# $CO_2$ Splenoportography for Evaluating the Splenic and Portal Veins before or after Liver Transplantation

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**The authors report their experience with $CO_2$ splenoportography in a retrospective review of 15 studies performed in 13 patients before or after liver transplantation. The studies were performed by injecting $CO_2$ through a small caliber needle introduced into the splenic parenchyma with ultrasound guidance and imaging with conventional digital subtraction techniques. The findings were compared with clinical follow-up and other imaging studies when available. Eight of the 15 studies were normal, of which two were confirmed by additional studies. Six of the 15 studies were abnormal, all of which were compared with additional studies. There was one nondiagnostic study and two false positives. There were no reported complications. The authors' experience suggests that $CO_2$ splenoportography is a minimally invasive method for safely and accurately evaluating the splenic and portal veins.**

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LIVER transplantation has become the accepted method of treatment of patients with end-stage liver disease. Possible complications following liver transplantation include stenoses at the arterial, venous, and biliary anastomoses. Portal vein complications are uncommon with rates of thrombosis and stenosis reported to be between 2% and 7% and 0.6% and 1.2%, respectively (1). Portal vein stenosis is more common in the pediatric population, especially in the instances of split-liver or living-related grafts (1–3). With the increasing number of liver transplantations being performed, the need for portal vein imaging has also increased.

There are a variety of methods available for imaging the portal vein. Most centers use ultrasound (US) because it is noninvasive and does not require intravenous contrast material or ionizing radiation. It also provides not only anatomic information, but hemodynamic information as well. However, it does have limitations. Overlying bowel gas can obscure the extrahepatic portal vein. This is a particular problem in the pediatric transplant population, where most patients receive reduced or split-livers, requiring a Roux-en-Y biliary anastomosis (2,3). In addition, US may also overestimate the degree of stenosis or mistake a collateral vessel as a patent portal vein in the setting of portal vein occlusion (3).

Magnetic resonance (MR) imaging and computed tomography (CT) have taken on a larger role in both the pre- and posttransplant evaluation. Several studies have looked at the use of three-dimensional gadolinium-enhanced MR angiography in the evaluation of the hepatic vasculature (4,5). Cheng et al (4) found a 100% correlation with conventional arterial portography when evaluating portal vein anatomy preoperatively and Kim et al (5) report an overall accuracy of 84% when evaluating for >50% portal vein stenosis. With the advent of multidetector CT scanners and three-dimensional CTA techniques, some authors have advocated their use in both pretransplant evaluations and assessing for post transplant complications (6,7). Multidetector CT has several advantages. It is quick and convenient, and does not, in general, require general anesthesia. However, CT does have limitations. It relies on appropriate timing to ensure adequate opacification of the portal vein and only provides anatomic data with little to no hemodynamic information. Furthermore, in the pediatric population, the overall accuracy may be limited by the small caliber of the portal vein and the general lack of intra-abdominal fat.

When noninvasive methods fail to adequately visualize the portal vein, arterial portography may be used. However, this is an invasive procedure and requires an arterial puncture. The risk of associated complications is not insignificant in the pediatric population whose vessels are small in caliber and more prone to vasospasm and subsequent common femoral artery thrombosis.

Recently there has been renewed interest in another way to image the portal vein: splenoportography. With use of $CO_2$ as a contrast medium, splenoportography may be performed with very small needles, reducing the risk of bleeding complications. This report presents the authors experience

