Nonoperative management of unruptured visceral artery aneurysms: Treatment by transcatheter coil embolization

Osamu Ikeda, MD, Yoshitaka Tamura, MD, Yutaka Nakason, MD, Yasuhiko Iryou, MD, and Yasuyuki Yamashita, MD, Honjo Kumamoto, Japan

Purpose: To describe our experiences with the treatment of visceral artery aneurysms (VAA) by transcatheter coil embolization and to propose indications for treating VAA by this method.

Methods: We treated 22 patients with VAA by coil embolization; 9 had splenic-, 7 renal-, 4 pancreaticoduodenal arcade-, and 2 proper hepatic artery aneurysms. All nine splenic artery aneurysms patients presented with chronic hepatitis-C; four had hepatocellular carcinoma. Of the seven renal artery aneurysms patients, four were hypertensive and three had rheumatoid arthritis. Both pancreaticoduodenal arcade artery aneurysms patients manifested severe stenosis of the celiac axis. Our transcatheter coil embolization procedure includes coil embolization and coil-packing of the aneurysmal sac, preserving the native arterial circulation.

Results: Transcatheter coil embolization with aneurysm packing was technically successful in 16 (72.7%) of the 22 patients and the native arterial circulation was preserved. Postprocedure angiograms confirmed complete disappearance of the VAA. In four of the nine splenic artery aneurysm patients, the native arterial circulation was not preserved. In one renal artery aneurysm patient, stenosis at the aneurysmal neck necessitated placement of a stent before transcatheter coil embolization. Magnetic resonance angiographs obtained during the follow-up period (mean 27 months) demonstrated complete thrombosis of the VAA in all 22 patients. Infarction occurred in one splenic- and two renal artery aneurysms patients; the latter developed flank pain and fever after the procedure.

Conclusions: Transcatheter coil embolization is an effective alternative treatment for patients with saccular and proximal VAA. In particular, the isolation technique using coil embolization is advantageous in splenic artery aneurysm patients.

Visceral artery aneurysms (VAA) are rare. Among vascular aneurysms detected at autopsy, 0.1% to 0.2% were VAA. Unlike peripheral artery aneurysms, which are largely attributable to arteriosclerotic degeneration, the pathogenesis of VAA are variable and may be secondary to arteriosclerosis, medial dysplasia, trauma, gestational alterations, connective tissue disorders, and mycotic embolization. Advances in abdominal imaging techniques have led to an increase in the detection rate of VAA. The clinical presentation of these rare lesions is often vague, and there are no clear signs alerting to their imminent rupture. As untreated VAA enlarge progressively and may rupture spontaneously, their early detection and effective treatment are necessary to improve the prognosis of patients with these aneurysms.

Traditionally, VAA have been managed by close surveillance or surgical intervention that included resection with revascularization, ligation, or end-organ resection (eg, splenectomy). Transcatheter embolization is a viable alternative to conventional open surgery; its advantages are low procedure-related morbidity and mortality, especially in patients who are poor surgical candidates. We report our experience with the treatment of VAA by coil embolization therapy and propose the indication for treating VAA by this method.

MATERIALS AND METHODS

Patients. We reviewed 22 patients (8 men and 14 women, age range 46-73 years; mean 63 years) who underwent coil embolization to treat VAA at Kumamoto University Hospital between April 2002 and May 2007. There were 9 patients with splenic-, 7 with renal-, 4 with pancreaticoduodenal arcade-, and 2 with proper hepatic artery aneurysms.

