Abdominal and Pelvic Vascular Ultrasonography

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Introduction

Indications for abdominal color flow mapping (CFM) include nearly all suspected vascular abnormalities in the abdomen, i.e., the vessels of the portal circulation, upper abdominal arteries, renal vessels, abdominal aorta, vena cava inferior, and blood vessels of the pelvis [1]. However, the quality of CFM data depends greatly on the anatomical site of the vessel, the patient's condition (bowel gas, obesity, compliance, ascites, postoperative dressings), operator's skill and experience. The sonographer performing abdominal CFM should be thoroughly familiar with normal B-mode sonography, standard Duplex techniques, and the anatomy of the abdominal organs and their vasculature. Correct data interpretation also requires an understanding of vascular pathology and hemodynamic principles. An operational understanding of color (Doppler) imaging, instrumentation, and technology is also needed to avoid misinterpretation of artifacts.

Establishing a routine abdominal CFM protocol aids in producing consistent and reproducible results. To avoid respiratory effects on venous hemodynamics it is preferable to acquire all quantitative data during breath holding. Fasting also facilitates the examination and is necessary for the validity of quantitative data of portal flow measurements. Gentle pressure on the transducer avoids interference with venous hemodynamics. It is essential that examinations begin with conventional B-mode sonography to define the topography and morphology of the abdominal organs. The operator notes the position, size, and texture of the parenchymal organs and documents any structural abnormality [2]. CFM is then used to identify the vessels of interest and to determine their flow characteristics. Whenever possible the vessels are examined in both longitudinal and transverse along the standard imaging planes [3]. To minimize errors the vessels should be examined along their complete course. Basic imaging planes and transducer orientations for an abdominal CFM examination have recently been outlined. Quantitative flow is measured at present using the standard Doppler methods [4]. To perform reliable Doppler and gray-scale imaging related measurements the examiner should be familiar with the potential sources of errors [5, 6] and with the essentials of splanchnic hemodynamics [7]. Quantitative assessments of flow directly from the CFM data will become increasingly available in the future [8].

In this chapter flow velocity is given as the maximum flow velocity (corrected for Doppler angle and time averaged in veins) because this does not depend critically on the electronic equipment or geometry of the ultrasound beam, both responsible for systematic errors (overestimation of mean flow velocity). In vessels with laminar flow conditions, for example, the portal circulation in patients with portal hypertension, mean flow velocity (averaged over the cross-section) can be approximated using the relation:

\[ \text{mean flow velocity} = 0.5 \times \text{maximum flow velocity} \]

Flow rates are estimated by multiplying mean flow velocity with the cross-section area of the vessel.

Portal System

Potential indications for a CFM examination of the portal system include:

- Liver cirrhosis
- Portal hypertension, ascites of unknown etiology, esophageal varices
- Thrombosis of the portal vein, superior mesenteric vein, splenic vein
- Venoocclusive disease, Budd-Chiari syndrome
- Splenomegaly
- Monitoring of portosystemic shunts
- Space-occupying lesions in the liver
- Abdominal trauma
- Gastrointestinal bleeding without endoscopically confirmed cause
- Liver transplantation

Examination Technique

A complete examination of the portal circulation should include evaluation of (a) portal vein, (b) intrahepatic branches of the portal vein in both the right and left liver lobe, (c) hepatic veins, (d) hepatic arteries (see below), (e) splenic vein, (f) superior mesenteric vein, (g) collateral vessels and (h) a check of the celiac trunk and the superior and inferior mesenteric arteries (see below). The topographic anatomy and hemodynamics [9, 10] of the portal venous system should be reviewed and well understood.

The examination begins by locating the portal vein. The ultrasonic beam is directed obliquely in the right upper quadrant between the umbilicus and the costophrenic angle. In this orientation the portal vein can be visualized in its long axis from the venous confluence to its division into the right and left branches (Fig. 1). For quantitative analysis a large anatomic angle between the course of the vein and the ultrasonic beam makes a more caudal approach necessary. In patients with ascites, bowel gas, or abdominal dressings the vein can be imaged laterally from the right side using an oblique transducer orientation. The left main portal branch is imaged from ventral epigastric with a transverse transducer orientation. Higher order portal vein branches are identified within the liver parenchyma.

The hepatic veins are imaged from the right upper quadrant with a transverse transducer orientation at the midclavicular line. The imaging of the left veins is often facilitated from a more left lateral orientation while the patient holds his breath in deep inspiration. The veins of the right liver lobe are frequently better visualized from a more right lateral oblique position (Fig. 2).

The splenic vein is typically examined from the epigastrium longitudinally in a coronal plane or transversely in a left parasagittal plane. This approach allows visualization of the vessel from the end at the portal vein to the tail of the pancreas (Fig. 3). The hilar segment can be visualized from the left lateral using the spleen as an echogenic window. Blood flow should be also assessed in several parenchymal branches if splenic infarction is suspected.

The superior mesenteric vein can be imaged following its oblique course by orienting the transducer from left caudal to right lateral in the right upper quadrant. Frequently large angles of insonation require moving the transducer more cranially or caudally from its original position to obtain Doppler flow measurements.

The inferior mesenteric vein displays a more variable anatomic course and is frequently identified at the confluence with the splenic vein or the superior mesenteric vein.

The right and left gastric veins can be identified close to the venous confluence where they empty into the portal vein or into the splenic vein, respectively. The recognition of a retrograde gastric venous flow is important in diagnosis of portal hypertension (Fig. 4). Infrequently, downstream filling of a thrombosed portal vein via the right gastric vein is observed.

The umbilical vein joins the left branch of the portal vein where it is easily identified (Fig. 5). Varicose veins of the gastric cardia and the esophagus are recognized as tortuous vascular structures at the level of the epigastrium and the left upper quadrant. When there is splenic obstruction, the short gastric veins can be visualized as short stumps originating from the splenic vein close to the hilus and moving upward toward the greater curvature of the stomach. Other small vessels providing collateral circulation in the presence of a portal hypertension move from the hilar segment of the splenic vein downward and into the retroperitoneum. Other portacaval collateral pathways occasionally documented by CFM are the veins of the gallbladder walls emptying into the veins of the liver capsula. Small veins originating in the territory of the inferior mesenteric vein and joining the hemorrhoidal plexus of the inferior and middle rectal vein are also occasionally seen with CFM.

In addition to the evaluation of the native portal vasculature, CFM is becoming an important method to assess the functional status of surgically constructed portosystemic shunts [11]. Proximal and distal splenorenal shunts are best seen in a cross-sectional view with the transducer in the left lateral or anterior position. Portacaval shunts are visualized using techniques described for portal vein imaging in short- and long-axis views along the hepatoduodenal ligament (Fig. 6). Mesocaval shunts are visualized along the superior mesenteric vein (Fig. 7). If the shunt is functioning, flow reversal is seen at the level of its