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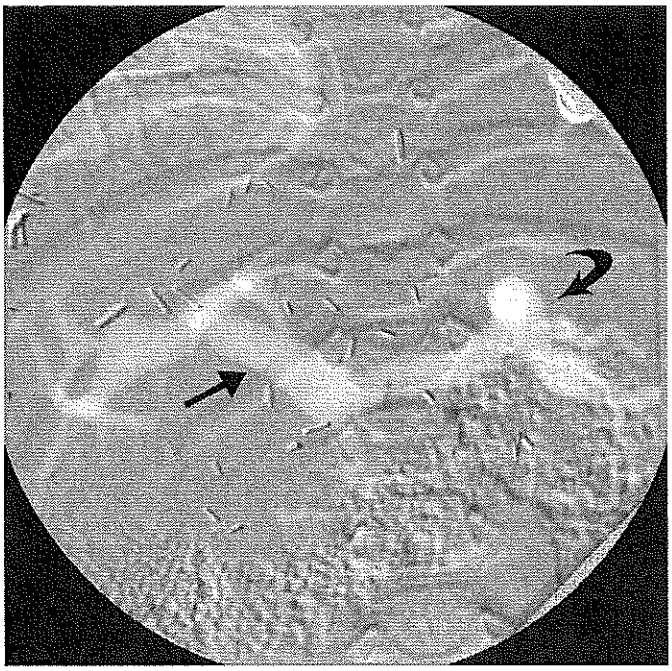

**Figure 1.** Normal $CO_2$ splenoportogram in 6-month-old female with biliary atresia being evaluated for liver transplant. Flow is identified in portal vein (arrow) and splenic vein (curved arrow).

with the use of $CO_2$ splenoportography as a minimally invasive way to image the splenic and portal veins.

## MATERIALS AND METHODS

Institutional review board approval was obtained for this study. This is a retrospective review of 15 $CO_2$ splenoportograms obtained in 13 patients between January 2000 and February 2003. Five studies were performed as part of a pretransplant evaluation, and the remaining 10 studies were performed to evaluate US abnormalities after transplantation. Two patients had repeat studies. In both instances, the patients underwent initial splenoportography as part of a pretransplant evaluation and subsequently returned for an additional study to further evaluate a US abnormality after transplantation. The study included nine males (age range, 2 months to 54 years; median, 18 years) and six females (age range, 4 months to 51 years; median age, 2 years).

Informed consent was obtained from each patient or from parent or guardian as necessary. The patient was placed on the angiography table in a supine position. General anesthesia was used in 10 pediatric cases. The remaining five cases were performed with regional anesthesia and intravenous sedation. The left upper quadrant was sterilely prepped and draped. With US guidance, a small-caliber needle was inserted into the splenic parenchyma. The needle tip was placed at least 2 to 3 cm within the splenic pulp while avoiding any visible vessels. The needle size was operator dependent. A 21-gauge needle was used in six cases and a 27-gauge needle was used in the remaining nine.

With the use of a three-way stopcock, medical grade $CO_2$ was drawn up into a 20-mL syringe and purged three to five times before collecting the gas for injection. The gas-filled syringe was then connected to the needle with 10-cm-long connector tubing and a two-way stopcock. The needle position was confirmed with US and the needle was purged with 2 to 5 mL $CO_2$. With standard digital subtraction angiography imaging, 3 seconds of masking images were obtained and up to 15 mL of $CO_2$ was hand injected in a constant fashion for 2 to 3 seconds. Multiple injections were performed at different magnification levels as well as with different obliquities of the image intensifier as needed to fully evaluate the portal vein anastomosis. Each injection was filmed at a high rate (4–6 frames per second) because of the often brisk flow through the splenic vein into the portal vein. When the splenic and portal veins were fully evaluated, the needle was removed. Before the patient was discharged from the angiography suite, US was performed over the left upper quadrant of the abdomen to evaluate for possible perisplenic hemorrhage.

## RESULTS

A total of 15 studies were performed in 13 patients. Of these, eight studies were interpreted as normal and six studies were interpreted as abnormal. One study was considered nondiagnostic. In six of the eight normal studies, no further imaging was performed (**Fig 1**). Within this group, four patients subsequently underwent successful liver transplantation without complication. The remaining two patients have continued to do well, and have been followed clinically. Two studies were normal and confirmed with conventional splenoportography in one patient and confirmed with MR imaging in the other. Both patients subsequently underwent successful liver transplantation.