Table I shows the characteristics of these patients and Table II shows the indication for transcatheter coil embolization of VAA used at Kumamoto University Hospital. We chose to perform transcatheter coil embolization for splenic-, renal-, proper hepatic artery aneurysms in patients presenting with more than two indications; all pancreaticoduodenal arcade were subjected to this procedure. Pseudoaneurysms were not included in this study. None of the 22 patients presented with clinical symptoms of VAA. The nine splenic artery aneurysm patients were referred to us for further abdominal computed tomography (CT) study because initial CT scans revealed an abdominal mass; another 12 (7 renal artery aneurysms, 3 pancreaticoduodenal arcade aneurysms, and 2 proper hepatic artery aneu-
rysms) were referred in the course of imaging examinations. One of the pancreaticoduodenal arcade aneurysm patients, a heavy drinker with a history of chronic pancreatitis, was referred to us for abdominal CT study to determine the cause of his severe back pain. An abdominal mass, later identified as pancreaticoduodenal aneurysm, was detected on the initial CT scan. A soft tissue density lesion indicating inflammatory process was recognized at the celiac axis contiguous with the pancreas on CT. These changes were not seen at the site of aneurysm. Therefore, we believe the cause of the aneurysm as secondary change related to severe stenosis of the celiac axis due to pancreatitis, and the aneurysm was considered as a true aneurysm due to hemodynamic changes.

Before transcatheter coil embolization, we acquired CT scans, one for all 22 patients on a 16-row multidetector CT (MDCT) scanner (IDT16, Philips Medical Systems, Best, The Netherlands). We used a bolus injection of 100 ml iopromide (Iopamiron 300; Nihon Schering) delivered at a rate of 3 ml/s. All images were obtained through the abdomen in a craniocaudal direction; the parameters were 1.5-mm collimation, 17.5-mm/s table speed during a single breath-hold, 15- to 20-second helical acquisition, and 1.5-mm reconstruction interval. The VAA size ranged from 1.2 to 5.0 cm (mean 2.2 cm).

**Table I.** Characteristics of the patients with visceral artery aneurysms

<table>
<thead>
<tr>
<th>Type of visceral artery aneurysm</th>
<th>No of cases</th>
<th>Age range (mean)</th>
<th>Sex (M/F)</th>
<th>Size range (mean)</th>
<th>Location (proximal/distal)</th>
<th>Shape (saccular/fusiform)</th>
<th>Disease background (number of patients)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Splenic artery aneurysm</td>
<td>9</td>
<td>50-73 (65)</td>
<td>3/6</td>
<td>15-25 mm (19 mm)</td>
<td>7/2</td>
<td>5/4</td>
<td>Chronic hepatitis C (9) HCC (4)</td>
</tr>
<tr>
<td>Renal artery aneurysms</td>
<td>7</td>
<td>55-73 (65)</td>
<td>3/4</td>
<td>12-50 mm (20 mm)</td>
<td>5/2</td>
<td>4/2</td>
<td>Hypertension (4) rheumatoid arthritis (3) Stenosis of celiac axis (4)</td>
</tr>
<tr>
<td>Pancreaticoduodenal arcade aneurysm</td>
<td>4</td>
<td>46-66 (55)</td>
<td>1/3</td>
<td>12-22 mm (19 mm)</td>
<td>4/0</td>
<td>4/0</td>
<td>Chronic pancreatitis (4)</td>
</tr>
<tr>
<td>Proper hepatic artery aneurysms</td>
<td>2</td>
<td>69-71 (70)</td>
<td>1/1</td>
<td>20-30 mm (25 mm)</td>
<td>2/0</td>
<td>2/0</td>
<td>Idiopathic (1)</td>
</tr>
</tbody>
</table>

