3-5% with non-gestational mortality improved to <10%,. Most ruptures are diagnosed at the time of presentation and several series support no incidence of rupture during the surveillance of non-operative RAAs out to 270 months. Most recent estimates suggest a median annualized growth rate
of 0.06-0.6mm. The most recent and largest multi-institutional retrospective series of non-operative RAA surveillance found no difference in growth rate based on aneurysm morphology or calcification. These authors also report the successful surveillance of 88 aneurysms measuring 2-3cm and 7 aneurysms measuring >3cm without complication or rupture.

Ruptured renal artery aneurysms are associated with a mortality of approximately 10% in the general population and maternal and fetal death in 55% and 85%, respectively. Emergent surgery is required to prevent exsanguination; aortic control may be necessary. In many cases, renal artery reconstruction and renal salvage may not be feasible and, thus, nephrectomy should be considered.

Pregnancy has been associated with increased risk and rates of rupture presumptively secondary to hemodynamic changes and increased vascular volume and flow during pregnancy, abdominal pressure changes secondary to mass effect from the gravid uterus and hormonal changes that may disrupt the vessel wall. Pregnancy-associated rupture appears to complicate the third trimester in most cases, with post-partum rupture infrequently referenced in case reports only. While no large scale studies detail the true incidence of gestational renal aneurysm rupture, in a series of 180,000 pregnancies brought to term no ruptures were identified. Despite this, small aneurysm size (ie: 1cm) at rupture and high historical rates of maternal and fetal mortality which approximate 56-92% and 82-100% respectively support the more aggressive treatment of renal artery aneurysms.
in women of childbearing potential. Contemporary outcomes for both mother and fetus may be improving, as there are reports of gestational rupture resulting in both maternal and fetal survival.

Two-thirds of patients with RAA also have hypertension (HTN). Clinically relevant renal artery stenosis is present in 7-66% of patients with RAA across series, and while renal artery occlusive disease is not evidence in all RAA patients with HTN, it does remain a valid indication for intervention. While the mechanism driving HTN in RAA patients remains elusive, additional hypothesis include: distal parenchymal embolization, compression or kinking of associated renal artery branches and hemodynamic changes from turbulent blood flow within the aneurysm results in decreased distal renal artery perfusion pressures. Whatever the etiology, most series suggest improvement or cure in the majority of hypertensive patients undergoing RAA reconstruction, particularly if renovascular HTN is identified during the preoperative work-up. Martin et al evaluated for renovascular HTN preoperatively and demonstrated that 100% of those operated upon with documented renovascular HTN improved or were cured of HTN while only 60% of those with an unremarkable work-up were cured or improved. Pfeiffer et al similarly noted a differential improvement in HTN following aneurysm repair in those with documented renal artery stenosis (67%) in comparison to those without stenosis (29%).

3. TREATMENT OPTIONS
## Recommendations for Treatment of Renal Artery Aneurysms

Supporting studies are summarized in appendix.

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Strength of Recommendation</th>
<th>Quality of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 We suggest daily anti-platelet therapy (ie: Aspirin, 81mg) for patients with renal artery aneurysm</td>
<td>2 (Weak)</td>
<td>C (Low)</td>
</tr>
<tr>
<td>3.2 We suggest open surgical reconstructive techniques for the elective repair of most renal artery aneurysms</td>
<td>2 (Weak)</td>
<td>B (Moderate)</td>
</tr>
<tr>
<td>3.3 We suggest ex vivo repair and autotransplantation for complex distal branch aneurysms over nephrectomy when technically feasible</td>
<td>2 (Weak)</td>
<td>B (Moderate)</td>
</tr>
<tr>
<td>3.4 We suggest endovascular techniques for the elective repair of anatomically appropriate RAAs to include stent graft exclusion of main renal artery aneurysms and embolization of distal and parenchymal aneurysms</td>
<td>2 (Weak)</td>
<td>B (Moderate)</td>
</tr>
<tr>
<td>3.5 We suggest consideration of laparoscopic and robotic techniques as an interventional alternative based on institutional resources and surgeon experience with minimally invasive techniques</td>
<td>2 (Weak)</td>
<td>C (Low)</td>
</tr>
</tbody>
</table>

Distal parenchymal embolization has been described in 8-11% of patients with RAA and may be associated with the presence of mural thrombus within the aneurysm sac.\(^{19, 50}\) Duplex sonography may demonstrate evidence of microembolization, although elevated resistive in this setting may be difficult to differentiate from nephrosclerosis.\(^{26}\)

There are variable conventional in situ reconstructions available that include aneurysm resection with (1) primary angioplastic closure (+/- branch reimplantation), (2) patch angioplasty, (3) primary re-anastomosis, (4) interposition
bypass, (5) aorto-renal bypass, (6) splanchno-renal bypass, and (7) plication of small aneurysms. Surgery consistently offers low morbidity and elective mortality rates that approach zero across series.\textsuperscript{31, 33, 36-39, 49, 51, 56-58} Perioperative morbidity is mainly reported <20% following in situ reconstruction and secondary nephrectomy rates when reported are 0-21%.\textsuperscript{30, 31, 33, 36-39, 49, 51} Additionally, the reported durable primary patency rates (93-100%) are of utmost importance in light of the young age of many patients and excellent projected long-term survival that averages 90% at 10 years.\textsuperscript{30, 31, 49, 59}

The technical approach selected should be dictated entirely by patient arterial and aneurysmal anatomy. While there is prospective or randomized data comparing open surgical techniques, Henke et al noted no difference in long-term event-free outcome between those patients undergoing aneurysmectomy with angioplastic closure or aneurysmectomy with bypass with mean lifespan calculated at 108 and 130 months respectively.\textsuperscript{36} Pfeiffer et al demonstrated superior patency rates for angioplastic repairs in comparison to those reconstructions requiring saphenous vein interposition (100% v. 73%).\textsuperscript{50} Moreover, this latter technique yields no recurrent aneurysmal degeneration with follow-up.\textsuperscript{36, 50} While cooled (4\degree) renal perfusion supplemented with mannitol or Prostaglandin E has been advocated by several authors either routinely or when >30-40 minutes of warm renal ischemia is anticipated to reduce the risk of acute tubular necrosis, there is no prospective or randomized data to support this practice.\textsuperscript{36, 49, 50, 60}
While historically treated with nephrectomy, current data support that complex distal branch lesions are best approached with ex vivo repair and auto-
transplantation. The largest series of such follow: Murray et al have described a 92% success rate with in situ bifurcation and ex vivo multi-branch replacement with branched and un-branched internal iliac artery autograft in twelve patients without mortality or major morbidity. \textsuperscript{61} Gallagher et al reported on seven ex vivo reconstructions following laparoscopic nephrectomy for complex aneurysmal disease to avoid incisional morbidity; these authors describe excellent technical success, no mortality, no ureteral morbidity and a 28% incidence of perioperative morbidity. \textsuperscript{62} Chandra et al compared in situ and ex vivo reconstructions for renal aneurysm across 10 patients and noted no significant difference in hospital LOS, morbidity (20%), mortality (null) or need for reoperation at follow-up. \textsuperscript{37} Additionally, 100% of reconstructions were patent by imaging obtained during the first year of follow-up. Case reports and small series that suggest indications for endovascular repair have broadened with the introduction of three dimensional detachable coils, non-adhesive liquid embolic agent (ie: Onyx), remodeling techniques (which include balloon- and stent-assisted coiling) and flow diverter stents (ie: the Cardiatis multilayer stent), although traditional endovascular therapies have utilized simply embolization techniques for distal and parenchymal aneurysms and stent graft exclusion for main renal artery lesions. \textsuperscript{63-70} Technical success across larger series is reported as 73-100% with highly variable rates of morbidity (13-60%) that include
mainly evidence of end organ malperfusion radiographically from thromboembolism
and subsequent post-embolectomy syndrome.\textsuperscript{6, 33, 71-75} Mid-term follow is available
out 3-4 years in certain series.\textsuperscript{72, 74, 76} Access-related complication, arterial
dissection and renal compromise are uncommon and low rates of recanalization
have been observed requiring re-intervention (4-13\%).\textsuperscript{6, 71-75}

Prospective comparisons of open and endovascular therapies for RAAs are
needed, although the feasibility of such a trial is limited primarily by the low
frequency of this pathology. To this end, there have been retrospective
comparisons. A recent state-wide database review identified 215 patients that
underwent RAA repair between 2000 and 2006.\textsuperscript{32} These authors noted a significant
increase in the number of RAA repairs with a stable number of open repairs and an
increase in the number of endovascular repairs. Analysis of in-hospital outcome
events revealed similar mortality rates (1.1\% endo v. 3.3\% open) and variable
patterns of perioperative morbidity; open repair was associated with more cardiac
(P = 0.053) and infectious (P = 0.053) complications, while endovascular repair was
associated with more hemorrhagic complications (P = 0.08) presumed access-
related. Importantly, a significant reduction in median hospital length of stay and
need for post-discharge nursing services was identified in the endovascular cohort
accompanied by a trend toward lower cost. Additional retrospective comparisons of
open and endovascular procedures have reported no significant difference in
mortality, perioperative morbidity, freedom from re-intervention or decline in renal
function and the benefit of a shortened length of stay.\textsuperscript{2, 33, 77}
Robotic-assisted laparoscopic techniques for renal artery aneurysm repair have only more recently been described.\textsuperscript{78-82} This approach typically requires a multi-disciplinary collaborative procedural team of vascular, general, transplant and/or urologic surgeons. The dexterity of the robotic arms reportedly confers a technical advantage to complex aneurysmectomy and intracorporeal vascular suturing for reconstruction. Technical success has been reported in case series with warm ischemic times that range 15-60 minutes, however a direct comparison to open and endovascular techniques has yet to be performed.\textsuperscript{78, 79, 82}

4. ADDITIONAL SCREENING

<table>
<thead>
<tr>
<th>Recommendations for Treatment of Renal Artery Aneurysms</th>
<th>Strength of Recommendation</th>
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<tbody>
<tr>
<td>Supporting studies are summarized in appendix</td>
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<tr>
<th>Recommendation</th>
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<tbody>
<tr>
<td>4.1</td>
<td>We suggest screening female patients for fibromuscular dysplasia with a focused history and one-time axial imaging study (ie: CTA or MRA) to assess for cerebrovascular, mesenteric and iliac arterial dysplasia</td>
<td>2 (Weak)</td>
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<td></td>
<td></td>
<td>C (Low)</td>
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Renal artery aneurysms are associated with fibromuscular dysplasia in up to 68% of cases and concomitant arterial aneurysms affecting the aorta, visceral and iliac vessels in 7-30% of cases.\textsuperscript{30, 33, 35, 36, 38-40, 50, 51, 58} The most recent scientific statement from the American Heart Association recommends a focused vascular review of symptoms for all patients diagnosed with FMD, with an emphasis on
quality of life–impairing symptoms like migraine headache, tinnitus and neck pain. Additionally, one-time screening for occult aortic / arterial aneurysm in these patients is recommended.

5. **FOLLOW UP AND SURVEILLANCE**

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Strength of Recommendation</th>
<th>Quality of Evidence</th>
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</thead>
<tbody>
<tr>
<td><strong>5.1</strong> We suggest completion imaging following open surgical reconstruction for renal artery aneurysm, prior to hospital discharge, by way of arteriogram or ultrasound and long-term follow-up with surveillance imaging</td>
<td>2 (Weak)</td>
<td>C (Low)</td>
</tr>
<tr>
<td><strong>5.2</strong> For patients managed non-operatively, we suggest annual surveillance imaging until two consecutive studies are stable; thereafter surveillance imaging may be extended to every 2-3 years</td>
<td>2 (Weak)</td>
<td>B (Moderate)</td>
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Most authors advocate completion imaging before hospital discharge by way of arteriogram or ultrasound and long-term follow-up with surveillance imaging.8, 30, 36, 49, 50, 61

The natural history of RAAs appears to be that of slow to null growth. Most recent estimates suggest a median annualized growth rate of 0.06-0.6mm.38^40 The most recent and largest multi-institutional retrospective series of non-operative RAA surveillance found no difference in growth rate based on aneurysm morphology or calcification.13 While short-term follow-up at 1 year remains prudent for a newly
diagnosed RAA, longer intervals between surveillance imaging may be appropriate, provided patient compliance with follow-up can be ensured.

