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## Portal vein aneurysm-etiology, multimodal imaging and current management

Kurtcehajic A *et al* Portal vein aneurysm-un update

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### Abstract

6 Portal vein aneurysm (PVA) is a rare vascular abnormality, representing 3% of all venous aneurysms in the human body, and is not well understood. It can be congenital or acquired, located mainly at the level of confluence, main trunk, branches and bifurcation. A PVA as an abnormality of the portal venous system was first reported in 1956 by Barzilai and Kleckner. A review from 2015 entitled "Portal vein aneurysm: What to know" considered fewer than 200 cases. In the last seven years, there has been an increase in the number of PVAs diagnosed thanks to routine abdominal imaging. 3 The aim of this review is to provide a comprehensive update of PVA, including aetiology, epidemiology, and clinical assessment, along with an evaluation of advanced multimodal imaging features of aneurysm and management approaches.

**Key Words:** Aneurysm; Portal vein; Abdominal imaging; Treatment; Follow-up

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**Core Tip:** The number of reported portal vein aneurysms (PVAs) across the world with this review stands at about 280. In relation to a new acquired aetiology of PVA, the following conditions are noted: Budd-Chiari syndrome, splenomegaly in thalassaemia major, giant splenic artery aneurysm and a long-term cholelithiasis. Percentage of 30 to 50 of patients experienced non-specific abdominal pain, the most frequent

complications of PVA are thrombosis and biliopathy. Recently, endoscopic ultrasound and intraductal ultrasonography, as an additional tool have also been used for assessment of PVA in more detail. With this review we have highlighted treatment of PVA with comorbidities based on the transjugular intrahepatic portosystemic shunt, percutaneous approach, and endoscopic approach.

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## INTRODUCTION

A portal vein aneurysm (PVA) is the abnormal focal saccular or fusiform dilatation of the portal venous system, and it is defined as a PV diameter exceeding 19 mm in cirrhotic patients and 15 mm in a normal liver. It is a rare vascular abnormality, representing 3% of all venous aneurysms in the human body, and is not well understood<sup>[1-7]</sup>.

Douglass *et al*<sup>[8]</sup> studied 92 autopsies and reported that the diameter of the PV was between 0.64 mm and 12.1 mm in patients without cirrhosis and those without portal hypertension. In 1976, Doust *et al*<sup>[9]</sup> conducted a vascular study of 53 patients to assess the size of the PV and underlying liver status through abdominal ultrasound, and they detected that the maximum calibre of the PV was 19 mm in cirrhotic patients and 15 mm in patients with normal livers. Hence, a portal vein diameter of > 20 mm is universally regarded as the threshold for diagnosis of a PVA.

In a retrospective study by Koc *et al*<sup>[10]</sup>, involving 4186 patients who had undergone routine abdominal contrast-enhanced computed tomography (CT), the prevalence of PVAs was 0.43%. The location of a PVA can be extrahepatic or intrahepatic. Extrahepatic PVAs often occur in the main trunk of the PV, the splenomesenteric confluence, at the level of the PV bifurcation, the main branches of the PV, the splenic vein (SV) and the superior mesenteric vein (SMV). A study by Doust *et al*<sup>[9]</sup> characterized intrahepatic PVAs as having a diameter measuring more than 7 mm in normal patients and 8.5 mm in cirrhotic patients. PVA as an abnormality of portal venous system firstly was reported 1956 by Barzilai and Kleckner<sup>[11]</sup>. A review from

2015 entitled “Portal vein aneurysm: What to know” considered 96 reports and included 190 patients<sup>[1]</sup>.

Aiming to clarify novelty as regards this visceral vascular abnormality, we performed a literature search of the PubMed database for all articles relating to PVA between January 2015 and July 2022. We collected 57 reports, involving 62 patients with a PVA<sup>[3-7,12-16,19,21-25,27,29-68]</sup>; we also found one retrospective study with 18 PVA patients<sup>[2]</sup>, and three cases of PV pseudoaneurysm<sup>[69-71]</sup>.

## **ETIOLOGY, MULTIMODAL IMAGING AND CURRENT MANAGEMENT**

### ***Epidemiological characteristics***

Of the 62 patients in the review, 33 (53%) were male; the patients were between 1 (youngest) and 95 (oldest) years of age, and the mean patient age at diagnosis was 54.85 years ( $\pm 21.72$ ). A number of reported PVA cases per year is shown in Figure 1.

In terms of aetiology, the frequency of congenital PVAs was 29 (46.7%), and it was 17 (27.4%) for acquired PVAs. In 16 (25.8%) patients, the aetiology of the PVAs was unclear. Regarding the location of PVAs, 27.41% were at the level of the splenomesenteric confluence; 19.35% were at the main trunk; 17.74% were at branches; 6.45% were at the PV bifurcation; 6.45% were at the SV; and 4.83% were at the SMV; 14.51% were classified as intrahepatic PVAs. A retrospective study by Ahmed *et al*<sup>[2]</sup> included 18 patients [13 of whom were female (72.2%)], aged between 20 years and 101 years, with an average age of 56 years. Our review also covered three patients (all male) with a PV pseudoaneurysm resulting from trauma.

### ***Etiopathogenesis***

The aetiology of PVA is not clear. Postulated origins include both congenital and acquired causes. It is well known that the main cause of acquired PVA is chronic liver disease (cirrhosis and fibrosis) with portal hypertension. Long-standing portal hypertension causes intimal thickening with compensatory medial hypertrophy of the PV. Over time, medial hypertrophy is replaced by fibrous tissue, leading to weakening

of the vein wall, thus making it susceptible to aneurysmal dilatation<sup>[12,13]</sup>. However, the incidence of portal hypertension and PVA is disproportionate, suggesting the existence of other contributory factors.