**Table II.** Indication of transcatheter coil embolization for visceral artery aneurysms

<table>
<thead>
<tr>
<th>Site of aneurysm</th>
<th>Factors for treatment indication</th>
<th>Treatment is indicated if</th>
</tr>
</thead>
<tbody>
<tr>
<td>Splenic artery aneurysm</td>
<td>(1) More than 3 cm in size</td>
<td>Present three factors from (1) to (3) or present (4) and two factors from (1) to (3)</td>
</tr>
<tr>
<td></td>
<td>(2) No calcification in an aneurysmal wall</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3) No intracavitary thrombus</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(4) With chronic liver disease</td>
<td></td>
</tr>
<tr>
<td>Renal artery aneurysm</td>
<td>(1) More than 1.5 cm in size</td>
<td>Present three factors from (1) to (3) or present (4) and two factors from (1) to (3)</td>
</tr>
<tr>
<td></td>
<td>(2) No calcification in an aneurysmal wall</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3) No intracavitary thrombus</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(4) With hypertension, steroid treatment, or pregnancy</td>
<td></td>
</tr>
<tr>
<td>Proper hepatic artery aneurysms</td>
<td>(1) More than 2 cm in size</td>
<td>Present all three factors</td>
</tr>
<tr>
<td></td>
<td>(2) No calcification in an aneurysmal wall</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3) No intracavitary thrombus</td>
<td></td>
</tr>
<tr>
<td>Pancreaticoduodenal arcade aneurysms</td>
<td>Any pancreaticoduodenal arcade aneurysms require treatments</td>
<td></td>
</tr>
</tbody>
</table>

The celiac- and superior mesenteric arteries were catheterized with a 4F catheter (Medikit); small arterial branches were catheterized with a 2.5F microcatheter (Target, Boston Scientific Corp, Watertown, Mass). To aid in the placement of the 4F catheter, we used a 0.035-inch diameter torque Radifocus guidewire (Terumo Co, Tokyo, Japan).

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Introduction of the microcatheter was with a .014-inch outside diameter featuring a free transformation tip (Dasher-14 guidewire; Target, Boston Scientific Corp., Watertown, Mass) and a .016-inch outside diameter with a fixed-angle tip (GT wire; Terumo Co., Tokyo, Japan).

In patients with splenic artery aneurysm, we confirmed the collateral arteries to avoid splenic infarction. A 5F vascular sheath (Medikit) was placed and secured with the Seldinger technique. Then a 5F balloon catheter with an 11-mm diameter balloon (Moijan, Miyano, Osaka, Japan) was inserted from the contralateral femoral artery for angiographic- and transcatheter coil embolization procedures and wedged into the splenic artery just proximal to the splenic artery aneurysm. We then inflated the balloon and...
obtained celiac- and superior mesenteric artery angio-
grams.

**Interventional radiology techniques.** We performed
transcatheter coil embolization and packing of the aneurys-
mal sack, preserving the native arterial circulation. We
introduced three-dimensional (3D) Guglielmi detachable
coils (GDCs; Boston Scientific) and placed interlocking
detachable coils (IDCs; Boston Scientific) in the aneurys-
mal sac. We completed the procedure after obtaining
angiographic confirmation that flow in the aneurysm had
ceased.

In 21 patients, we introduced one (20/30 mm/cm)
3D-GDC (Boston Scientific) and placed 3 to 22 (mean 11)
IDCs (Boston Scientific) into the aneurysmal sac. The renal
artery aneurysm patient who required stenting was treated
with 102 IDCs; no 3D-GDC was introduced.

**Analysis and study endpoints.** MDCT- and angio-
graphic images were analyzed by two interventional radiol-
ogists (OI, YY); determinations were reached by consensus.
In all 22 patients, the location and size of the VAA and the
width of the aneurysmal neck were evaluated on MDCT
scans and angiograms.

Technical success was defined as the absence of flow in
the aneurysm and preservation of the native circulation on
angiograms obtained just after the transcatheter coil embo-
lization procedure, and on magnetic resonance angiogra-
phy (MRA) acquired in the arterial phase at 1 week post-
transcatheter coil embolization. We compared the number
of coils used with the aneurysmal size. All patients were
monitored with MRA because on MRA images artifact due
to coil embolization is reduced. We evaluated follow-up
MRA scans obtained at 1, 3, and 6 months after percuta-
aneous coil embolization to ascertain that there was no
increase in the aneurysmal size and no flow in the aneurysm.
In all 22 patients, MRA was obtained during the follow-up
period (mean 27 months).

Transcatheter coil embolization-related complications
were classified as infarction with or without symptoms.
Complications related to the interventional radiology tech-
niques were classified as major and minor according to the
reporting standards of the Society of Cardiovascular &
Interventional Radiology.

