Chapter 12
Portal Vein Hemodynamics: 3DCT

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Abstract In patients with portal hypertension, portosystemic venous collateral pathways are frequently formed. Three-dimensional computed tomography (3DCT) using multidetector computed tomography (MDCT) is one of the most important modalities for detecting collaterals because of its high resolution and whole body scanning features. The method of constructing 3DCT images and representative collateral pathways are described in this chapter.

Keywords 3DCT · MDCT · Portosystemic shunt · Collaterals

12.1 Significance of Portal Vein Collaterals in Portal Hypertension

12.1.1 Portal Hypertension and Portosystemic Collaterals

Portosystemic venous collateral pathways are frequently formed as a result of portal hypertension. The presence of these portal collaterals is usually evidence of portal hypertension. A famous physical finding is distended varicose veins of the abdominal wall, known as a caput medusae. Esophageal varices may be interpreted as collaterals in the hemiazygos venous system. In addition, numerous microcollaterals in the liver that do not supply the liver lobules in the setting of liver cirrhosis or idiopathic portal hypertension can also be considered to be part of the portosystemic collateral circulation.

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12.1.2 Portal Vein Collaterals: A Historical Background

Surgeons in the 1950s [1] identified apparent collaterals (Fig. 12.1) during selective shunt surgery. Prof. Lunderquist in Sweden first performed percutaneous transhepatic portography (PTP) [2] in the early 1960s without laparotomy. PTP involved forcibly injecting contrast medium through a catheter inserted through the portal vein, allowing for detection of all small vessels in the abdominal cavity. The locations of collaterals identified by PTP are shown in Table 12.1. However, PTP is invasive in nature, so it has not been widely used in Japan. The 1990s saw the introduction of multidetector computed tomography (MDCT), which is minimally invasive and involves short examination times. During one breath hold, MDCT can scan not only the thorax but also the abdomen. Further, advanced computer processing methods make 3D analysis possible, and many software programs to perform the analysis have become available.

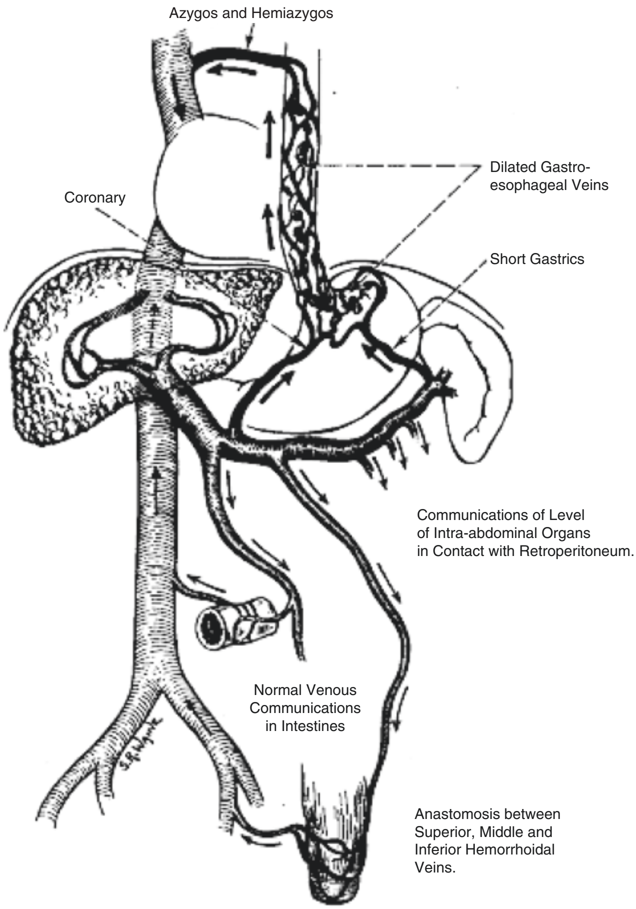


Fig. 12.1 Portosystemic shunts classified by surgeons [1]

Table 12.1 Portosystemic collaterals in 93 cases revealed by percutaneous transhepatic portography (PTP) [2]

