EDITORIAL

Endovascular management of visceral artery aneurysms: When to watch, when to intervene?

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Abstract

Visceral artery aneurysms (VAA) include splanchnic and renal artery aneurysms. They represent a rare clinical entity, although their detection is rising due to an increased use of cross-sectional imaging. Rupture is the most devastating complication, and is associated with a high morbidity and mortality. In addition, increased percutaneous endovascular interventions have raised the incidence of iatrogenic visceral artery pseudoaneurysms (VAPAs). For this reason, elective repair is preferable in the appropriately chosen patient. Controversy still exists regarding their treatment. Over the past decade, there has been steady increase in the utilization of minimally invasive, non-operative interventions, for vascular aneurysmal disease. All VAAs and VAPAs 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. However, in the emergent setting it may carry a higher morbidity and mortality. The decision for intervention has to take into account the size and the natural history of the lesion, the risk of rupture, which is high during pregnancy, and the relative risk of surgical or radiological intervention. For splanchnic artery aneurysms, we should recognize that we are not, in reality, well informed about their natural history. For most asymptomatic aneurysms, expectant treatment is acceptable. For large, symptomatic or aneurysms with a high risk of rupture, endovascular treatment has become the first-line therapy. Treatment of VAPAs is always mandatory because of the high risk of rupture. We present our point of view on interventional radiology in the splanchnic arteries, focusing on what has been achieved and the remaining challenges.

Core tip: This editorial deals with interventional radio-logical techniques in the splanchnic arteries, focusing on

what has been achieved and the remaining challenges. For splanchnic artery aneurysms, we should recognize that we are not, in reality, well informed about their natural history. The indications for the embolization of aneurysms are limited depending on the morphology of the aneurysm and surrounding vessels. Rotational angiography and other recently developed imaging techniques can help analyze the vascular anatomy of every lesion in decision making on the appropriate treatment for each patient when choosing between embolization, surgery and surveillance.

INTRODUCTION

Visceral aneurysms represent a rare clinical entity; however, 10%-20% will rupture and this is accompanied by a significant mortality rate of 20%-70%, depending on the location of the aneurysm. Their incidence is increasing and controversy still exists regarding their treatment[1]. The decision for intervention has to take into account the size and the natural history of the lesion, the risk of rupture, which is high during pregnancy, and the relative risk of surgical or radiological intervention. For most asymptomatic aneurysms, expectant treatment is acceptable. For large, symptomatic or aneurysms with a high risk of rupture, endovascular treatment has become the first-line therapy[2]. Treatment of visceral artery pseudoaneurysms (VAPAs) is always mandatory because of the high risk of rupture. The purpose of this article is to answer some questions about the current use of interventional techniques in the treatment of visceral artery aneurysms (VAAs) and VAPAs.

WHAT ARE THE CURRENT THRESHOLDS FOR INTERVENTION IN VISCERAL ANEURYSMS?

We can divide the discussion between true VAAs and VAPAs because the thresholds are completely different. For VAPAs due to inflammation or pancreatitis [*e.g.*, splenic, gastroduodenal (GDA), superior mesenteric artery (SMA), hepatic, or even renal aneurysms], trauma, or those occurring after surgery, the thresholds for treatment are very low. Even small aneurysms (2-5 mm) should be treated regardless of diameter because the risk of rupture for VAPAs is not related to their size. The type of aneurysm may (rarely) spontaneously heal, but in most cases, VAPAs will increase over time and eventually rupture. We should treat all of these aneurysms immediately after diagnosis, irrespective of

their location or origin[1-3].

For true aneurysms, the treatment threshold is different and depends mainly on anatomic location. The threshold for most true splenic artery aneurysms is 2 cm in diameter at the largest axis. Even if peripheral thrombus is present, these aneurysms should be treated in cases of an overall diameter larger than 2 cm. Women of childbearing age should be treated regardless of the diameter because the risk increase significantly during pregnancy[3].