**SPLENIC ARTERY ANEURYSMS (SAA)**

1. **DIAGNOSIS AND EVALUATION**

<table>
<thead>
<tr>
<th>Recommendations for Diagnosis and Evaluation of Splenic Artery Aneurysms</th>
<th>Strength of Recommendation</th>
<th>Quality of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.1</strong> We recommend computerized tomographic angiography (CTA) as the initial diagnostic tool of choice for splenic artery aneurysms.</td>
<td>1 (Strong)</td>
<td>C (Low)</td>
</tr>
<tr>
<td><strong>1.2</strong> In patients with suspected splenic artery aneurysms and pre-existing renal insufficiency limiting the use of iodinated contrast material, we suggest magnetic resonance angiography (MRA) to establish diagnosis.</td>
<td>1 (Strong)</td>
<td>C (Low)</td>
</tr>
<tr>
<td><strong>1.3</strong> We recommend using arteriography when non-invasive studies have not sufficiently demonstrated the status of relevant collateral blood flow, and when endovascular intervention is planned.</td>
<td>1 (Strong)</td>
<td>B (Moderate)</td>
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</table>

Although they were once thought to be uncommon, splenic and other visceral artery aneurysms are being diagnosed with increasing frequency with the use of advanced imaging techniques. The increasing diagnosis of incidental splenic artery aneurysms in the United States is primarily related to the liberal use of cross-sectional imaging studies. Most SAAs currently are detected incidentally.
during diagnostic imaging performed for other indications. While plan
radiographs, sonography, computerized tomography (CT), magnetic resonance
arteriography (MRA) and arteriography have identified SAAs, computerized
tomographic arteriography (CTA) remains the initial diagnostic and evaluative tool
of choice.\textsuperscript{85}

CTA is an important imaging modality for the vascular system and has been
established as the method of choice for the diagnosis, treatment planning and follow
up of most diseases of the abdominal arteries including the aorta and visceral
vessels. Besides being able to assess the location and size of the SAA, CTA may also
reveal rupture, intraabdominal hemorrhage, and associate underlying diseases.
Additionally nearly all necessary data for planning endovascular treatment can be
obtained by multidimensional CTA.\textsuperscript{85} Sonography of visceral vessels is inhibited by
shadowing from bowel gas as well as obesity; however, its sensitivity to detect SAA
of less than 3 cm is poor.\textsuperscript{85, 87} MRA may certainly play a role in patients in whom
CTA is contraindicated. However, in 2006 Pilleul et al compared the use of MRA
and CTA for the analysis of splanchnic aneurysms and felt that the sensitivity of
MRA was suboptimal in the case of very small aneurysms.\textsuperscript{85, 88}
Formal arteriography may rarely be necessary for pre-interventional planning when
the above non-invasive studies have not sufficiently demonstrated the status of
relevant anatomy or collateral blood flow; however, it is most frequently performed
at the time of a planned endovascular intervention.
## 2. Treatment Indications / Size Criteria / True Versus False Aneurysms

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<tr>
<th>Recommendation</th>
<th>Strength of Recommendation</th>
<th>Quality of Evidence</th>
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</thead>
<tbody>
<tr>
<td>2.1 We recommend emergent intervention for ruptured splenic artery aneurysms.</td>
<td>1 (Strong)</td>
<td>A (High)</td>
</tr>
<tr>
<td>2.2 We recommend treatment of non-ruptured splenic artery pseudoaneurysms of any size in patients of acceptable risk due to the possibility of rupture.</td>
<td>1 (Strong)</td>
<td>B (Moderate)</td>
</tr>
<tr>
<td>2.3 We recommend treating non-ruptured splenic artery true aneurysms of any size in women of child-bearing age due to the risk of rupture.</td>
<td>1 (Strong)</td>
<td>B (Moderate)</td>
</tr>
<tr>
<td>2.4 We recommend treating non-ruptured splenic artery true aneurysms more than 2 cm in size, with a demonstrable increase in size, or with associated symptoms in patients of acceptable risk due to the risk of rupture.</td>
<td>1 (Strong)</td>
<td>C (Low)</td>
</tr>
<tr>
<td>2.5 We suggest observation over repair for small (&lt; 2 cm), stable asymptomatic splenic artery true aneurysms, or those in patients with significant medical comorbidities or limited life expectancies.</td>
<td>2 (Weak)</td>
<td>C (Low)</td>
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</table>

The natural history of visceral aneurysms and their potential for rupture or other complications is relatively poorly defined due to their overall scarcity. However, it is clear even from the numerous case series in the literature that a significant proportion of visceral artery aneurysms present with rupture; therefore, a relatively aggressive approach towards their diagnosis and management certainly...
seems warranted. The overall mortality of ruptured splenic artery aneurysms is as high as 25%.

Splenic artery aneurysms in young women are thought to have a particular tendency towards rupture, especially during the third trimester of pregnancy. Pregnancy may be associated with 20% to 50% of all ruptures. Rupture of a splenic artery aneurysm during pregnancy has devastating maternal and fetal mortality rates of 80% and 90% respectively.

Depending on the entirety of vessel wall involvement, SAA can be subdivided into true aneurysms or pseudoaneurysms. Splenic artery pseudoaneurysms certainly have a higher rupture potential than true aneurysms. Furthermore, some evidence suggests that pseudoaneurysms display relatively rapid growth rates implicating a focus on early intervention regardless of size. In the series by Tulsyan, in which 48 visceral aneurysms were treated, 80% of 28 pseudoaneurysms were symptomatic at presentation as opposed to 30% of 20 true aneurysms. Pitton, et al, reported a review of 233 patients with 253 visceral artery aneurysms. The rate of rupture at presentation was noted to be significantly higher in visceral pseudoaneurysms than in true aneurysms (76.3% vs. 3.1%). There were 35 ruptures in their series. There was no significant difference in size between ruptured and non-ruptured visceral aneurysms. The authors concluded that visceral pseudoaneurysms are at increased risk for rupture, and that diameter is not necessarily a reliable predictor of rupture.
Nevertheless, several large case series of SAA management have included an observation cohort with acceptable results. General guidelines state that SAAs less than 2 cm in size, asymptomatic, and showing little to no growth can be safely observed and monitored with serial imaging studies. As indicated above, women who are either pregnant or of childbearing age should have any SAA treated regardless of size. There is no firm evidence to show that aneurysm calcification protects against growth or rupture, but calcified SAA aneurysms may be associated with smaller size at initial diagnosis.

A large review was reported from the Mayo Clinic involving 217 patients with SAAs. Of these patients, 168 underwent nonoperative management for a mean period of 75 months. The mean size in the nonoperative group was 2.1 cm with a range from 0.8 to 5 cm in diameter. Approximately half of these aneurysms were monitored with serial imaging, of which only 10% were noted to have growth averaging 0.06 cm/year. No rupture or other complications related to the SAAs occurred, and only 3 of the original 168 required eventual intervention due to aneurysm growth. Similar results were reported by Lakin, et al when reviewing the Cleveland Clinic experience of 128 SAAs managed over a 15-year period. This observational cohort of 66 SAAs had a mean size of 1.7 cm at presentation with a range from 0.8 to 4.2 cm. Serial imaging was available for 94% of the aneurysms, and these patients received an average of 2.5 CT scans over 4.6 follow-up years. The average growth rate was a nominal 0.2 mm/year over 3.1 follow-up years. There were again no ruptures or other complications attributed to the aneurysms in
the observed group. Observation of small, true aneurysms therefore seems an appropriate approach.

Additional suggested indications for intervention in splenic artery aneurysms include: patients with portal hypertension, patients who may require liver transplantation, patients whose aneurysm has a non-atherosclerotic or non-degenerative etiology, and patients whose aneurysm demonstrates interval growth > 0.5 cm / year.99

3. TREATMENT OPTIONS

<table>
<thead>
<tr>
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<tbody>
<tr>
<td><strong>Recommendation</strong></td>
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</tr>
<tr>
<td><strong>3.1 In patients with ruptured SAA discovered at laparotomy, we suggest treatment with ligation with or without splenectomy depending on the aneurysm location.</strong></td>
<td>2 (Weak)</td>
<td>B (Moderate)</td>
</tr>
<tr>
<td><strong>3.2 In patients with ruptured SAA diagnosed on preoperative imaging studies, we suggest treatment with open surgical or appropriate endovascular techniques based upon the patient’s anatomy and underlying clinical condition.</strong></td>
<td>2 (Weak)</td>
<td>B (Moderate)</td>
</tr>
<tr>
<td><strong>3.3 We suggest elective treatment of SAA using an endovascular approach if anatomically feasible. However, elective treatment may appropriately involve open surgical, endovascular or laparoscopic methods of intervention depending on the patient’s anatomy and underlying clinical condition.</strong></td>
<td>2 (Weak)</td>
<td>B (Moderate)</td>
</tr>
<tr>
<td><strong>3.4 When treating SAA, we suggest that the splenic artery does not routinely</strong></td>
<td>2 (Weak)</td>
<td>C (Low)</td>
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<td><strong>require preservation or revascularization.</strong></td>
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<tr>
<td><strong>3.5</strong> When treating distal SAA adjacent to the hilum of the spleen, we suggest open surgical techniques including possible splenectomy as opposed to endovascular methods given concern regarding the possibility of end organ ischemia, including splenic infarction and/or pancreatitis.</td>
<td>2 (Weak)</td>
<td>B (Moderate)</td>
</tr>
<tr>
<td><strong>3.6</strong> In pregnant women with SAA, we recommend that treatment decisions be individualized and consider the potential morbidity to both the mother and fetus.</td>
<td>Ungraded Best Practice Statement</td>
<td></td>
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</table>
arteries. For more distal lesions adjacent to the splenic hilum, splenectomy has been the most commonly traditionally performed operation. This is clearly required when the aneurysm involves intrasplenic branches within the splenic parenchyma. Distal pancreatectomy may occasionally be warranted in treatment of these distal lesions as well.\textsuperscript{100, 101} Laparoscopic repair of SPAA by clipping or exclusion has been reported; intraoperative ultrasonography is felt to be an important adjunct to this procedure.\textsuperscript{102} Combined laparoscopic occlusion and coil embolization has been proposed as a treatment method for aberrant SPAA located in the retropancreatic position, in which traditional surgical exposure would be exceedingly difficult.\textsuperscript{103} Endovascular approaches to managing VAA offer the benefit of low procedural morbidity and mortality, and are generally considered to be the preferred initial approach to most anatomically suitable visceral aneurysm considered appropriate for intervention.\textsuperscript{1} Endoluminal ablation of SAAs has been shown in multiple reported series to be highly technically successful, but there is some concern of end-organ malperfusion, and aneurysm reperfusion during follow up.\textsuperscript{1, 104}

Endovascular treatment options include coil embolization of the splenic artery both proximal and distal to the aneurysm itself, effectively “trapping” the lesion. Other options for a saccular type aneurysm include embolization of the aneurysm sac itself with coils and/or cyanoacrylate glue, or occlusion of the lesion with percutaneous or open thrombin injection.\textsuperscript{105} In addition, stent-grafting has been performed, particularly for saccular lesions of the mid splenic artery. There has been concern regarding splenic infarction and/or pancreatitis when
embolization of very distal splenic artery lesions has been performed. In a review of 48 endovascular procedures for visceral artery pseudoaneurysms, interventions on the splenic artery were performed. Six end-organ infarcts in this series were identified: all were within the splenic bed. Two additional patients displayed splenic atrophy on CT scanning after prior embolization of the splenic artery, without obvious clinical evidence for initial splenic infarction. In another report, one episode of splenic infarction associated with severe pancreatitis was noted following embolization of a distal splenic artery lesion. However, other authors have noted splenic infarction after embolization of even more proximal SAA as well.