Six of the 15 studies were abnormal. Portal vein stenosis was identified in two patients leading to transhepatic portography. Each of these patients was referred for possible stenosis identified on US. In each patient, the stenosis was confirmed and treated with angioplasty (**Fig 2**). Two studies demonstrated occlusion of the main portal vein. This was confirmed with MR imaging in one patient and conventional splenoportography in the other. There were two false positives (14%) in this study. In one instance, the intrahepatic portal veins were not visualized and thought to be obstructed. The subsequent conventional splenoportogram was normal. A stenosis was identified in another patient leading to transhepatic portography. This demonstrated a mild stenosis with no associated pressure gradient. Of these two false positives, the first occurred when with use of a 21-gauge

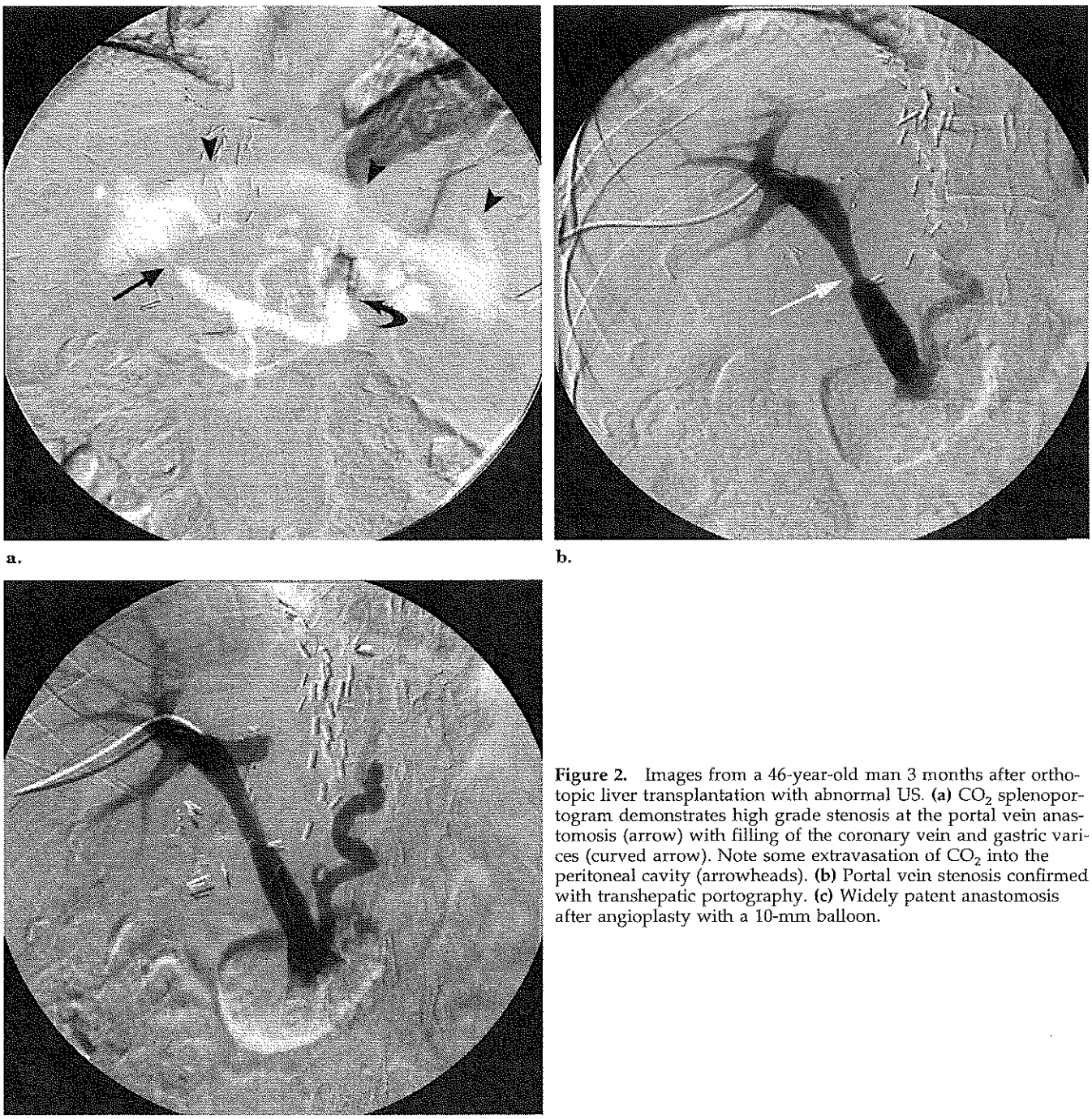

**Figure 2.** Images from a 46-year-old man 3 months after orthotopic liver transplantation with abnormal US. **(a)** $CO_2$ splenoportogram demonstrates high grade stenosis at the portal vein anastomosis (arrow) with filling of the coronary vein and gastric varices (curved arrow). Note some extravasation of $CO_2$ into the peritoneal cavity (arrowheads). **(b)** Portal vein stenosis confirmed with transhepatic portography. **(c)** Widely patent anastomosis after angioplasty with a 10-mm balloon.

needle and the second with use of a 27-gauge needle.

One of the 15 $CO_2$ splenoportograms was nondiagnostic. In this instance, the $CO_2$ preferentially diffused into the peritoneal cavity with minimal opacification of the splenic vein and nonvisualization of the portal vein. This occurred with the 27-gauge needle despite repositioning this needle multiple times in the splenic parenchyma. It also occurred repuncturing the spleen in a different location. This patient then underwent transhepatic portography, which was normal.

No complications were reported with any of these procedures.

## DISCUSSION

Splenoportography was first described in 1951 by Abeatici and Campi et al (8). Since that time, splenoportog-

raphy has become widely used as a method for imaging the splenic and portal veins. The traditional technique involves placing an 18- or 20-gauge needle with a teflon sheath into the splenic parenchyma, through which 20 to 50 mL of iodinated contrast material may be injected (8).