One of the vascular complications of portal hypertension, which could occur in cirrhotic patients, is the development of intrasplenic or extrasplenic aneurysms. These lesions should not be treated systematically except in cases of aneurysms > 4 cm in diameter and in extrasplenic locations. In most cases, multiple, diffuse, small aneurysms related to portal hypertension should be left untreated and followed by repeat computed tomography (CT) or magnetic resonance imaging (MRI) examinations. Once the portal hypertension and underlying cirrhotic disease is treated (*e.g.*, *via* liver transplantation), the aneurysm may spontaneously decrease and completely disappear over time.

Other types of true aneurysms such as GDAs or those in the pancreaticoduodenal arcades, which can be caused by chronic hyperkinetic flow, should be treated as soon as they are diagnosed because they are at high risk of rupture, even when small in size. In such aneurysms associated with celiac trunk stenosis, inversion of the flow in the pancreaticoduodenal arcades to revascularize the liver or spleen needs to be preserved during the embolization procedure, which is sometimes a technical challenge[4].

For true hepatic or SMA aneurysms, the threshold for treatment is slightly lower than for splenic aneurysms. In most cases, we treat hepatic or SMA aneurysms when the large axis is > 1 to 1.5 cm.

The treatment of renal aneurysms is intended to prevent rupture either in the urinary tract or in the unclosed retroperitoneal space, as well as the development of systemic hypertension or renal failure in cases of intrarenal arteriovenous fistula development. Even small aneurysms could be the cause of changes to intrarenal hemodynamics and systemic hypertension and should, in this case, be treated endovascularly or surgically, depending on the type (saccular or fusiform) and location. In the case of isolated, non-symptomatic aneurysms in the renal arteries, the treatment threshold is around 1 to 1.5 cm[1-4].

For both visceral and renal arteries, extraparenchymal aneurysms take priority over intraparenchymal aneurysms because the risks and severity of major rupture and hemorrhage seem significantly higher for proximal extraparenchymal lesions.

HOW HAVE THRESHOLDS EVOLVED OVER THE LAST TWO DECADES?

The threshold for aneurysm treatment due to pancreaticoduodenal arcade has evolved and is now very

low. This was different 15 to 20 years ago. Considering this type of true aneurysm, the relationship between the celiac trunk or SMA stenosis and the development of hyperkinetic aneurysms was not well known. Only in the last 8 to 10 years has the relationship between these two conditions been established[4].

The threshold for treatment of renal, hepatic, SMA, or splenic aneurysm has been established for 10 or 15 years, and it has not significantly changed. However, we actually can treat all of these types of aneurysms by endovascular approaches instead of a more aggressive, invasive surgical approach. It's easier to treat these aneurysms now due to the evolution of endovascular techniques through a better understanding of peripheral conditions, as well as employment of neurovascular techniques. For the last 10 years, we have been performing peripheral interventions, applying neuro techniques for peripheral purposes with success. We know that the risks of rupture are very low in SMA or hepatic aneurysms < 1 cm, but we can treat these small aneurysms efficiently and safely with the endovascular approach. Most clinicians and patients prefer that these aneurysms are treated, because after treatment, the problem is solved. These patients, if left untreated, should have follow-up with CT scan, MRI, or ultrasonography each year or even every 6 mo.

ARE THERE DIFFERENT THRESHOLDS FOR PATIENTS WITH OTHER UNDERLYING CONDITIONS?

Patients with vasculitis such as Ehlers-Danlos disease type Ⅳ who develop even very small, true aneurysms should be treated regardless of the size because the risk of rupture is very high due to intrinsic defects in the vascular wall. Aneurysms in patients with Ehlers-Danlos syndrome will invariably increase over time and should be treated as soon as the diagnosis has been established, preferentially by endovascular reconstruction or segmental vascular exclusion instead of simple aneurysm coiling[1,2].

IS THERE A RELATIONSHIP BETWEEN THE TREATMENT THRESHOLD AND THE TYPE OF MATERIAL USED?