Acquired PVA can also be part of severe acute pancreatitis, likely to be due to leakage of digestive enzymes, causing localized inflammation of the PV. Malignancy was also noted as a cause of acquired PVA<sup>[1]</sup>.

In several reports<sup>[69-71]</sup> a pseudoaneurysm of the PV is defined as post-traumatic (surgical pancreatic procedure, liver transplantation, or other rare clinical situations) uncommon finding (dilation) of the portal venous system. It is a serious condition followed life-threatening complications requiring an interventional approach.

In relation to a new acquired aetiology of PVA, the following conditions were noted: Budd-Chiari syndrome<sup>[14]</sup>, splenomegaly in thalassaemia major<sup>[15]</sup> and giant splenic artery aneurysm<sup>[16]</sup>. Long-term cholelithiasis was also considered as a possible cause of PVA<sup>[17]</sup>.

Some PVAs are congenital. During gestation, three pairs of veins are developed: the cardinal veins, umbilical veins and vitelline veins. The PV, hepatic veins and part of the inferior cava vein (ICV) come from umbilical veins and vitelline veins. Generally, cranial segments of the left vitelline vein and caudal segments of the right vitelline vein regress during the foetal period, and the SV and SMV are derived from the left vitelline vein<sup>[18]</sup>.

Evidence supporting a congenital cause includes reported cases of *in utero* diagnosis of PVA, evidence of PVA in patients with histologically proven normal livers (particularly in children and young adults), normal portal venous pressure in the presence of a PVA, and the frequent stability of aneurysms at follow-up imaging. Theories for a congenital cause involve inherent weakness in the vessel wall or incomplete regression of the distal right primitive vitelline vein, leading to a vascular diverticulum that ultimately develops into an aneurysm. Congenital PVAs are usually incidentally diagnosed later in life (not in neonatal or paediatric age groups) when an abdominal ultrasound is carried out because of some other indication<sup>[4,6,19]</sup>. Burdall *et*

*al*<sup>[20]</sup> evaluated the relation between trisomy 21 (Down's syndrome) and congenital vascular malformation of the liver in a study of 45 children, seven of whom had vascular malformation and two of whom had evidence of a PVA.

### ***Clinical presentation of patients with a PVA***

The clinical presentation of PVA is controversial and poorly understood. According to the review article by Laurenzi *et al*<sup>[1]</sup>, 30% of patients with a PVA <sup>1</sup> were asymptomatic, and 50% experienced non-specific abdominal pain. In our review, we found that up to 25% of patients were asymptomatic; for 15% of patients, the authors did not provide clear presenting symptoms relating to the PVA, and approximately 30% of patients experienced non-specific abdominal pain. In patients with a PVA, the nature of non-specific abdominal pain should be clarified. The main question is whether PVA low-pressure truly the source of the pain; gastritis, duodenitis and cholecystitis, *etc.*, should be ruled out. A retrospective study by Ahmed *et al*<sup>[2]</sup> showed that in eight (44.4%) patients with abdominal pain, a PVA was actually the source of the pain in only one patient.

Up to 10% of cases involve portal hypertension, gastrointestinal bleeding (varices) or presenting <sup>29</sup> symptoms related to compression of adjacent organs (abdominal swelling or jaundice)<sup>[1]</sup>. With a PVA, presenting symptoms or complications such as portal hypertension and bleeding are discussible. One thing that should be clarified is whether a PVA <sup>3</sup> is a consequence of portal hypertension or whether the PVA is causing portal hypertension. Khan *et al*<sup>[16]</sup> found coexistence of a giant splenic artery aneurysm, portal hypertension without liver cirrhosis and a PVA at the level of bifurcation. In this case, the PVA and portal hypertension were presumed to be secondary to the pressure effect from the splenic artery aneurysm. Güngör *et al*<sup>[21]</sup> presented an 11-mo-old girl with a congenital PVA, and oesophageal and fundal varices with bleeding. This was the only case in our review where PVA caused portal hypertension complications.

Clinical presentation has a close relation with morphology, size and location of the PVA. When it grows, there can be contact with the biliary tract, the ICV and duodenum,



*etc.*, and complications can arise from compression of these organs. Six patients in our review (9.67%) had compression complications, including four biliopathies<sup>[22-25]</sup>, one thrombosis in the ICV<sup>[7]</sup> and one intestinal obstruction<sup>[19]</sup>.

Laurenzi *et al*<sup>[1]</sup> reported PVA complications such as thrombosis (which happened in 20% of cases) and a rupture (which occurred twice). A recent retrospective study by Ahmed *et al*<sup>[2]</sup> reported 18 patients with a PVA; 22.22% of patients had thrombosis, and no ruptures were reported. PVA with a complication of thrombosis is reported in the literature as nearly always being symptomatic, with 91% of patients reporting abdominal pain, 53% reporting fever and 38% presenting with ascites<sup>[26]</sup>.

In our review, thrombosis occurred in 12 (19.35%) patients (six of whom were female), with a median age of 38.33 years. Abdominal pain was reported in 10 of 12 patients; in a one-year-old girl, the symptoms manifested as haematemesis and melena<sup>[21]</sup>; a 69-year-old female with a congenital PVA followed by thrombosis did not experience any symptoms<sup>[5]</sup>. In five patients, treatment was based on anticoagulation medication; seven patients underwent open surgery or invasive radiology procedures. In our review, a rupture as a complication of a PVA was not reported.

