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CLINICAL INVESTIGATIONS

Wedged Hepatic Venography for Targeting the Portal Vein During TIPS: Comparison of Carbon Dioxide and Iodinated Contrast Agents

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Abstract

Purpose: Carbon dioxide (CO_2) can traverse the hepatic sinusoids better than iodinated contrast medium and has been used by many interventionalists for wedged hepatic venography during transjugular intrahepatic portosystemic shunt (TIPS) procedures. Our study was designed to compare the extent of the portal vein opacification using either CO_2 or iodinated contrast medium.

Methods: Wedged hepatic venography for portal vein opacification during TIPS was performed using hand injection through a 6.5 Fr diagnostic catheter. Portograms of 36 patients performed with 10 ml of iodinated contrast medium were retrospectively compared with portograms of 45 patients performed with 30–40 ml of CO_2. Opacification of the right portal vein branch including the portal vein bifurcation was defined as a successful study.

Results: Using CO_2 the right portal vein branch and the portal vein bifurcation were opacified in 87% of patients (39 of 45); only a part of the right portal vein branch was opacified in 6% of patients and no opacification of any portal vein branch was seen in 7% of patients. Using iodinated contrast medium, there was opacification of the portal vein bifurcation in 25% of patients (9 of 36), of a part of the portal vein branch in 36% and no opacification of any branch in 39%. There was one case of hepatic laceration from CO_2 wedged venography which was treated with microcoil embolization.

Conclusions: Using CO_2 as a contrast medium, opacification of the portal vein bifurcation by wedged hepatic venography was seen in 87% of patients, in comparison with only 25% when iodinated contrast medium was used ($p < 0.001$). CO_2 is superior to iodinated contrast medium for wedged hepatic venography during TIPS.

Key words: Carbon dioxide—Contrast media, comparative studies—Liver, interventional procedure—Portal vein—Shunts, portosystemic

The most difficult and critical step of a transjugular intrahepatic portosystemic shunt (TIPS) procedure is gaining access from the hepatic vein to the intrahepatic portal vein branch. This part of a TIPS procedure is important both for minimizing severe procedural complications [1] and potentially also for long-term patency of the shunt. Perforation of the liver capsule, puncture of the hepatic artery or biliary duct from errant needle passes, and puncture of the extrahepatic portal vein bifurcation can lead to intraperitoneal bleeding [2, 3]. Puncture of the biliary duct can cause shunt thrombosis [4]. To reduce the number of needle passes required to puncture the portal vein, the operator has to have a thorough understanding of the relative location of the hepatic and portal veins in each individual patient [5].

The methods which have been used for imaging of the portal vein have included preoperative CT or ultrasound (US) scan, percutaneous periportal placement of a platinum coil as a marker under either US or CT guidance [6], preoperative percutaneous ultrasonographic placement of a small catheter [7] or wire [8] into the portal vein, or hepatic artery, real-time US guidance [9], and transarterial or wedged hepatic portography using either an iodinated contrast medium or carbon dioxide gas (CO_2) [10–12].

The use of CO_2 is now preferred over iodinated contrast media in wedged hepatic portograms because the viscosity of CO_2 as a gas is 400 times lower than that of liquid contrast media. The gas can better traverse the hepatic sinusoids. The portal vein bifurcation or even the main portal vein are more often opacified by CO_2 than by liquid contrast media.

Because the efficacy of CO_2 in wedged hepatic portography over iodinated contrast media has not been established, we decided to compare the portal vein opacification by wedged hepatic portography using CO_2 in one group of

