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CO₂ Splenoportography: Preliminary Results

OBJECTIVE. Previously, splenoportography with 18-gauge needles provided excellent portal imaging. However, because of concern about bleeding, this technique was replaced with arterial portography and noninvasive techniques, which are not always accurate. We present a modification of splenoportography using CO₂ and an ultrafine needle in eight patients whose previous imaging studies were inconclusive.

CONCLUSION. CO₂ splenoportography is safe and expedient and provides adequate visualization of the portal system for surgical planning in selected patients.

From 1951 to the mid 1970s, splenoportography provided excellent imaging of the portal venous system with some limitations [1, 2]. Because initial publications reported significant rates of bleeding complications (4.3%) with splenoportography, it was not widely accepted [3]. Consequently, the technique was replaced with arterial portography, which has a greater risk in patients with renal failure and in infants with small femoral arteries. In recent years, noninvasive methods including sonography, CT, and MR angiography have been used to evaluate the portal system; however, their sensitivities are 60–100% [4]. We present a modification of splenoportography that we believe to be safe, reliable, and capable of providing adequate portal imaging in patients for whom noninvasive techniques result in inconclusive findings.

Materials and Methods

We performed a retrospective analysis of eight patients requiring additional splenoportal evaluation because of inconclusive sonographic, CT, or MR angiographic results. The patient cohort included five pediatric and three adult patients (five male, three female), 5 months to 73 years old.

All three adult candidates who were studied for transjugular intrahepatic portosystemic shunt (TIPS) procedures had inconclusive sonographic and MR

angiographic findings. Two pediatric patients with biliary atresia (ages, 5 months and 2 years) who were awaiting liver transplantation had no portal vein seen on sonography or CT. A 12-year-old girl with cystic fibrosis and liver and pancreatic transplants, experiencing left upper quadrant pain and massive splenomegaly, had undergone sonography and CT that showed equivocal patent portal and splenic veins. A 4-year-old girl with cavernous transformation had findings of a patent splenorenal shunt on CT but a clinical presentation of shunt occlusion. Sonographic and CT findings in a 2-year-old boy with recurrent hepatoblastoma who had undergone trisegmentectomy showed what appeared to be an occluded portal vein.

Four of the eight patients had coagulopathy as revealed by abnormally elevated prothrombin times (14–16 sec), partial thromboplastin times (34–42 sec), and platelet counts of 55–121 × 10³ μL. One adult was given platelets and one child was given fresh frozen plasma during the procedure. Two adults had ascites (one moderate and one massive). Only the five pediatric patients presented with splenomegaly.

In preparation for the procedure, general anesthesia was administered to the five pediatric patients and two of the adult patients. The remaining adult received minimal IV sedation.

The patients were placed in a supine position and evaluated using sonography to locate the position of the spleen and adjacent structures. The site for needle entry was marked on the skin. The left upper quadrant was subsequently prepared and draped in a sterile fashion, and local anesthesia was

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administered. A 25-gauge spinal needle (Spinocan; Braun Medical, Bethlehem, PA) was advanced into the splenic pulp using direct sonographic guidance during a breath-hold (a 22-gauge needle was used in a 2-year-old girl). The needle was connected to a modified fluid management system that can be used for safe CO₂ delivery (Angioflush III Fluid Management System and Angiofill Fluid Collection Bag; AngioDynamics, Glens Falls, NY) as previously described [5].

The CO₂ delivery system was filled with 99.99% laboratory-grade CO₂ from a disposable cylinder (CMD, Gainesville, FL). Initially, a test injection of 3–10 mL of CO₂ was made using digital subtraction angiography to confirm appropriate placement of the needle. Definitive injections of CO₂ (children, 5–20 mL; adults, 30–40 mL) were administered by hand over 1–2 sec with digital subtraction angiography (1024 × 1024) at 3.5 frames per second. All CO₂ injections were made with the patient in the supine position except in the case of the infant with suspected portal vein thrombosis; that patient was placed in the Trendelenburg's position during two injections to attempt to fill the superior mesenteric vein. Patients were not placed in the left lateral decubitus position after the procedure to tamponade the needle entrance site.