Patients with a PVA have a normal laboratory results, including complete blood count, inflammatory parameters, basic metabolic profile and liver function tests<sup>[1]</sup>.

### **Imaging of PVA**

Increased use of abdominal cross-sectional imaging in recent years has led to a growing number of cases describing PVA, and as such, proper handling of this lesion is increasingly relevant to both diagnostic and interventional radiologists. Evaluation of PVA by multiple imaging modalities is important because a PVA can mimic solid, cystic or hypervascular abdominal masses<sup>[1-7]</sup>.

Sonography assessment can be performed for differential diagnosis to determine whether anechoic area or cyst at porta hepatis are PVA, hepatic artery aneurysm or choledochal cyst. Abdominal ultrasound based on the greyscale of the PVA produces an anechoic structure with a “*smoke effect*” within, which simulates a natural contrast agent,

determined by slowed venous flow (Figure 2A). Spectral Doppler sonography reveals the presence of a monophasic, non-pulsatile venous flow pattern inside the aneurysm (Figure 2B). With colour Doppler sonography of a PVA, anechoic areas will be completely filled, looking like the Korean flag or a “yin-yang” sign. Hepatic artery aneurysms show a colour flow with arterial waveform, but choledochal cysts do not show such colour flow and are connected to biliary channels<sup>[6,15]</sup>.

Contrast-enhanced CT with angiography shows the filling of PVA. On a CT and magnetic resonance imaging (MRI) scan, a PVA will appear as a well-defined contrast-enhanced focal saccular anomaly or fusiform dilatation of the portal venous system during the portal venous phase<sup>[4,27]</sup>.

In one case, CT angiography facilitated better assessment of the portal venous system, which contained some thin calcifications in the aneurysmal wall and the main portal trunk<sup>[13]</sup>. Iimuro *et al*<sup>[28]</sup> presented “computational fluid dynamics software”, analyzing the haemodynamics of the portal venous system, including congenital saccular PVA at the level of confluence. Turbulent flow was obvious in PVA, and the wall shear stress against the upper-posterior part of the aneurysm wall was greater than in other parts of the aneurysm. In order to prevent the PVA from growing and avoid thrombosis or a rupture, an aneurysmectomy of the PVA was performed.

The diagnostic role of endoscopic ultrasound (EUS) was highlighted in congenital PVA at the level of the splenomesenteric confluence. EUS confirmed the presence of anechoic lesions adjacent to the neck of the pancreas<sup>[29]</sup>. EUS as a diagnostic tool was also used for assessment of an intrahepatic aneurysmal portosystemic venous shunt<sup>[30]</sup>.

“Intraductal ultrasonography” (IDU) was used for the first time to identify an adjacent PVA as the cause of a common hepatic duct stricture, showing a lobulated hypoechoic mass containing a mobile echogenic substance, outside of the biliary tract, highly suggestive of a vascular lesion<sup>[24]</sup>.

### ***Management and treatment of PVA***



Because of their <sup>6</sup> rarity, the natural history of PVA remains unclear, and the optimal strategy for management is controversial. Following diagnosis of a PVA, treatment will depend on the size, presenting symptoms and location of the PVA, and comorbidities.

If the PVA is asymptomatic (as in 30% of cases), it does not require any <sup>17</sup> active treatment, and monitoring (a policy of “wait and see”) should be adopted<sup>[1]</sup>. While asymptomatic aneurysms smaller than 30 mm can be clinically observed, surgical intervention may be necessary in large asymptomatic aneurysms (> 30 mm)<sup>[1,10]</sup>. The origin, morphology and symptomatology of a PVA, along with comorbidities and conservative treatment, are shown in Table 1.

Where there is thrombosis due to a PVA, anticoagulation treatment should be considered. In a recently published case, a 10-year-old boy with PVA thrombosis was treated with enoxaparin. The thrombosis disappeared completely after 6 mo<sup>[31]</sup>. In a case involving biliopathy, where the PVA comprised hepatic ducts, ursodeoxycholic acid was used to decrease the level of conjugated bilirubin<sup>[22]</sup>.

<sup>9</sup> While, in some studies, a CT scan every 12 mo was the preferred monitoring strategy, most published studies indicate that sonography is <sup>9</sup> the preferred imaging technique for monitoring PVA growth, as it is relatively inexpensive and does not involve radiation exposure<sup>[32]</sup>.

**Open surgery approach:** If the PVA is growing and constricting adjacent organs, thrombosis occurs, aiming to prevent potential rupture, open surgery <sup>8</sup> methods should be considered. An aneurysmectomy for fusiform aneurysms (aneurysm resection, followed by insertion of a synthetic or cadaveric graft as a replacement conduit) and an <sup>31</sup> aneurysmorrhaphy for saccular aneurysms (restores the normal diameter of the portal vein, if the remaining venous wall is of good quality) are considered for symptomatic aneurysms and to prevent a negative PVA prognosis.

The origin, morphology, PVA symptomatology and comorbidities as regards invasive treatment are shown in Table 2.

Fleming *et al*<sup>[33]</sup> demonstrated the efficacy of open surgery (aneurysmectomy) in three cases (two patients with an autograft and one with ePTFE). The two women with an autogenous graft remained asymptomatic at 85 mo and 65 mo, respectively; the third woman with ePTFE got thrombosis during pregnancy. The same report also included an aneurysmorrhaphy as the chosen treatment in one woman with a PVA.