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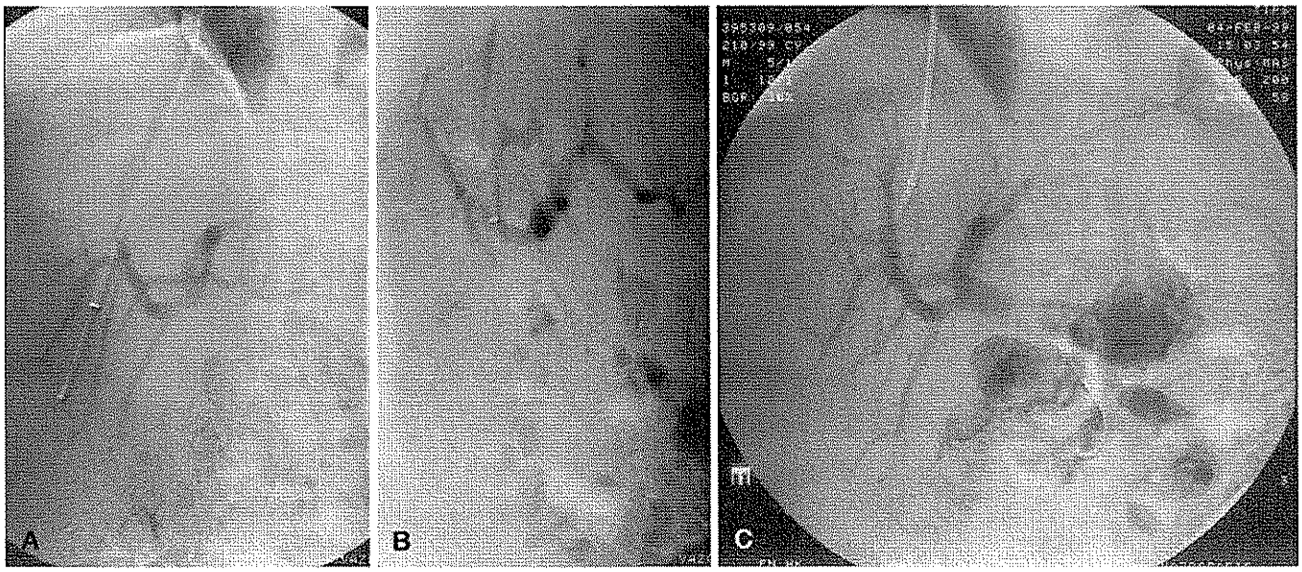

Fig. 1. Wedged CO_2 venography performed in anteroposterior (**A**) and lateral view (**B**). These images demonstrate the relative location of the hepatic vein, which is represented by position of the catheter and the both branches of the portal vein. **C** The CO_2 transjugular portogram of the same patient performed through the catheter introduced into the portal vein.

patients treated with TIPS with a second group of patients in whom wedged hepatic portography was performed using iodinated contrast medium.

Materials and Methods

The wedged hepatic portograms of 45 patients performed using CO_2 (medical grade CO_2, AGA, Ostrava, Czech Republic) were retrospectively compared with portograms of another 36 patients performed using iodinated contrast medium [Omnipaque 350, Nycomed Amersham, Norway (60% of patients); Telebrix, Byk Gulden, Germany (40% of patients)].

There were 11 women and 34 men of mean age 53.8 years (range 39–79 years) in the CO_2 group and 11 women and 25 men of mean age 51.9 years (range from 8–79 years) in the iodinated contrast medium group. All patients were referred for TIPS because of symptomatic portal hypertension. The mean portosystemic gradient was 20.73 mmHg (range 20–31 mmHg) in the CO_2 group and 18.53 mmHg (range 17–30 mmHg) in the iodinated contrast medium group. There were six patients (13%) with hepatofugal flow in the CO_2 group and six patients (17%) in the iodinated contrast medium group.

Wedged hepatic portography was performed using hand injection of 30–40 ml of CO_2 through a 6.5 Fr diagnostic endhole catheter (Rösch celiac, Cook, Denmark) (Fig. 1). For each procedure, the CO_2 tank was attached through a reducing valve to a sterile connecting tube leading to a three-way stopcock, to which was attached the 60 ml syringe. The three-way stopcock facilitates the purging of all room air from the tube filling the syringe. Once filled with 50 ml of CO_2, the syringe was disconnected and immediately attached to the hub of the diagnostic catheter and hand injection of CO_2 was administered.

