Visceral Artery Aneurysms and Pseudoaneurysms—Should They All be Managed by Endovascular Techniques?

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Visceral artery aneurysms (VAA) and pseudoaneurysms (VAPA) can be life-threatening conditions with high incidence of rupture and hemorrhage. Greater availability and increased use of advanced imaging technology has led to the increased incidental detection of asymptomatic visceral aneurysms. In addition, increased percutaneous endovascular interventions have raised the incidence of iatrogenic pseudoaneurysms. Due to this, both VAA and VAPA have become an increasingly frequent diagnosis confronting the vascular surgeon. Over the past decade, there has been steady increase in the utilization of minimally invasive, non-operative interventions, for vascular occlusive and aneurysmal disease. All VAA and VAPA can technically be fixed by endovascular techniques but that does not mean they should. These catheter-based techniques constitute an excellent approach in the elective setting, particularly in patients who are poor surgical candidates due to their comorbidities or who present a hostile abdomen. However, in the emergent setting it may carry a higher morbidity and mortality. We review the literature about open and endovascular approach for the treatment of VAA and VAPA both in the elective and emergent setting.

Keywords: visceral artery aneurysm, splanchnic, pseudoaneurysm, endovascular

INTRODUCTION

Visceral artery aneurysms (VAA) are relatively rare phenomena that were first reported in 1809 when Wilson discovered an hepatic artery aneurysm as a post-mortem finding in a 50-year-old man who exsanguinated after its rupture.¹⁾ In 1903, Kehr performed the first successful operative repair by ligating a proper hepatic artery aneurysm proximally and distally.²⁾ It was not until 1951, when Paul performed the first successful VAA treatment

by ligation and revascularization of a large traumatic aneurysm of the hepatic artery.³⁾

VAA and pseudoaneurysms (VAPA) can be life-threatening conditions with high incidence of rupture and hemorrhage. Greater availability and increased use of advanced imaging technology including computed tomography, magnetic resonance, ultrasonography, and arteriography has led to the increased incidental detection of asymptomatic visceral aneurysms.⁴⁾ In addition, increased instrumentation of the biliary tract and percutaneous vascular interventions has increased the incidence of iatrogenic pseudoaneurysms.⁵⁾ Due to this, both VAA and VAPA have become an increasingly frequent diagnosis confronting the vascular surgeon.

Over the past decade, there has been steady increase in the utilization of minimally invasive, non-operative interventions, for vascular occlusive and aneurysmal disease. The purpose of this manuscript is to review the natural history of these rare but potentially catastrophic entities and to compare the different management options. Specifically, we compare endovascular techniques to open traditional surgical treatment for VAA and VAPA in both

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Table 1 Visceral artery aneurysm by location

Location	Incidence/ Prevalence (%)	Risk of rupture (%)	Mortality after rupture (%)	M:F ratio	Indications for surgery
Splenic artery	50–75/ <0.1	2–10	20–30	1:3–4	≥2 cm, female childbearing age, OLTx, symptomatic
Hepatic artery	20	14–80	21–43	3:2	≥2 cm, multiple, non- atherosclerotic, symptomatic
Pancreaticoduodenal arcade	2–6	75	50	4:1	≥2 cm, symptomatic
Renal artery	15–22/ 0.01–0.09	2.8–5.6	6–10, 80 in pregnancy	1:1.5–2	≥1.5 cm, renovascular HTN, female childbearing age, symptomatic

Data from ^{4,6,21,22}. OLTx: orthotopic liver transplantation; HTN: hypertension

the asymptomatic patient and in the emergent setting and analyze their outcomes.

PATHOGENESIS AND NATURAL HISTORY OF VAA

The pathogenesis of VAA is poorly characterized but may be due to atherosclerosis (32% of cases), medial degeneration/dysplasia (24%), abdominal trauma (22%), infection and inflammatory disease (10%), connective tissue disorders (Marfan syndrome, Ehlers-Danlos syndrome, Osler-Weber-Rendu disease, fibromuscular dysplasia, Kawasaki, hereditary hemorrhagic telangiectasia), and hyperflow conditions (portal hypertension, pregnancy).^{4,6} In true aneurysms, all 3 layers of the vessel wall are intact but thinned and dilated. Pseudoaneurysms or false aneurysms result from a tear in the vessel wall with subsequent formation of a peri-artery hematoma. VAPA may be caused iatrogenically during surgical, endoscopic and interventional radiological procedures, or secondary to trauma, infectious and inflammatory conditions.⁷