Left gastric vein	80	Left inferior phrenic vein	16
Short gastric veins	54	Spleno-gastro-renal collaterals	24
Esophageal veins	82	Para-umbilical vein	27
Para-esophageal veins	27	Inferior mesenteric vein	55
Upper splenic hilum veins	11	Colon veins	22
Lower splenic hilum veins	24	Retroperitoneal veins	28
Right intercostal veins	3	Inferior epigastric veins	8
Left intercostal veins	21	Posterior pancreatico-duodenal vein	25
Diaphragm veins	8	Anterior pancreatico-duodenal vein	11
Mediastinal veins	15	Azygos/hemiazygos veins	18

12.1.3 Method of Obtaining MDCT Images of the Collateral Circulation

Over a period of about 50 s, 100 mL of nonionic contrast media is infused into a peripheral vein with a dedicated injector using a needle thicker than 20 G. Fifty-five seconds after the end of the infusion, during the portal phase, images are obtained from 1-mm-thick slices captured from the chest to the pelvis. Because breath-holding with deep inspiration is required, patients with impaired consciousness cannot be examined.

MDCT should use 16 or more detector rows. In recent years, MDCT with 126 rows has become available, and as a result, shorter imaging times are now possible.

12.1.4 Method of Reconstructing 3DCT Images with the Image Processing Software "ZAIO"

Data stored in pixels are reconstructed using several imaging technologies and visualized as 3DCT images. Several reconstruction methods are available, including volume rendering (VR) and maximum intensity projection (MIP) with colorization. The tracing function for small vessels is also useful to track small and winding veins, but such reconstruction is time-consuming. Blood vessels in 3DCT images should be detected along with the surrounding organs. In order to do so, a single cross section is obtained by multi-planar reconstruction (MPR) as described in the figures below ("Mishuku Hospital Method" [3]). In our implementation of 3DCT, we chose to display the bones along with other structures in order to clarify the spatial orientation. A 3DCT image of esophageal varices and the portal venous

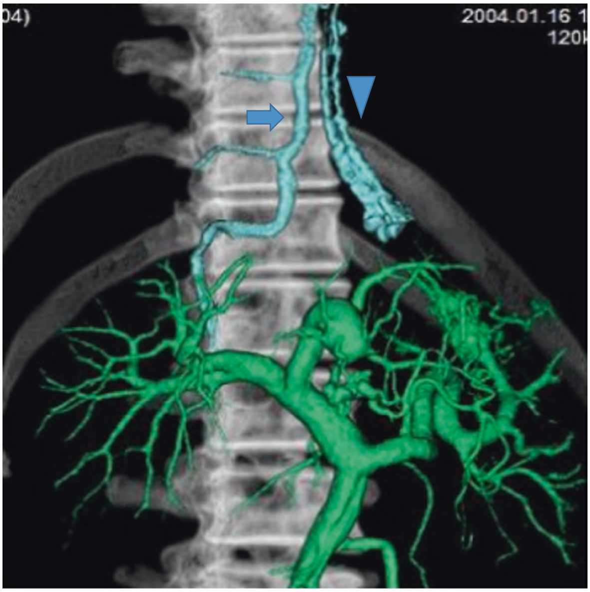


Fig. 12.2 3DCT image of esophageal varices

system is displayed in Fig. 12.2. In the frontal view, esophageal varices can be visualized as tortuous vessels (arrowhead) in front of the vertebra. The blood supply route of the esophageal varices is not clear in Fig. 12.2. The hemiazygos vein (arrow) is visualized near the esophageal varices and is thought to be the drainage pathway. The relative positional relationship between the blood vessels and the stomach or esophagus is difficult to grasp in Fig. 12.2. To clarify this relationship, we resynthesized the MPR image on the same screen (Fig. 12.3). Creating this type of composite image by selecting appropriate cases contributes greatly to attaining an accurate diagnosis.

12.2 Typical Images of the Portal Circulation Collaterals

The collateral circulation revealed by 3DCT is described in this chapter according to the classification of the Japan Society for Portal Hypertension [4], as this system is useful for treatment purposes.

