Venous Applications of CO_2 (Clinical and Experimental)

Kyung J. Cho, MD

CO_2 Guided PICC Placement

Placement of central venous catheters allows for long-term treatment with antibiotics, chemotherapeutic agents, nutrition and hemodialysis. The upper-arm venous access is commonly chosen for insertion of peripherally inserted central catheters (PICC). The procedure involves puncture of the basilic vein in the upper arm under fluoroscopic guidance during the peripheral injection of nonionic contrast material or venipuncture under ultrasonic guidance. With peripheral injection, CO_2 consistently fills the arm veins, allowing for venipuncture under fluoroscopy. Filling of the target vein with CO_2 is good to excellent in 88% of patients. Using this technique, PICCs can be successfully placed in over 90% of patients. There have been no instances of significant changes in vital signs and oxygen saturation during or after injection of CO_2 for central venous access procedures. Studies have shown that the mean amount of CO_2 injected for PICC placement is 35 mL (range, 5 mL to 300 mL) as compared to 27 mL of nonionic contrast medium (range, 8 mL to 120 mL). When multiple upper-arm punctures are made during PICC placement, extravasation of iodinated contrast material from the puncture holes may obscure the target vein, making subsequent punctures difficult. However, extravasation is not a problem with CO_2 as the gas passes through the puncture sites. CO_2 is a viable alternative contrast medium in patients with renal insufficiency and contrast allergy.

CO_2 Venography to Guide Hickman Placement

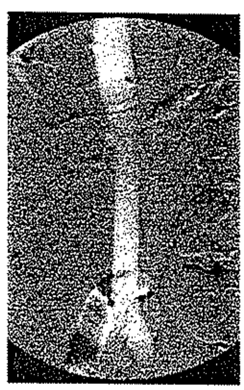
The safety and efficacy of Hickman catheters in bone marrow transplant recipients, chemotherapy patients, and those requiring long-term parenteral nutrition have been well documented. Because of its demonstrated safety and cost effectiveness, fluoroscopic guidance has been used for Hickman catheter placement with increasing frequency. The image-guided technique usually employs peripheral injections of contrast medium to evaluate patency of the subclavian vein and to opacify the vein for puncture. We currently use carbon dioxide (CO_2) gas as an alternative contrast agent for digital subtraction subclavian venography and image guidance for venipuncture. Digital subtraction subclavian venography is performed in a 120 to 150 craniocaudal angled view with the peripheral injection of CO_2. The reference image of the digital subtraction CO_2 venogram is used as guidance for venipuncture.

CO_2 Venacavography Before Filter Placement

Contrast venacavography is usually performed prior to filter placement to document caval patency, to identify the level of renal veins and to exclude caval anomaly. We currently use CO_2 as a contrast agent for venacavography before filter placement in patients with renal failure or history of allergic reaction to iodinated contrast medium (Figure 1). CO_2 cavography is performed with injection of 30 cc to 50 cc of CO_2 using a pigtail catheter in the

FIGURE 1

CO_2 VENACAVOGRAM



GREENFIELD FILTER

supine and left anterior oblique projections. If CO_2 fails to visualize the renal veins, the renal veins are catheterized using a cobra-shaped or shepherd hook catheter, and injected with CO_2 for DSA.

CO_2 Wedge Hepatic Venography

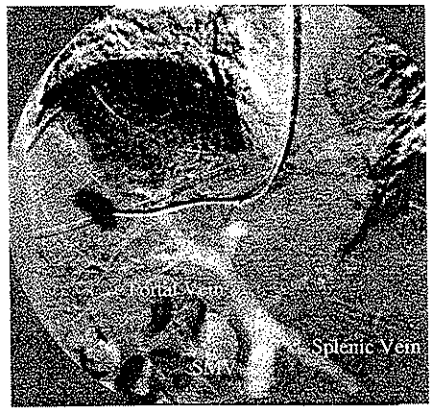
CO_2 wedge hepatic venogram is an excellent means of opacifying the portal vein and portasystemic collaterals in patients with cirrhosis and portal hypertension. The technique is commonly used to guide portal vein puncture during TIPS procedure (Figure 2). The method is also useful for the diagnosis of portal vein occlusion. CO_2 can visualize the portal vein in 96% of cases whereas the portal vein will not be seen if the portal blood is hepatopetal. If wedged hepatic injection of CO_2 fails to fill the portal vein, CO_2 can be injected into the liver parenchyma for visualization of the portal vein. Our animal studies have shown that intraparenchymal injection of CO_2 in amounts of up to 100 mL/sec causes no capsular tear or intrahepatic hematoma. Unlike iodinated contrast material, CO_2 has been shown to flow against the blood flow in the portal vein secondary to buoyancy. This is particularly useful during direct portagraphy in the patient with hepatofugal portal flow; the portal vein can be filled with injection of CO_2 into the splenic vein in patients with reversed portal blood flow. However, the tendency of CO_2 flow independent of blood flow may make evaluation of portal hemodynamics difficult.

