Carbon Dioxide Gas as a Venous Contrast Agent to Guide Upper-Arm Insertion of Central Venous Catheters

Seong T. Hahn,[1,2] Thomas Pfammatter,[1] Kyung J. Cho[1]

[1]Department of Radiology, University of Michigan Hospitals, 1500 E. Medical Center Dr., Ann Arbor, MI 0030/48109, USA
[2]Department of Radiology, St. Mary's Hospital, Catholic University Medical College, Catholic Medical Center, #62 Youido-dong, Yongdungpo-gu, Seoul 150–010, Korea

Abstract

Purpose: Evaluate in a prospective randomized study carbon dioxide (CO_2) gas compared to iodinated contrast agent for image-guided placement of peripherally inserted central venous catheters (PICCs).

Methods: The upper-arm approach to the central vein was used for placement of PICCs in 74 patients requiring intermediate or long-term central venous access. Fluoroscopy was used to obtain venous access during peripheral injection of CO_2 (n = 41) or low osmolar contrast material (Omnipaque 240 mgI/ml) (n = 33).

Results: Placement of PICCs was accomplished in 88% of the CO_2 group and in 100% of the contrast group, with a mean venipuncture of two in both groups. Venous access was unsuccessful in five patients with CO_2 due to a small vein, venous spasm, or technical failure. The mean and range of procedure times were 22.8 min (13–64 min) with CO_2 and 23.2 min (12–60 min) with contrast material. The average and range of CO_2 and nonionic contrast volumes injected during the procedure were 35.4 ml (5–300 ml) and 27.8 ml (8–120 ml), respectively. Vital signs and oxygen saturation did not change significantly during or after injection of CO_2. There was no incidence of adverse reaction following CO_2 injection.

Conclusion: CO_2 gas is a useful contrast agent to guide upper-arm insertion of PICCs and may be a safe alternative in patients with renal insufficiency and/or allergy to iodinated contrast material.

Key words: CO_2 gas—Arm venography—Central venous access—Contrast allergy

Placement of a catheter into the superior vena cava or right atrium allows for long-term treatment with anti-

biotics, chemotherapeutic agents, nutrition, and hemodialysis [1–3]. The catheter may be placed percutaneously through the subclavian, internal jugular, or upper arm veins. Recently, the upper-arm venous access has been used for insertion of peripherally inserted central venous catheters (PICCs) with increasing frequency [1, 2, 4]. The procedure involves puncture of a basilic or brachial vein in the middle one-third of the upper arm under fluoroscopic guidance during more peripheral injection of iodinated contrast material. Another method of guiding venipuncture that is useful in patients with renal failure or hypersensitivy to contrast material is ultrasound-guided venipuncture [1]. We have used carbon dioxide (CO_2) gas as an alternative contrast agent to aid upper-arm placement of PICCs. The purpose of this study was to determine the safety and efficacy of CO_2 as a contrast agent for visualization of the upper arm veins to guide venipuncture for placement of PICCs.

Materials and Methods

The upper-arm venous approach for insertion of PICCs was used in 74 patients, 30 men and 44 women, from February 1, 1994 to June 30, 1994. The patients' ages ranged from 13 to 86 years (mean 51 years). Indications for central venous access included long-term treatment with antibiotics (n = 37), total parenteral nutrition (n = 11), chemotherapy (n = 13), long-term intravenous hydration (n = 2), pain control (n = 1), and others (n = 10). Because the safety of intravenous CO_2 injection was unknown, the patients with pulmonary insufficiency, asthma, and diabetes were excluded from the study. The study patients were randomized into two groups. Group 1 (male/female = 17/24, mean age = 51 years) received CO_2 through a more peripheral venous access to visualize the target vein to guide venipuncture. In Group 2 (male/female = 13/20, mean age = 51 years), low osmolar contrast material (Omnipaque 240 mg I/ml) was used to visualize the target vein. Success rate, number of venipunctures made to obtain venous access, total procedure time, volume of CO_2, and contrast material used were recorded. After completion of the

Correspondence to: K.J. Cho, M.D.
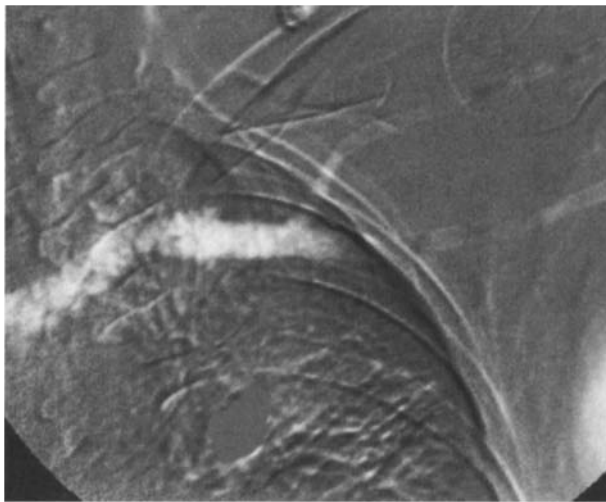
Fig. 1. CO_2/DSA of upper arm veins showing patent subclavian and innominate veins.

procedure, the patients were questioned about any discomfort or pain during the injection of CO_2.