Results

Anatomic delineation of the splenoportal system adequate to permit definitive disposition was obtained in all eight patients. In the three candidates for TIPS, splenoportography confirmed MR angiography findings of an occluded portal vein in one patient and an occluded portal vein, which had appeared patent by MR angiography and equivocal by sonography, in a second patient. In a third patient, who had a TIPS, splenoportography corroborated sonographic and MR angiography findings of a patent portal vein and an occluded splenic vein. The parenchymal CO₂ injections during the attempted TIPS procedures in these three adults agreed with the splenoporto-

graphic findings [6]. Only one adult patient had surgical confirmation of portal vein occlusion, during placement of a mesocaval shunt 12 days after undergoing splenoportography.

One candidate for a TIPS developed transient chest pain and mild to moderate respiratory distress after two injections of 30 mL of CO₂; however, no significant changes were noted in blood pressure or ECG findings. The complication was thought to be associated with a reaction caused by platelet infusion.

In both pediatric patients awaiting liver transplantation, splenoportography showed patency of the superior mesenteric vein, which was essential for transplantation evaluation. During liver transplantation in the 2-year-old girl with an apparent occluded portal vein shown on sonography and MR angiography, the portal vein was patent, verifying the splenoportographic findings (Fig. 1). During liver transplantation in the 5-month-old boy, a small patent portal vein was noted that was misinterpreted on the splenoportogram as a collateral vein (Fig. 2A). No portal or splenic veins were imaged with sonography or CT. The retroperitoneal collateral veins that communicated with the inferior vena cava were ligated at surgery, preventing thrombosis of the anastomosed portal vein (Fig. 2B).

A 12-year-old girl with cystic fibrosis underwent a splenectomy 54 days after the study, which confirmed the patency of the portal and splenic veins as seen on sonography, CT, and splenoportography. Examination of the excised spleen at pathology showed no evidence of trauma. Splenoportography in a 9-year-old girl revealed cavernous transformation and no evidence of the splenorenal shunt, which had appeared to be patent on CT (Fig. 3). A mesocaval shunt was performed better 25 days after splenoportography. A 2-year-old boy with recurrent hepa-

toblastoma and trisegmentectomy underwent hepatojejunostomy 3 days after splenoportography, which confirmed the splenoportographic, sonographic, and CT findings of portal vein occlusion (Fig. 4).

No bleeding complications occurred. Surgical follow-up in six patients 3–54 days after splenoportography showed no gross evidence of splenic trauma. The spleen was specifically examined in only one patient; histology of the liver revealed no evidence of trauma. MR angiography after the procedure revealed no evidence of splenic trauma in another adult patient. The remaining adult patient received neither surgical nor imaging follow-up but showed no clinical evidence of splenic bleeding.

Discussion

Although splenoportography never gained widespread acceptance because of its risks for hemorrhage, only two studies, to our knowledge, have documented significant complications with bleeding when 18-gauge needles were used in adults and 20-gauge needles, in pediatric patients [3, 7]. Brazzini et al. [7] studied 37 patients who had undergone splenoportography. Twenty-five of the 37 patients in whom the needle tract was occluded had no bleeding complications. In the remaining 12 patients who had no Gelfoam ([gelatin sponge particles] Pharmacia and Upjohn, Kalamazoo, MI) embolization, five were found to have varying degrees of intraabdominal bleeding. In an earlier study [3], investigators tried decreasing the risk of bleeding by using sheath or sleeve needles. In that investigation, three of 69 patients (110 procedures) experienced significant bleeding complications that required intervention.

Ironically, many splenoportography studies with no or few bleeding complications have been reported in the past 30 years—even in cases in which 18-gauge needles were used. In fact, 63 patients have been studied as outpatients without complications [8]. Digital subtraction angiography has permitted the use of even smaller needles (21- to 22-gauge) without bleeding complications [9].