Kim *et al*<sup>[34]</sup> presented a case with a PVA at the level of the main trunk, growing and with thrombosis complications. An aneurysm excision with an interposition bypass was successfully performed. The patient's postoperative recovery was rapid and uneventful, with normal portal flow revealed by colour Doppler ultrasonography and a contrast-enhanced CT scan.

Khan *et al*<sup>[16]</sup> presented a case where splenomegaly, a giant splenic artery aneurysm and a PVA were found to coexist. The patient underwent a splenectomy and excision of the splenic artery aneurysm. It was determined that her PVA shrank considerably. Das *et al*<sup>[15]</sup> presented a case with thalassaemia major, splenomegaly and a PVA. After a splenectomy (necessitated by the existence of hypersplenism), the PVA significantly reduced.

Chadha *et al*<sup>[35]</sup> reported the case of a 66-year-old male with an acquired SV aneurysm and described novel use of a "Sundt external carotid endarterectomy shunt" as a temporary portacaval shunt to control portomesenteric hypertension, before transplantation of the liver. A giant SV aneurysm 98 mm in size developed as a consequence of a splenectomy, an arteriovenous fistula and portal hypertension; this aneurysm was treated successfully with open surgery<sup>[36]</sup>.

Male and female patients, both of whom had a congenital PVA and subsequent thrombosis complications, were treated with a hybrid operative repair involving a transhepatic catheter thrombectomy, and their aneurysms were operated on in open surgery<sup>[25,37]</sup>.

The limited number of PVAs that have been reported means that there are no clear indications for open surgery on PVA. Koc *et al*<sup>[10]</sup> studied the size of PVA and concluded that aneurysms larger than 30 mm should be surgically treated with the aim of

preventing thrombosis or rupture. On the other hand, a recently reported case of a patient with a congenital PVA 35 mm in size, with subsequent thrombosis complications, showed spontaneous resolution after 10 years<sup>[5]</sup>.

Sura *et al*<sup>[38]</sup> reported the case of an 80-year-old man who had open surgery on a 37-mm PVA at the level of the main trunk. The reasons for PVA surgery were not postulated, but given the congenital origin, advanced age of the patient and absence of symptoms or thrombosis, it is our view that surgery was not the best treatment choice.

**Interventional radiology procedures:** In cases where a PVA is a consequence of portal hypertension and/or coexists with life-threatening conditions (injuries), the high risk associated with open surgery methods means that interventional radiology procedures *via* a percutaneous approach, endovascular approach and even more endoscopic approach should be considered<sup>[1,2]</sup>.

**Percutaneous approach:** Shukla *et al*<sup>[39]</sup> successfully demonstrated percutaneous embolization of a saccular intrahepatic PVA, which prevented further growth or other clinical sequelae. Shrivastava *et al*<sup>[27]</sup> presented the largest intrahepatic PVA and the first case where the endovascular technique was used for treatment of the same. Under sonography and fluoroscopy guidance, the PVA was directly punctured with an 18G needle and embolized with a Lipiodol-Glue combination.

Juscafresa *et al*<sup>[40]</sup> reported the case of an elderly female treated for an acquired SV aneurysm 45 mm in size, through a transhepatic percutaneous approach, using a Viabahn covered stent. Marmor *et al*<sup>[41]</sup> presented the case of a patient with a congenital SV aneurysm 40 mm in size. Because the aneurysm was getting larger, it was treated with an expandable stent *via* a transhepatic approach.

In one case, after liver transplantation necessitated by HCV cirrhosis, the patient subsequently developed an arterioportal fistula with an intrahepatic PVA. The first step of the treatment was transarterial embolization, and the second step was stent graft exclusion of the PVA. As there was leakage, the patient underwent liver re-

transplantation<sup>[42]</sup>. Oguslu *et al*<sup>[43]</sup> demonstrated two techniques for treatment of an arterioportal fistula with a giant saccular PVA at the level of the left branch. After failure of an endovascular approach due to tortuosity and angulation of the celiac artery, access to the hepatic artery was obtained directly via a percutaneous transhepatic route, and the fistula site was embolized with an Amplatzer Vascular Plug II and coils.

**Treatment of portal vein pseudoaneurysm:** Our review covered three patients (all males) with a PV pseudoaneurysm, all of which were a consequence of abdominal trauma or injury. In a patient with a traumatic pseudoaneurysm at the level of the splenomesenteric confluence, Ierardi *et al*<sup>[69]</sup> demonstrated a novel management strategy with a percutaneous transhepatic self-expanding stent graft.

A patient with a PV pseudoaneurysm at the level of the main trunk, resulting from invasive medical procedures [*e.g.*, a percutaneous biopsy or endoscopic retrograde cholangiopancreatography (ERCP)] to address lymphomatous infiltration of the pancreatic head (with symptoms of haemobilia), was treated using percutaneous transhepatic covered stenting<sup>[70]</sup>.

In the last case, involving a patient with a pseudoaneurysm of the portal venous system resulting from a motor vehicle collision, the patient was brought into the emergency department with diffuse abdominal pain and bowel shock. Unfortunately, the patient soon succumbed to his injuries<sup>[71]</sup>.

**Endovascular approach:** Gaining access to the treatment zone can be challenging, and the target vessel may have tortuosity and elongation due to haemodynamic changes created by the hyperdynamic flow. Kimura *et al*<sup>[44]</sup> presented a case involving a hepatectomy (hepatocellular carcinoma), where the patient subsequently developed an arterioportal fistula with hepatofugal flow and a 40-mm-diameter PVA. After selective embolization of the anterior hepatic artery, the PVA disappeared, and portal flow was normalized.