Trans-splenic CO_2 Portography

Conventional splenoportography using an 18-gauge needle with a Teflon sheath is infrequently used because of the risk of bleeding following the examination. Recently Dr. Hawkins performed CO_2 splenoportography in two pediatric patients using 25-gauge needle for the evaluation of portal vein patency and a distal splenorenal shunt. An experimental study in swine demonstrated that CO_2 in amounts of up to 60 mL/sec can be injected into the spleen without producing capsular tear or intrasplenic hematoma.

FIGURE 2

CO_2 WEDGE HEPATIC VENOGRAM



Other Applications

CO_2 has been used as a venous contrast agent for the evaluation of malfunctioning central venous catheters, ports and dialysis fistula.

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Venous Applications of CO_2 (Clinical and Experimental)

Kyung J. Cho, MD

In the 1950s, the primary applications of CO_2 as a venous contrast agent were in the study of the central veins, right heart and pericardial effusion. CO_2 is currently used as an arterial and venous contrast agent for a variety of diagnostic and interventional procedures, however, little data are available of its effects on cardiopulmonary function. The objectives of this presentation are to: 1) examine the cardiopulmonary effects of venous injection of CO_2; 2) evaluate the available monitoring systems for early diagnosis of venous gas embolism; and 3) describe the clinical applications of CO_2 venography.

Effects of Carbon Dioxide on Cardiopulmonary Function

The effects of intravenous injection of CO_2 on cardiopulmonary function were studied in swine to assess its safety as a venous contrast agent. Pulmonary arterial and systemic blood pressure, CVP, SaO_2, pO_2, and pCO_2, and blood pH were recorded prior to and 1, 3, 5 and 10 minutes after increasing single doses of CO_2 (0.2 cc/kg to 6.4 cc/kg). Hemodynamic and ventilatory response to CO_2 and time required to reach the maximal response, and return to the control level were recorded. The animals survived following injections of CO_2 in amounts of up to 6.4 cc/kg. CO_2 consistently increased pulmonary arterial pressure, rising 10 to 15 seconds after injection of CO_2, reaching a maximum level at 45 to 60 seconds, and then gradually returning to the control level by 3 to 5 minutes. Progressively increasing the dose of CO_2 increased the magnitude of maximal changes (1 minute after injection) in all other parameters. The lowest amounts of CO_2 in cc/kg producing significant parameter changes in the supine position and their mean percent changes in parentheses are: pulmonary artery pressure, 0.4 (10.75 ±8.9); pO_2, 0.4 (10.10±10.06); SaO_2, 0.8 (1.44±1.71); blood pH, 1.6 (0.50±0.25); blood pressure, 3.2 (23.77±21.1); pCO_2, 3.2 (12.27±8.22); and CVP, 6.4 (140.53±125.9). The current monitoring methods can be used to detect early venous CO_2 embolism. Arterial blood gas monitoring and pulmonary arterial pressure recording is the most sensitive means of detecting venous gas embolism.

Clinical Applications of CO_2

Because of its low atomic number and density than the surrounding tissue, imaging of CO_2 venous injection requires digital subtraction technique. A thorough knowledge of the physical properties of CO_2 (low viscosity, compressibility and buoyancy) is important in the use of CO_2 for venous study. When injected into a vein, CO_2 flows through the venous system rapidly, usually faster than contrast material, and passes through the right heart into the pulmonary arteries. In the left lateral decubitus position (right side up position), the majority of CO_2 bubbles injected for diagnostic studies are trapped in the right atrium and will be absorbed completely within 1 to 2 minutes.