Ruptured SAA are challenging and represent a true surgical emergency. Patients should be expeditiously transferred to the operating room for exploratory laparotomy in the setting of hemodynamic collapse. Ligation of the splenic artery proximally and distally is required. Patients presenting with ruptured SAA are most often treated with concomitant splenectomy and without vascular reconstruction.

The immediate benefits associated with endovascular intervention include local anesthesia, a shorter hospital stay, and faster recovery. Drawbacks to endovascular therapy include end-organ embolization, and a relatively higher rate of failure compared to open surgery. Lastly, patients with splenic artery ablation for SAA can develop post-embolization syndrome with ongoing pain, fevers, and other systemic symptoms. Complete exclusion of flow within the aneurysm sac
occurred in 97% interventions with follow-up imaging in the Cleveland Clinic experience. In the Mayo Clinic experience, initial intervention was successful 98% of the time. Coiling was used alone in 75% of the cases, and in combination with at least one other technique in 11% of cases.

The risk of end-organ ischemia appears to be an especially salient concern pertaining to endovascular repair. Some authors have concluded that patients with aneurysmal disease at the splenic hilum may be better managed with open repair and splenectomy.\textsuperscript{107}

Recently, a study utilizing a Markov decision model was used to compare open surgery vs. endovascular repair vs. conservative therapy for a patient with SAA\textsuperscript{108} Endovascular repair was found to be associated with highest quality of life and the most cost-effective strategy for most groups and was superior to open surgery in this model. However, the authors concluded that elderly patients should be considered for conservative therapy given the small incremental benefit and high cost.

An open surgical approach may remain appropriate in cases of rupture and pregnancy related SAAs.\textsuperscript{109}

\textbf{4. SCREENING}

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<tr>
<th>Recommendation</th>
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<th>Quality of Evidence</th>
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<tbody>
<tr>
<td>4.1 We suggest screening of patients with</td>
<td>2 (Weak)</td>
<td>B (Moderate)</td>
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</table>

Recommendations for Screening in Patients with Splenic Artery Aneurysms

Supporting studies are summarized in appendix.
Splenic artery aneurysms may be multiple, and may be found in association with other visceral and non-visceral aneurysms. In a review of 212 cases of splenic artery aneurysms seen over a two-decade period at a single institution, 3.3% of patients were found to have concomitant visceral aneurysms with the most common location being extrahepatic (2.3%), and additionally including aneurysms in the celiac, superior mesenteric, gastric and pancreaticoduodenal territories.\textsuperscript{110} Additionally, 14.3% of patients were found to have concomitant non-visceral aneurysms with the most common location being renal (7.4%) and abdominal aortic (3.7%), and additional including aneurysms in the carotid, intracerebral, thoracic aortic and popliteal territories.\textsuperscript{110}

5. **SURVEILLANCE AND FOLLOW UP**

<table>
<thead>
<tr>
<th>Recommendations for Surveillance and Follow-up of Splenic Artery Aneurysm Patients</th>
<th>Strength of Recommendation</th>
<th>Quality of Evidence</th>
</tr>
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<tbody>
<tr>
<td><strong>5.1</strong> In patients in whom a splenic artery aneurysm is being followed with a non-operative / non-interventional approach, we suggest annual surveillance with CT scans to assess for growth in size.</td>
<td>2 (Weak)</td>
<td>B (Moderate)</td>
</tr>
<tr>
<td><strong>5.2</strong> Following endovascular intervention for splenic artery aneurysms, we suggest periodic surveillance with appropriate imaging studies to assess for the possibility of endoleak or other continued aneurysm perfusion which</td>
<td>2 (Weak)</td>
<td>B (Moderate)</td>
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</table>
could lead to a continued risk of aneurysm growth or rupture.

Splenic artery aneurysms selected for conservative management with observation require surveillance to assess for progression and size growth. The mode of assessment and the appropriate imaging technique would depend on the visibility of the aneurysm to the various imaging techniques available. CT scan or ultrasound should be performed every 12 months; CT scan is generally preferred due to the detailed cross-sectional imaging provided.

A large review was reported from the Mayo Clinic involving 217 patients with SAAs. Of these patients, 168 underwent nonoperative management for a mean period of 75 months. The mean size in the nonoperative group was 2.1 cm with a range from 0.8 to 5 cm in diameter. About half of these aneurysms were monitored with serial imaging, of which only 10% were noted to have growth averaging 0.06 cm/year. No rupture or other complications related to the SAAs occurred and only 3 of the original 168 required intervention due to aneurysm growth. Similar results were reported by Lakin, et al when reviewing the Cleveland Clinic experience of 128 SAAs managed over a 15-year period. The observational cohort of 66 SAAs had a mean size of 1.7 cm at presentation with a range from 0.8 to 4.2 cm. Serial imaging was available for 94% of the aneurysms, and these patients received an average of 2.5 CT scans over 4.6 follow-up years. The average growth rate was a nominal 0.2 mm/year over 3.1 follow-up years. There were again no ruptures or other complications attributed to the aneurysms in the observed group.
In the Saltzberg study, a total of 38 visceral aneurysms were observed over a mean follow up period of 31 months, including 5 celiac aneurysms and 25 splenic aneurysms. The mean diameter in the observation group was 2 cm. No known ruptures or interventions occurred in the observation group, but complete follow up was available in only 50% of the patients.\textsuperscript{107}

Continued surveillance, even after secondary technical success, is imperative as the natural history of splanchnic artery aneurysms following endovascular treatment remains unclear. This is especially true of saccular aneurysms treated with coil or thrombin embolization; unlike formal exclusion with a covered stent, these aneurysms are not technically ‘excluded’ from arterial circulation. Indeed, sac thrombosis may not protect the aneurysm sac from pressure transmitted through thrombus, and eventual sac growth or rupture may still occur.\textsuperscript{111,112} Reports of reperfusion and even rupture following ‘successful’ embolization of splanchnic aneurysms support the notion that a thrombosed aneurysm may not represent the definitive treatment in all cases.\textsuperscript{113,114} Other authors also note that regular follow up with Doppler or CT is necessary for patients with visceral aneurysms treated by embolization.\textsuperscript{115} The recanalization rates following endovascular intervention were 18% and 30% respectively in two reported series.\textsuperscript{113,116}

Treatment failure including persistent perfusion, recanalization and coil migration have been observed. The potential for early or late failure such as growth in sac size or leak which would require reintervention requires early and serial imaging follow up.\textsuperscript{95,99} Because the radiopaque materials used may make sensitive
CT evaluation difficult due to artifact, some authors recommend contrast enhanced US or MRI as follow up imaging techniques.\textsuperscript{6, 99}

**CELIAC ARTERY ANEURYSMS**

## 1. DIAGNOSIS AND EVALUATION

<table>
<thead>
<tr>
<th>Recommendations for Diagnosis and Evaluation of Celiac Artery Aneurysms</th>
<th>Strength of Recommendation</th>
<th>Quality of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.1</strong> We suggest computerized tomographic angiography (CTA) as the initial diagnostic tool of choice for celiac artery aneurysms.</td>
<td>2 (Weak)</td>
<td>B (Moderate)</td>
</tr>
<tr>
<td><strong>1.2</strong> We suggest magnetic resonance angiography (MRA) in patients with suspected celiac AA and pre-existing renal insufficiency limiting the use of iodinated contrast material.</td>
<td>2 (Weak)</td>
<td>B (Moderate)</td>
</tr>
<tr>
<td><strong>1.3</strong> We suggest arteriography when non-invasive studies have not sufficiently demonstrated the status of relevant collateral blood flow or when endovascular intervention is planned.</td>
<td>2 (Weak)</td>
<td>C (Low)</td>
</tr>
</tbody>
</table>

Although they were once thought to be uncommon, splenic and other visceral artery aneurysms are being diagnosed with increasing frequency with the use of advanced imaging techniques.\textsuperscript{84, 85} The increasing diagnosis of incidental splenic artery aneurysms in the United States is primarily related to the liberal use of cross-sectional imaging studies.\textsuperscript{86} Most visceral aneurysms currently are detected incidentally during diagnostic imaging performed for other indications. \textsuperscript{85} While
plan radiographs, sonography, computerized tomography (CT), magnetic resonance arteriography (MRA) and arteriography have identified SAAs, computerized tomographic arteriography (CTA) remains the initial diagnostic and evaluative tool of choice.\textsuperscript{85}

CTA is an important imaging modality for the vascular system and has been established as the method of choice for the diagnosis, treatment planning and follow up of most diseases of the abdominal arteries including the aorta and visceral vessels. Besides being able to assess the location and size of the SAA, CTA may also reveal rupture, intraabdominal hemorrhage, and associate underlying diseases. Additionally nearly all necessary data for planning endovascular treatment can be obtained by multidimensional CTA.\textsuperscript{85} Sonography of visceral vessels is inhibited by shadowing from bowel gas as well as obesity; however, its sensitivity to detect SAA of less than 3 cm is poor.\textsuperscript{85, 87} MRA may certainly play a role in patients in whom CTA is contraindicated. However, in 2006 Pilleul et al compared the use of MRA and CTA for the analysis of splanchnic aneurysms and felt that the sensitivity of MRA was suboptimal in the case of very small aneurysms.\textsuperscript{85, 88}

Formal arteriography may rarely be necessary for pre-interventional planning when the above non-invasive studies have not sufficiently demonstrated the status of relevant anatomy or collateral blood flow; however, it is most frequently performed at the time of a planned endovascular intervention.

\textbf{2. TREATMENT INDICATIONS/ SIZE CRITERIA/ TRUE VERSUS FALSE ANEURYSMS}
### Recommended Intervention Criteria for Celiac Artery Aneurysms

Supporting studies are summarized in appendix

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Strength of Recommendation</th>
<th>Quality of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 We recommend emergent intervention for ruptured celiac artery aneurysms.</td>
<td>1 (Strong)</td>
<td>A (High)</td>
</tr>
<tr>
<td>2.2 We recommend treatment of non-ruptured celiac artery pseudoaneurysms of any size in patients of acceptable risk due to the possibility of rupture.</td>
<td>1 (Strong)</td>
<td>B (Moderate)</td>
</tr>
<tr>
<td>2.3 We recommend treatment of non-ruptured celiac artery true aneurysms more than 2 cm in size, with a demonstrable increase in size, or with associated symptoms in patients of acceptable risk due to the risk of rupture.</td>
<td>1 (Strong)</td>
<td>C (Low)</td>
</tr>
<tr>
<td>2.4 We suggest observation over intervention for small (&lt; 2 cm), stable asymptomatic celiac artery aneurysms, or those in patients with significant medical comorbidities or limited life expectancy</td>
<td>2 (Weak)</td>
<td>C (Low)</td>
</tr>
</tbody>
</table>

The natural history of splanchnic aneurysms and their potential for rupture or other complications is relatively poorly defined due to their overall scarcity. However, it is clear even from the numerous case reports and series in the literature that a significant proportion of celiac artery aneurysms present with rupture; therefore, an aggressive approach towards their diagnosis and management certainly seems warranted. Reported mortalities following ruptured celiac artery aneurysms approach 100%. CAA appear to have a strong tendency to rupture with a resultant high mortality rate; it was reported that 33 or 34 patients with CAA diagnosed in 1943
died from rupture. The overall reported risk for rupture appears to range from 10% to 20%. The majority of patients reported with CAA have been symptomatic at presentation, although occult asymptomatic aneurysms are more likely to be diagnosed radiologically in the current era. It has been reported that that rupture occurs in approximately 5% of celiac trunk aneurysms that range in 15-22 mm in diameter, and in 50-70% of those that exceed 32 mm in diameter.