Fluoroscopic imaging quality of target vein visualization with CO_2 was assessed by one author (STH), as was image quality of CO_2 digital subtraction venograms (KJC). In this study, acute renal function impairment was defined as an increase in serum creatinine by 50% and/or 1 mg/dl within 48 h after the procedure, resulting in a creatinine level above the normal range.

Technique

The technique for placement of PICCs was described previously [4]. A modification of the previously described technique was performed using a 21-gauge micropuncture kit (Cook Inc., Bloomington, IN, USA) to access the vein. In all patients, 20–40-ml boluses of CO_2 or 20–30-ml boluses of iodinated contrast material were injected through a peripheral venous access, to document patency of the subclavian and innominate veins using digital subtraction angiography (DSA) (Fig. 1). The largest vein, usually basilic or brachial, was punctured under fluoroscopic guidance during injection of contrast agent (Fig. 2). Roadmapping technique was not used for venipuncture. No tourniquet was applied around the upper arm during the venipuncture with CO_2. When spasm developed following the venipuncture, 50–100 µg of nitroglycerine was injected into the peripheral vein. After placement, the PICC was flushed with 10 ml of normal saline containing 1000 units of heparin, and covered with an occlusive dressing. PICC placement was then confirmed by a chest radiograph (Fig. 2). The PICCs used for this study were 5 Fr single lumen (Cook) or 4.5 Fr double lumen (HDC Corporation, San Jose, CA, USA) catheters.

Medical grade CO_2 gas (Airco Cylinder Corp., Ann Arbor, MI, USA) was used for the procedure. A hand-held syringe, connected to a specially designed closed system, was employed for a safe, reliable delivery of carbon dioxide. The system included a manifold (Morse Manifold, NAMIC, Medical Production Division, Glens Fall, NY, USA) for delivery of CO_2 and vent, and a three-way high pressure stopcock (Sorenson Intralock, Abbott Critical Care System, Abbott Laboratories/Hospital Products Div., North Chicago, IL, USA) for infusion of heparinized normal saline. In order to minimize discomfort due to explosive delivery of the gas, the fluid in the delivery system was displaced by injecting 5–10 ml of the gas before CO_2/DSA of the subclavian vein. Vital signs, including pulse rate, respiratory rate, oxygen saturation, blood pressure, and EKG, were mon-
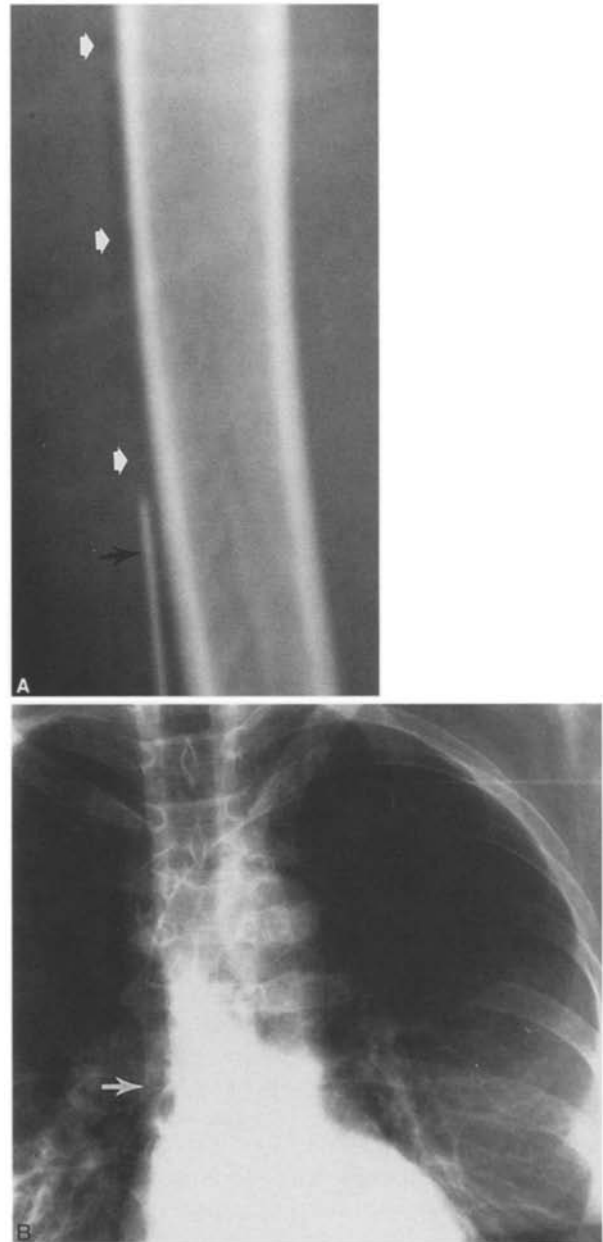
Fig. 2. Radiograph taken during PICC insertion. **A** A 21 gauge needle (arrow) is inserted into the brachial vein filled with CO_2 (arrowheads). The target vein is poorly seen due to the poor resolution of the 105-mm photocamera picture. The gas in the vein was better seen under fluoroscopy. **B** Postplacement radiograph confirms optimal placement with catheter tip at the junction of superior vena cava and right atrium (arrow).