The threshold to decide if we treat is never directly related to the material we use. For example, a proximal 3-cm-diameter splenic aneurysm can be treated with coiling, stent graft placement, segmental vascular exclusion, or even potentially a flow diverter.

Ten years ago, we only used coils or glue, because we didn't have very smooth and flexible microcoils. We also didn't have flexible stent grafts or flow diverters, and we couldn't use an imaging-guided direct per-cutaneous approach in cases of inaccessible lesions due to vascular sinuosity or proximal obstruction. With

the tools and techniques we have today, by preserving vessel patency, we can conservatively treat even large-neck and fusiform aneurysms that could have only been treated by segmental vascular exclusion before. Now, we can exclude the entire aneurysm and preserve the afferent arteries in more than 90% to 95% of cases. It is particularly important for splenic and renal function that we can treat extraparenchymal or hilar aneurysms while preserving the parent arteries and distal flow[1-3].

WHAT ARE SOME ADVANCEMENTS IN ACCESS TECHNOLOGIES AND TECHNIQUES FOR THE TREATMENT OF VISCERAL ANEURYSMS?

We have now the opportunity to use neuroendovascular tools for peripheral aneurysm exclusion. Over the last 10 years, many neurological techniques have been developed into dedicated peripheral applications. For instance, the use of a balloon remodeling technique was created initially for neurointerventions by Moret *et al*[5] 15 years ago. Ten years ago, one main limiting factor in treating visceral aneurysms with large necks was the risk of coils protruding outside the aneurysm or occluding the parent arteries. The first use of a balloon remodeling technique to increase coil density and avoid protrusion of coils in the parent artery was performed by Moret *et al*[5] in 1997. This technique is routinely used in some centers to overcome limitations due to broad neck, unstable microcatheter, or to treat complex renal/splenic/SMA aneurysms. The combination of Onyx (Covidien) as an embolic agent with Onyx-compatible remodeling balloon has been used by several physicians to treat hilar renal and SMA aneurysms[6]. To preserve the parent artery, we can use bare stents and coiling through the mesh of the stent with a microcatheter and microcoils[7-11]. Alternatively, we can use kissing stents in cases of aneurysms located at bifurcations, which is often the case with renal arteries. To preserve vascularization of the kidney, we use a double-kissing stent or kissing-balloon remodeling technique and detachable coils. Another great technical advancement is the use of detachable coils instead of pushable coils. For neurointerventions, 20 years ago, radiologists started using exclusively detachable coils for cerebral aneurysm embolization, and now there are many types of detachable coils for peripheral applications provided by various companies (*e.g.*, Terumo Interventional Systems, Boston Scientific Corporation, Cook Medical, and Covidien).

This is a significant advancement because it has increased the safety of treatment of even large-necked aneurysms by reducing the risk of periprocedural distal embolization of coils, especially for splenic and renal locations.

Hepatic artery aneurysms are probably the easiest to treat, as there is dual flow to the liver (arterial and portal), and we can we can completely exclude seg-

mentally the parent artery that is responsible for the aneurysm without any risk of ischemia to the liver. Hepatic aneurysms can be treated by different methods including coil packing of the aneurysm sac, segmental coil trapping of the parent artery ("sandwich technique"), placement of a covered stent in cases of proximal or relatively straight distal artery, or a combination of bare stent and microcoils through the mesh[8-10].

The main challenge is with the SMA and renal arteries because we must preserve distal flow and therefore maintain parent vessel patency by using remodeling coils/Onyx techniques, stent grafts, or a combination of bare stent and microcoils. Conversely, in cases of extraparenchymal splenic aneurysm, we use a different approach. The splenic artery is sometimes difficult to navigate, even with small and soft microcatheters. However, in most cases of splenic aneurysm, we can perform segmental splenic artery exclusion by deploying coils distally and proximally. Coil placement on both sides of the aneurysm is safe because there is enough collateralization through the gastric and pancreatic arteries, and this collateralization will revascularize the spleen at the ileum and help to preserve the intrasplenic blood flow.