Because the mortality rate associated with ruptured CAA approaches 100%, it is reasonable to consider treatment appropriate for most patients in whom a CAA is diagnosed, unless medical comorbidities absolutely preclude effective treatment. There are no absolute size criteria with which to direct the indication for treatment; however, treatment for lesions greater than 2 cm seems appropriate. Despite this, in a reported series of 18 CAA in which nonoperative management was performed in eight asymptomatic patients, only one subsequent rupture was noted to occur. The other observed CAAs had no evidence of enlargement or rupture during a mean 91 month follow-up period.

As with other visceral aneurysms, pseudoaneurysms of the celiac artery appear more prone to rupture than true aneurysms, and most authors recommend treatment of all visceral pseudoaneurysms in any anatomic territory. In the series by Tulsyan, in which 48 visceral aneurysms were treated, 80% of 28 pseudoaneurysms were symptomatic at presentation as opposed to 30% of 20 true aneurysms. Pitton, et al, reported a review of 233 patients with 253 visceral artery aneurysms. The rate of rupture at presentation was noted to be significantly
higher in visceral pseudoaneurysms than in true aneurysms (76.3% vs. 3.1%). There were 35 ruptures in their series. There was no significant difference in size between ruptured and non-ruptured visceral aneurysms. The authors concluded that visceral pseudoaneurysms are at increased risk for rupture, and that diameter is not necessarily a reliable predictor of rupture. In an additional series of 155 patients with visceral aneurysms, Guo, et al found no significant difference of the diameters between symptomatic and asymptomatic patients (36.9 vs. 33.6 mm). Pseudoaneurysms were more common in the patients who presented with rupture. Symptomatic patients had a significantly higher 30 day mortality. Celiac aneurysms were more likely to be in the symptomatic group; while splenic aneurysms were more likely to be in the asymptomatic group. Most of the ruptures were in pseudoaneurysms (80%). Of a total of 8 celiac lesions, 5 were symptomatic. Tetreau, et al, reviewed 112 patients with splanchnic aneurysms, including 44 splenic aneurysms and 6 celiac aneurysms. Patients with splenic aneurysms were significantly less likely to be symptomatic than those with aneurysms with other visceral territories. Of splenic artery aneurysms, 23% were symptomatic and 18% were ruptured. The mean size at rupture was 28 mm. Of the celiac aneurysms, one was ruptured at a diameter of 17 mm.

3. TREATMENT OPTIONS

<table>
<thead>
<tr>
<th>Recommendations for Treatment of Celiac Artery Aneurysms</th>
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<tbody>
<tr>
<td>Supporting studies are summarized in appendix</td>
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<tr>
<td>Recommendation</td>
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51
<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Evidence</th>
</tr>
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<tbody>
<tr>
<td><strong>3.1</strong> In patients with ruptured CAA discovered at laparotomy, we suggest ligation if sufficient collateral circulation to the liver can be documented.</td>
<td>2 (Weak) C (Low)</td>
</tr>
<tr>
<td><strong>3.2</strong> In patients with ruptured CAA diagnosed on preoperative imaging studies who are stable, we suggest treatment with open surgical or appropriate endovascular methods based upon the patient’s anatomy and underlying clinical condition.</td>
<td>1 (Strong) B (Moderate)</td>
</tr>
<tr>
<td><strong>3.3</strong> For the elective treatment of CAA, we suggest using an endovascular intervention if anatomically feasible. However, elective treatment may appropriately involve open surgical, endovascular or laparoscopic methods of intervention depending on the patient’s anatomy and underlying clinical condition.</td>
<td>2 (Weak) B (Moderate)</td>
</tr>
<tr>
<td><strong>3.4</strong> To determine the need for revascularization of the celiac artery and its branches when treating CAA, we suggest evaluating the status of the superior mesenteric artery, gastroduodenal artery, and other relevant collateral circulation which must be carefully documented on preoperative imaging studies.</td>
<td>2 (Weak) B (Moderate)</td>
</tr>
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</table>

Historically, surgical treatment of celiac aneurysms was the only feasible option for management. Open surgical options included aneurysmectomy, aneurysmorrhaphy, aorto-ceeliac or aorto-hepatic bypass, and ligation. The necessity of celiac or celiac branch revascularization depends upon several factors, including the location of the aneurysm, and the nature of the collateral mesenteric
circulation. Simple ligation of the celiac artery is a viable option in a meaningful proportion of cases, and has been undertaken in as much as 35% of reported surgically treated cases in the literature. Ligation of the celiac artery is reportedly well tolerated in most cases, however, may be problematic in patients with underlying hepatic disease. Ligation can be used for emergency treatment of celiac trunk aneurysms with a relatively low risk of hepatic ischemia. When ligated, collateral flow is provided by the superior mesenteric, pancreaticoduodenal and gastroduodenal arteries. The standard surgical approach involving revascularization is celiac aneurysmectomy with aorto celiac bypass grafting, most commonly using prosthetic materials. In one reported series of nine patients undergoing elective open surgical repair, revascularization was performed in 89%. Aneurysmorrhaphy for isolated saccular lesions of the celiac artery has also been reported.

Endovascular approaches to managing celiac aneurysms offer the potential benefit of low procedural morbidity and mortality, and are generally considered to be the preferred initial approach to most anatomically suitable visceral aneurysm considered appropriate for intervention. The preferred treatment for an individual patient and aneurysm must be carefully based upon the particular anatomy and any associated clinical conditions, as well as the underlying condition of the patient. Reported successful endovascular techniques have included coil or glue embolization, percutaneous or open thrombin injection, and endovascular stent-grafting. One report of five cases of endovascular occlusion of CAA
revealed no ischemic sequelae, and uniformly good technical results.  
Late development of coil migration into the stomach, and development of a fatal aortogastric fistula has been reported following coil embolization of a CAA. However, there are significantly fewer reports in the literature of celiac artery aneurysms being treated by endovascular techniques as compared to splenic artery aneurysms. Because celiac aneurysms typically involve the proximal portion of the celiac trunk, absence of a proximal landing zone may limit endovascular treatment with coils. 

As with other visceral artery aneurysms, the potential advantages of endovascular intervention include reduced morbidity and mortality. Regus, et al, reported a series of 31 true visceral artery aneurysms. The mean diameter of intact aneurysms was 30.1 mm as compared to 38 mm for ruptured aneurysms, which was not a statistically significant different. There was a lower 30-day mortality rate after endovascular repair of visceral aneurysms in both the electively treated and urgently treated cohorts. Roberts et al reported on a series of emergently treated hemorrhaging celiac or mesenteric artery aneurysms using an initial endovascular approach to all patients in whom the diagnosis was made on preoperative imaging studies. Ultimately, open surgical treatment was required in less than 5% of cases.

4. SCREENING

<table>
<thead>
<tr>
<th>Recommendations for Screening in Patients with Celiac Artery Aneurysms</th>
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<tbody>
<tr>
<td>Supporting studies are summarized in appendix</td>
</tr>
<tr>
<td>Recommendation</td>
</tr>
</tbody>
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54
4.1. Celiac artery aneurysms are associated with other splanchnic artery aneurysms in 40% of cases, and with aortic aneurysms in 20% of cases.\(^1\)\(^2\)\(^3\) Of patients with a celiac artery aneurysm, 18\%-20\% will have an aortic aneurysm, and 18\%-38\% will have an additional visceral artery aneurysm.\(^4\) Peripheral artery aneurysms are seen in 18\%-67\% of patients.\(^5\)

5. **FOLLOW-UP AND SURVEILLANCE**

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<tr>
<th>Recommendation</th>
<th>Strength of Recommendation</th>
<th>Quality of Evidence</th>
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<tbody>
<tr>
<td><strong>5.1</strong> In patients in whom a celiac artery aneurysm is being followed with a non-operative / non-interventional approach, we suggest annual surveillance with CT scans to assess for growth in size.</td>
<td>2 (Weak)</td>
<td>B (Moderate)</td>
</tr>
<tr>
<td><strong>5.2.</strong> Following endovascular intervention for celiac artery aneurysms, we suggest periodic surveillance with appropriate imaging studies to assess for the possibility of endoleak or other continued aneurysm perfusion which could lead to a continued risk of aneurysm growth or rupture.</td>
<td>2 (Weak)</td>
<td>B (Moderate)</td>
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</table>

In a reported series of 18 CAA in which nonoperative management was performed in eight asymptomatic patients, only one subsequent rupture was noted.
to occur. The other observed CAAs had no evidence of enlargement or rupture during a mean 91 month follow-up period. Because rupture of celiac artery aneurysms has been reported to occur at diameters less than 20 mm, close radiologic follow up of those selected for observation with yearly CT scans is appropriate.

Continued surveillance, even after secondary technical success, is imperative as the natural history of splanchnic artery aneurysms following endovascular treatment remains unclear. This is especially true of saccular aneurysms treated with coil or thrombin embolization: unlike formal exclusion with a covered stent, these aneurysms are not technically ‘excluded’ from arterial circulation. Indeed, sac thrombosis may not protect the aneurysm sac from pressure transmitted through thrombus, and eventual sac growth or rupture may still occur. Reports of reperfusion and even rupture following ‘successful’ embolization of splanchnic aneurysms support the notion that a thrombosed aneurysm may not represent the definitive treatment in all cases. Other authors also note that regular follow up with Doppler / or CT is necessary for patients with visceral aneurysms treated by embolization. The recanalization rates following endovascular intervention were 18% and 30% respectively in two reported series. Treatment failures including persistent perfusion, recanalization and coil migration have been observed. The potential for early or late failure such as growth in sac size or leak which would require reintervention requires early and serial imaging follow up. Because the radiopaque materials used may make sensitive
CT evaluation difficult due to artifact, some authors recommend contrast enhanced US or MRI as follow up imaging techniques.\textsuperscript{6, 99}

**GASTRIC AND GASTROEPIPLOIC ANEURYSMS**

### 1. DIAGNOSIS AND EVALUATION

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Strength of Recommendation</th>
<th>Quality of Evidence</th>
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</thead>
<tbody>
<tr>
<td>1.1 In patients who are suspected to have GA/GEA, we recommend computed tomographic angiography (CTA) as the diagnostic tool of choice</td>
<td>1 (Strong)</td>
<td>B (Moderate)</td>
</tr>
</tbody>
</table>
| 1.2 In patients suspected to have GA/GEA and have high radiation exposure risks or renal insufficiency, we recommend non-contrast MRA (NC-MRA) for diagnosis.  
*Technical remark: NC-MRA is best suited to children and women of childbearing potential or those who have contraindications to CT or MR contrast materials (i.e. pregnancy, renal insufficiency, or gadolinium contrast material allergy).* | 1 (Strong) | B (Moderate) |
| 1.3 We recommend the use of catheter-based angiography for all emergent cases presenting with rupture (1B) and electively for preoperative planning (1C). | 1 (Strong) | B (Moderate) C (Low) |

Gastric and gastroepiploic artery aneurysms account for approximately 4-5% of all splanchnic aneurysms affecting men more frequently than women (three to
Etiologic risk factors include primarily arterial dyplasia with segmental arterial mediolysis and peri-arterial inflammation like pancreatitis and vasculitis; atherosclerosis when present is felt to be a secondary process. Axial imaging, ideally with CT-angiogram, remains the diagnostic study of choice as it detects incidental and asymptomatic aneurysms and guide surgical and endovascular planning.