We attempted to minimize the risk of splenic hemorrhage by using an ultrafine 25-gauge spinal needle. Our first CO₂ splenoportography was performed in a 5-month-old boy who had very poor femoral pulses. Our experience with fine-needle (21-gauge) TIPS [6] caused us to think that the use of an even smaller, flexible 25-gauge needle would be safer than attempting a femoral artery ap-

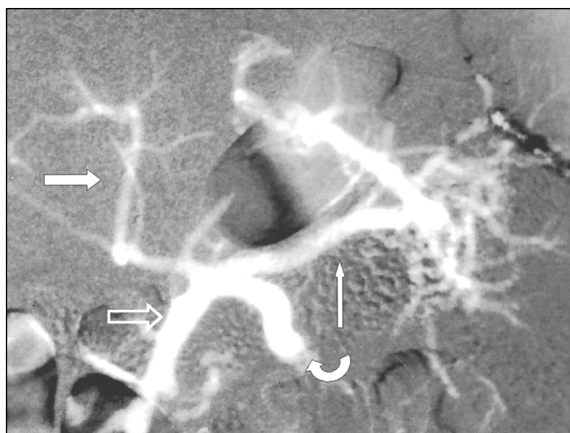


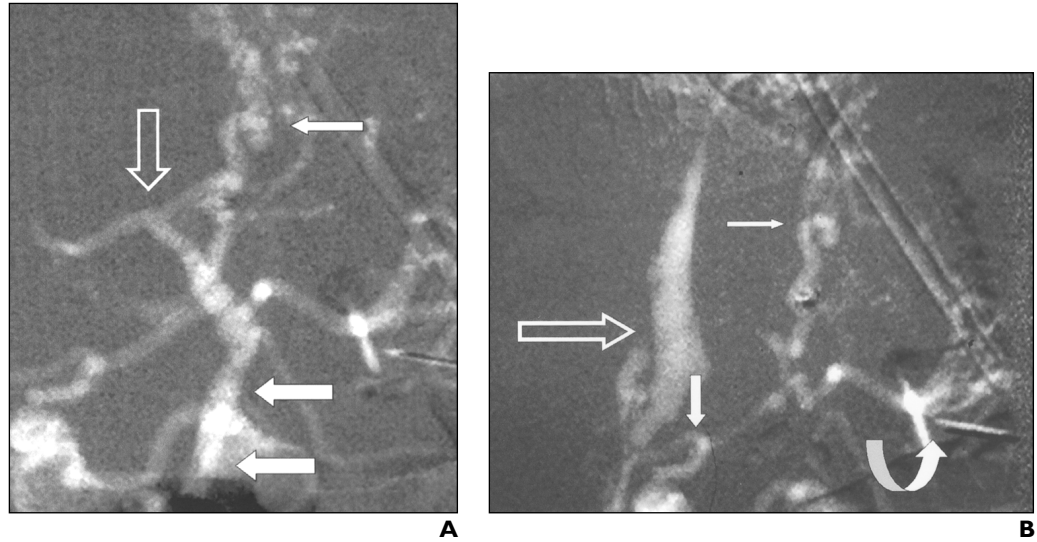
Fig. 1.—CO₂ splenoportogram in 2-year-old girl with biliary atresia shows patent splenic (*thin solid arrow*) and intrahepatic veins and small portal vein (*thick solid arrow*). Note reflux in superior (*open arrow*) and inferior (*curved arrow*) mesenteric veins. Sonography and MR angiography (not shown) showed no portal vein.

CO₂ Splenoportography

Fig. 2.—5-month-old boy with biliary atresia.

A. CO₂ splenoportogram shows splenic superior mesenteric vein (*thick solid arrows*), coronary and gastroesophageal varices (*thin solid arrow*), and patent diminutive portal veins (*open arrow*), which were incorrectly interpreted as collateral vein. CO₂ injection was performed with patient in Trendelenburg's position.

B. Splenoportogram shows needle in spleen (*curved arrow*) and CO₂ filling inferior vena cava (*open arrow*) via multiple retroperitoneal collateral veins (*thick solid arrow*). Coronary collateral veins (*thin solid arrow*) also fill. No filling of either superior mesenteric or portal veins was revealed.



proach. The cross-section area (size of splenic hole) of the 25-gauge needle is one third the size of a "safe" 21-gauge needle and 6.2 times smaller than the most frequently used 18-gauge needle. Fine needles (20- to 22-gauge) are commonly used for biopsies of the liver without significant bleeding complications [10].

In addition, we had previously injected CO₂ into the splenic pulp in five swine, incrementally increasing the dose from 10 to 50 mL with a 22-gauge needle (unpublished data, 2001). No histologic evidence was found of intrasplenic hematoma, laceration, or extravasation. The entire portal system was well seen in all animals, with reflux into the superior mesenteric vein with the larger volumes.