When using iodinated contrast agent, the injection was performed through the same type of catheter using the automatic injector (5 ml/sec for a total 10 ml of liquid contrast agent). The portogram was stored on a second monitor for reference during intrahepatic puncture.

The right or middle hepatic veins were used for the wedged hepatic portograms in both groups because these are the veins primarily considered for TIPS creation.

Digital subtraction angiography (Polytron S plus, Siemens, Germany) was used for all angiographic sequences with a 1024 × 1024 matrix, filming at 3 frames per second; the single frame mask without stacking of images was used in both groups of patients. Wedged venography was performed in all patients separately in anteroposterior and lateral views since only a single-plane fluoroscopy unit was available.

Opacification of the portal vein branch including the portal vein bifurcation was defined as the criterion of a successful study. A failed portogram was defined as no opacification of any part of the right or left main portal branch.

The data of both groups were statistically evaluated to prove their comparability (using cross-tabulation and Fisher's exact test) in the following parameters: gender, age, flow direction in the portal vein, pressure in the portal and hepatic veins. In all these parameters the two groups were not statistically different. The effectiveness of portal vein imaging in the two groups was compared using a nonparametric test (Wilcoxon test).

Results

Using CO_2, the right portal vein and the portal vein bifurcation were opacified in 87% of patients (39 of 45); only a part of the right portal vein branch was opacified in 6% of patients and no opacification of any portal vein branches was observed in 7%. The main portal vein was opacified in 53% of cases.