**RESULTS**

**Comparison of angiographic- and MDCT findings
in VAA patients.** In all patients, the location of the VAA
was identical on angiograms and MDCT scans. All four pan-
creaticoduodenal arcade aneurysm patients presented with
stenosis or occlusion of the proximal celiac trunk on MDCT
scans. The hepatic and splenic artery could be visualized
through a dilation of the pancreaticoduodenal arcade on
superior mesenteric artery angiograms (Fig 1, A, B).

**Fig 1.** A 63-year-old man with an aneurysm of the inferior pancreaticoduodenal artery and a concomitant finding of
occlusion of the celiac artery due to compression by the median arcuate ligament. A, Multiplanar reformatted images
showing narrowing of the celiac trunk from extrinsic superior compression. B, On the superior mesenteric artery
angiogram, the hepatic artery can be visualized through a dilation of the pancreaticoduodenal arcade. Note the 12-mm
aneurysm arising from the origin of the inferior pancreaticoduodenal artery.
Technical success of transcatheter coil embolization. Transcatheter coil embolization was technically successful in 16 (72.7%) of the 22 patients and the native circulation was preserved; post-transcatheter coil embolization angiograms showed complete disappearance of the VAA (Fig 3, A, B, and C).

On angiograms obtained after transcatheter coil embolization, the native circulation was not preserved in four patients with splenic artery aneurysms. Additionally, in two patients with renal artery aneurysms, packing coils migrated into the renal artery, and the native circulation was not preserved. One renal artery aneurysm patient with stenosis at the aneurysmal neck required placement of an uncovered self-expanding nitinol stent (Luminexx; Bard Inc., Covington, Ga) before transcatheter coil embolization to preserve flow of the native circulation (Fig. 4, A through D).

In all 22 patients, MRA demonstrated complete thrombosis of the VAA. Follow-up MRA scans showed no increase in the aneurysmal size and no flow in the aneurysm.

Complications. Kidney and spleen infarcts occurred in the distal branches in two and one patient, respectively, with fusiform aneurysms. After the procedure, two renal artery aneurysm patients developed flank pain and fever and required the administration of antibiotics and analgesics for 1 week. Their infarcts involved less than one-third of the kidney. The one splenic artery aneurysm patient had no symptoms. In these cases, packing coils migrated into the distal artery, and the native circulation was not preserved.
DISCUSSION

Transcatheter coil embolization is an effective alternative treatment for patients with saccular and proximal VAAs. In this article, we described our experiences with treatment of VAAs by transcatheter coil embolization and propose indications for treating VAAs by this method. In particular, the packing technique using coil embolization is advantageous in saccular artery aneurysm patients.

VAAs have multiple etiologies either in true aneurysms or pseudoaneurysms. The most frequent causes of true aneurysms are: arteriosclerosis, fibrodysplasia, connective-tissue disorders, and hyperflow conditions such as portal hypertension. True aneurysms undergo dilation and thinned arterial wall, although the blood is still contained within the complete vessel wall. True aneurysm consists of two kinds of aneurysms in the saccular- and fusiform configuration. Pseudoaneurysms (aneurysms where there is a tear of the vessel wall with successive peri-artery hematoma) can be caused by trauma, iatrogenic lesions due to surgical, endoscopic or radiological interventional procedures, or by inflammatory or infectious condition.6 Pseudoaneurysm indicates ruptured arterial wall.

True- and pseudoaneurysms require different transcatheter coil embolization techniques. Pseudoaneurysms should be treated by proximal and distal coil embolization, but true aneurysms may be treated only by coil-packing. We treated true aneurysms by coil-packing, preserving the native arterial circulation. The choice of embolization technique also depends on the site and morphology of the true aneurysms.