12.2.1 Abdominal Wall Venous System

Paraumbilical veins in the portal venous umbilical region in the left hepatic lobe form shunts extending into veins of the abdominal wall. In the case shown in Fig. 12.4, the abdominal wall veins that act as drainage veins exist on the right and left and can be shallow or deep. A large, deep, tortuous vein on the right abdominal

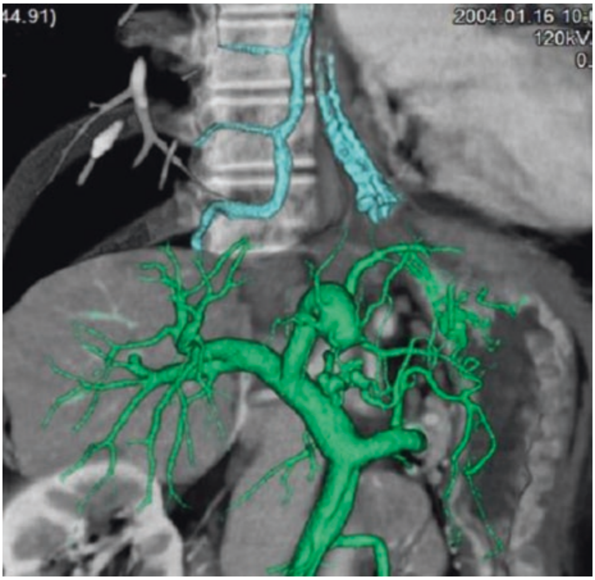


Fig. 12.3 Esophageal varices detected by "Mishuku Hospital Method"

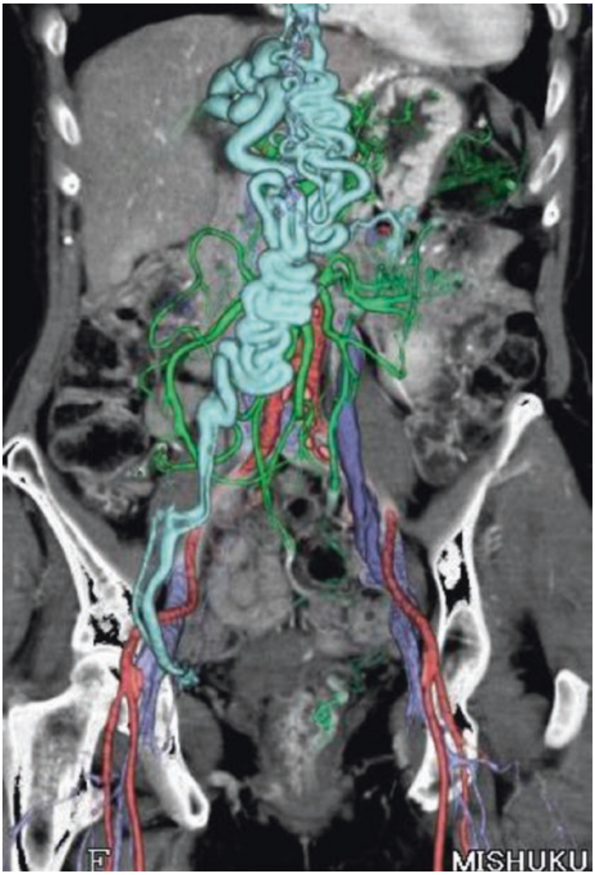


Fig. 12.4 3DCT image of abdominal venous wall collaterals

wall drains into the right common iliac vein and the femoral vein. Since 3DCT permits visualization of vessel diameters, it is useful to estimate blood flow volume. These abdominal wall veins are larger than the mesenteric veins, and therefore occlusion of the collaterals using a catheter temporarily improves hyperammonemia. Drainage through the upper side of the chest wall occurs through the subclavian vein.

12.2.2 Renal Venous System Shunt (Figs. 12.5 and 12.6)

This type of collateral occurs frequently. Gastric varices can be seen when the shunt runs through the gastric mucosa. The posterior gastric vein or the left gastric vein is the supply vein forming gastric varices, through the descending branch of the left inferior phrenic vein and merging into the left adrenal and renal veins. When the collaterals are well-developed, there is a backflow of blood into the splenic vein, leading to hyperammonemia and hepatic encephalopathy. Sometimes, the drainage pathway involves the left gonadal vein.