2. SIZE CRITERIA FOR INVASIVE INTERVENTION

<table>
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<tr>
<th>Recommendation</th>
<th>Strength of Recommendation</th>
<th>Quality of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 We recommend treatment of all gastric and gastroepiploic aneurysms, any size</td>
<td>1 (Strong)</td>
<td>B (Moderate)</td>
</tr>
</tbody>
</table>

Gastric artery aneurysms are ten-times more common than gastroepiploic artery aneurysms. While patients may present with abdominal pain, up to 90% of patients have historically presented acutely ruptured with evidence of GI bleeding more common than intra-peritoneal rupture (1/3). Treatment is recommended for all gastric and gastroepiploic arterial aneurysms, regardless the size, in light of this rupture risk at relatively small aneurysm sizes.

3. TREATMENT OPTIONS
3.1 **We recommend endovascular embolization first-line for gastric and gastroepiploic aneurysms**

<table>
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<tbody>
<tr>
<td>3.1</td>
<td>1 (Strong)</td>
<td>B (Moderate)</td>
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Surgical management has historically relied on simple arterial ligation or excision without reconstruction while intramural aneurysms required a wedge excision of involved gastric wall. Contemporaneous literature supports catheter-based embolization of gastric and gastroepiploic aneurysms as the new standard for care with multiple case reports and small series documenting successful aneurysm occlusion with coils and thrombin injection.

Embolization for gastric and gastroepiploic aneurysms, even ruptured, offers >90% technical success and low morbidity and mortality. Stent grafting has been described, but remains anecdotal.

### 4. SCREENING FOR CONCOMITANT ANEURYSMS

<table>
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<th>Recommendation</th>
<th>Strength of Recommendation</th>
<th>Quality of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 <strong>We recommend abdominal axial imaging to screen for concomitant abdominal aneurysms</strong></td>
<td>2 (Weak)</td>
<td>B (Moderate)</td>
</tr>
<tr>
<td>4.2 <strong>We recommend a one-time screening CTA (or MRA) of the head, neck and chest for those patients with segmental arterial mediolysis</strong></td>
<td>2 (Weak)</td>
<td>C (Weak)</td>
</tr>
</tbody>
</table>
Axial imaging as recommended above will screen for concomitant non-aortic intra-abdominal arterial aneurysms, which are common.\textsuperscript{138, 141, 147}

We recommend screening for cerebrovascular and coronary artery aneurysm when the diagnosis of segmental arterial mediolysis is suspected given the systemic nature of this arterial dysplasia with a one-time screening CT-angiogram or MR-angiogram of the head, neck and chest.\textsuperscript{138, 148}

### 5. FOLLOW UP AND SURVEILLANCE

<table>
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<tr>
<td><strong>5.1</strong> We suggest interval surveillance (ie: every 12-24 months) with axial imaging (ie: CTA or MRA) in cases of segmental medial arteriolysis in light of reported cases of rapid arterial transformation</td>
<td>2 (Weak)</td>
<td>B (Moderate)</td>
</tr>
<tr>
<td><strong>5.2</strong> We suggest post-embolization surveillance at every 1-2 years with axial imaging to assess for vascular remodeling and evidence of aneurysm reperfusion</td>
<td>2 (Weak)</td>
<td>B (Moderate)</td>
</tr>
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</table>

We recommend routine interval surveillance (ie: every 12) with axial imaging (ie: CTA or MRA) in cases of segmental medial arteriolysis in light of reported cases of rapid arterial transformation.\textsuperscript{149}

We recommend post-embolization surveillance at every 1-2 years with axial imaging to assess for vascular remodeling and evidence of aneurysm reperfusion.\textsuperscript{1, 150, 151}
HEPATIC ARTERY ANEURYSM

1. DIAGNOSIS AND EVALUATION

<table>
<thead>
<tr>
<th>Recommendations for Diagnosis and Evaluation of Hepatic Artery Aneurysms</th>
<th>Supporting studies are summarized in appendix</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.1</strong> In patients who are suspected to have hepatic artery aneurysm (HAA), we recommend computed tomographic angiography (CTA) as the diagnostic tool of choice</td>
<td>1 (Strong)</td>
</tr>
<tr>
<td><strong>1.2</strong> In patients with HAA who are considered for intervention, we recommend mesenteric angiography for preoperative planning</td>
<td>1 (Strong)</td>
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Hepatic artery aneurysm (HAA) is the second most common type of visceral artery aneurysm reported. The actual incidence of hepatic artery aneurysm (HAA) is unknown; the commonly used incidence figures are derived from small case series, autopsy and anecdotal evidence. In a large series reported from Mayo, the incidence of HAA was noted to be 0.002% among the 2,091,965 patients seen at Mayo from 1980-1986. Most HAA are diagnosed incidentally on CT done for unrelated issues and are most commonly observed during the sixth decade of life with a 3:2 male predominance. Given the numerous collaterals from the gastroduodenal artery and right gastric branches, both open surgical ligation or endovascular embolization of these aneurysms are reported. In order to evaluate the collaterals, selective angiogram and high resolution computed tomography angiography is recommended.
## 2. SIZE CRITERIA FOR INVASIVE INTERVENTION

### Recommendations for Diagnosis and Evaluation of Hepatic Artery Aneurysms

Supporting studies are summarized in appendix.

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<tr>
<td><strong>2.1</strong></td>
<td>Given the high propensity of rupture and significant antecedent mortality, we recommend that all hepatic artery pseudoaneurysms, regardless of cause, be repaired as soon as the diagnosis is made</td>
<td>1 (Strong)</td>
</tr>
<tr>
<td><strong>2.2.a</strong></td>
<td>We recommend repair of all symptomatic hepatic artery aneurysm regardless of size</td>
<td>1 (Strong)</td>
</tr>
<tr>
<td><strong>2.2.b</strong></td>
<td>In asymptomatic patients without significant comorbidity, we recommend repair if (true) hepatic artery aneurysm is larger than 2 cm (Grade 1A) or if aneurysm enlarges &gt;0.5 cm/year (Grade 1C). In patients with significant comorbidities, we recommend repair if HAA is larger than 5.0 cm (Grade 1B)</td>
<td>1 (Strong)</td>
</tr>
<tr>
<td><strong>2.3</strong></td>
<td>We recommend repair of HAA in patients with vasculopathy or vasculitis, regardless of size (Grade 1C). Strong consideration should also be given in HAA patients with positive blood cultures (Grade 1C)</td>
<td>1 (Strong)</td>
</tr>
</tbody>
</table>

### Hepatic artery Pseudoaneurysm (HAPA)

False aneurysm of the HA accounts for 25% to 80% of reported cases and often occurs after iatrogenic injury, or penetrating or blunt liver trauma leading to symptomatic presentation of these aneurysms. These antecedent clinical events along with specific imaging distinguish false aneurysms from true aneurysms. Imaging findings, which include focal...
arterial disruption in the setting of otherwise normal arteries or inflammatory changes around an irregular aneurysm sac, are reported. The majority of psedoaneurysms are symptomatic at presentation thereby differing from true aneurysms, with gastrointestinal bleeding or hemobilia.1, 153

True Hepatic Artery Aneurysm (HAA). The true natural history of HAA is unknown due to the rarity of these aneurysms making any recommendation for repair of asymptomatic HAA controversial. In the series published by Mayo, these aneurysms appeared to be relatively benign with a slow rate of enlargement and relatively uncommon rate of rupture.152 Retrospective series of ruptured aneurysms suggest that the majority of these lesions rupture when they are larger than 2 cm in diameter.95 In one series when patients were followed non-operatively for 68 months, only 27% of patients showed enlargement of their aneurysm without any complication.152 Given these findings, Abbas and colleagues recommend careful observation for aneurysms smaller than 5 cm among high risk patients and repair for lesions >2 cm only among low risk patients unless these aneurysms enlarge or become symptomatic.152 Given the significant high rate of morbidity and mortality after HAA rupture (30% mortality rate in one series152) and overall low rate of morbidity and mortality after elective HAA (0% mortality in the same series152), the current recommendation is for repair of aneurysms larger than 2.0 cm in diameter in low risk patients and larger than 5.0 cm among high risk patients.
There is an association between HAA and the patients with fibromuscular dysplasia, vasculitis, systemic lupus erythematosus or polyarteritis nodosa (PAN), Takayasu arteritis, and Wegener granulomatosis. Congenital causes of HAA such as Marfan syndrome, Ehlers-Danlos syndrome and Osler-Weber-Rendu syndrome are reported. Patients with fibromuscular dysplasia and PAN are at significant risk of HAA rupture accounting for 50% of ruptured HAA in one series. Bacterial endocarditis was the main cause of HAA before the adequate treatment of endocarditis with antibiotics was widespread. Aneurysm rupture is reported with a wide range of 14-80% but given the retrospective nature of these studies, the true risk of rupture is unknown. Non-atherosclerotic aneurysms, however, are at significantly higher risk of rupture as they often present as multiple aneurysms.

3. TREATMENT OPTIONS FOR HEPATIC ARTERY ANEURYSM

<table>
<thead>
<tr>
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<th>Strength of Recommendation</th>
<th>Quality of Evidence</th>
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<tbody>
<tr>
<td><strong>3.1</strong> We recommend endovascular first approach to all HAA</td>
<td>1 (Strong)</td>
<td>A (High)</td>
</tr>
<tr>
<td><strong>3.2</strong> In patients with extrahepatic aneurysms, we recommend open and endovascular techniques to maintain liver circulation</td>
<td>1 (Strong)</td>
<td>A (High)</td>
</tr>
<tr>
<td><strong>3.3</strong> In patients with intrahepatic aneurysms, we recommend coil embolization of the affected artery (Grade 1B). In patients with large intrahepatic artery aneurysm, we</td>
<td>1 (Strong)</td>
<td>B (Moderate) C (Low)</td>
</tr>
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</table>
recommend resection of the involved lobe of liver to avoid significant liver necrosis (Grade 1C)

Both open and endovascular options exist for HAA repair. All retrospective case series have shown that the outcome for visceral artery aneurysm after open or endovascular repair yielded similar long term results but morbidity of open repair is significantly worse than endovascular approach.\(^2,7\) With the improvement of endovascular techniques and relative low morbidity associated with endovascular repair, endovascular techniques should be preferentially offered in anatomically suitable candidates.

The majority of these aneurysms are extrahepatic (75-80%).\(^{152, 154, 160}\) Most are solitary aneurysms with multiple HAAs reported in only 8% of these series.\(^{152}\) The procedure of choice should allow for the exclusion of aneurysm either by resection of the aneurysm with interposition graft or by placement of a stent graft and endovascular exclusion of the aneurysm. Given the possibility of central liver necrosis despite adequate collateral flow\(^95\), in low risk patients open surgical revascularization using autologous vein conduit is recommended.\(^{161}\) Temporary occlusion of the hepatic artery during reconstruction may guide in revascularization or ligation of the HAA.\(^{161}\) More distal extrahepatic HAA branches are often associated with biliary inflammation making these repairs challenging.

Endovascular repair of extrahepatic HAA depends on the collaterals and location of the HAA, similar to open repair. Given that maintenance of distal organ perfusion
is important, in patients with proper hepatic artery, endovascular repair requires covered stent exclusion of the aneurysm rather than coil embolization.

The table below represents the summary of treatment recommendations for all extrahepatic aneurysms.