CO_2 Subclavian Venography

CO_2 is a useful alternative contrast agent for visualization of the subclavian and innominate veins. Because of the large size, the superior vena cava is filled with CO_2 incompletely. The low viscosity of CO_2 allows injection of CO_2 through small needles or angiocath placed in a peripheral vein. The venographic findings of CO_2 are different from those of iodinated contrast material. CO_2 tends to break, forming gas bubbles. As the bubbles flow through the veins, CO_2 displaces blood. CO_2 venography is an excellent means of evaluating patency of the subclavian vein. In the presence of venous occlusion, collateral veins are well opacified, which reconstitutes the contralateral veins.

The more rapid flow of CO_2 may also be responsible for less subtraction artifact due to less patient motion during the study. This, too, probably contributed to the superior quality of some of the CO_2 images compared with IC. One negative quality of CO_2 as a contrast agent is segmentation of the contrast column. Review of multiple sequential images generally resolves any uncertainty.

Safety

Pain was experienced by some patients during CO_2 injection. Gas compressed in the syringe prior to delivery could lead to rapid expansion of small peripheral veins, resulting in pain.

There have been reports of CO_2 emboli leading to cardiopulmonary collapse during laparoscopic surgery with CO_2 insufflation of the peritoneum [5–7]. One liter of CO_2 was inadvertently injected into a vein rather than the peritoneum in one reported case, leading to a cardiac murmur without hemodynamic compromise [7]. In another case, all or part of 3.5 L of CO_2 used to insufflate the peritoneum entered the venous system, leading to cardiovascular collapse [5]. However, in a series of 90 patients receiving intravenous injections of 50–60 ml of CO_2 during cineangiocardiography to evaluate pericardial disease, none experienced complications; this series included one patient with an atrial septal defect [8]. Unlike our patients, though, these patients were placed in the left lateral decubitus position to capture CO_2 in the right atrium. This maneuver probably permitted some CO_2 to dissolve prior to entering the pulmonary artery. Information on the volume of intravenous CO_2 needed to produce major complications is available from animal studies. Mice developed seizures after intravenous injection of 34.2 ml of CO_2/kg of body weight [9]. A 70-kg person would require 2.4 L of intravenous CO_2 to produce seizures at this dose.

None of the patients reported here experienced signs or symptoms of cardiovascular collapse. CO_2 is soluble in water, which may partly explain the lack of symptoms. However, dissolution was not rapid enough to prevent CO_2 from entering the pulmonary artery in the gaseous state. The pulmonary artery was visualized in some patients during upper extremity venography. The transient presence of CO_2 in the pulmonary artery appeared to be well tolerated.

Additional experience will be needed to determine the role of CO_2 in imaging veins of patients without contraindications to IC or suboptimal IC studies.

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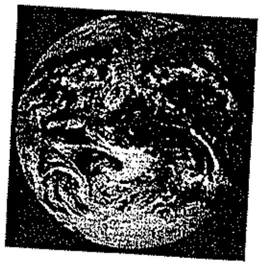
Physics and Techniques of DSA Imaging for Iodinated and CO_2 Contrast

Stephen Balter, PhD

Subtraction

Difference between images



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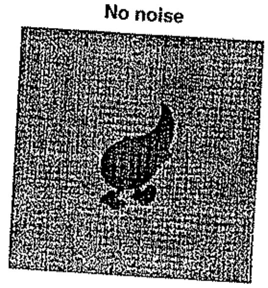
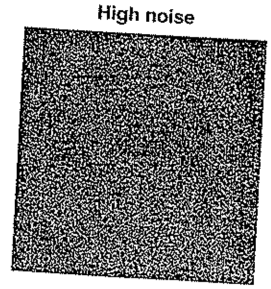
Difference images

No noise



High noise



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Carbon dioxide in the laboratory

- CO_2 hydraulics
- Gas handling
- Image processing requirements

SB9705 CO_2 – 15

CO_2 angiograms

SB9705 CO_2 – 16

CO_2 media properties

- Gas - compressible
  - –low viscosity
- Negative contrast
- Displaces blood
  - –buoyant
- Moves faster than blood
- Can move against blood flow

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Iodine media properties

- Liquid - not compressible
  - –high viscosity
- Positive contrast
- Mixes with blood
  - –denser than blood
- Moves with speed of blood flow
- Moves with direction of blood flow

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Physics and Techniques of DSA Imaging for Iodinated and CO_2 Contrast

Stephen Balter, PhD

CO_2 injection technique

- Fast injection
- Fast acquisition (at least 4 fps)
- Immediately flush catheter with saline.