12.2.3 Azygos Venous System Shunt

The most frequent type of collateral is the azygos venous system shunt. In the case in Fig. 12.7, the left gastric vein joins the hemiazygos vein, forming esophageal varices. Other collateral circulation is not visualized. It should be noted that 3DCT

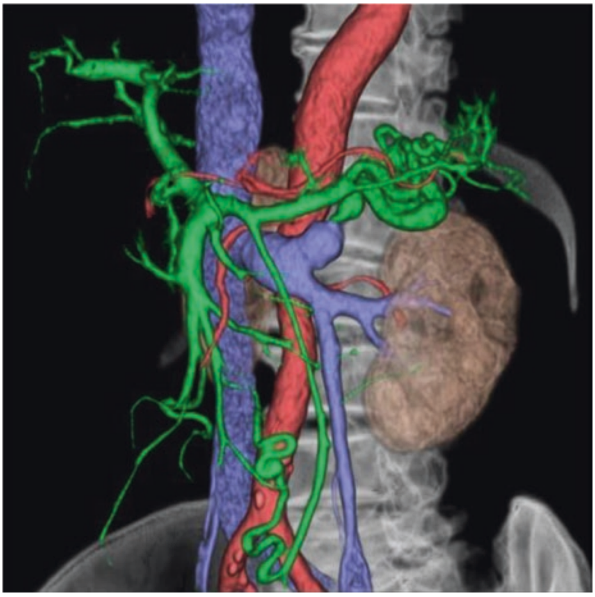


Fig. 12.5 3DCT image of renal venous and inferior mesenteric venous system shunt (frontal view)

Fig. 12.6 3DCT image of renal venous system shunt (dorsal view)

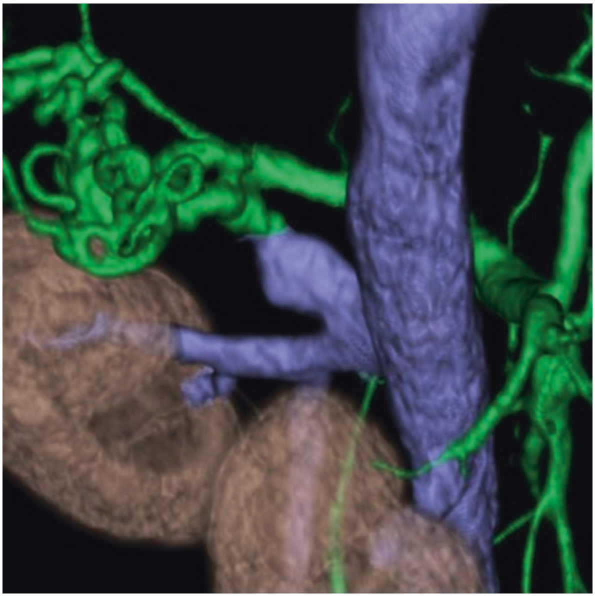
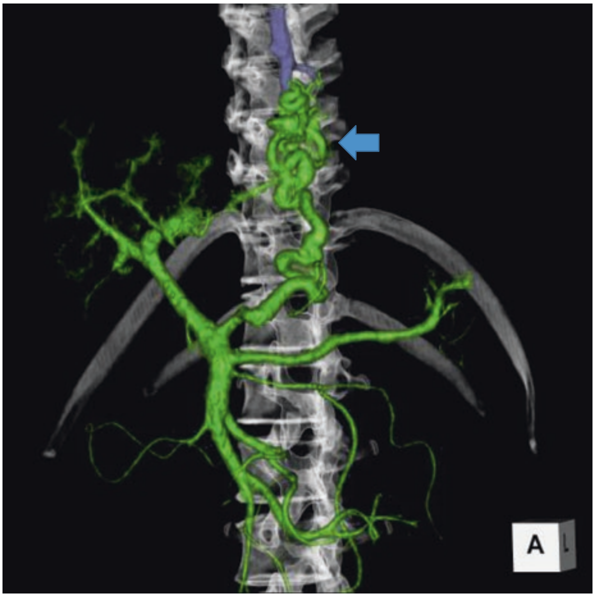


Fig. 12.7 3DCT image of azygos venous system shunt (frontal view)



cannot distinguish collaterals in close proximity to either the inside or outside of the esophageal wall, and conventional CT is necessary in such situations. Thus, the tortuous vessels (arrow) in the case in Fig. 12.7 are paraesophageal veins outside the esophageal wall.

12.2.4 Mesenteric Venous System Shunt

This type of collateral circulation may cause hepatic encephalopathy. Shunts from the inferior mesenteric vein (IMV) are particularly important. In the case shown in Fig. 12.8, there is a well-developed vascular network (arrow) in the retroperitoneal cavity in the lower abdomen. The IMV (arrowhead) is highly dilated. The vein responsible for direct drainage in this case is the inferior vena cava.