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An endovascular approach includes creation of a transjugular intrahepatic portosystemic shunt (TIPS). In patients with portal hypertension, an attempt may be made to decrease portal venous pressure in order to reduce the size of the aneurysm. Our review covered four patients with a PVA where the treatment of choice was a TIPS. Tsao *et al*<sup>[14]</sup> presented a case involving a PVA resulting from portal hypertension associated with Budd-Chiari syndrome. For the first time, a TIPS was created without complications. The patient's abdominal pain completely ceased within two days, and she remained asymptomatic during the one-year follow-up. Ding *et al*<sup>[45]</sup> presented a case with a PVA at the level of bifurcation, with comorbidities such as portal hypertension, liver cirrhosis and HBV chronica. A TIPS successfully decreased the patient's portal hypertension and reduced the size of the PVA from 53 mm × 76 mm to 23 mm × 25 mm. Two years later, a CT scan and digital subtraction angiography revealed that the aneurysm had disappeared. The patient remained asymptomatic for 72 mo<sup>[45]</sup>. Dunlap *et al*<sup>[46]</sup> also used a TIPS successfully to treat a PVA resulting from portal hypertension and liver cirrhosis. Kohlbrenner *et al*<sup>[47]</sup> demonstrated transhepatic pharmacomechanical thrombolysis of a large thrombosed PVA. 2  
This was followed by insertion of a TIPS, along with an additional trans-TIPS thrombectomy to improve sluggish portal outflow and prevent re-thrombosis. Nine months later, an MRI showed complete resolution of the thrombosis.

**Endoscopic approach via ERCP:** In older patients with a PVA and complication of biliopathy and jaundice, ERCP with biliary stenting can be an appropriate treatment choice. 1  
In an 80-year-old male with liver cirrhosis and portal hypertension, an acquired PVA at the level of the left branch was found. The patient had developed biliopathy due to compression of the common bile duct; this complication was successfully treated endoscopically via ERCP with a biliary stent<sup>[23]</sup>. Sun *et al*<sup>[24]</sup> reported the case of an 85-year-old man with cholangitis complications from PVA-induced compression. Given the age of the patient, surgery was not considered, and instead an ERCP biliary stent was deployed several times.



## CONCLUSION

PVA is a rare morphological abnormality of the portal venous system, accounting for 3% of all venous aneurysms in the human body. The number of reported PVAs across the world now stands at about 280: The 200 PVAs covered in the previous review published in 2015<sup>[1]</sup>, the 18 cases in the retrospective study<sup>[2]</sup> and the 62 PVAs in our review covering the last seven years. PVA can be congenital or acquired, located mainly at the level of confluence, main trunk, branches and bifurcation. Up to 30% of patients can be asymptomatic, and non-specific abdominal pain should be investigated to exclude other pathological causes, such as cholecystitis or peptic ulcer disease, *etc.* Thrombosis complications occur in approximately 19%-23% of patients, and biliopathy occurs in approximately 4%-6% of patients. Other complications can also arise from compression due to a PVA, including thrombosis of the ICV and intestinal obstruction. Diagnosis of a PVA is based on spectral and colour Doppler sonography, and CT and MRI. EUS and IDU have also been used as a diagnostic tool. If a PVA is asymptomatic, it does not require any active treatment, and monitoring (a policy of “wait and see”) should be adopted. The first choice for treatment of PVA thrombosis is anticoagulation medication. If the PVA is getting larger and compressing adjacent organs, thrombosis will occur, so to prevent a potential rupture, open surgery methods such as an aneurysmectomy or an aneurysmorrhaphy should be considered. Given the risk associated with open surgery methods, interventional radiology procedures *via* a percutaneous approach, endovascular approach or, better still, an endoscopic approach should be considered for cases where a PVA is a consequence of portal hypertension and/or coexists with life-threatening conditions (injuries).

### **Figure Legends**

**Figure 1 Number of reported portal vein aneurysms per year, from January 2015 until December 2021.** PVA: Portal vein aneurysms.

**Figure 2 Sonography assessment of portal vein aneurysm.** A: Abdominal ultrasound shows portal vein aneurysms (PVA) at the level of bifurcation; B: Spectral Doppler sonography shows nonpulsatile <sup>23</sup> blood flow through the portal venous system with PVA.

Table 1 Clinical features of the patients with portal vein aneurysm, regards the conservative treatment