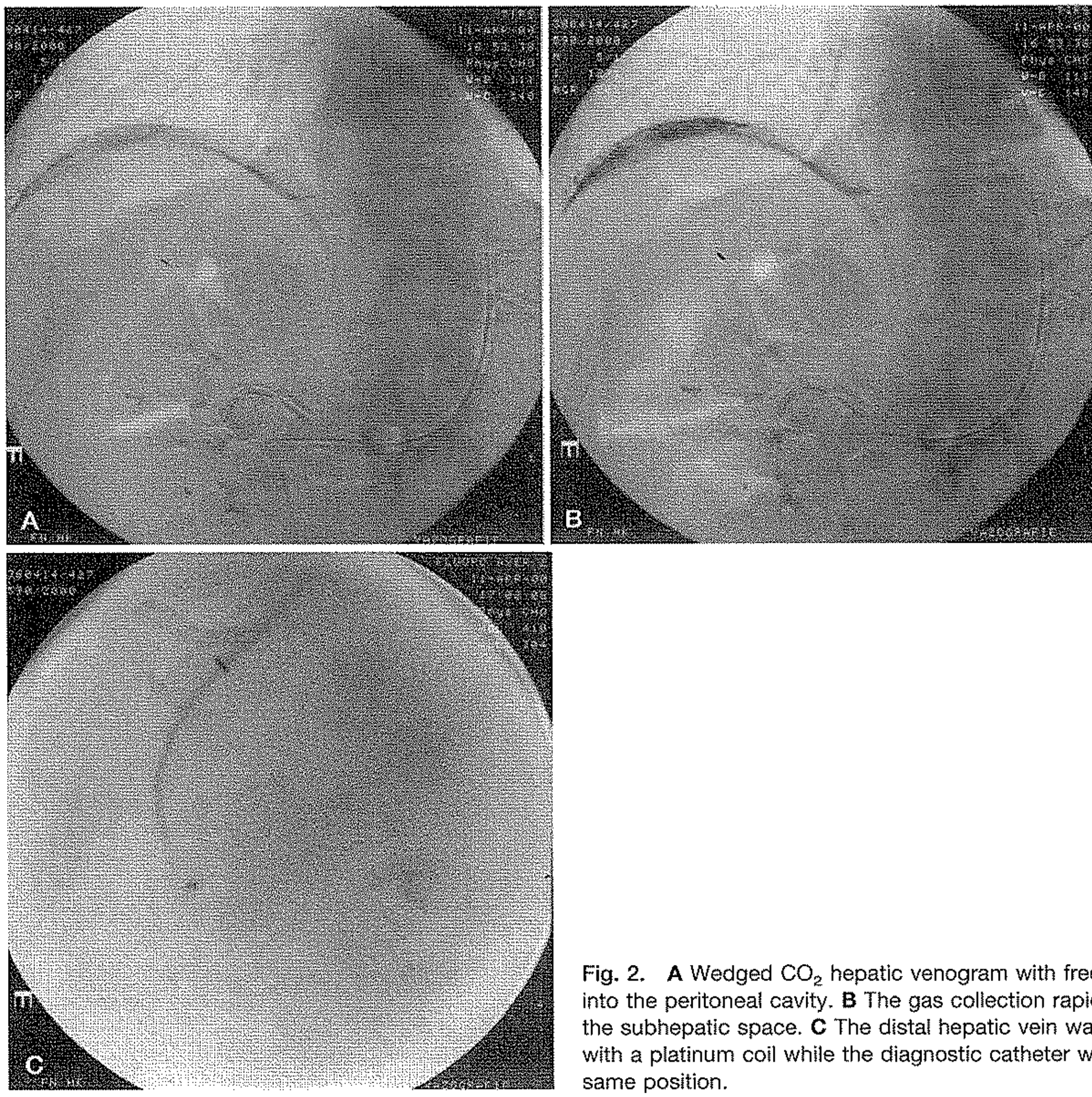

Fig. 2. **A** Wedged CO_2 hepatic venogram with free extravasation into the peritoneal cavity. **B** The gas collection rapidly moved into the subhepatic space. **C** The distal hepatic vein was embolized with a platinum coil while the diagnostic catheter was kept in the same position.

Using iodinated contrast medium, there was opacification of the portal vein bifurcation in 25% of patients (9 of 36); in all these patients the main portal vein was simultaneously opacified. There was hepatofugal flow in the portal vein in five of these nine patients (56%). A part of the right portal vein branch was opacified in 36% and no opacification of any part of the main right portal vein branch was observed in 39%.

If we consider as the criterion of successful portography the opacification of the portal vein bifurcation, the difference between the 87% success rate in the CO_2 group versus 25% in the iodinated contrast medium group is statistically highly significant ($p < 0.001$).

There was one case of hepatic laceration from wedged CO_2 venography (Fig. 2). The intraperitoneal leak was recognized and the diagnostic catheter was kept wedged. To prevent bleeding, one microcoil (Tornado, Cook, Denmark) was placed using a microcatheter (MicroFerret, Cook, Denmark) introduced through the inner lumen of the diagnostic catheter. This complication was without any clinical sequelae and the TIPS procedure was successfully completed. There was no other complication related to the hepatic vein injection through the wedged catheter or using CO_2.

Discussion

Of the several steps in the TIPS procedure, transvenous access to the portal vein is by far the most crucial and unfortunately also the most unpredictable. During 10 years of clinical use, TIPS interventionalists have attempted to make this essentially blind puncture more targeted, and thus to shorten the procedure time and enhance its safety.

In our experience with more than 330 TIPS procedures we have used the following methods to reveal the portal and hepatic vein anatomy: Doppler ultrasonography, CT scan of the liver and CO_2 wedged hepatic portography. The use of CO_2 injection in our experience does not extend the time of the procedure, is now very simple and is considered by all our operators to be useful, so we employ it routinely as a part of every TIPS procedure.

Imaging the portal vein bifurcation in two views was considered by us, and also by others [12], to be sufficient enough to complete the portal vein puncture. We therefore decided to take visualization of the portal vein bifurcation as the criterion of successful portography in our study. Opacification of a part of the right or left portal vein branch was considered also useful, and therefore this degree of portal vein opacification was mentioned in our study. The imaging of more peripheral branches was considered only minimally helpful for the planning of portal vein puncture.