We believe that the medial or proximal part of the splenic artery can be completely excluded without risk. It is probably the best treatment for splenic aneurysms, especially for pancreatitis-related pseudoaneurysm.

As mentioned previously, pseudoaneurysm due to inflammation, pancreatitis, trauma, and mycotic aneurysm should normally not be treated by packing the aneurysm alone, even if good results have been reported with this technique[12]. These pseudoaneurysms should preferentially be treated by segmental artery exclusion because the aneurysm is secondary to progressive regional arterial wall deterioration. If we only treat the aneurysm, the patient is at risk of aneurysm recurrence on both sides of the occluded neck because the wall is destroyed by the inflammatory process. In this case, the best and only efficient and safe treatment is to completely exclude the parent artery, distally and proximally, to be sure you've completely solved the regional problem. Placement of a covered stent with extensive proximal and distal landing zones could be an acceptable alternative.

Stent grafts may be useful to preserve the distal vascularization. We have used coronary stent grafts because of their high flexibility; they can be navigated through tortuous arteries[9-11]. These balloon-expandable stent grafts are mounted on very thin microcatheters and can reach distal aneurysms. Coronary stent grafts are limited by the length and diameters available, which range between 9 and 22 mm and 2 and 4.5 mm, respectively. Small dedicated stents are now available on the market for visceral aneurysms (V12, Maquet).

Inaccessible small aneurysms or pseudoaneurysms in the GDA or pancreaticoduodenal arcades may also be treated with liquid embolics, such as N-butyl cyanoacrylate glue (Glubran2, GEM) or Onyx instead of coils[6,13]. If we cannot reach a distal aneurysm due to a tortuous access, we place a small catheter as close as possible to the aneurysm and inject a mixture of glue diluted by Lipiodol (Guerbet) in variable ratios depending on the flow and distance between the point of injection and the target. We can inject the glue slowly, moving distally to exclude both the aneurysm and the arterial segments beyond and behind the aneurysm. This is the so-called front-and-back-door occlusion.

In the same way, for inaccessible aneurysms, we can use liquid embolics injected through collaterals when the main artery has been occluded for another reason and the aneurysm still grows or after previous artery occlusion, or if coils have been placed but were not sufficiently packed. The aneurysm remains open because collaterals revascularize the aneurysm, requiring navigation of very thin neuro microcatheters through tortuous collaterals to occlude the aneurysm using Onyx or glue[6,13].

In cases when the aneurysms cannot be accessed by an endovascular approach or if proximal injection of liquid embolic agents is considered too dangerous, we can use a direct percutaneous ultrasound/CT-guided approach. This method could be used not only for intraparenchymal aneurysms in the spleen, liver, kidney, and pancreas, but also for extraparenchymal aneurysms, especially for SMA, GDA, or pancreaticoduodenal aneurysms that we cannot access safely.

Using cone-beam CT imaging guidance or conventional spiral CT, an 18-G guiding needle is first placed from the abdominal or back entry site to the target to stiffen the tract, and a microcatheter is navigated through the external needle into the aneurysm. Thrombin or even glue is slowly injected to get an immediate occlusion. Sometimes, we can fill the aneurysm with microcoils. If the lesion is clearly visible by ultrasonography, it's easy to place the needle through the splenic/renal or hepatic parenchyma into the aneurysm. The needle tip is clearly visible in the aneurysm by using color duplex ultrasonography. This is a major improvement in the treatment of visceral aneurysms inaccessible by an endovascular approach.

ARE THERE ANY OTHER DEVICES OR TECHNIQUES THAT ARE AVAILABLE?

In cases of small aneurysms, there is a risk of perforation when you place the first coils. If this occurs, the coils should be completely placed and detached as quickly as possible to stop the bleeding. When using the balloon technique, inflation of the balloon stops the flow or the bleeding if it occurs and helps solve the problem. During placement of the first coil in a small aneurysm, the remodeling balloon technique is very useful to avoid or address bleeding complications.