itored during the procedure. Pre-and postprocedure serum creatinine levels were recorded.

Results

PICCs placement was accomplished in 36/41 patients using CO_2 gas and in 33/33 patients using contrast ma-

terial. In the five patients who had failed venipuncture with CO_2, venous access was obtained subsequently with contrast medium. The mean number of venous punctures required to obtain venous access was comparable between the two groups, with a mean puncture of two in both groups. The number of punctures in the patients with successful PICCs placement ranged from 1 to 9 in Group 1 and from 1 to 8 in Group 2. The mean procedure time was 22.8 min (range 13–64 min) in Group 1 and 23.2 min (range 12–60 min) in Group 2. The mean volume of CO_2 and contrast material injected was 35.4 ml (range, 5–300 ml) in Group 1 and 27.8 ml (range, 8–120 ml) in Group 2. The results are summarized in Tables 1 and 2.

Vital signs and oxygen saturation did not change during and after the injection of CO_2. No patient developed complications or renal failure following the placement of PICCs under CO_2 guidance. The mean and range of pre- and postprocedure serum creatinine levels in both groups are summarized in Table 3. Two patients in Group 2 developed transient elevation of creatinine lasting a few days. In the first patient, serum creatinine levels increased from 1.0 mg/dl before the procedure to 1.5 mg/dl after the procedure. In the second patient, serum creatinine increased 0.8 mg/dl to a postprocedure creatinine of 1.6 mg/dl.

Fluoroscopic images of the target veins filled with CO_2 were rated as excellent (complete filling of target veins of normal caliber) in 39%, good (incomplete filling of target veins of normal caliber) in 49%, and poor (incomplete filling of target veins of small caliber) in 12%. The quality of the CO_2/DSA images of the subclavian veins was rated as excellent (complete image of the subclavian vein) in 54%, good (adequate image of the subclavian vein, but with incomplete filling of the venous lumen) in 37%, and poor (inadequate image of the subclavian vein with incomplete filling of the venous lumen) in 9%. The CO_2/DSA images documented patency of the subclavian and innominate veins in all patients studied. The five failures in the CO_2 group could be attributed to the small veins (n = 3), venous spasm (n = 1), and technical failure (n = 1). Four patients complained of mild pain and discomfort at the injection site when a 20–30-ml CO_2 bolus was injected for visualization of the subclavian veins.

Discussion

The upper arm approach for placement of PICCs for long-term venous access has been used with increasing frequency at this institution. The central location of the catheter tip provides extended central venous access for administration of hyperalimentation, chemotherapy, or antibiotic therapy. Because of higher success rate and lower complications when inserted under fluoroscopic

Table 1. Summary of the clinical findings and results of PICCs placement

	Group 1 (CO₂) (n = 41)	Group 2 (ICM) (n = 33)
Mean age (yrs)	51 (13–86)	51 (23–79)
Sex distribution (M/F)	17/24	13/20
Puncture success	88%	100%
Mean number of punctures to access	2 (1–9)	2 (1–8)
Mean procedure time (min)	22.8 (13–64)	23.2 (12–60)
Mean volume for puncture (ml)	35.4 (5–300)	27.8 (8–120)

ICM = iodinated contrast medium; ( ) = range

Table 2. Number of venipunctures in two groups with successful PICC placement (mean = 2 in both groups)

Number of punctures	Group 1 (CO₂) Number cases (%)	Group 2 (ICM) Number cases (%)
1	24 (67)	19 (58)
2	5 (14)	5 (15)
3	3 (8)	4 (12)
4–9	4 (10)	5 (15)