Use of wedged hepatic CO_2 portography was introduced into the TIPS procedure by Rees and colleagues [10]. The idea of using CO_2 for examination of the splenoportal venous system had been studied in dogs by Hipona and Park before TIPS development [13]. Besides wedged hepatic portography, CO_2 has been used for following purposes during TIPS: hepatic venography to identify the most suitable hepatic vein from which to make the portal vein puncture, direct portography after pigtail catheter placement in the portal vein, and additional injections after tract dilatation and stent placement.

The absence of nephrotoxicity of CO_2 as a contrast medium can have other indications, such as a desire to avoid iodinated contrast medium-induced nephrotoxicity in patients with reduced glomerular filtration rates. Some patients with liver cirrhosis may have normal serum creatinine levels, often with profound wasting of muscle tissue. A history of severe allergic reaction to contrast medium can also be a possible indication, since CO_2 is sufficient for completion of the entire TIPS procedure without the use of iodinated contrast medium.

The much better results in revealing the portal anatomy using CO_2 instead of iodinated contrast medium are explained by the low viscosity of CO_2 (more than 400 times lower than that of liquid contrast medium). The gas can better traverse the hepatic sinusoids in a volume large enough to cause temporary reversal of the portal vein blood flow. Gravity plays an important role in the distribution of injected gas in the portal vein. The buoyancy of the gas has the advantage of preferentially filling the nondependent left portal branch when it is injected from the dependent right or middle hepatic veins. This preferential filling of the left portal branch and the low viscosity of CO_2 are the two main reasons why the portal vein bifurcation or even the main portal vein are more often opacified by CO_2 than by liquid contrast medium. We have only limited experience in using the left hepatic vein for wedged hepatic venography since all our CO_2 studies were primarily performed through the right or middle hepatic veins. There is a probability that filling of the dependent right portal vein branch from the left hepatic vein is less effective because of CO_2 buoyancy.

Using a double-lumen occlusion balloon catheter for performing either liquid or gas injection through the inner lumen while an inflated balloon occludes the flow in the hepatic vein has been advocated for several reasons [14]. When performing balloon occlusion venography, the balloon catheter can be positioned in a more central hepatic vein and therefore the injection force is distributed over a larger area of the venous tributaries from a larger volume of the liver. There is also no reflux of contrast medium into the free hepatic vein. The reflux can potentially decrease the volume and pressure of injected liquid or gas contrast medium. The inflated balloon also stabilizes the position of the catheter during injection.

The injection from the more central position of the balloon catheter decreases the potentially dangerous jet from a peripherally wedged endhole catheter [15]. We did not use a double-lumen balloon catheter because of its additional expense. Except for one case of documented hepatic capsule laceration out of 72 wedged catheter portograms, which was without any clinical sequelae, we have not observed any complication resulting from injection through a single-lumen wedged catheter. We are aware of reported fatal complications due to hepatic capsule laceration [15], and therefore tried to avoid peripheral positioning of the diagnostic catheter.

There are possible complications unique to CO_2 because of its gaseous state. Iodinated contrast medium mixes with blood, whereas CO_2 displaces blood. Thus, when injected in large volumes, CO_2 can displace the blood from the right heart and the main trunk of pulmonary artery, causing so-called vapor lock and resulting in transient hypotension and cardiac arrest. To avoid this potentially lethal complication it is recommended that the pulmonary artery be checked in the supine position after a small (10 ml) test injection of CO_2. If the gas remains there longer than 20–30 sec, the patient should be placed in the left lateral decubitus position to release the flow through the right heart. Pure CO_2 should be absorbed into solution in 15–30 sec [16, 17]. More significant episodes of vapor lock can occur with very large volume injections (greater than 60 ml) or when room air is inadvertently injected along with CO_2 from an incompletely cleared syringe. Use of dedicated CO_2 injection sets is recommended to prevent both injection of excessively large volumes of CO_2 and the inadvertent injection of room air. The main pulmonary artery is also the most frequent location of small air bubbles arising from intravenous drug administration [18].