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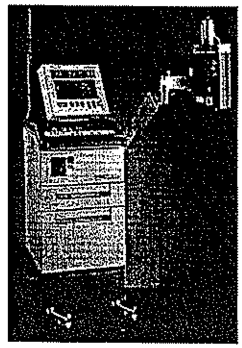
CO_2 automated injector



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CO_2 imaging implications

- Low contrast
  - adequate image receptor dose
- Rapid passage of bolus through vessel
  - adequate acquisition rates
- Negative contrast
  - special software for optimal detection
- Lack of mixing with blood
  - stacking software to summate images

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Imaging equipment requirements

- Low system noise (for both)
  - Electronic
  - Digital
- Iodine
  - Spectral optimization
- Carbon Dioxide
  - High detector dose

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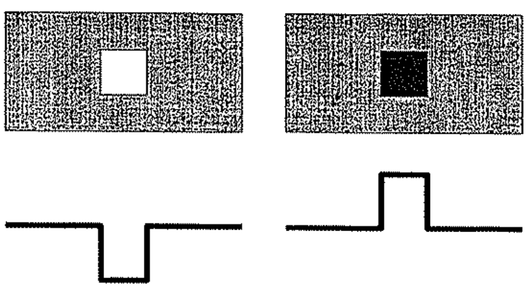
Positive or negative contrast



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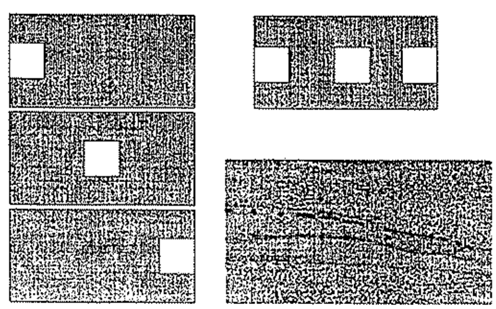
MIP reconstruction



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1	24	SHIFRIN

Record 1 of 1 - MEDLINE EXPRESS (R) 1990

TI: Cerebral angiography with gaseous carbon dioxide CO2.

AU: Shifrin-EG; Plich-MB; Verstandig-AG; Gomori-M

AD: Vascular Surgery Unit, Sackler School of Medicine, Ichilov Medical Center, Tel-Aviv, Israel.

SO: J-Cardiovasc-Surg-Torino. 1990 Sep-Oct; 31(5): 603-6

*LHM: HSC Library owns this title. Check LUIS for specific holdings.

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ISSN: 0021-9509

PY: 1990

LA: ENGLISH

CP: ITALY

AB: Large quantities of gaseous carbon dioxide CO2 were rapidly injected into the ascending aorta or common carotid artery of 14 dogs. Good filling of the arteries and intracranial veins was documented by cineangiography or digital subtraction angiography. No adverse effects occurred as a result of this procedure: the electroencephalogram showed no changes throughout the experiments and the dogs were neurologically normal for up to 6 months of follow-up. Further investigation of carbon dioxide as an arterial and cerebrovascular contrast agent is justified based on these results.

MESH: Angiography,-Digital-Subtraction-methods; Aortography-methods; Carotid-Arteries-radiography; Cineangiography-methods; Dogs-

MESH: *Carbon-Dioxide-diagnostic-use; *Cerebral-Angiography-methods; *Contrast-Media

TG: Animal; Female; Male

PT: JOURNAL-ARTICLE

RN: 0; 124-38-9

NM: Contrast-Media; Carbon-Dioxide

AN: 91035569

UD: 9102

Detection of Bleeding in CO_2 DSA

Subaru Hashimoto, MD

Transcatheter Arterial Embolization (TAE) is a good alternative to surgery in many patients with active hemorrhage if the bleeding point is identified. Conventional iodine contrast angiography, however, fails to detect arterial hemorrhage at a rate of 0.5 mL/minute or less. We have developed a new method of detecting minute arterial hemorrhage and eliminating angiographer's frustration in the field of emergency medicine.