In the case in Fig. 12.9, the shunt from the superior mesenteric vein is seen in the right abdomen, shunting into the right gonadal vein, which in turn drains into the proximal portion of the right renal vein.

12.2.5 Diaphragmatic Venous System Shunt

Varicose veins passing through the stomach cardia and flowing into the left inferior phrenic vein are shown in Fig. 12.10. These also run along the upper and dorsal sides of the left hepatic lobe and drain directly into the inferior vena cava. These collaterals sometimes flow into the pericardial or pericardiophrenic veins that empty into the left subclavian vein.

12.2.6 Intrahepatic Shunt (Fig. 12.11)

Large-diameter blood vessels (arrow) in the right hepatic lobe can penetrate the liver. Most portal vein blood flows into the intrahepatic shunt, resulting in narrowing of other branches of the portal vein and subsequent liver atrophy.

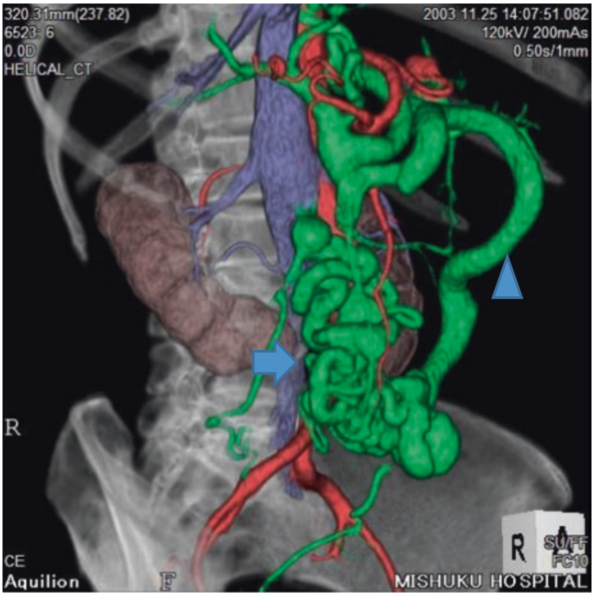


Fig. 12.8 3DCT image of mesenteric venous system shunt

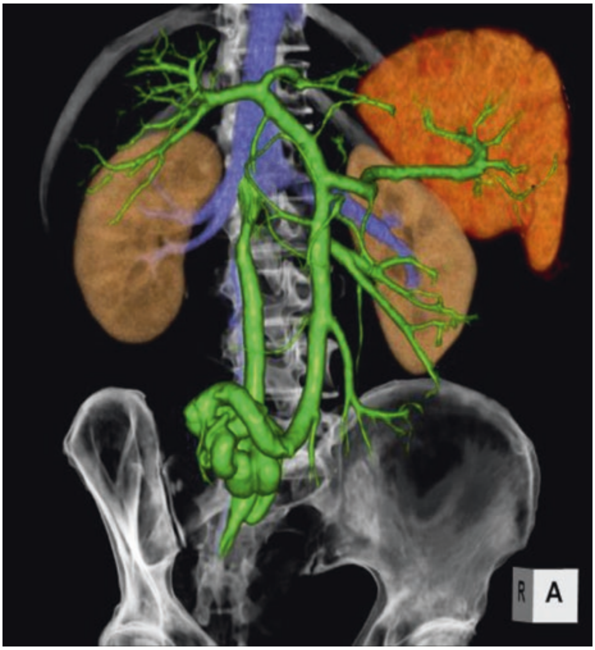


Fig. 12.9 3DCT image of superior mesenteric venous system shunt

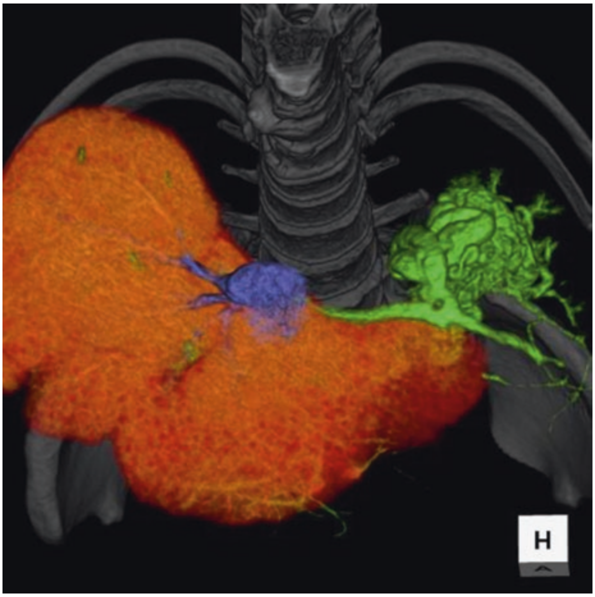


Fig. 12.10 3DCT image of diaphragmatic venous system shunt (cranial view)