Due to the lack of prospective studies on this topic there is no standardized consensus regarding the indications for treatment of VAA and VAPA. VAPA carry a higher risk for rupture and thus are typically treated when identified. Renal and splanchnic artery aneurysms carry an incidence of 0.01%–0.09% and 0.1%–2%, respectively.⁸ They present as clinical emergencies in 22% of the cases and have an overall mortality rate of 8.5%.⁹ Depending on the size and the location, rupture of these lesions may be associated with a 25%–70% mortality rate (Table 1).⁴ Generally speaking, however, VAAs are treated if symptomatic, are larger than 2 cm in a good-risk surgical candidate, have a rapid growth of more than 0.5 cm/year, when present in a pregnant women or those of childbearing age, or in patients undergoing an orthotopic liver

Table 2 Proposed guidelines for surgical management

VAPA require treatment
Symptomatic and ruptured VAA require treatment
Splanchnic artery aneurysm with vessel diameter ≥2 cm
Renal artery aneurysm with vessel diameter ≥1.5 cm
VAA with rapid growth rate: ≥0.5 cm/year
VAA in women of childbearing age or pregnant
VAA in orthotopic liver transplant recipients

VAA: visceral artery aneurysms; VAPA: visceral artery aneurysms and pseudoaneurysms

Table 3 Surgical management

Traditional open technique
Excision of the aneurysm
Revascularization
End organ resection (i.e. splenectomy, nephrectomy)
Ligation of aneurysm
Minimally invasive
Laparoscopic clipping
Robotic assisted interventions
Endovascular technique
Coil embolization
Covered stent placement
Plug deployment
Gluing
Endoluminal thrombin injection
Polyvinyl alcohol injection
Particle injection
Gelfoam injection

transplantation (Table 2).^{9,10} Furthermore, hepatic artery aneurysms carry a higher rupture risk (80%) compared to other VAA, with a mortality rate of 20%.⁸ In contrast, rupture of the splenic artery aneurysm is less commonly encountered, with a rupture risk of 20%. Considering such high associated mortality, most hepatic artery aneurysms warrant treatment. Also, patients with hepatic aneurysms have been described to present multiple aneurysms involving the visceral (31%) and non-visceral circulation (42%).⁶

Fig. 1 Traditional open surgical management. (a) Splenic artery aneurysm, (b) Ligation and exclusion of splenic artery aneurysm.

Fig. 2 (a) Celiac artery aneurysm, (b) Resection and revascularization of celiac artery aneurysm.

TREATMENT OPTIONS

The goal of treatment of VAA and VAPA consists of exclusion of the aneurysmal sac from the systemic circulation while ideally preserving distal blood flow. This may be accomplished by either surgical or endovascular techniques (**Table 3**).

Surgical

Traditional surgical management generally involves an open exposure to excise the aneurysm with or without re-establishment of vascular continuity or end organ resection (i.e. splenectomy, nephrectomy) (**Figs. 1 and 2**). Minimally invasive surgical approach includes laparoscopic clipping as well as robotic assisted interventions. Surgery offers the advantage of durability, reduced need for follow-up studies, and low mortality rates of <0.5% in elective repairs.^{8,11,12)}

However, open repair in a hostile environment (i.e. in the setting of abdominal sepsis, pancreatic inflammation) becomes technically difficult and carries a higher morbidity and mortality. Patients with significant comorbidities may be at increased risks for complications and poor outcomes. Medical optimization might not be feasible on those that may present acutely with bleeding or rupture. Surgical access to the aneurysm may be challenging depending on the location, previous surgeries, and acuteness of the conditions.

Endovascular

The endovascular treatment armamentarium continues to expand with techniques such as coil embolization, placement of covered stents, plug deployment, gluing, and injection of endoluminal thrombin, polyvinyl alcohol, particles, or gelfoam (**Fig. 3**).⁵⁾ These minimally invasive endovascular techniques may offer a distinct advantage to conventional open repair. This is true, in particular, in the presence of a hostile environment such as in the setting of pancreatitis, sepsis, or multiple previous abdominal surgeries. The main advantages of the endovascular approach are its reduced invasiveness, decreased length of hospital stay, and better quality of life in the peri-operative period.^{13,14)}

Anatomic considerations play a big role in determining the feasibility and utility of an endovascular approach. For stent graft exclusion of aneurysms there is the need for sufficient vessel length and minimal tortuosity. Vessel tortuosity may not permit stent graft deployment. The risk of stent thrombosis or restenosis resulting in occlusion and potential subsequent end-organ ischemia and necrosis also has to be taken into consideration. Large

Fig. 3 Endovascular management. (a) Coil embolization of arterial inflow and outflow, (b) Coil embolization of aneurysm, (c) Stent graft exclusion of aneurysm.

saccular aneurysms may have poor long-term outcomes with coil embolization, as the coils may not be stable within the aneurysm and carry a higher risk of displacement and migration. True aneurysms may be treated with coil packing, thereby preserving the arterial circulation. Pseudoaneurysms, in general, should undergo proximal and distal coil embolization.