Fig 3. A 48-year-old man with a history of heavy drinking and chronic pancreatitis. Note the aneurysms of the inferior pancreaticoduodenal artery at the bifurcation of the pancreaticoduodenal arcade and pancreatic transverse artery. A, CT shows occlusion of the celiac artery and multiple calcifications in the pancreas due to chronic pancreatitis. B, On the superior mesenteric artery angiogram, the hepatic and splenic artery can be visualized through a dilation of the pancreaticoduodenal arcade. Note the 10-mm aneurysm of the inferior pancreaticoduodenal artery at the bifurcation of the pancreaticoduodenal arcade and pancreatic transverse artery. C, Complete angiogram demonstrating obliteration of the aneurysm by coils. Note patency of the collateral flow to the hepatic- and pancreatic transverse artery.
Arterial patency can be preserved in saccular aneurysms in which catheterization of the neck allows embolization to be limited to the sac. This is done by using coils and/or cyanoacrylate or thrombin, or treatment with a stent graft may be selected. Fusiform aneurysms involving bifurcations require “endovascular exclusion” requiring the positioning of the coils in the efferent branches and in the afferent artery in order to obtain complete exclusion. In these cases, the
perfusion of the end-organ can be at least partially maintained by the collateral vessels. In cases with pseudoaneurysms, on the other hand, we used packing and isolation of the aneurysm and occluded both the aneurysmal sac and native artery. Because the incidence, risk of rupture, treatment indications, and its potential complications differ among aneurysms in different locations, we will discuss each aneurysm separately.

**Splenic artery aneurysms.** Splenic artery aneurysms account for 60% of all VAAs. Between 2% and 10% of splenic artery aneurysms are at risk for rupture and the mortality rate of patients with ruptured splenic artery aneurysm is 20% to 30%. Although treatment indications have not been established, surgery is thought to be indicated in patients with symptoms, patients with enlarging aneurysms, patients who are pregnant or anticipate pregnancy, patients with portal hypertension scheduled for liver transplantation, and patients whose aneurysms are larger than 2 cm in diameter. At our institution, splenic artery aneurysm patients whose aneurysms are larger than 2 cm in diameter are considered eligible for transcatheter coil embolization. Splenic artery aneurysm patients with hepatitis B or C whose lesions that are smaller than 2 cm are also considered eligible for the procedure.

A concern exists for splenic insufficiency after main splenic artery embolization. It was of interest that evidence of splenic ischemia, such as infarcts or significant atrophy, was noted in 40% of cases after splenic artery ablation with one minimal clinical sequelae. This was primarily noted after embolization of distal splenic artery or hilar/intrasplenic aneurysms. In our cases, spleen infarcts occurred in the distal branches in one patient with fusiform aneurysms, but this patient had no symptoms.

Conventional repair of these lesions, with morbidity, would typically require distal splenic artery ligation or splenectomy. Recently, stent graft repair of splenic artery aneurysms has received increasing attention. It offers the potential benefit of maintaining splenic perfusion excluding the aneurysm, thereby eliminating the risk of rupture.

**Renal artery aneurysms.** Renal artery aneurysms are one of the most frequent aneurysms of the abdominal cavity; their detection rate was 0.01% to 0.09% in an autopsy series and 0.6% to 1.0% on arteriograms. At 2.8% to 5.6%, renal artery aneurysms are at low risk for rupture, and there is no correlation between their size and rupture. Treatment has been recommended for patients at risk for aneurysm rupture and for those with hypertension, hematuria, and aneurysms larger than 1.5 cm. At our institution, renal artery aneurysm patients whose aneurysms are larger than 1.5 cm in diameter are considered eligible for transcatheter coil embolization. Renal artery aneurysm patients with hypertension, steroid treatment, or pregnancy whose lesions are smaller than 1.5 cm are also considered eligible for the procedure.

The best surgical treatment option is resection of the aneurysm and reconstruction of the artery. However, such an operation carries a significant morbidity (12%) and mortality (1.6%). Endovascular treatments for renal artery aneurysms have recently been described as an alternative to open surgical repair. These reports have described two general approaches; transcatheter embolization and endovascular grafting. In one of the largest experiences using embolization, Klein et al treated 12 renal artery aneurysms with microcoils. In their series, there were two complications related to therapy, but each aneurysm was successfully thrombosed.