| Year | Ref.                          | Gender | Age | Etiology   | Location              | Morphology/size      | Symptomatology     | Complications   | Comorbidity            | Imaging     | Treatment        | Follow-up |
|------|-------------------------------|--------|-----|------------|-----------------------|----------------------|--------------------|-----------------|------------------------|-------------|------------------|-----------|
| 2015 | Prabhakar <i>et al</i> [48]   | Male   | 47  | None       | Intrahepatic, left br | 18 mm                |                    |                 | Shunt                  | CT          | Surveillance     | Alive     |
| 2015 | Srikanth <i>et al</i> [49]    | Female | 12  | Congenital | Right branch          | Saccular             |                    |                 |                        | US, CT      | Surveillance     |           |
| 2015 | Starikov <i>et al</i> [50]    | Male   | 27  | None       | SMV aneurysm          | 86 mm                | Abdominal pain     | Thrombosis CTPV | Acute pancreatitis     | CT, MRI     | Anticoagulation  | 24 mo     |
| 2016 | Gaba <i>et al</i> [3]         | Female | 61  | None       | Confluence            | 50 mm                |                    |                 | Ca colon; surgery      | US, CT      | Surveillance     |           |
| 2016 | Hanafiah <i>et al</i> [12]    | Male   | 70  | Acquired   | Right branch          | Fusiform, 22 mm      |                    |                 | HBV; cirrhosis, HCC    | US, CT      | No treatment     | Died      |
| 2016 | Nayman <i>et al</i> [51]      | Female | 48  | Congenital | Intrahepatic, two br  | Right 43, left 13 mm | Abdominal pain     |                 |                        | US, CT      | Surveillance     |           |
| 2016 | Kurtcehajic <i>et al</i> [22] | Female | 75  | Congenital | Bifurcation           | Saccular             | Jundice            | Biliopathy      |                        | US, CT, MRI | Usodeoxolic acid | Alive     |
| 2016 | Khairallah <i>et al</i> [13]  | Female | 68  | Acquired   | Bifurcation           | Fusiform, 40 mm      | Bleeding           |                 | Cirrhosis; portal Hyp  | US, CT      | No treatment     |           |
| 2017 | Jaiswal <i>et al</i> [52]     | Female | 59  | Congenital | Confluence            | 53.7 mm              | Abdominal pain     |                 | Cholelithias           | US, CT      | Surveillance     | 18 mo     |
| 2017 | Guilbaud <i>et al</i> [53]    | Male   | 88  | Congenital | Main trunk            | Saccular, 59 mm      |                    |                 | Cholecystectomy        | CT          | Surveillance     |           |
| 2018 | Maia <i>et al</i> [54]        | Female | 67  | Congenital | Main trunk            | 35 mm                | Abdominal pain     |                 | Diabetes, arterial Hyp | US, CT      | Surveillance     | 12 mo     |
| 2018 | Ashmore <i>et al</i> [55]     | Female | 62  | None       | Confluence            |                      | Abdominal pain     |                 |                        | CT          | Surveillance     |           |
| 2018 | Martínez <i>et al</i> [56]    | Female | 29  | Congenital | Left branch           | Saccular, 28 mm      |                    |                 |                        | US, CT      | Surveillance     |           |
| 2018 | Hirji <i>et al</i> [57]       | Male   | 62  | Congenital | Confluence            | 50 mm                |                    |                 | Diabetes, Parkinson    | CT          | Surveillance     | 6 mo      |
| 2018 | Alur <i>et al</i> [58]        | Female | 45  | Congenital | Left branch           | 21.5 mm              |                    |                 |                        | US, MRI     | Surveillance     |           |
| 2018 | Chaubard <i>et al</i> [59]    | Male   | 66  | Congenital | Confluence            | Saccular, 40 mm      | Abdominal pain     |                 | T-cell hemopathy       | US, CT      | Surveillance     |           |
| 2019 | Ramamoorthy <i>et al</i> [60] | Female | 42  | Congenital | Confluence            | Fusiform, 26 mm      | Abdominal pain     |                 |                        | US, MRI     | Surveillance     | Alive     |
| 2019 | De Vloo <i>et al</i> [4]      | Male   | 67  | None       | Confluence            | Fusiform, 55 mm      | Abdominal pain     | Thrombosis CTPV | Neuroendocrinem        | US, CT      | Anticoagulation  |           |
| 2020 | Kabir <i>et al</i> [61]       | Male   | 77  | Congenital | Intrahepatic, left br | 28 mm                | Abdominal Pain     |                 | Abd. aortic aneurysm   | US, MRI     | Surveillance     | 3 mo      |
| 2020 | Rana <i>et al</i> [29]        | Female | 51  | Congenital | Confluence            | 38 mm                | Abdominal pain     |                 |                        | US, EUS, CT | Surveillance     | 30 mo     |
| 2020 | Shams <i>et al</i> [62]       | Male   | 67  | None       | SMV aneurysm          |                      | Abdominal pain     | Thrombosis      |                        | US, EUS, CT | Anticoagulation  | 12 mo     |
| 2020 | Watanabe <i>et al</i> [5]     | Female | 69  | Congenital | Right branch          | 35 mm                |                    | Thrombosis      |                        | US, CT      | Surveillance     | 120 mo    |
| 2020 | Schilardi <i>et al</i> [6]    | Male   | 86  | Congenital | Right branch          | 55 mm                |                    |                 | Heart failure; COPD    | US, CT      | Surveillance     | 24 mo     |
| 2021 | Hernando <i>et al</i> [63]    | Female | 51  | Congenital | Right branch          | 25 mm                | Abd. pain, jundice |                 |                        | US, MRI     | Surveillance     |           |
| 2021 | Priadko <i>et al</i> [32]     | Male   | 81  | Acquired   |                       | 48 mm                |                    |                 | Cholelithias           | US          | Surveillance     | 36 mo     |