ICM = iodinated contrast medium

Table 3. Serum creatinine levels before and after PICC placement

	Preprocedure mean serum creatinine (range) mg/dl	Postprocedure mean serum creatinine (range) mg/dl
Group 1 (CO₂)	1.1 (0.4–5.5)	1.1 (0.4–3.5)
Group 2 (ICM)	1.2 (0.1–6.7)	1.2 (0.2–6.0)

ICM = iodinated contrast medium

guidance, the PICCs are inserted by interventional radiologists, usually after an unsuccessful placement attempt by our intravenous nurse team. Our first step is the puncture of an upper arm vein under fluoroscopic guidance after injection of iodinated contrast material into a more peripheral vein. The clinical utility, high success rate, and lower complications have been documented [1, 2, 4]. With the use of iodinated contrast material, there are risks in patients with renal insufficiency and/or a history of allergy to contrast material. Two of our patients in group 2 with iodinated contrast had transient increase in serum creatinine levels lasting a few days. This is similar to the reported incidence of renal function impairment following angiographic studies [5].

Because of its lack of known renal toxicity and hypersensitivity reactions, CO_2 is an attractive alternative to iodinated contrast material. Since Hawkins [6] described the use of CO_2 as arterial contrast agent in 1982, the gas has been used as contrast medium for DSA in multiple organs [6, 7]. Clinical and experimental stud-

ies revealed that relatively large amounts of CO_2 can enter the right heart and pulmonary circulation without producing a clinically significant pulmonary gas embolism [8–10]. CO_2 has been used for the diagnosis of pericardial disease with an antecubital injection of 50 or 60 ml of the gas over a 2–3-sec interval [10]. A canine study [11] revealed that a right atrial bolus of CO_2 usually disappeared within 15–30 seconds after injection. It was also demonstrated that intravenous injections of CO_2 at a rate of 100 ml/min for a total volume of 10,000 ml caused no demonstrable adverse effects in dogs. The volumes of CO_2 injected per second in our patients were much smaller than those used for the diagnosis of pericardial effusion with intracardiac CO_2. Because CO_2 is 20 times more soluble in blood than oxygen or air [9], the gas is rapidly dissolved in blood and exhaled through the lungs. When CO_2 is used as contrast agent, pre-procedure preparation with hydration is not necessary because it is not hyperosmolar. The low viscosity of CO_2 allows injections of large amounts through a small catheter or needle.

The results of our study have demonstrated that CO_2 gas is a safe and useful alternative contrast agent for upper-arm venography and placement of PICCs. The gas was well tolerated when injected into a peripheral vein in amounts of up to 300 ml. Visualization of the veins with CO_2 was sufficient to guide puncture of the target vein under fluoroscopy in 86% of patients attempted. Patency of the subclavian and innominate veins could be easily documented with injections of 20–30 ml of CO_2 into a peripheral vein prior to insertion of PICCs. Even in the patients with slow venous flow, CO_2 produced excellent digital subtraction imaging of the subclavian and innominate veins.

The angiographic appearance of CO_2 is different from that of iodinated contrast material. When injected into a peripheral vein, CO_2 tends to break and form gas bubbles. Their appearances vary with the amount of gas injected and the size of the vessels. As it flows through the vessel, CO_2 displaces blood from the vessel lumen and reaches the upper arm veins within 5 sec after hand injection into a peripheral vein. It should be noted that blood may not return when the needle is aspirated immediately after puncture because of the residual gas in the vein. Therefore, needle aspiration should be slightly delayed to allow refilling of the veins with blood.

When multiple upper-arm punctures were made during a central venous access procedure, we experienced extravasation of iodinated contrast material from the puncture holes. This usually obscured the target vein, making subsequent punctures difficult. Extravasation was not a problem with CO_2 as the gas passed through the puncture sites. However, as venous puncture was frequently accompanied by spasm, diversion of gas flow through adjacent veins around the spasm site resided. Unless the spasm is relieved by intravenous nitroglyerine, repuncture should be made at other sites where the veins are filled with the gas.

Another physical property of CO_2 that plays an important role in CO_2/DSA is compressibility. CO_2 delivery by a standard power injector or manual injection would initially compress the gas and result in delivery of the majority of CO_2 in an explosive manner. This form of CO_2 delivery may result in unsatisfactory filling of the arterial system. In the venous system, the explosive delivery of CO_2 may cause pain and discomfort at the delivery site. To diminish such explosive delivery of CO_2, a specially designed injection system and technique are necessary. To clear the fluid and blood in the catheter that cause gas compression, 5–10 ml of CO_2 should be injected over 5–10 sec before bolus injection of the gas.

CO_2 is a useful venous contrast agent for upper extremity venography and allows visualization of the target vein for insertion of PICCs. It is a viable alternative in patients with renal insufficiency and hypersensitivity reactions to iodinated contrast material.

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