Our materials include 64 consecutive patients with presumed abdominal and pelvic bleeding who underwent both conventional iodine contrast angiography and CO_2-IADSA at our hospital. There were 47 males and 17 females. Ages ranged from 15 to 80. Seventy-one angiographic procedures were performed for those patients, emergency in 58 procedures and elective in 13. The site of bleeding was gastrointestinal in 12 procedures, urinary tract in 16, peritoneal in 27, retroperitoneal in 17 and others in 2. Etiology of the lesion was benign in 6, malignant in 9, blunt trauma in 31, iatrogenic/postoperative in 13 and idiopathic in 12.

Conventional iodine contrast angiography was performed with the catheter tip placed near the suspected bleeding artery using nonionic iodinated contrast. CO_2-IADSA was performed by injecting 10 mL to 50 mL of medical grade CO_2 gas manually for 2 to 5 seconds, prior to or following conventional iodine contrast angiography. In unconscious patients or those with shortness of breath, IADSA was performed while patients breathed freely, with sufficient number of mask images obtained prior to the injection of the contrast medium.

Overall sensitivity in detecting extravasation was 20% in iodine contrast angiography and 52% in CO_2-IADSA. When we focus on the gastrointestinal bleeding, the sensitivity was 33% in iodine contrast angiography and 75% in CO_2-IADSA. Normal tissue never showed staining in CO_2-IADSA. Spatial resolution was better in iodine contrast angiography. Images of CO_2-IADSA generally had a poor contrast to noise ratio.

The most straightforward indicator of active bleeding is the extravasation of the contrast medium out of the vessel. It is not easy to detect extravasation if the bleeding is intermittent or below the threshold of the examination. It order to enhance the efficacy of angiography, one can employ pharmacoangiography with heparin, torazolin or even urokinase as Roesch indicated earlier. Another way to enhance the efficacy of angiography is to use carbon dioxide gas as a negative contrast material for IADSA.

CO_2 gas as a contrast medium has various features. CO_2 gas is compatible with about 37 mgI/mL of iodine contrast and thus CO_2-IADSA images have a poor contrast to noise ratio and are extremely susceptible to misregistration artifact. Buoyancy may play a significant role in CO_2-IADSA.

In the detection of bleeding, extremely low viscosity, high solubility in serum and the tendency to inflate by itself after extravasation play significant role in the detection of minute arterial hemorrhage. CO_2 has extremely lower viscosity than iodine contrast, and according to the Poiseille's equation, it passes through the tiny hole in the arterial wall much easier than iodine contrast does. Also, after CO_2 gas extravasates, it inflates by itself. This never happens when aqueous iodine contrast is used. And, CO_2 gas is highly soluble in serum, and not considered to reach capillary circulation. This explains the reason why no stain is obtained in CO_2-IADSA that can mask the extravasation. Those features are best suited for detecting minute arterial hemorrhage.

Detection of Bleeding in CO_2 DSA

Subaru Hashimoto, MD

Materials

Patients with abdominal and pelvic bleeding who underwent both iodinated contrast angiography and CO2-IADSA from April, 1988 to December, 1996.

64 Patients; Male 47 Female 17
15y.o. - 80y.o. (42±19)
71 Angiographic Procedures
Emergency 58, Elective 13

Materials

Site of Hemorrhage		Etiology	
G.I.Tract	12	Blunt Trauma	[illegible]
Peritoneal	27	Benign	[illegible]
Retroperitoneal	17	Malignant	[illegible]
Urinary Tract	16	Iatrogenic/Postoperative	[illegible]
Others	2	Idiopathic	[illegible]

Results: Iodinated Contrast Media

Sensitivity	
G. I. Tract	33.3% (4/12)
Trauma	13.0% (3/23)
Overall	19.7% (14/71)
Image Quality	Fair/Exellent
Capillary Stain	Frequent

Results: Carbon Dioxide Gas

Sensitivity	
G. I. Tract	75.0% (9/12)
Trauma	52.2% (12/23)
Overall	52.1% (37/71)
Image Quality	Essentially Poo
Capillary Stain	Never

77 y.o. male: Advanced gastric ca.
Left gastric Artery