|      |   |        |    |            |                        |                 |  |  |                   |                        |              |                 |
|------|---|--------|----|------------|------------------------|-----------------|--|--|-------------------|------------------------|--------------|-----------------|
| 2021 | Tan <i>et al</i> <sup>[64]</sup>          | Female | 52 | None       | Saccular, 42.3 mm      |                 |  |  |                   | US, CT, MRI            | Surveillance | 60 mo           |
| 2021 | López <i>et al</i> <sup>[65]</sup>        | Male   | 73 | None       | Intrahepatic, right br | 27 mm           |  |  |                   | US                     | Surveillance | 12 mo           |
| 2021 | Tan <i>et al</i> <sup>[64]</sup>          | Male   |    | Congenital | Main trunk             | 26 mm           |  |  |                   | CT                     | Surveillance | Alive           |
| 2021 | López <i>et al</i> <sup>[65]</sup>        | Female | 41 | None       | SMV aneurysm           | 43 mm           |  |  | Abdominal pain    | Splenorenal shunt      | CT           | Surveillance    |
| 2022 | Tri <i>et al</i> <sup>[31]</sup>          | Male   | 10 | Congenital | Main trunk             | 36 mm           |  |  | Abdominal pain    | Thrombosis             | CT           | Anticoagulation |
| 2022 | Villani <i>et al</i> <sup>[66]</sup>      | Male   | 73 | Acquired   | Main trunk             | Saccular, 40 mm |  |  |                   | Cirrhosis, ascites     | US, CT       | Surveillance    |
| 2022 | Mortazavi <i>et al</i> <sup>[67]</sup>    | Male   | 49 | Congenital | Main trunk             | 21 mm           |  |  | Abdominal pain    | Cholelithias           | CT           | Surveillance    |
| 2022 | Mohamadnejad <i>et al</i> <sup>[30]</sup> | Female | 76 | None       | Intrahepatic, left br  | 25 mm           |  |  |                   | Aneurysm, shunt        | CT, EUS      | Surveillance    |
| 2022 | Kanamalla <i>et al</i> <sup>[7]</sup>     | Male   | 95 | Congenital | Confluence             | Saccular, 35 mm |  |  | Thrombosis of IVC | Diabetes, arterial Hyp | CT           | Anticoagulation |

abd: Abdomen; br: Branch; Ca: Carcinoma; COPD: Chronic obstructive pulmonary disease; CT: Computed tomography; CTPV: Cavernous transformation of the portal vein; EUS: Endoscopic ultrasound; HBV: Hepatitis B virus; HCC: Hepatocellular carcinoma; Hyp: Hypertension; IVC: Inferior cava vein; MRI: Magnetic resonance imaging; SMV: Superior mesenteric vein; tm: tumor; US: Ultrasound.

**Table 2 Clinical features of the patients with portal vein aneurysm, regards the surgery/invasive treatment**

| Year | Ref.                                 | Gender | Age | Etiology     | Location        | Morphology /size    | Symptomatology | Complications   | Comorbidity             | Imaging | Treatment             | Follow-up |
|------|--------------------------------------|--------|-----|--------------|-----------------|---------------------|----------------|-----------------|-------------------------|---------|-----------------------|-----------|
| 2015 | Fleming <i>et al</i> <sup>[33]</sup> | Female | 70  | None         | Confluence, SMV | From 30 mm to 50 mm |                |                 |                         | CT      | Aneurysmectomy        | 85 mo     |
|      |                                      | Female | 47  | None         | Confluence, SMV | From 35 mm to 60 mm | Abdominal pain |                 | HCV                     | US, CT  | Aneurysmectomy        | 65 mo     |
|      |                                      | Female | 29  | None         |                 | 40 mm               | Abdominal pain | Thrombosis/CTPV |                         | CT      | Aneurysmectomy        | 144 mo    |
|      |                                      | Female | 49  | None         | Confluence, SMV | 40 mm               | Abdominal pain |                 |                         |         | Aneurysmorrhaphy      | 17 mo     |
| 2015 | Tsauo <i>et al</i> <sup>[14]</sup>   | Female | 65  | Acquired     | Right branch    | Saccular, mm        | Abdominal pain |                 | Budd Chiari Sy          | CT      | TIPS                  | 12 mo     |
| 2016 | Khan <i>et al</i> <sup>[16]</sup>    | Female | 40  | Acquired     | Bifurcation     | 34 mm               |                |                 | Splenic artery aneurysm | US, CT  | Aneurysmectomy        | Alive     |
| 2016 | Ierardi <i>et al</i> <sup>[69]</sup> | Male   | 42  | Car accident | Confluence      | PSA, 23 mm          | Abdominal pain |                 | Liver trauma            | CT      | Expanding stent graft | 13 d      |