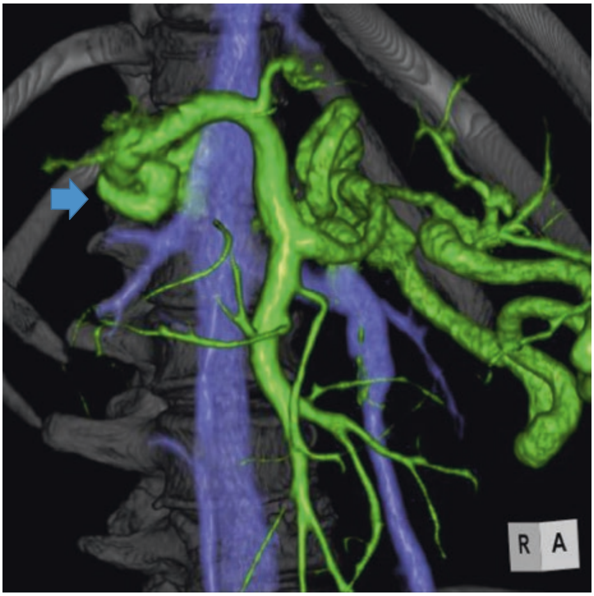


Fig. 12.11 3DCT image of intrahepatic venous shunt

Fig. 12.12 VR reconstruction of 3DCT in case of portal vein thrombosis

12.2.7 Portal Vein Thrombosis

In Fig. 12.12 (VR construction) and Fig. 12.13 (MIP), 3DCT images show diffuse portal vein thrombosis. There are multiple stenotic vessels in the portal and mesenteric venous systems, and main branches such as the portal trunk are obscure. Esophageal varices are present, and portal thrombi are difficult to identify. Using

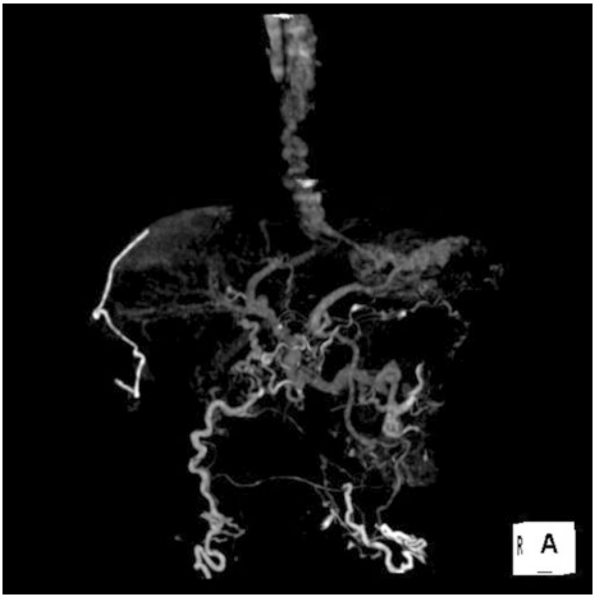


Fig. 12.13 MIP reconstruction of 3DCT in case of portal vein thrombosis

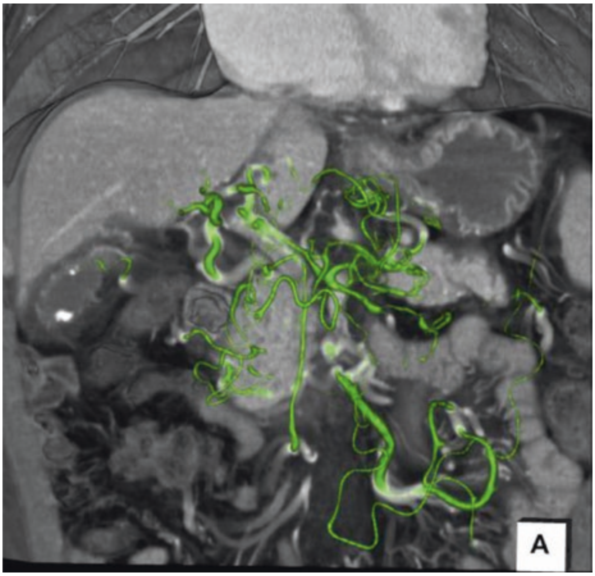


Fig. 12.14 "Mishuku Hospital Method" reconstruction of 3DCT in case of portal vein thrombosis

the "Mishuku Hospital Method" (Fig. 12.14), we can simultaneously display thrombosed veins and venous thrombosis.