Although several large studies have documented the safety of this technique, there has continued to be some reluctance to perform splenoportography out of concern for possible intra-abdominal hemorrhagic complications (8,9). The risk of clinically insignificant intra-abdominal hemorrhage is reported at 2% to 4% with significant bleeding complications at about 1% (10). However, with the use of smaller caliber needles, this risk may be reduced. In one particular study, there were no hemorrhagic complications reported in more than 1,000 splenic punctures, with use of 22-gauge needles performed during a 10-year period (11). The use of gelfoam pledgets to plug the tract and further reduce the risk of bleeding complications has also been reported (9,10).

$CO_2$ has been used as a vascular contrast media since the 1950s, when it was first used to diagnose pericardial effusions and later the venous structures within the liver (12). Since that time, the use of $CO_2$ has expanded and it is now used as an alternative to iodinated contrast material in a variety of procedures in both the arterial and venous circulations. The primary advantage of $CO_2$ is the safety profile. $CO_2$ is non-nephrotoxic and nonallergenic, making it an ideal alternative in patients with either severe renal insufficiency or a history of severe allergy to contrast material. The accuracy of $CO_2$ is well established (12,13) and there have been no reports of false negative examinations. Thus, if the $CO_2$ study is normal, no further imaging is required.

The use of $CO_2$ in the liver is likewise well established. Its low viscosity allows for rapid diffusion through the hepatic sinusoids, making it the ideal agent for wedged hepatic portography. When used in this fashion, $CO_2$ provides excellent delineation of the intrahepatic portal anatomy and is commonly used in this setting to provide guidance for a TIPSS procedure. However, with this technique, it can often be difficult to image the entire extrahepatic portal vein as well as the splenic vein or varices. Recently, a technique of percutaneous transhepatic portography with $CO_2$ was described (14). In this report, $CO_2$ was injected directly into the hepatic parenchyma with a 22-gauge needle providing very good visualization of the intrahepatic portal veins in an animal model.