Complications following an endovascular repair include distal thromboembolic event, non-target vessel embolization, coil migration, end-organ infarction, and intra-procedural aneurysm rupture. Splenic atrophy or infarct has been reported in 20%–40% of cases following endovascular treatment of distal or hilar splenic artery aneurysms.⁵⁾ Stent thrombosis and occlusion is a concern, however, no consensus exists regarding antithrombotic or antiplatelet agents. Other downsides, include higher re-intervention rates, incomplete exclusion, unknown long term durability, and need for repeated imaging.

FUTURE DIRECTION

Multilayer fluid modulating stent is a spatial three dimensional stent design that slows and laminates blood flow inside an aneurysm allowing an organized thrombus to form. They reduce the flow velocity, by up to 90% within saccular aneurysms, allowing for physiological thrombosis of the aneurysm. Ferrero, et al.¹⁵⁾ reported the treatment of two patients with hepatic artery aneurysms of 34 mm and 48 mm diameter, using multilayer stents. Both of these patients were elderly and high risk for surgery due to their multiple comorbidities. The procedure was successful, with no peri-procedural complications, and 12-month follow-up revealed aneurysmal sac thrombosis and patency of all the branches of the hepatic artery.

Ruffino, et al. reported a 12 center-experience over one year using the multilayer stent. Nineteen patients, with mean VAA of 32.8 mm ($\pm$ 21.6 mm), underwent treatment. They had one peri-operative death due to pulmonary embolism with a 5.3% mortality rate. Two cases of stent occlusion were observed within 2 weeks leading to a 30-day patency rate of 87.5%. At 6 month follow-up the patency rate with collateral vessels remained the same.¹⁶⁾

Henry described the case of a 78-year-old with multiple comorbidities that was found to have an incidental 28 × 30 mm saccular renal artery aneurysm. The patient underwent deployment of a multilayer stent with immediate significant reduction of blood flow within the sac. The renal artery branches remained patent and blood pressure returned to normal after the procedure. Angiography at 6 months revealed complete shrinkage of the aneurysm wall and patency of all renal artery branches.¹⁷⁾

OUTCOMES COMPARING ENDOVASCULAR VS. SURGICAL TREATMENT

A 20% to 70% mortality rate is reported with the rupture of a VAA depending on the location and size.¹⁸⁾ Surgery in the setting of a rupture is also associated with high morbidity and lethality. For this reason, it is generally accepted that these lesions should be treated in an elective manner whenever recognized. This is especially true with the incorporation of endovascular techniques to our therapeutic armamentarium. Lesions that in the past would have been observed over time with serial imaging studies are now being treated aggressively with endovascular techniques. These catheter-based procedures carry the benefits of minimal invasiveness, including less post-operative pain, decreased wound complications, shorter

Table 4 Vascular and endovascular management of VAA/VAPA

Author	Patients/ Aneurysms	Endovascular Treatment	VAA	VAPA	Symptomatic/ Rupture	Technical Success	Overall Peri- Op Mortality	Open Peri- Op Mortality
Fankhauser et al.	176/185	100% (185)	36%	64%	48.8% (86)	98% (177)	6.20%	—
Tulshyan et al.	90	60% (48)	42%	58%	60% (29)	98%	8.30%	—
Sachdev et al.	59/61	61% (36)	50%	50%	50%	89%	2.9% (1/35)	4.2% (1/24)
Marone et al.	94	21.3% (20)	—	—	7%	90%	0%	1.3% (1/74)
Ferrero et al.	32	28.1% (9)	—	—	18.80%	67%	9.40%	—
Ding et al.	35	57.1% (20)	0%	100%	100%	87%	22.90%	42.90%
Etezadi et al.	40/41	100% (41)	73%	27%	47%	98%	0%	—
Pulli et al.	55/59	1.8% (1)	—	—	3.6% (2)	—	1.80%	—
Boufi et al.	10	100% (10)	0%	100%	80%	80%	20%	—
Ikeda et al.	22	100% (22)	100%	0%	0%	72.70%	0%	—