Laceration of the spleen during deep aspiration is a potential danger of splenoportography. No lacerations with 21-gauge needles have been reported [9]. We used general anesthesia in all the children and two adults, which provided controlled respiration. We think that the risk is minimal if a flexible 25-gauge needle is used; however, this technique should probably be performed only with anesthesia in potentially uncooperative patients. A disadvantage of using the fine needle is that it does not allow accurate measurement of splenic pulp pressure. The pulp pressure obtained using a larger needle system provides an estimate of the portal pressure, which may be important in equivocal cases of significant portal hypertension.

The use of a 25-gauge spinal needle is made possible by using low-viscosity CO₂ as the imaging agent. We think that the very low viscosity of CO₂, as compared with iodinated

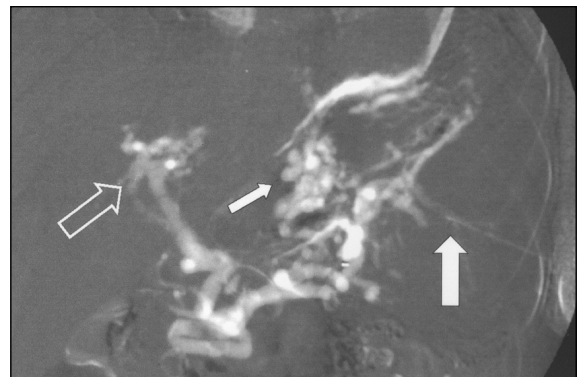
contrast material, increases the portal venous filling with injection into the splenic pulp. This response is similar to the excellent portal filling we have seen when we have injected CO₂ into the liver parenchyma via the transjugular route during TIPS procedures. For splenic injections, we chose volumes of CO₂ similar to those used for our TIPS intraparenchymal hepatic injections [6]. The small lumen of the 25-gauge needle obviously precluded comparison of CO₂ with iodinated contrast material.

An experimental study similar to our procedure was performed by Hipona and Park [11] in 1967. These researchers placed a needle in the surgically exposed spleen of dogs and made multiple injections of CO₂ (2–3 mL/kg) into the splenic pulp, filming the portal system with conventional X-ray film. Artificial portal hypertension was created in five dogs. Opacification of the portal vein with CO₂ and iodinated contrast material with elevation of the right side of the five dogs showed that CO₂ filled the intrahepatic portal vein much better

than the iodinated contrast material because of the buoyancy of the CO₂. The disadvantage of that buoyancy is that it does not permit accurate hemodynamic evaluation; on the other hand, it allows CO₂ to be used to fill veins that are not seen when liquid contrast material is used. In patients with hepatofugal flow, the extrahepatic portal vein may appear to be occluded with liquid contrast material during both contrast-enhanced splenoportography and arterial portography. Although in this study we did not use buoyancy to fill the portal vein, Hipona and Park [11] did improve portal filling by elevating the right side of the dogs they imaged.

When we elevated the patient's feet during CO₂ splenoportography, the buoyant CO₂ filled the superior mesenteric vein in the first child we examined (Fig. 2A). This imaging does not usually occur with contrast-enhanced splenoportography because the superior mesenteric vein flow is always cephalad. Also in this patient, the low-viscosity CO₂ was

Fig. 3.—CO₂ splenoportography in 9-year-old girl postsplenorenal shunt with 25-gauge needle (*thick solid arrow*) in spleen shows cavernous transformation of portal vein (*open arrow*) and short gastric collateral veins (*thin solid arrow*) with no evidence of splenorenal shunt. CT (not shown) revealed patent shunt.



shunted into the inferior vena cava during splenoportography and provided critical information for the transplant surgeon. If these collateral