12.2.8 Retroperitoneal System Shunt (Fig. 12.15)

In this case, a patient with type B viral cirrhosis had undergone balloon-occluded retrograde transvenous obliteration (B-RTO) for gastric varices 10 years previously. Broadly expanded varicose veins can be visualized in the deep abdominal wall,

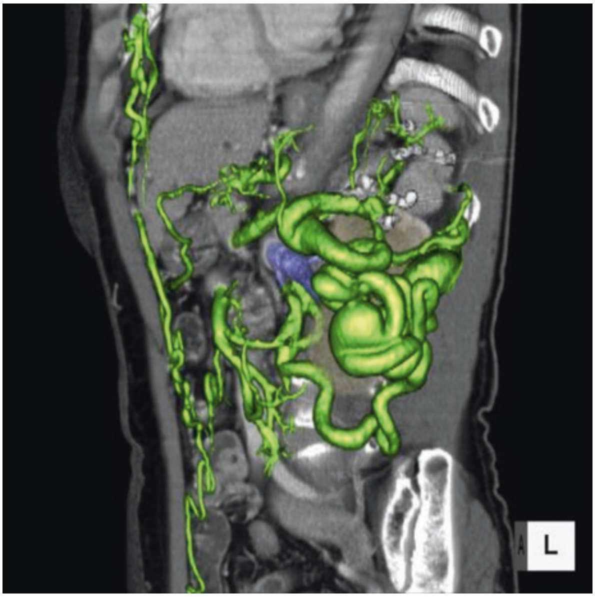


Fig. 12.15 3DCT image of retroperitoneal system shunt (lateral view)

along with retroperitoneal lesions and liver atrophy. The patient experienced repeated episodes of overt hepatic encephalopathy, followed by liver failure. Esophageal and gastric varices are not depicted in this figure. In this case of liver cirrhosis, portosystemic collaterals continued to develop slowly over the course of several years despite narrowing of the main portal branches.

12.2.9 Portopulmonary Venous Shunt (Fig. 12.16)

Paraesophageal veins usually flow into the hemiazygos venous system but sometimes flow directly into the main trunk of the pulmonary vein (portopulmonary venous anastomosis (PPVA); arrow). With these types of collaterals, sclerotherapy may cause cerebral or renal infarction and is therefore contraindicated.

12.3 Incidence of Portosystemic Shunt Detected by 3DCT

A total of 170 consecutive patients with liver cirrhosis who were recruited at Mishuku Hospital were investigated. The frequency of collateral blood vessels to be visualized by MDCT was determined by Dr. Satoshi Nakayama. Collateral pathways were detected in 88 patients (47%). Shunts occurred most frequently in the azygos venous system (31.8%). Azygos and renal system shunts were observed simultaneously in 15 cases (17.0%) (Fig. 12.17). Figure 12.18 shows a three-shunt system. The details and incidence of these multiple portosystemic shunts are shown in Table 12.2.

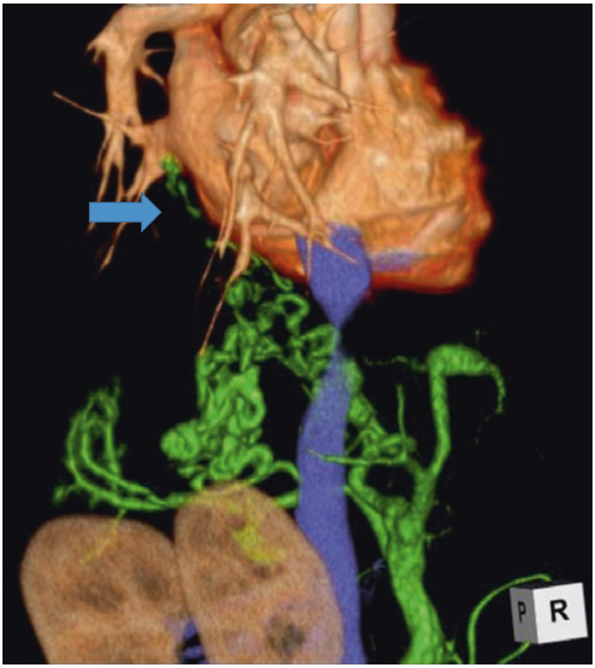


Fig. 12.16 3DCT image of portopulmonary venous shunt (dorsal view)