VAA: visceral artery aneurysms; VAPA: visceral artery aneurysms and pseudoaneurysms

hospital stay, and soon incorporation to regular activities. They demonstrate excellent results with low morbidity and mortality in the elective setting (**Table 4**). However, in the emergent setting the results are less desirable despite the various case reports that may suggest the contrary. Endovascular techniques have been associated in some series with up to a 25% morbidity, related mainly to transient post-embolization syndrome or incomplete aneurysm exclusion. Furthermore, an incompletely excluded aneurysm remains at risk of rupture.⁶⁾

In the emergent setting, ligation of the aneurysm without vascular reconstruction is preferred, if possible. Endovascular treatment may be the better option in the hemodynamically stable patient, especially when at high operative risk secondary to comorbidities, in the setting of a hostile abdomen, or when the aneurysm is poorly accessible.

A large retrospective case series from the Mayo Clinic, reviewed the 10-year experience, of minimally invasive endovascular management of VAA and VAPA. Between 1999 and 2009, 185 aneurysms (64% VAPA and 36% VAA) were identified in 176 patients. A 98% success rate was reported after initial intervention. In 46% of the patients, the indication was bleeding or rupture. The 30-day overall and aneurysm-related mortality was 6.2% and 3.4%, respectively. All of their deaths occurred in those patients undergoing emergent repair.¹⁹⁾

At the Cleveland Clinic, ninety patients with VAA/VAPA were identified between 1997 and 2005. Of these, 23 patients underwent only surveillance and did not undergo an intervention, 19 underwent an open aneurysm repair (4 of which were ruptured), and the remaining was treated with catheter-based procedure. The endovascular technique was successful in 98% of 48 procedures (20 VAA and 28 VAPA). Coil embolization was used in 96% of the cases for aneurysmal exclusion. The 30-day mortality was 8.3%, all of which occurred in patients requiring urgent or emergent intervention. There were no mortalities on those undergoing elective intervention.¹⁰⁾

A group from Milan, Italy, treated 94 patients with VAA/VAPA between 1988 and 2010. Seventy-four patients were managed with open traditional surgical technique and the remaining 20 with an endoluminal technique. One hundred percent success was reported with the open approach, but had one mortality (1.3%) and a morbidity of 9.4%. The endovascular group had no perioperative mortality but a 10% peri-operative morbidity.¹¹⁾

A retrospective single institution study over nearly 15 years, between 1991 and 2005, was performed at Mount

Sinai in New York. Fifty-nine patients with 61 aneurysms involving branches of the superior mesenteric and celiac arteries were identified of which 24 underwent the traditional open treatment and 35 had an endovascular approach. The authors reported an 89% success rate with the endovascular technique with the use of coil embolization or stent-graft therapy. They had a 100% favorable outcome of repeat coil embolization in the failure cases.²⁰⁾

Multiple other studies have shown technical success and good patient outcome with the endovascular approach, in the elective setting. In ruptured or symptomatic cases the mortality increases significantly particularly when attempting the minimal invasive method (**Table 4**).

SUMMARY

Aneurysmal degeneration of visceral vessels constitute a rare entity, however, it is detected more often than in the past due to the increased use of cross sectional body imaging and ultrasonography. It also remains a challenging problem with an imminent threat to life. Its natural history is not well defined and thus there is no consensus regarding indications for treatment.

Surgical (open, laparoscopic or robotic) and percutaneous endovascular interventions are options of operative management. Regardless of the approach used, it is important to take into consideration the location or vessel involved to determine the treatment. Those vessels with no collateral flow, such as the renal artery, or with inadequate flow, such as the SMA, require maintenance of end organ perfusion. Thus, a surgical bypass or endovascular covered stent will be necessary. In the case of those vessels with good collateral vascular flow, such as the splenic, celiac, proximal SMA or common hepatic artery, proximal and distal ligation of the artery or endovascular coiling may be adequate.

The contemporary approach for VAA/VAPA is early intervention over serial surveillance. They all can technically be fixed by endovascular techniques but that does not mean they should. Endovascular technique constitutes an excellent approach in the elective setting, particularly on those patients who are poor surgical candidates due to their comorbidities or who present a hostile abdomen. Open technique may still be the preferred method in the emergent setting due to the higher morbidity and mortality associated with endovascular techniques in this setting. However, in the emergency cases where surgery may be prohibitive, the endovascular technique provides

a reasonable alternative. When electively performed, endovascular treatment has shown good results in the short term. Further studies need to be done in order to assess the long-term effectiveness of the endovascular repair.

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