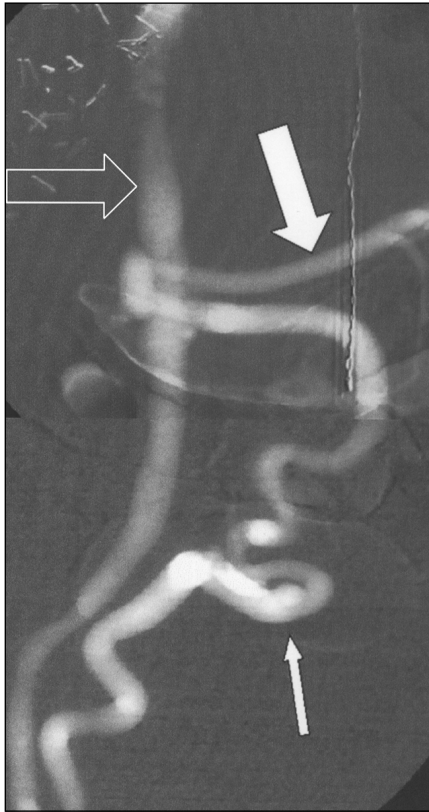


Fig. 4.—2-year-old boy with recurrent hepatoblastoma and occluded portal vein who had undergone trisegmentectomy. CO₂ splenoportogram shows splenic vein as patent (*thick solid arrow*). Large hypogastric collateral vein (*thin solid arrow*) fills inferior vena cava (*open arrow*).

veins are not ligated, the portal flow may bypass the liver with resulting portal thrombosis. In this initial patient, blood flow ceased after the portal vein was anastomosed; however, the collateral veins were ligated and good hepatopedal portal flow was reestablished.

CO₂ digital subtraction angiography has been used safely in a large number of patients for more than 20 years [12]. Its unique combination of properties—very low viscosity, buoyancy, and absence of nephrotoxicity—makes CO₂ ideal for improving the safety and efficacy of splenoportography. Although we studied only a small number of patients, we believe that this technique is a safe and effective method for evaluating the portal system.

When splenoportography is performed using an ultrafine needle and CO₂, the procedure is simple and of short duration; it presents a minimal risk of bleeding and no risk of renal toxicity or allergic reaction. The buoyant CO₂ provides information beyond that which can be obtained using iodinated contrast material. For these reasons, CO₂ splenoportography is a viable option for patients who are at risk for arterial injury (primarily pediatric patients), patients who have renal failure, those in whom the patency of the portal vein must be ascertained because splenomegaly or hepatofugal flow is suspected, patients in whom the patency of splenorenal shunts must be evaluated, and those in whom portal vein status must be evaluated during transjugular intrahepatic portosystemic shunt procedures.

Until more clinical experience is obtained, CO₂ splenoportography should be used only

when noninvasive imaging studies have failed to provide necessary information about portal vein patency.

References

1. Figley M. Splenoportography: some advantages and disadvantages. *AJR* **1958**;80:313–323
2. Burchell AR, Moreno AH, Panke WF, Rousselot LM. Some limitations of splenic portography. *Ann Surg* **1965**;162:981–995
3. Foster JH, Conkle DM, Crane JM, Burko H. Splenoportography: an assessment of its value and risk. *Ann Surg* **1974**;179:773–781
4. Silverman JM, Podesta L, Villamil F, et al. Portal vein patency in candidates for liver transplantation: MR angiographic analysis. *Radiology* **1995**;197:147–152
5. Hawkins IF Jr, Caridi J, Klioze S, Mladinich CRJ. Modified plastic bag system with O-ring fitting connection for carbon dioxide angiography. *AJR* **2001**;176:229–232
6. Hawkins IF Jr, Caridi JG. Fine-needle transjugular intrahepatic portosystemic shunt procedure with CO₂. *AJR* **1999**;173:625–629
7. Brazzini A, Hunter DW, Darcy MD, et al. Safe splenoportography. *Radiology* **1987**;162:607–609
8. Dilawari JB, Chawla YK, Raju GS, Kaur U, Bambery P. Safety of splenoportovenography as an outpatient procedure. (letter) *Lancet* **1987**;2:101
9. Braun SD, Newman GE, Dunnick NR. Digital splenoportography. *AJR* **1985**;144:1003–1004
10. Hertz G, Reddy VB, Green L, et al. Fine-needle aspiration biopsy of the liver: a multicenter study of 602 radiologically guided FNA. *Diagn Cytopathol* **2000**;23:326–328
11. Hipona FA, Park WM. Capnosplenoportography: assessment of portal vein patency in dogs with carbon dioxide gas. *AJR* **1967**;99:606–611
12. Hawkins IF Jr, Caridi JG. Carbon dioxide digital subtraction angiography: 26-year experience at the University of Florida. *Eur J Radiol* **1998**;8:391–402