Because of neurotoxicity CO_2 should not be used in the presence of a pre-existing right-to-left heart shunt (this is also a contraindication for TIPS). In patients with chronic obstructive pulmonary disease the volume per injection should be decreased and the interval between injections should be increased. CO_2 is not a problem unless the patient has severe obstructive pulmonary disease with baseline CO_2 retention and is not able to respond by increased ventilation.

When general anesthesia is used for TIPS nitrogen monoxide should be avoided because it diffuses from the soft tissues into the gas bubble, intensifying it and diluting its contents. The resulting mixed bubble becomes larger and lasts longer than if it were pure CO_2 [16].

In comparison with hyperosmolar contrast agents, the use of CO_2 and hypo-osmolar contrast media reduces hepatic tissue damage in the area of contrast staining when used for wedged hepatic vein injection [19]. In addition, extensive persistent staining of the hepatic parenchyma by iodinated contrast medium can obscure the small portal vein branch injection after its puncture. CO_2 injections do not cause any hepatic parenchymal staining.

A CO_2 portogram is now considered an accepted part of the TIPS procedure by many operators. As a technique for portal vein localization during TIPS it has been compared in a prospective randomized study with percutaneous placement of a small catheter into the portal vein. The investigators concluded that in spite of higher technical success rates of TIPS in 20 patients ($p = 0.045$) in whom the portal vein was localized using a percutaneously placed catheter, CO_2 wedged portography was faster and safer in 17 patients [7].

The diagnostic efficacy of CO_2 wedged hepatic portography was compared with direct transjugular and indirect arterial portography. CO_2 portography depicted the right portal vein in 95% of cases and the left and main portal vein in 90% of cases. Arterial portography provided better imaging of the variceal network [20].

Some simple methods of portal vein targeting are routinely utilized by many operators [21–23], some methods are work in progress [24] and some are considered by us to be time-consuming and potentially prone to complications and need further evaluation [8, 25]. Some reported failures and complications of the TIPS procedure are probably consequences of the learning curve for this procedure. This reflects the fact that the technical success rates in both our groups, in spite of different levels of portal vein imaging, was 100%. We assumed that good imaging of the portal vein is an important precondition for easy completion of the procedure but not the only one. Procedural complication rates in experienced hands are far lower [26], and since TIPS is not the treatment of first choice for variceal bleeding, routine performance of this procedure should be concentrated in specialized medical centers.