The same properties that make $CO_2$ an attractive agent in wedged hepatic portography make it an attractive agent in splenoportography. Specifically, the low viscosity allows $CO_2$ to be injected through small-caliber needles and to diffuse rapidly through the splenic parenchyma. The first report of the use of $CO_2$ in this way was only recently published looking at its safety and efficacy in a swine model (15). In this study, 22-gauge needles were used to inject $CO_2$ into the splenic pulp of five pigs. The spleens were then removed and examined histologically. This demonstrated no subcapsular dissection or intrasplenic hematomas. Caridi et al (16) recently published the use of $CO_2$ splenoportography in eight patients all of whom had inconclusive noninvasive imaging. A 25-gauge needle was used to inject the $CO_2$. In each case, the splenoportogram provided sufficient anatomic information to base treatment decisions, and there were no bleeding complications.

When one considers the primary drawback to splenoportography in the transplant patient is the risk of a bleeding complication, the use of $CO_2$ is logical. As Soderstrom (11) illustrated, reducing the size of the needle helps minimize the risk of bleeding complications with splenic punctures. A 27-gauge needle was used in more than half of our patients with a similar diagnostic accuracy (78%) as in the group studied with a 21-gauge needle (83%). No bleeding complications were noted with either group. It is, therefore, reasonable to conclude that the smaller needle should be used routinely.

In this series, the authors did have two false positive examinations. In one instance a mild stenosis was overestimated on the $CO_2$ splenoportogram. Although a mild stenosis was present on transhepatic portography, this was not associated with a pressure gradient and required no intervention. There have been reports of overestimation of stenoses (13). This is most likely due to underfilling of the vessel. If the $CO_2$ fails to fully displace the blood within the vessel, only the upper portion of the vessel will be opacified creating the appearance of a vessel that is narrower than it really is giving a false positive examination. This is most likely the case for this particular lesion. The other false positive study occurred when the intrahepatic portal veins could not be visualized and were thought to be occluded. They were found, however, to be patent on transhepatic portography. The reason for this finding is most likely related to vessel underfilling and the buoyancy of $CO_2$. $CO_2$ will tend to preferentially fill more anterior structures. In this case, the $CO_2$ flowed preferentially into the most anterior venous structure: the superior mesenteric vein. The poor flow in the portal vein was then likely exacerbated by under-filling/under-injection of the $CO_2$.

There was one nondiagnostic study (6.7%) in this patient group. In this case, there was preferential diffusion of the $CO_2$ into the peritoneal cavity rather than into the splenic vein. The reason for this is uncertain. It occurred despite repositioning the needle and reinserting into a new location. It is not felt to be related to any physiologic reason with the portal and splenic veins as these were later confirmed by transhepatic portography to be normal. The authors postulate that the $CO_2$ was diffusing along to the path of least resistance, or in this case, back along the needle tract rather than diffusing through the splenic pulp into the splenic vein.

There are limitations to this study. There is no correlate imaging in six of 15 (40%) studies. These studies were all normal. Because there are no reported cases of false negative angiograms with $CO_2$ despite extensive literature, it is felt justified in accepting a negative result without correlate imaging. The second limitation is that complications were determined by chart review, and minor complications may have gone unnoticed and, thus, unreported.

In conclusion, the use of $CO_2$ splenoportography provides a minimally invasive method for safely and accurately evaluating the splenic and por-

tal veins. With the use of very skinny needles (25 or 27 gauge), there is very minimal risk of bleeding even in patients at increased risk due to poor liver function or thrombocytopenia. Furthermore, if the $CO_2$ splenoportogram is normal, no further tests are required. However, when a stenosis is detected, it can be treated in the same setting, and in the case of pediatric patients, with the same general anesthesia.

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