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CO_2 Digital Subtraction Splenoportography with the "Skinny" Needle: Experimental Study in a Swine Model

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Abstract

Purpose: To evaluate the safety and the effectiveness of CO_2 splenoportography with the "skinny" needle.
Methods: A flexible, 22 gauge needle ("skinny" needle) was introduced into the exteriorized spleens of five pigs. After checking the intrasplenic positioning with CO_2 injection, increasing doses of CO_2 (10–60 cm^3) were injected using a dedicated CO_2 injector with digital imaging. The puncture sites were observed during and after CO_2 injections, and after removal of the needle. The spleens were then removed for gross and microscopic examination.
Results: In all animals digital subtraction CO_2 splenoportograms showed the splenic, extra- and intrahepatic portal veins, and the most distal portion of the superior mesenteric vein. No CO_2 extravasation occurred in the spleen. There was no significant bleeding from the puncture site after removal of the needle. Gross and microscopic examination revealed no evidence of splenic rupture or intrasplenic hematoma.
Conclusion: CO_2 splenoportography with the "skinny" needle is a safe and simple method of visualizing the portal vein and its branches. Careful appraisals of the clinical usefulness of the method will be needed in various clinical settings.

Key words: Splenoportography—Carbon dioxide—Skinny needle—Portal hypertension—Splenic rupture—Digital subtraction angiography

Since the reports in 1951 that the portal vein could be visualized by intrasplenic injection of contrast material, splenoportography has been used for evaluation of patients with cirrhosis and portal hypertension, before and after portosystemic shunt surgery [1–8]. The procedure involves percutaneous introduction of a needle (16 to 22 gauge) into the spleen and intrasplenic injection of 24–30 cm^3 of contrast material in 4–5 sec [5, 6, 8]. Although the method was proven to be safe and effective, it has been replaced by arterial portography (visualization of the portal vein and its branches by intra-arterial injection of contrast material) and noninvasive imaging methods (ultrasound, computed tomography, and magnetic resonance venography).

Recently a 2-year-old female underwent a successful, uncomplicated CO_2 splenoportogram using a 22 gauge "skinny" needle after unsuccessful visualization of the portal vein by noninvasive imaging methods. She was a candidate for liver transplantation for liver failure secondary to biliary atresia. This experimental study was undertaken in swine to examine the safety and effectiveness of CO_2 splenoportography using the "skinny" needle.

Materials and Methods

Five pigs (25–35 kg) were anesthetized with intramuscular injection of ketamine (35 mg/kg) followed by halothane. The trachea was cannulated low in the neck and the lungs were ventilated with 30% oxygen in air on a mechanical ventilator. The abdomen was opened in the midline and the spleen was exteriorized and placed outside the abdominal cavity (Fig. 1). A flexible, 10 cm long, 22 gauge needle (0.5 mm inner diameter, 0.7 mm outer diameter; Cook, Bloomington, IN, USA) was used to puncture the spleen. Digital subtraction angiography (DSA) with a 5 cm^3 CO_2 injection was used to check the positioning, and the needle was connected to a dedicated CO_2 injector (AngioDynamics, Queensbury, NY, USA). CO_2 was injected at the rate of 5, 10, 20, and 30 cm^3/sec for 2 sec and digital subtraction images were obtained at the rate of 4 exposures/sec using a Mobile Digital Imaging System (OEC Medical Systems, Salt Lake City, Utah, USA). CO_2 injections were separated by 5 min. The spleens were observed during and after CO_2 injections.

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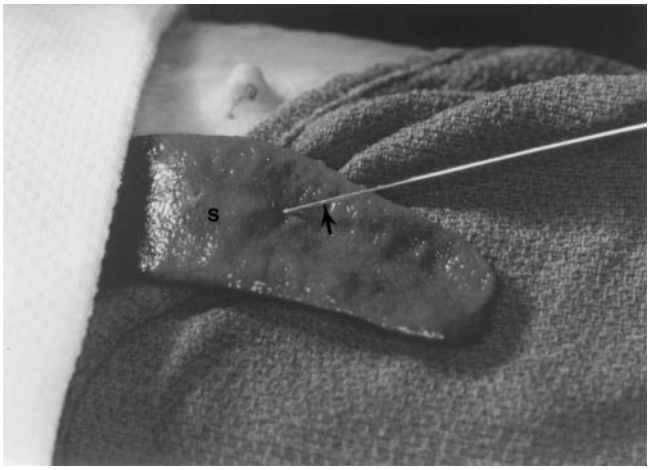

Fig. 1. Photograph of an exteriorized spleen (s) with a 22 gauge needle (arrow) introduced into its lower pole.