|      |  |        |    |                   |                         |                               |                     |                              |             |                        |       |
|------|--|--------|----|-------------------|-------------------------|-------------------------------|---------------------|------------------------------|-------------|------------------------|-------|
| 2016 | Shukla <i>et al</i> <sup>[39]</sup>      | Male   | 55 | None              | Intrahepatic, right br  | Saccular, 30 mm               |                     | Sigmoid hemicolectomy        | CT          | Percut embolisation    | Alive |
| 2017 | Shrivastava <i>et al</i> <sup>[27]</sup> | Male   | 55 | Acquired          | Intrahepatic, right br. | 62 mm                         |                     | Portal Hyp, pancreatitis     | US, CT      | Percut embolisation    | 12 mo |
| 2017 | Ding <i>et al</i> <sup>[43]</sup>        | Male   | 48 | Acquired          | Bifurcation             | 70 mm                         |                     | HBV, cirrhosis               | CT          | TIPS                   | 72 mo |
| 2017 | Kim <i>et al</i> <sup>[34]</sup>         | Female | 34 | Congenital        | Main trunk              | Fusiform, from 57 mm to 62 mm | Abdominal pain      | Thrombosis                   |             | Aneurysmectomy         | 6 mo  |
| 2017 | Das <i>et al</i> <sup>[15]</sup>         | Female | 18 | None              | Confluence              | Fusiform, 30 mm               |                     | Thalassemia major            | US, CT      | Splenectomy            |       |
| 2017 | Ding <i>et al</i> <sup>[23]</sup>        | Male   | 80 | Acquired          | Left branch             | Fusiform                      | Abd. pain, jaundice | Cirrhosis, portal Hyp.       | US, CT, MRI | ERCP, biliary stent    | 3 mo  |
| 2018 | Walton <i>et al</i> <sup>[70]</sup>      | Male   | 42 | Percut Biopsy     | Main trunk              | PSA, 13 mm                    | Haemobilia          | Lymphomatousus of pancreas   |             | Percut, covered stent  |       |
| 2018 | Kimura <i>et al</i> <sup>[44]</sup>      | Male   | 62 | Acquired          | Branch                  | 40 mm                         |                     | HCV, HCC, art portal fistula | MRI         | Selective embolisation |       |
| 2018 | Sun <i>et al</i> <sup>[24]</sup>         | Male   | 85 | Congenital        | Main trunk              | 32 mm                         | Abdominal pain      | Diabetes, ulcer disease      | IDUS, CT    | ERCP, biliary stent    | 42 mo |
| 2018 | Chandran <i>et al</i> <sup>[19]</sup>    | Male   | 1  | Congenital        |                         |                               |                     |                              |             | Ligation of PVA        | 3 mo  |
| 2018 | Chadha <i>et al</i> <sup>[35]</sup>      | Male   | 66 | Acquired          | SV aneurysm             | 39 mm                         | Colonic obstruction | HCV, cirrhosis               |             | External carotid shunt | 6 mo  |
| 2018 | Güngör <i>et al</i> <sup>[21]</sup>      | Female | 1  | Congenital        | Intrahepatic, right br  | Fusiform                      | Hematemesis, melena | Portal Hyp, thrombosis       | US, CT      | Sugiura oper           |       |
| 2018 | Ktenidis <i>et al</i> <sup>[36]</sup>    | Male   | 43 | Acquired          | SV aneurysm             | 98 mm                         |                     | Splenectomy, AV shunt        | CT          | Open surgery           | Alive |
| 2019 | Cleveland <i>et al</i> <sup>[71]</sup>   | Male   | 68 | Vehicle collision |                         | PSA                           | Abdominal pain      | Shock bowel                  | CT          |                        | Dead  |
| 2019 | Juscafresa <i>et al</i> <sup>[40]</sup>  | Female | 77 | Acquired          | SV aneurysm             | 45 mm                         |                     | Pancreatitis                 | CT          | Percut, Viabahn stent  | 12 mo |



|      |   |        |    |            |                        |                               |                |                        |                                 |                      |                             |       |
|------|---|--------|----|------------|------------------------|-------------------------------|----------------|------------------------|---------------------------------|----------------------|-----------------------------|-------|
| 2019 | Bremer <i>et al</i> <sup>[42]</sup>     | Male   | 65 | Acquired   | Intrahepatic, right br | 64 mm                         | Abdominal pain |                        | Cirrhosis, transplantation      | TAE, graft exclusion | stent                       | 6 mo  |
| 2019 | Oguslu <i>et al</i> <sup>[43]</sup>     | Female | 58 | Acquired   | Left branch            | Saccular, 130 mm              | Abdominal pain | Thrombosis             | Art. portal fistula, portal Hyp | US, CT               | Percut embolisation         | 9 mo  |
| 2020 | Field <i>et al</i> <sup>[25]</sup>      | Male   | 25 | Congenital | Main trunk             | 55 mm                         | Abdominal pain | Biliopathy, thrombosis |                                 | CT, MRI              | Thrombolysis, thrombectomy  | 12 mo |
| 2021 | Sura <i>et al</i> <sup>[38]</sup>       | Male   | 80 | Congenital | Main trunk             | Saccular, 37 mm               |                |                        | Diaphragmatic hernia            | CT                   | Open surgery                | 6 mo  |
| 2021 | Marmor <i>et al</i> <sup>[41]</sup>     | Male   | 67 | Congenital | SV aneurysm            | Saccular, 40 mm               |                |                        | Ca bladder                      | CT                   | Balloon expandable stent    | 12 mo |
| 2021 | Matsumoto <i>et al</i> <sup>[68]</sup>  | Male   | 75 | Acquired   | Main trunk             | 42 mm                         | Abdominal pain |                        | Ca pancreas                     | CT                   | Open surgery, omental graft | 3 mo  |
| 2021 | Gorolay <i>et al</i> <sup>[37]</sup>    | Female | 36 | Congenital | Confluence             | Saccular, from 45 mm to 65 mm | Abdominal pain | Thrombosis             |                                 | US, CT               | Hybrid operative repair     | 36 mo |
| 2021 | Dunlap <i>et al</i> <sup>[46]</sup>     | Male   | 32 | Acquired   | Confluence             | From 52 mm to 57 mm           |                |                        | Cirrhosis, portal Hyp           |                      | TIPS                        | 6 mo  |
| 2022 | Kohlbrener <i>et al</i> <sup>[47]</sup> | Male   | 37 | Congenital | Confluence             | Fusiform, 51 mm               | Abdominal pain | Thrombosis, ischemia   |                                 | CT                   | Thrombolysis, TIPS          | 24 mo |

Abd: Abdomen; art: Artery; br: Branch; Ca: Carcinoma; CT: Computed tomography; CTPV: Cavemous transformation of the portal vein; ERCP: Endoscopic retrograde cholangiopancreatography; HBV: Hepatitis B virus; HCC: Hepatocellular carcinoma; HCV: Hepatitis C virus; Hyp: Hypertension; IDUS: Intraductal ultrasonography; MRI: Magnetic resonance imaging; percut: percutaneous; PSA: Pseudoaneurysm; PVA: Portal vein aneurysm; SMV: Superior mesenteric vein; SV: Splenic vein; Sy: Syndrome; TAE: Transarterial embolisation; TIPS: Transjugular intrahepatic portosystemic shunt; US: Ultrasound.

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