In two of our seven renal artery aneurysms patients, packing coils migrated into the renal artery and the native circulation was not preserved; these patients suffered from partial renal infarcts. The reports on renal artery aneurysm exclusion with stent grafts are limited so far. With the development of more flexible and low profile endoprosthesis with accurate deployment, these stent grafts will become more usable, even in complex lesions.

**Pancreaticoduodenal arcade aneurysms.** Pancreaticoduodenal arcade aneurysms are rare; 2% of all splanchnic artery aneurysms arise at the pancreaticoduodenal artery. Of the reported pancreaticoduodenal arcade aneurysms cases, 65% were diagnosed upon rupture; the mortality rate in pancreaticoduodenal arcade aneurysms patients after rupture was nearly 50%. Therefore, pancreaticoduodenal arcade aneurysms patients may require treatment regardless of the size of the aneurysm.

The mortality rate in surgically treated patients with unruptured pancreaticoduodenal arcade aneurysms was 19% compared with 0% in those treated by transcatheter coil embolization. As the success rate for aneurysm exclusion was similar irrespective of treatment choices (surgery or transcatheter coil embolization), we suggest that unruptured pancreaticoduodenal arcade aneurysms be treated endovascularly. Conventional surgery may be selected in pancreaticoduodenal arcade aneurysm patients who present with concomitant celiac artery stenosis or occlusion.

Surgical intervention in patients with pancreaticoduodenal arcade aneurysms includes division of the median arcuate ligament of the diaphragm, ligation, and resection of the aneurysm with concomitant revascularization procedures. Studies are underway in our institution to investigate the feasibility of treating pancreaticoduodenal arcade aneurysms by combining transcatheter coil embolization and laparoscopic surgery.

**Proper hepatic artery aneurysms.** Proper hepatic artery aneurysms are the second most common after splenic artery aneurysms; their incidence is 20%. Proper hepatic artery aneurysms carry a higher risk for rupture (14% to 80%) and the mortality rate in patients with ruptured proper hepatic artery aneurysms is 21% to 43%. At our institution, proper hepatic artery aneurysms patients whose aneurysms are larger than 2 cm in diameter are considered eligible for transcatheter coil embolization.

Hepatic artery aneurysms tend to be solitary and confined to intra- or extrahepatic structures. They can be saccular or fusiform; the smaller aneurysms tend to be fusiform. Treatment options include conventional open
surgery with or without resection of the hepatic tissues and minimally invasive endovascular procedures.

Multiple intrahepatic aneurysms usually require ligation of the branch hepatic arteries and resection of some parts of the hepatic structures.\textsuperscript{2,3} On the other hand, extrahepatic aneurysms can be treated by reconstruction of the artery or other, less invasive methods. One of our two proper hepatic artery aneurysm patients presented with a saccular aneurysm, and the other with a fusiform aneurysm at the bifurcation of the GDA; both were extrahepatic. The patient with the saccular aneurysm was treated by coil packing, and the other by isolation and packing with successful results.

Our study has some limitations. First, the small size of our study population precludes meaningful statistical analysis. Second, due to the retrospective nature of our study, we could not compare our treatment outcomes with those of other modalities used to address VAA including covered stent and surgical treatment, and percutaneous ablation. Further randomized trial may be indicated in the future. Third, our series did not include patients with ruptured VAA.

In conclusion, transcatheter coil embolization is an effective alternative treatment for patients with saccular and proximal VAA. In particular, the packing technique using coil embolization is advantageous in saccular artery aneurysm patients.

**AUTHOR CONTRIBUTIONS**

Conception and design: OI, YY
Analysis and interpretation: OI
Data collection: OI, YT, YN
Writing the article: OI
Critical revision of the article: OI
Final approval of the article: OI
Statistical analysis: OI
Obtained funding: OI
Overall responsibility: OI, YY

**REFERENCES**