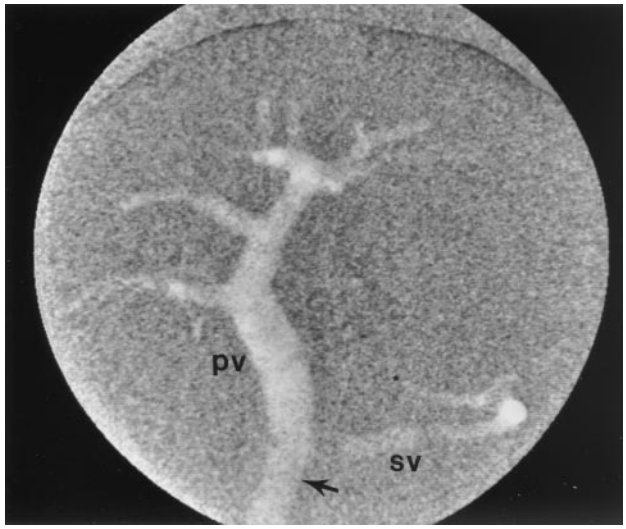

Fig. 2. Digital subtraction splenoportogram with the injection of CO_2 at 10 ml/sec for 2 sec shows opacification of the splenic (sv) and portal (PV) veins, and intrahepatic portal venous branches. There is reflux of CO_2 into the superior mesenteric vein (arrow). The asterisk indicates the tip of the needle and CO_2 injection site in the spleen.

After completion of CO_2 injections in each animal, the needle was removed, and the puncture site was checked for evidence of bleeding for 30 min. All animals were killed, and the spleens were removed. Serial sections were made through the areas of punctures sites. Random sections of the spleens were fixed in 10% buffered formalin for microscopic examination. All images were evaluated for the quality of splenoportograms.

Results

All animals survived the experimental period. No complications occurred. Vital signs and SaO_2 remained stable after CO_2 injections. The spleens appeared unremarkable during and after CO_2 injections. After removal of the needle, a small amount of venous bleeding occurred from the puncture site, which ceased spontaneously in 3–5 min.

All digital subtraction CO_2 splenoportograms showed the portal vein and its branches. There was no evidence of CO_2 extravasation at the injection site (Fig. 2). The intrahepatic portal branches filled to the periphery of the liver, but no hepatogram was seen. CO_2 disappeared from the portal vein gradually over 2–3 min. Visualization of the portal vein improved with increasing injection doses of CO_2. The entire portal venous system filled when injected with 20 cm^3/sec for a total volume of 40 cm^3. Neither the hepatic vein nor the inferior vena cava was visualized. The superior mesenteric vein was opacified due to reflux of the gas.

Grossly, the spleens were normal. There was no evidence of subcapsular dissection or intrasplenic hematoma (Fig. 3). Microscopically, the splenic capsule was intact and there was no subcapsular hematoma.

Discussion

For years splenoportography was used to obtain the anatomic and hemodynamic information necessary for the diagnosis and treatment of patients with cirrhosis and portal hypertension in both adult and pediatric age groups [9–12]. Many reports have described the safety and usefulness of the method in visualizing the portal vein and its branches as well as the portosystemic collateral veins [5, 7, 9, 13]. When the spleen is successfully punctured, a contrast injection predictably opacifies the portal vein and its branches. Despite the advantages of the procedure, it has become a very infrequently used angiographic method. This can in part be attributed to the risk of bleeding related to the splenic puncture, fear by most physicians concerning the fragility of the splenic capsule, and the advent of arterial portography and noninvasive imaging methods. It seems that general unawareness of the technique and inexperience with splenoportography will further reduce the use of the method.

Although the technique of CO_2 splenoportography is similar to those of traditional procedures [2, 5, 6, 12], it has some advantages. The most significant of these is the safety of the procedure. This can be ascribed to the use of the "skinny" needle to puncture the spleen and to the use of CO_2 as a contrast agent. The safety of using the "skinny" needle has been well documented in percutaneous transhepatic cholangiography, percutaneous biopsy, and other organ access procedures [14, 15]. Unlike contrast material, the intrasplenic injection of CO_2 does not cause extravasation because of the low viscosity of the gas. The "skinny" needle allows injection of large quantities of CO_2 into the spleen. When contrast material is used for splenoportography, dilute contrast should be used at a lower rate [6, 8]. One disadvantage of the use of the "skinny" needle is the inability to measure the splenic pulp pressure, as blood would not return through the needle.

CO_2 splenoportography seems to be safe enough for clinical applications, considering the fact that splenic hem-