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References

1. Freedman AM, Sanyal AJ (1994) Complications of transjugular intrahepatic portosystemic shunts. Semin Interv Radiol 11:161–177
2. Schultz SR, LaBerge JM, Gordon RL, Warren RS (1994) Anatomy of the portal vein bifurcation: Intra versus extrahepatic location—implications for transjugular intrahepatic portosystemic shunts. J Vasc Interv Radiol 5:457–459
3. Krajina A, Hulek P, Ferko A, Nozicka J (1997) Extrahepatic portal venous laceration in TIPS treated with stent graft placement. Hepato-Gastroenterol 44:667–670
4. LaBerge JM, Ferrell LD, Ring EJ, Gordon RL, Lake JR, Roberts JP, Ascher NL (1991) Histopathologic study of transjugular intrahepatic portosystemic shunts. J Vasc Interv Radiol 2:549–556
5. Uflacker R, Reichert P, D'Albuquerque LC, de Oliviera e Silva A (1994) Liver anatomy applied to the placement of transjugular intrahepatic portosystemic shunts. Radiology 191:705–712
6. Warner DL, Owens CHA, Hibbeln JF, Ray CHE (1995) Indirect localization of the portal vein during a transjugular intrahepatic portosystemic shunt procedure: Placement of a radiopaque marker in the hepatic artery. J Vasc Interv Radiol 6:87–90
7. McEniff NJ, Kane RA, Kruskal JB, Underhill J, Rafeeque B, Clouse ME (1996) Optimal portal vein localization techniques during transjugular intrahepatic portosystemic shunt procedure: Preliminary results of a prospective randomized study. Radiology 201(B):140
8. Teitelbaum GP, Van Allan RJ, Reed RA, Hanks S, Katz MD (1993) Portal venous branch targeting with a platinum-tipped wire to facilitate transjugular intrahepatic portosystemic shunt (TIPS) procedures. Cardiovasc Intervent Radiol 16:198–200
9. Longo JM, Bilbao JI, Rosseau HP, Joffre FG, Vinel JP, Garcia-Villarreal L, Sangro B (1992) Color doppler US guidance in transjugular placement of intrahepatic portosystemic shunts. Radiology 184:281–284
10. Rees CHR, Niblett RL, Lee SP, Diamond NG, Crippin JS (1994) Use of carbon dioxide as a contrast medium for transjugular intrahepatic portosystemic shunt procedures. J Vasc Interv Radiol 5:383–386
11. Saxon RR, Keller FS (1997) Technical aspects of accessing the portal vein during the TIPS procedure. J Vasc Interv Radiol 8:733–744
12. Borge MA, Marsan R (1998) Wedged hepatic venography with biplane digital subtraction imaging to facilitate accessing the portal venous system for TIPS. J Vasc Interv Radiol 8:853–854
13. Hipona A, Park WM (1967) Capnosplenoportography: Assessment of portal vein patency in dogs with carbon dioxide gas. AJR 99:606–611
14. Taylor FC, Smith DC, Watkins GE, Kohne RE, Suh RD (1999) Balloon occlusion versus wedged hepatic venography using carbon dioxide for portal vein opacification during TIPS. Cardiovasc Intervent Radiol 22:150–151
15. Semba CHP, Saperstein L, Nyman U, Dake MD (1996) Hepatic laceration from wedged venography performed before transjugular intrahepatic portosystemic shunt placement. J Vasc Interv Radiol 7:143–146
16. Caridi JG, Hawkins IF (1997) CO2 digital subtraction angiography: Potential complications and their prevention. J Vasc Interv Radiol 8:383–391
17. Hawkins IF, Caridi JG (1998) Carbon dioxide (CO2) digital subtraction angiography: 26-year experience at the University of Florida. Eur Radiol 8:391–402
18. Groell R, Schaffler GJ, Rienmueller R, Kern R (1997) Vascular air embolism: Location, frequency, and cause on electron-beam CT studies of the chest. Radiology 202:459–462
19. Culp WC, Mladinich CHR, Hawkins IF (1999) Comparison of hepatic damage from direct injections of iodinated contrast agents and carbon dioxide. J Vasc Interv Radiol 10:1265–1270
20. Martinez-Cuesta A, Elduayen B, Vivas I, Delgado C, Gonzalez-Crespo I, Bilbao JI (2000) CO2 wedged hepatic venography: Technical considerations and comparison with direct and indirect portography with iodinated contrast. Abdom Imaging 25:576–582
21. Kerns SR (1993) "Tunnel sign" in transjugular intrahepatic portosystemic shunts. AJR 160:421
22. Ghyses MP, Le Moire O, Dreviére J (1996) Hepatic lymphography: Another trick for portal vein location during transjugular intrahepatic portosystemic shunts. AJR 166:467–468
23. Darcy MD, Sterling KM (1996) Comparison of portal vein anatomy and bony anatomic landmarks. Radiology 200:707–710
24. Solomon SB, Magee C, Acker DE, Venbrux AC (1999) TIPS placement in swine, guided by electromagnetic real-time needle tip localization displayed on previously acquired 3-D CT. Cardiovasc Intervent Radiol 22:411–414
25. Matsui O, Kadoya M, Yoshikawa J, Gabata T, Miyayama S, Takashima T (1994) A new coaxial needle system, hepatic artery targeting wire, and biplane fluoroscopy to increase safety and efficacy of TIPS. Cardiovasc Intervent Radiol 17:343–346
26. Barton RE, Rösch J, Saxon RR, Lakin P, Petersen BD, Keller FS (1995) TIPS: short- and long-term results: A survey of 1750 patients. Semin Interv Radiol 12:364–367