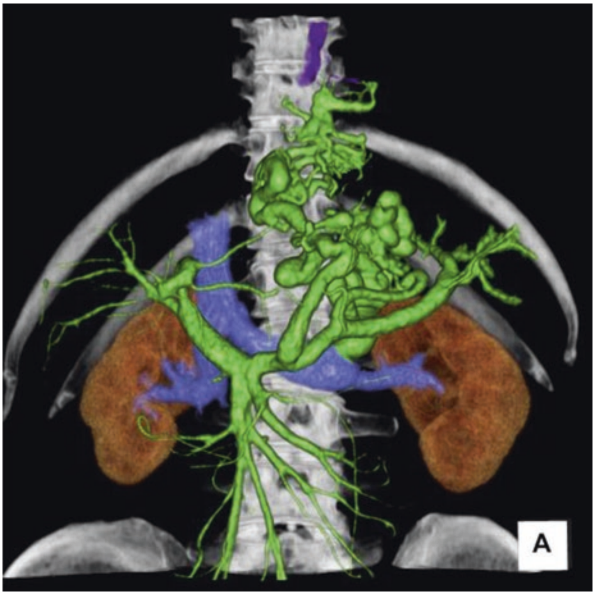


Fig. 12.17 3DCT image of azygos and renal venous system shunts

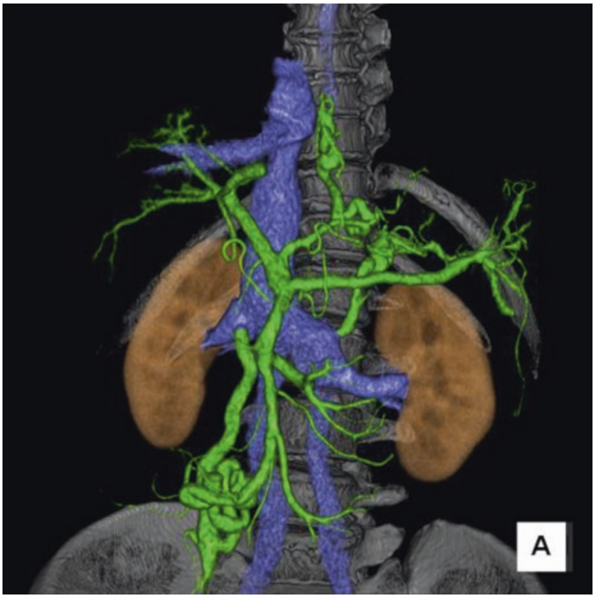


Fig. 12.18 3DCT image of azygos, renal, and mesenteric venous system shunts

Table 12.2 Summary of portosystemic shunt revealed by 3DCT (170 cirrhotics)

Anatomical location of shunts	*n*	Incidence (%)
Abdominal wall venous system shunt only	2	2.3
Renal venous system shunt only	16	18.2
Azygous venous system shunt only	28	31.8
Mesenteric venous system shunt only	4	4.5
Azygous shunt + Abdominal wall shunt	5	5.7
Azygous shunt + Renal shunt	15	17.0
Azygous shunt + Phrenic venous system shunt	1	1.1
Azygous shunt + Mesenteric shunt	2	2.3
Renal shunt + Mesenteric shunt	2	2.3
Renal shunt + Phrenic shunt	2	2.3
Renal shunt + Others	2	2.3
Azygous shunt + Renal shunt + Abdominal wall shunt	2	2.3
Azygous shunt + Renal shunt + Phrenic shunt	2	2.3
Azygous shunt + Renal shunt + Mesenteric shunt	2	2.3
Azygous shunt + Abdominal wall shunt + Mesenteric shunt	2	2.3
Renal shunt + Mesenteric shunt + Mesenteric shunt	1	1.1
Total	88	100

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