Another interesting technical approach to treat pseudoaneurysms with liquids while avoiding distal untargeted embolization is to inject liquid embolic or glue

through the microcatheter just in front of the aneurysm. The exact volume of contrast media necessary to fill the aneurysmal cavity and segmental arteries in front and back is estimated. Before injecting the glue, epinephrine, a vasoconstrictor, is injected to induce occlusive spasm of the artery distal to the aneurysm[13]. Using this technique, there is no risk of glue migration far into the distal arteries and parenchyma.

ARE THERE ANY CLINICAL SCENARIOS IN WHICH A SURGICAL APPROACH IS PREFERRED?

The remaining indications for a surgical approach for visceral aneurysms are few, even for the less common types of fusiform aneurysms. These aneurysms are normally not treated if the dilatation is less than two times the normal diameter of the artery. These may be treated wit a combination of stents and coils, stent grafts (often too rigid), as well as by new devices used for neurointervention, such as flow diverters or multilayer uncovered metallic stents. Due to vascular intima remodeling combined with modification of the hemodynamic flow leading to progressive thrombotic phenomena inside the aneurysm, the placement of such a new device leads to complete aneurysm occlusion in most cases while the arterial lumen is kept patent. Flow diverter stents are more and more often used to treat aneurysms with very large necks or that cannot be managed by a remodeling technique or covered stent placement because of insufficient safe landing zone[14]. When using a covered stent, especially for renal aneurysms, we often do not have sufficient landing zones on both sides of the aneurysm. This angiographic condition seems to be a good indication to use a flow diverter stent because there is no need for a landing zone with flow diverter implantation. Flow diverters keep the side branches patent, which is the main advantage of these devices compared to stent grafts.

Some European physicians have used multilayer stents to treat fusiform renal artery aneurysms or visceral aneurysms that cannot be coiled for technical reasons[14]. Preliminary results of the use of multilayer intra-arterial stents for peripheral applications are very promising. However, flow diverter placement requires dual-antiplatelet therapy for a minimum of 4 to 6 mo because of the risk of platelet aggregation on the dense metallic surface.

For splenic aneurysms, or aneurysms that can be treated by parent artery occlusion, we can also place Amplatzer plugs (St. Jude Medical). Plugs deployed distally and proximally to the aneurysm will lead quickly to complete occlusion of the parent artery[1-4]. This technique, mainly used for splenic aneurysms as well as hepatic aneurysms, seems very promising because it is quick, highly efficient, and probably less expensive compared to other treatment options. Furthermore, Amplatzer vascular plugs are safe in high-flow or short-segmental lesion cases, because the device can be retrieved and repositioned if the initial location is unsatisfactory. The main limiting factor is the rigidity of the device. The AVP Ⅳ family from St. Jude Medical is the most flexible, but we are still limited because the device requires a 4-F, 0.0038-inch inner lumen catheter. A new, more flexible microplug from Reverse Medical, the MVP microvascular plug, is available in two sizes for peripheral vascular use. Comparative trials with conventional microcoils are needed.

WHAT TRIALS ARE NEEDED IN THIS FIELD?

The thresholds for indication to treat are well known, but understanding which type of treatment is best to use remains questionable. It will be interesting to see if we can get better results by using new devices such as flow diverters compared with more conventional coiling or balloon remodeling[5,14]. When we coil an aneurysm, we completely exclude the aneurysm, but the neck remains unclosed even if there is some endothelialization over time. When using flow diverter stents, we do not treat the aneurysm itself, but we treat the arterial wall defect by closing the neck and reinforcing the adjacent side wall.

For standard coiling of simple aneurysms, it will be interesting to know if better results can be obtained in terms of completion and stability of aneurysm occlusion if we use hydrogel-coated coils instead of conventional uncoated coils.

Studies could also compare the mid- and long-term results of coiling with hydrogel-coated coils to flow diverting stents. For cerebral aneurysms, interventional neuro are using more and more flow diverters instead of coiling so why not the same trends in visceral aneurysms?

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