Table XXX. Summary of treatment recommendations for extrahepatic aneurysms

<table>
<thead>
<tr>
<th>Location of Extrahepatic Hepatic Artery Aneurysm</th>
<th>Indication</th>
<th>Treatment$^{1, 2, 7, 153, 162}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common Hepatic artery</td>
<td>1. Ruptured</td>
<td>Open surgical ligation,</td>
</tr>
<tr>
<td></td>
<td>2. Symptomatic</td>
<td>Endovascular</td>
</tr>
<tr>
<td></td>
<td>3. Asymptomatic (&gt;2)</td>
<td>embolization,</td>
</tr>
<tr>
<td></td>
<td>4. Asymptomatic in patients w FMD/PAN</td>
<td>Resection/reconstruction,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aneurysmarrophy,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Endovascular:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Covered stent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coil embolization</td>
</tr>
<tr>
<td>Proper hepatic</td>
<td>Same as above</td>
<td>Resection w arterial</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reconstruction</td>
</tr>
<tr>
<td>Proximal right or left hepatic branches</td>
<td>Same as above</td>
<td>Resection w arterial</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reconstruction</td>
</tr>
</tbody>
</table>

$\text{Table XXX. Summary of treatment recommendations for extrahepatic aneurysms}$
Intrahepatic lesions will require resection of the lobe(s) in which the aneurysm is located. Given the significant comorbidities associated with liver resection, endovascular interventions have become the primary treatment modality for these intrahepatic lesions when feasible. Complications of embolization include hepatic ischemia, abscess, cholecystitis and possible recanalization.\textsuperscript{161,163,164} Coil embolization is discouraged in patients with large parenchymal lesions or if large segments of liver are at risk of ischemia. In these patients, liver lobe resection should be considered.

4. SCREENING FOR CONCOMITANT ANEURYSM AND VASCULAR PATHOLOGY:

<table>
<thead>
<tr>
<th>Recommendations for Screening in Patients with Hepatic Artery Aneurysms</th>
<th>Strength of Recommendation</th>
<th>Quality of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>4.1</strong> We suggest abdominal axial imaging to screen for concomitant intra-abdominal aneurysms in patients who did not have CTA at the time of HAA diagnosis</td>
<td>2 (Weak)</td>
<td>B (Moderate)</td>
</tr>
<tr>
<td><strong>4.2</strong> We suggest a one-time screening CTA or MRA of the head, neck and chest for those patients with non-atherosclerotic causes of hepatic artery aneurysm</td>
<td>2 (Weak)</td>
<td>B (Moderate)</td>
</tr>
</tbody>
</table>

As noted majority of patients with hepatic artery aneurysm are diagnosed with CT for other reasons.\textsuperscript{152} Given the sensitivity and specificity of CTA for
diagnosing other intra-abdominal, we recommend a CTA to diagnose other intra-abdominal aneurysms. In thin patients, abdominal Duplex is sensitive and specific in detecting abdominal or iliac artery aneurysms but this study needs to be performed on individual arteries and therefore, may miss other non-investigated vessels.

There is an association between HAA and the patients with fibromuscular dysplasia, vasculitis, systemic lupus erythematosus or polyarteritis nodosa (PAN), Takayasu arteritis, and Wegener granulomatosis. This screening study may detect other pathologies that will require attention. Additionally, congenital causes of HAA such as Marfan syndrome, Ehlers-Danlos syndrome and Osler-Weber-Rendu syndrome are reported. Axial CTA or MRA may detect thoracic or intra-cerebral aneurysms.

5. FOLLOW-UP AND SURVEILLANCE

<table>
<thead>
<tr>
<th>Recommendations for Follow-up and Surveillance of Hepatic Artery Aneurysm Patients</th>
<th>Strength of Recommendation</th>
<th>Quality of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1 We suggest annual follow-up with CTA or non-contrast CT to follow patients with asymptomatic hepatic artery aneurysm</td>
<td>2 (Weak)</td>
<td>B (Moderate)</td>
</tr>
</tbody>
</table>

Given that these are slow growing aneurysms annual follow-up is adequate. CTA with or without contrast provide the best modality to follow these
aneurysms. Abdominal Duplex can also be used in certain patients to follow these aneurysms.

**SUPERIOR MESENTERIC ARTERY ANEURYSM (SMAA)**

1. **DIAGNOSIS AND EVALUATION**

| Recommendations for Diagnosis and Evaluation of Superior Mesenteric Artery Aneurysms |
|-------------------------------|----------------|----------------|
| Recommendation                  | Strength of Recommendation | Quality of Evidence |
| 1.1 In patients with SMAA, we recommend computed tomographic angiography (CTA) as the diagnostic tool of choice | 1 (Strong) | B (Moderate) |
| 1.2 We recommend mesenteric angiography to delineate anatomy in preoperative planning for SMAA repair | 1 (Strong) | B (Moderate) |

Symptomatic SMAA presents with similar symptoms as other acute abdominal emergencies such as perforated viscous making the diagnosis rather difficult without appropriate level of suspicion. Although many SMAAs show a rim of calcification on plain KUB and Duplex ultrasound can be helpful in diagnosis, CTA is the most expeditious and reliable diagnostic tool. Isolated diagnosis of SMA dissection has been diagnosed more routinely due to an increase use of CTA among patients who present with abdominal pain.

2. **SIZE CRITERIA FOR INVASIVE INTERVENTION (TRUE AND FALSE ANEURYSMS)**

<table>
<thead>
<tr>
<th>Recommended Intervention Criteria for Hepatic Artery Aneurysms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supporting studies are summarized in appendix</td>
</tr>
</tbody>
</table>
### Recommendation Strength of Recommendation Quality of Evidence

<table>
<thead>
<tr>
<th>Number</th>
<th>Recommendation</th>
<th>Strength of Recommendation</th>
<th>Quality of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>We recommend repair of all SMA aneurysms and pseudoaneurysms as soon as the diagnosis is made regardless of size.</td>
<td>1 (Strong)</td>
<td>A (High)</td>
</tr>
<tr>
<td>2.2</td>
<td>We suggest careful observation of SMAA due to dissection unless the patient becomes symptomatic</td>
<td>2 (Weak)</td>
<td>B (Moderate)</td>
</tr>
</tbody>
</table>

SMAA represents 3.5-8% of the VAA cases\(^1\)\(^{100}\) and autopsy results suggests that these aneurysms constitute 1 in every 12,000-19,000 autopsies.\(^{172}\) Although the etiology of these aneurysms is diverse, SMAA most commonly results from an infectious etiology or dissection\(^{169}\), with the SMA the most common site of infection outside of aorta.\(^{169}\) The most common reason for mycotic aneurysm of SMA is subacute bacterial endocarditis infection by non-hemolytic streptococcus.\(^{169},^{172}\) Atherosclerosis accounts for 25% cases of SMAA while inflammatory conditions such as pancreatitis and trauma are the other causes of SMAA.\(^{172}\) Mycotic SMAA usually present in younger patients (<50 years of age) where as non-mycotic SMAA are seen among the older patients.\(^{172}\) Unlike other visceral aneurysms, 70-90% of SMAA are symptomatic at the time of presentation with abdominal pain the most common symptom, followed by abdominal mass, fever, nausea and GI bleeding.\(^{169},^{173}\) The natural history of SMAA appears to be one of expansion and rupture\(^94,^{169}\) with 38-50% of patients presenting with ruptured aneurysm\(^{173,94}\) and a mortality rate of 30-90%.\(^{94}\) At the same time, the overall mortality from elective repair for SMAA is <15\(^{174}\) and the mortality is even better when endovascular procedures
are used for elective SMAA repair.\textsuperscript{1} Given the significant incidence of rupture and
the high mortality after repair of ruptured SMAA, once SMAAs are diagnosed, the
SMAA should be treated.

Some authors have pointed to the possible association of dissection and
aneurysmal degeneration of the dissected artery.\textsuperscript{175} Yun and colleagues classified
these isolated dissections into three groups using angiographic findings.\textsuperscript{171} In
patients followed by Dong et al\textsuperscript{170} or Yun et al\textsuperscript{171} no aneurysmal degenerations were
observed. Initial treatment of these entities is often antiplatelet therapy unless
symptoms recur.\textsuperscript{171} Presence of SMA dissection is not an indication for repair as the
majority are treated conservatively without any need for intervention.\textsuperscript{170, 171}

**3. TREATMENT OPTIONS**

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Strength of Recommendation</th>
<th>Quality of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3.1</strong> We recommend endovascular first approach to all SMAA if anatomically feasible</td>
<td>1 (Strong)</td>
<td>A (High)</td>
</tr>
</tbody>
</table>

Treatment must be individualized based on anatomical and the
characteristics of SMAA. Angiography is critical to delineate SMA arterial anatomy
and collaterals. Both open and endovascular techniques must exclude the
aneurysm and maintain patency of the vessels. Endovascular procedures are
significantly less morbid than open procedures and should be preferentially offered
if anatomically feasible. Endovascular interventions include coil embolization or
use of covered stents$^{176}$ with very good results. Open options include open surgical
procedures such as simple ligation of aneurysm, aneurysmorrhaphy in case of
saccular aneurysms, or repair with an interposition graft. Open resection may
require intestinal resection particularly in symptomatic patients. Close observation
must be followed for occurrence of peritoneal symptoms.

4. **SCREENING FOR CONCOMITANT ANEURYSM**

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Strength of Recommendation</th>
<th>Quality of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 We suggest abdominal axial imaging to screen for concomitant intra-abdominal aneurysms in patients who did not have CTA at the time of diagnosis</td>
<td>2 (Weak)</td>
<td>B (Moderate)</td>
</tr>
</tbody>
</table>

CT of abdomen and pelvis has significant specificity and sensitivity of
detecting concomitant visceral artery aneurysm and has proven to be the best
modality in detecting visceral artery aneurysm.$^{122, 169}$

5. **FOLLOW-UP AND SURVEILLANCE**

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Strength of Recommendation</th>
<th>Quality of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1 We suggest annual CTA to follow postsurgical patients.</td>
<td>1 (Strong)</td>
<td>B (Moderate)</td>
</tr>
</tbody>
</table>
Annual CT scans are specific and sensitive in following up the repair and assess other vascular beds.\textsuperscript{122, 169}

**JEJUNAL, ILEAL AND COLIC ARTERY ANEURYSMS**

**1. DIAGNOSIS AND EVALUATION**

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Strength of Recommendation</th>
<th>Quality of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.1</strong> In patients who are suspected to have JA/IA/CA, we recommend computed tomographic angiography (CTA) as the diagnostic tool of choice</td>
<td>1 (Strong)</td>
<td>B (Moderate)</td>
</tr>
<tr>
<td><strong>1.2</strong> In patients with high radiation exposure risks or renal insufficiency, we recommend non-contrast MRA (NC-MRA) for diagnosis. Technical remarks: NC-MRA is best suited to children and women of childbearing potential or those who have contraindications to CT or MR contrast materials (i.e. pregnancy, renal insufficiency, or gadolinium contrast material allergy).</td>
<td>1 (Strong)</td>
<td>B (Moderate)</td>
</tr>
<tr>
<td><strong>1.3</strong> We recommend the use of catheter-based angiography for all emergent cases presenting with rupture (Grade 1B) and electively for preoperative planning (Grade 1O).</td>
<td>1 (Strong)</td>
<td>B (Moderate)</td>
</tr>
<tr>
<td><strong>1.4</strong> We suggest screening all patients with JA, IA and CA aneurysms for vasculitis with routine inflammatory markers</td>
<td>2 (Weak)</td>
<td>C (Moderate)</td>
</tr>
</tbody>
</table>
Aneurysms of the jejunal, ileal and colic arteries account for <3% of all splanchnic aneurysms, affecting men and women equally beyond the 6th decade of life. Most of the literature on these aneurysms is limited to case reviews and small case numbers within the context of larger series on splanchnic aneurysms. We recommend CT-angiogram as the diagnostic modality of choice for these aneurysms: often in asymptomatic patients this modality identifies a visceral branch aneurysm incidentally. MR-angiogram may also be considered. Axial imaging of the abdomen will facilitate the assessment of other abdominal aneurysms, which are common as referenced above. Arteriogram is invaluable for aneurysm identification preoperatively and operative planning and mandatory for patients with PAN to assess for additional aneurysms.