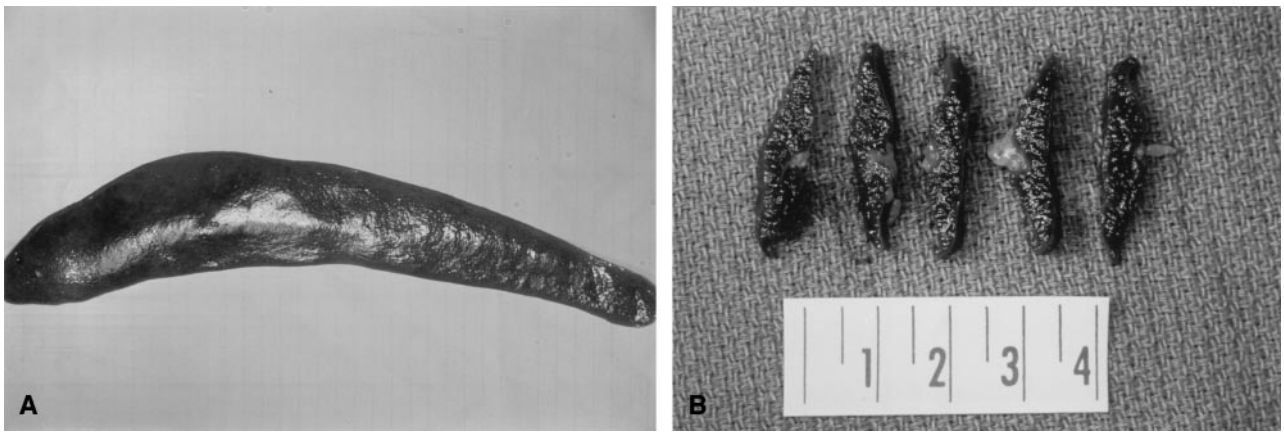

Fig. 3. A, B. Gross photograph of the spleen after CO_2 splenoportography. **A** The spleen appears normal with an intact splenic capsule. **B** Sections through the injection site show no intrasplenic hematoma.

orrhage did not occur following multiple intrasplenic injections of the gas at quantities more than sufficient for portal vein opacification. Thoughtful appraisals of the clinical usefulness of the method should be undertaken in various clinical settings. These may include evaluation of patients with cirrhosis and portal hypertension, prior to hepatic transplantation, evaluation of the resectability of pancreatic and biliary neoplasms, and visualization of the portal vein during TIPS procedures.

CO_2 is a useful alternative contrast agent for arterial and venous examinations in patients with hypersensitivity to iodinated contrast material and compromised renal function [16]. CO_2 has several unique physical properties that are important in CO_2 angiography. These include solubility, viscosity, buoyancy, and compressibility. CO_2 is at least 20 times more soluble than air, allowing an intravascular injection without causing clinically significant gas embolism. Proper use of the hand-held syringe and the plastic bag system [17] will minimize the risk of air contamination. The low viscosity of the gas is the primary reason for the safety of CO_2 splenoportography. It allows intrasplenic injection using the "skinny" needle, such as a 22 or a 25 gauge needle. Multiple injections can be made manually or using a dedicated CO_2 injector without the risk of bleeding or splenic laceration. Resistance to gas flow through the needle usually results in compression of the gas, and sudden expansion occurs upon exiting the needle. This is known as "explosive" delivery. However, we found no evidence of extravasation or splenic injury despite manual injections of large amounts of CO_2 into the splenic pulp.

Since the red pulp accounts for three-quarters of the volume of the human spleen, which comprises arteries, venous sinuses, and pulp veins, the needle tip seemed to be in a vascular space when introduced. When CO_2 was injected, the gas bubbles coalesced rapidly into larger bubbles filling the splenic and portal veins. There was no evidence of CO_2 extravasation at the injection site. The portal vein and its branches filled well because of the anterior location relative to the spleen. Understanding of the buoyancy of CO_2 is important, as the portal vein would be filled with CO_2 regardless of the direction of the venous blood flow in the portal venous system. In other words, the portal vein could be visualized with CO_2 in the presence of reversal of flow in the portal vein. In a canine experimental study, Hipona and Park [18] demonstrated much better filling of the portal vein and its intrahepatic branches with intrasplenic injections of CO_2 in the left posterior oblique position.

On the basis of this experimental study and our clinical experience with a pediatric patient, the following technique for CO_2 splenoportography is suggested. Preangiographic preparation of a patient for CO_2 splenoportography should be the same as for conventional angiography and percutaneous fine needle biopsy. To reduce bleeding from the puncture site, clotting abnormalities should be corrected. Ascites is not an absolute contraindication to splenoportography but attempts should be made to relieve ascites prior to the procedure. The procedure can be done with mild sedation; general anesthesia may be required in pediatric patients. The spleen can be punctured accurately under ultrasound guidance. When the needle is introduced into the spleen, a 5 cm^3 CO_2 injection is made, and imaged with digital subtraction technique to check the positioning. When the needle is properly located in the spleen, the splenic and portal veins should be opacified. The quantities and injection rates should vary, depending upon the clinical problem and the size of the portal vein and portosystemic collateral veins. In pediatric patients, 10–15 cm^3 of CO_2 will fill the portal vein and its branches. Larger quantities of CO_2 may be required to optimally visualize the portal vein and its branches in adults.

In summary, CO_2 is a safe and effective contrast agent for splenoportography with the benefit of low viscosity that allows injection through the "skinny" needle, thus reducing the risk of postprocedural bleeding. The method warrants further clinical evaluation of its diagnostic usefulness in various settings including evaluation of patients with cirrhosis and portal hypertension, variceal bleeding, portal vein

visualization prior to a TIPS procedure, portosystemic shunt procedure and liver transplantation candidates, suspected portal or splenic vein occlusion, and preoperative evaluation of resectability of biliary and pancreatic neoplasms.

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