Aneurysms of the jejunal, ileal and colic arteries are associated with medial degeneration, infection, inflammation, various autoimmune diseases [ie: polyarteritis nodosa (PAN) and Bechet’s Disease] and connective tissue disorders. Multiple aneurysms are identified in approximately 10% of cases. Atherosclerosis, when present, is felt to be a secondary process. We recommend confirmation of the diagnosis of PAN in any patient with a history of fever, arthralgia, weakness, abdominal pain, or pleuritic chest pain that accompanies mesenteric branch aneurysm.

2. SIZE CRITERIA FOR INVASIVE INTERVENTION (TRUE V. PSEUDO)
## Recommended Intervention Criteria for Jejunal, Ileal and Colic Artery Aneurysms

Supporting studies are summarized in appendix

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Strength of Recommendation</th>
<th>Quality of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 We recommend elective intervention for jejunal and ileal aneurysms &gt;2cm in maximal diameter and for all colic aneurysms, any size.</td>
<td>1 (Strong)</td>
<td>B (Moderate)</td>
</tr>
<tr>
<td>2.2 We recommend emergent intervention for any jejunal, ileal or colic aneurysm, any size, resulting in patient symptoms or rupture and all mesenteric branch vessel pseudoaneurysms.</td>
<td>1 (Strong)</td>
<td>A (High)</td>
</tr>
</tbody>
</table>

While patients may present with abdominal pain, most jejunal and ileal aneurysms are asymptomatic. Colic aneurysms however cause symptoms, primarily abdominal pain, in nearly 90% of patients.\(^{169}\) Rupture may complicate up to 30% of jejunal and ileal aneurysms and up to 70% of colic aneurysms resulting in gastrointestinal bleeding and mortality rates that approach 20-50%.\(^{142,169}\)

Treatment is recommended for all jejunal and ileal aneurysms >2cm in size and for all colic branch aneurysms, regardless the size.\(^{169,184}\)

We recommend emergent intervention for any jejunal, ileal or colic aneurysm, any size, resulting in patient symptoms or rupture and all mesenteric branch vessel pseudoaneurysms (1A).

Evidence: Emergent treatment should be considered for symptomatic and ruptured aneurysms and all mesenteric branch vessel pseudoaneurysms.
### 3. TREATMENT OPTIONS

#### Recommendations for Treatment of Jejunal, Ileal and Colic Artery Aneurysms

Supporting studies are summarized in appendix

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Strength of Recommendation</th>
<th>Quality of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 We suggest open surgical ligation or aneurysm excision for cases of jejunal, ileal and colic aneurysms when laparotomy is being considered for hematoma evacuation or bowel assessment for viability.</td>
<td>2 (Weak)</td>
<td>B (Moderate)</td>
</tr>
<tr>
<td>3.2 We suggest endovascular embolization for cases of jejunal, ileal, and colic aneurysm.</td>
<td>2 (Weak)</td>
<td>B (Moderate)</td>
</tr>
<tr>
<td>3.3 We suggest medical treatment of non-ruptured, asymptomatic ileal, jejunal and colic aneurysms associated with PAN.</td>
<td>2 (Weak)</td>
<td>B (Moderate)</td>
</tr>
</tbody>
</table>

Interpretation of the existing data on mesenteric branch aneurysms is limited by small numbers and anecdotal reports; additionally most of the existing studies do not delineate true aneurysms from false aneurysms and often the visceral bed is excluded from analysis.

Surgical management has historically relied on simple arterial ligation or aneurysm excision without reconstruction. This remains a conservative option for rupture in which case exploratory laparotomy facilitates the evacuation of hematoma, definitive aneurysm treatment and bowel assessment for viability. Enterectomy or colectomy may be required as intramural aneurysms and those associated with bowel necrosis require resection of the involved bowel at the time of aneurysm exclusion. Robust collateralization often permits simple aneurysm ligation or resection without reconstruction.
Trans-catheter embolization with namely coils, onyx and glue (N-butyl cyanoacrylate) has been increasingly utilized, especially for cases of acute rupture and GI bleeding.\textsuperscript{1, 7, 113, 186-188} Endovascular interventions offer precise localization of the aneurysm, assessment of collateral flow, lower risk for patients who are not good operative candidates, easier approach to aneurysms for which surgical exposure would be difficult, and decreased length of stay.\textsuperscript{1, 113} These benefits are balanced with a risk of intestinal necrosis, perforation and late stricture requiring reoperation in addition to primary technical failures and failed hemostasis in the setting of rupture.\textsuperscript{189-193}

Regression of aneurysms resulting from PAN after treatment with cytotoxic or immunosuppressive treatment is well documented.\textsuperscript{109} As such, medical therapy should be considered first line for these patients with non-ruptured, asymptomatic aneurysms with repeat arteriography staged 3 to 4 months to ascertain regression.

4. SCREENING FOR CONCOMITANT ANEURYSMS

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Strength of Recommendation</th>
<th>Quality of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 Recommendation 4.1: We suggest abdominal axial imaging to screen for concomitant abdominal aneurysms.</td>
<td>2 (Weak)</td>
<td>B (Moderate)</td>
</tr>
<tr>
<td>4.2 We suggest a one-time screening CTA</td>
<td>2 (Weak)</td>
<td>B (Moderate)</td>
</tr>
</tbody>
</table>
(or MRA) of the head, neck and chest for those patients with segmental arterial mediolysis.

Axial imaging as recommended above will screen for concomitant non-aortic intra-abdominal arterial aneurysms, which are common.

We recommend screening for cerebrovascular and coronary artery aneurysm when the diagnosis of segmental arterial mediolysis is suspected given the systemic nature of this arterial dysplasia with a one-time screening CT-angiogram or MR-angiogram of the head, neck and chest.\textsuperscript{183}

5. FOLLOW UP AND SURVEILLANCE

<p>| Recommendations for Follow-up and Surveillance in Jejunal, Ileal and Colic Artery Aneurysm Patients |
| Supporting studies are summarized in appendix |</p>
<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Strength of Recommendation</th>
<th>Quality of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>5.1</strong></td>
<td><strong>We suggest interval surveillance (ie: every 12-24 months) with axial imaging (ie: CTA or MRA), for cases of segmental medial arteriolysis in light of reported cases of rapid arterial transformation and to monitor regression in cases of PAN.</strong></td>
<td>2 (Weak)</td>
</tr>
<tr>
<td><strong>5.2</strong></td>
<td><strong>We suggest post-embolization surveillance at every 1-2 years with axial imaging to assess for vascular remodeling and evidence of aneurysm reperfusion.</strong></td>
<td>2 (Weak)</td>
</tr>
</tbody>
</table>
We recommend routine interval surveillance (ie: every 12) with axial imaging (ie: CTA or MRA) in cases of segmental medial arteriolysis in light of reported cases of rapid arterial transformation.\textsuperscript{149}

We recommend post-embolization surveillance at every 1-2 years with axial imaging to assess for vascular remodeling.\textsuperscript{1}

PANCREATICODUODENAL AND GASTRODUODENAL ARTERY ANEURYSMS

### 1. DIAGNOSIS AND EVALUATION

<table>
<thead>
<tr>
<th>Recommendations for Diagnosis and Evaluation of Pancreaticoduodenal and Gastroduodenal Artery Aneurysms</th>
<th>Supporting studies are summarized in appendix</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Recommendation</strong></td>
<td><strong>Strength of Recommendation</strong></td>
</tr>
<tr>
<td>1.1 <strong>In patients who are suspected to have GDAA and PDAA, we recommend computed tomographic angiography (CTA) as the diagnostic tool of choice.</strong></td>
<td>1 (Strong)</td>
</tr>
<tr>
<td>1.2 <strong>In patients in whom celiac stenosis is suspected, we suggest further work-up with duplex ultrasound to elucidate if the stenosis is hemodynamically significant.</strong></td>
<td>2 (Weak)</td>
</tr>
<tr>
<td>1.3 <strong>In patients with high radiation exposure risks or renal insufficiency, we suggest non-contrast MRA (NC-MRA) for diagnosis. Technical remark: NC-MRA is best suited to children and women of childbearing potential or those who have contraindications to CT or MR contrast materials (i.e. pregnancy,</strong></td>
<td>2 (Weak)</td>
</tr>
</tbody>
</table>
CTA has become the most common diagnostic tool for pancreaticoduodenal artery (PDAA) and gastroduodenal artery aneurysms (GDAA) given its accuracy, wide availability, and promptness. Enhancement patterns vary depending on the amount of thrombus within the aneurysm. Multiplanar reformations and 3-dimensional reconstructions can aid determine the relationship of the surrounding vasculature and parent vessels. In cases of ruptured GDAA and PDAA, CTA is the diagnostic tool of choice due to the fact that it can provide arterial phase, venous phase and non-contrast images in a rapid manner. Furthermore, findings of diaphragmatic crura hypertrophy, a focal narrowing of the proximal celiac axis with a hooked appearance, and retrograde filling of the dorsal pancreatic and pancreaticoduodenal arteries on 3-dimensional CTA are suggestive of median arcuate ligament syndrome and may direct the surgeon to consider a median arcuate ligament release in addition to treatment of the GDAA or PDAA. Non-contrast CT scans may only show a soft tissue mass in the aneurysm bed that can be confused with adenopathy, or pancreatic/duodenal neoplasm. Contrast enhanced magnetic resonance angiography (CE-MRA) has been shown to correlate well with CTA, but should not be used in emergent cases as acquisition times are longer than CTA. Post-processing maximum intensity projections (MIP) provide imaging similar to conventional angiography, providing a road map for therapeutic interventions. Finally, duplex ultrasound may delineate
larger aneurysms, but information on parent artery anatomy is insufficient.\textsuperscript{59}

Accuracy can be decreased due to patient body habitus, calcified vessel walls, and limited spatial resolution.\textsuperscript{198, 199}

Duplex ultrasound is one of the most common diagnostic techniques used to evaluate the celiac axis for median arcuate ligament syndrome.\textsuperscript{200} It can provide real time inspiratory and expiratory data helping elucidate the cause of the GDAA or PDAA and its treatment.\textsuperscript{201}

Although NC-MRA sequences can be more time-consuming than CE-MRA, NC-MRA has almost the same sensitivity for detecting vascular abnormalities and has a very high negative predictive value. NC-MRA (like CE-MRA) can be superior and complementary to ultrasound when evaluating most parts of the body because it is not limited by acoustic windows, particularly in the thoraco-abdominal vasculature.\textsuperscript{202-204}

2. SIZE CRITERIA FOR INVASIVE INTERVENTION

| Recommended Intervention Criteria Pancreaticoduodenal and Gastroduodenal Artery Aneurysms | Strength of Recommendation | Quality of Evidence |
| Recommendation | 1 (Strong) | B (Moderate) |
| 2.1 In patients with non-complicated GDAA and PDAA of acceptable risk, we recommend treatment no matter what the size of the aneurysm due to the risk of rupture. |

81
Previous studies have made the distinction in size threshold for repair of visceral artery aneurysms based on whether the aneurysm is a true aneurysm or a pseudoaneurysm. This is based on the fact that pseudoaneurysms are at higher risk of rupture and should, therefore, be repaired regardless of size. However, it is known that many of the PDAA and GDAA aneurysms that have ruptured can be small and <10mm. In fact, a recent single center review of all splanchnic aneurysms found that PDAA were strongly associated with rupture (P<.0002). Thus, GDAA and PDAA should be repaired regardless of size and regardless of true verses false aneurysm in patients who have acceptable operative or interventional risk.

A Markov model decision analysis was performed to assess the effectiveness of preventive treatment of patients with PDAA based on risk. The authors argued that, while 60% of PDAA present ruptured regardless of size, the natural history of unruptured aneurysms cannot be determined by that of ruptured aneurysms. Assuming a mortality rate of 21% after rupture, they found that preventive treatment was dominated by no treatment if mortality rates of preventive treatment were >1.4%, >2.6%, >3.8%, and >4.8% at annual rupture rates of 1%, 2%, 3%, and 4%, respectively, for an 80 year old patient. Preventive treatment was dominated by no treatment if mortality rates of preventive treatment were >3.3%, >5.9%, >8.0%, and >9.7% at annual rupture rates of 1%, 2%, 3%, and 4%, respectively, for a 50 year old patient.
Predictive factors of rupture, whether size, demographic or comorbid disease, are few. A review of the English literature found that 32% of ruptured cases were female and 61% were male. In one single center study, rupture was associated with male gender (P=.02) and a trend towards rupture in patients with celiac stenosis (P=.10). Thus, male patients should be considered for elective repair even in the presence of moderate operative risk.

3. TREATMENT OPTIONS

<table>
<thead>
<tr>
<th>Recommendations for Treatment of Pancreaticoduodenal and Gastroduodenal Artery Aneurysms</th>
<th>Supporting studies are summarized in appendix</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Recommendation</strong></td>
<td><strong>Strength of Recommendation</strong></td>
</tr>
<tr>
<td>3.1 In patients with intact and ruptured aneurysms, we recommend coil embolization as the treatment of choice.</td>
<td>1 (Strong)</td>
</tr>
<tr>
<td>3.2 In patients where coil embolization is not feasible, we suggest covered stenting or stent-assisted coil embolization as a treatment option in select cases of GDAA and PDAA.</td>
<td>2 (Weak)</td>
</tr>
<tr>
<td>3.3 In patients with appropriate anatomy, we suggest transcatheter embolization with liquid embolic agents as a treatment option for both GDAA and PDAA.</td>
<td>2 (Weak)</td>
</tr>
<tr>
<td>3.4 In patients with suitable anatomy, we suggest flow-diverting, multilayered stents as a treatment option for GDAA and PDAA, although these have not been adequately studied to recommend as a primary treatment modality.</td>
<td>2 (Weak)</td>
</tr>
<tr>
<td>3.5 In patients with non-ruptured aneurysms, we suggest open surgical</td>
<td>2 (Weak)</td>
</tr>
</tbody>
</table>
Coil embolization of both GDAA and PDAA aneurysms has recently become the treatment of choice whether the aneurysm is ruptured or not.\textsuperscript{4, 190, 195, 209, 211-213.} Different catheter configurations can be employed, but a triaxial system consisting of a sheath/guiding catheter, a 4/5Fr catheter, and a microcatheter provides stable support through tortuous vessels or when treating distal arterial beds, as well as rapid exchange of the microcatheter if necessary.\textsuperscript{1} While not imperative, exclusion of all inflow and outflow vessels is necessary to reduce the risk of recurrent sac pressurization from antegrade or retrograde perfusion.\textsuperscript{6} End organ perfusion is typically maintained by the dense collateral network of these vessels, but isolated coil packing of the aneurysm sac alone can be sufficient if the inflow vessel is vital for organ perfusion.\textsuperscript{217} Immediate technical success rates are above 90%.

Long-term success may be related to angiographic findings seen on completion imaging. The Raymond-Roy Occlusion Classification is a system for evaluating aneurysm occlusion after endovascular coiling with 3 classes based on completion imaging at the end of the procedure.\textsuperscript{218} Class I is defined as complete obliteration, Class II a residual neck, and Class III a residual aneurysm. Class III can be further subdivided into IIIa, residual contrast within coil interstices, and

| 3.6 | In patients with concomitant stenosis or occlusion, we suggest celiac reconstruction. | 2 (Weak) | B (Moderate) |
IIIb, residual aneurysm with contrast along the sidewall of the aneurysm. Class IIIa aneurysms tend to have a higher rate of subsequent thrombosis, while IIIb aneurysms tend to have a higher rate of retreatment. While survival is unrelated to operative technique when repairing intact aneurysms, endovascular repair of ruptured aneurysms is associated with both improved overall survival, as well as aneurysm-related survival, compared to open surgery. 

Covered stenting may be performed when the artery proximal and distal to the aneurysm is of suitable diameter with a low degree of tortuosity. Successful covered stenting with a Viabahn stent (W.L. Gore & Associates, Inc.), as well as an Advanta V12 stent graft (Atrium Medical, Hudson, NH), has been reported. Advantages of this technique include preservation of flow through the artery, however it may be limited by the discrepancy in arterial seal zone diameters as well as the ability to pass the stent through tortuous anatomy.

The liquid embolic agent N′-butyl 2-cyanoacrylate (NBCA) has been used to treat cases of both ruptured and unruptured GDAA and PDAA. A theoretical advantage of embolization with liquid embolic agents is the ability to embolize small, tortuous vessels that may be too small to selectively catheterize for coil embolization. The NBCA must be premixed with iodized oil to control its
polymerization and make it radiopaque.\textsuperscript{224} A 1:3 ratio, or 25% NBCA, increases the polymerization time to 4 seconds although distal embolization may still occur.\textsuperscript{225}

Ethylene-vinyl alcohol (Onyx; ev3, Irvine, CA) has also been used successfully to treat PDAA.\textsuperscript{65} Onyx is dissolved in dimethyl sulfoxide (DMSO) and is suspended in radiopaque micronized tantalum powder and does not need to be mixed. When concomitant balloon occlusion of the parent vessel is utilized, injection of the Onyx directly into the aneurysm via a microcatheter preserves the inflow and outflow vessels. When balloon occlusion is not used, the inflow and outflow vessels can be obliterated as well.

Flow diverting stents are a burgeoning technology that was first introduced for the treatment of intracranial aneurysms. Flow diverting stents are placed in the parent artery in an effort to improve laminar flow within the parent artery and reduce blood flow within the aneurysm sac to the point of thrombosis.\textsuperscript{226} Furthermore, these stents preserve flow through collateral side branches. The stents require an overall porosity of 50-70\%, or 30-50\% metallic coverage. Stents such as the Pipeline Embolization Device (PED; ev3, Plymouth, Minn), the SILK Arterial reconstruction Device (Balt Extrusion, Montmorency, France) and the Cardiatis Multilayer Stent (Cardiatis, Isnes, Belgium) are available, however only the Cardiatis Multilayer Stent has been used to treat a GDAA. At 6 months, the Cardiatis stent was patent with complete thrombosis of the aneurysm sac.\textsuperscript{227} Patients are treated with dual anti-platelet regimens postoperatively.
Open surgical therapy of GDAA and PDAA is technically feasible with a perioperative morbidity and mortality for non-ruptured aneurysms of approximately 9.4% and 1.3%, respectively. Techniques include ligation, or excision with end-to-end anastomosis. However, mortality for ruptured GDAA and PDAA undergoing open repair approaches 30%. Celiac axis stenosis or occlusion is frequently associated with aneurysms of the pancreaticoduodenal arcade. This is thought to result in retrograde flow through the pancreaticoduodenal arteries leading to turbulent flow which ultimately causes aneurysmal dilatation. Interestingly, celiac stenosis is more common in PDAA than GDAA. While coil embolization can lead to end organ hepatic ischemia and liver failure, the overall risk is likely low. However, a low threshold for celiac revascularization should be considered in patients with symptoms of mesenteric insufficiency at baseline or when there is a risk of compromising end organ perfusion with aneurysm treatment, and postoperative liver functions tests should be monitored closely. In cases of median arcuate ligament syndrome (MALS), celiac revascularization can be achieved with division of the MAL and celiac plexus, aortoceliac bypass, or reno-hepatic bypass. In cases not associated with MAL compression, primary stenting of a celiac stenosis is an option.
4. DE NOVO SCREENING AND SCREENING FOR CONCOMITANT ANEURYSMS

**Recommendations for Screening in Patients with Gastroduodenal Artery Aneurysms**

Supporting studies are summarized in appendix.

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<tr>
<th>Recommendation</th>
<th>Strength of Recommendation</th>
<th>Quality of Evidence</th>
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<td><strong>4.1</strong> In patients with median arcuate ligament syndrome, we suggest screening for GDAA or PDAA with CT angiography or duplex ultrasound.</td>
<td>2 (Weak)</td>
<td>C (Low)</td>
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Very little data exist regarding screening for GDAA and PDAA. However, based on the fact that celiac stenosis is associated with 50-60% of these aneurysms, it would seem prudent to examine the gastroduodenal artery and pancreaticoduodenal arcade using either duplex ultrasound or CT angiography once a celiac stenosis is diagnosed. Pulsed Doppler can distinguish between aneurysms and other masses of the pancreas, although it may be limited by patient factors such as bowel gas.

There is no association of GDAA or PDAA with aneurysms outside the splanchnic circulation and, therefore, screening for concomitant aneurysms outside the abdomen is of little value.

5. FOLLOW UP AND SURVEILLANCE

**Recommendations for Follow-up and Surveillance in Gastroduodenal Artery Aneurysm Patients**

Supporting studies are summarized in appendix.

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<tr>
<th>Recommendation</th>
<th>Strength of Recommendation</th>
<th>Quality of Evidence</th>
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<tbody>
<tr>
<td><strong>5.1</strong> In patients status post treatment of</td>
<td>1 (Strong)</td>
<td>B (Moderate)</td>
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GDAA and PDAA, we recommend follow up imaging after endovascular treatment of GDAA and PDAA in order to rule out persistent flow through the aneurysm sac

It is well known that endovascular treatment of GDAA and PDAA may be associated with the long-term complication of aneurysm reperfusion.\(^6,209\) While no studies have evaluated the recurrence rates of GDAA or PDAA after endovascular coiling, recanalization after endovascular treatment of visceral artery aneurysms occurs in 9-15% of patients.\(^113,115,190,234\) This may occur due to insufficient packing, long-term coil compaction or delayed coil migration.\(^235,236\) Thus, follow-up imaging is crucial.\(^59,235.\)

A radiopaque agent is necessary for embolization, however this creates a significant radioartifact on follow-up imaging.\(^1,56\) While CT angiography is the most commonly used follow-up study modality, certain reports have found that it cannot accurately determine reperfusion of an aneurysm sac due to the degree of radioartifact.\(^237\)

More recently, 3-dimensional CE-MRA has been shown to be a safe and effective way to provide postoperative follow-up.\(^238\) This technique has a 91% accuracy in defining hemodynamic status and complications with little metallic artifact.\(^239\)

Concerns over repeated radiation exposure have prompted some to recommend Duplex ultrasound as an alternative surveillance technique.\(^1,6,56,209\)
Contrast enhanced ultrasound (CEUS) is a less expensive and non-invasive technique that has been shown to clearly identify flow in and around a metallic coil pack.\textsuperscript{240} Thus, CEUS may be optimal for long-term surveillance.

Finally, digital subtraction angiography is the gold standard for defining reperfusion of the aneurysm sac. However, this is typically reserved for cases where reintervention of an enlarging aneurysm sac is necessary.\textsuperscript{1, 56, 72}

The frequency of surveillance imaging is not well established, but it is unlikely that aneurysm reperfusion will occur if the it is completely obliterated and thrombosed on the first post-procedural imaging. As such, the value of long term surveillance following embolization is not justified. In addition, given the lack of clear association of GDAA and PDAA with metachronous visceral aneurysms, surveillance for the development of new visceral aneurysms is also not well established.
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97


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