Excerpta Medica

The American Journal of Surgery

The American Journal of Surgery 185 (2003) 364–368

Scientific paper

Comparison of carbon dioxide and iodinated contrast for cavography prior to inferior vena cava filter placement

Robert B. Holtzman, M.D., Lawrence Lottenberg, M.D., Thomas Bass, M.D., Angeleke Saridakis, M.D., Vicki J. Bennett, R.N., M.S.N., Eddy H. Carrillo, M.D.*

Division of Trauma and Critical Care, Memorial Regional Hospital, 3501 Johnson St., Hollywood, FL 33021, USA

Manuscript received July 15, 2002; revised manuscript November 26, 2002

Abstract

Background: The use of iodinated contrast in the critically ill trauma patient has been associated with the development of acute renal failure. The low incidence of nephrotoxicity associated with carbon dioxide (CO_2) makes it an ideal contrast agent for cavography. However, the use of CO_2 has been limited, because reportedly it underestimates the diameter of the inferior vena cava (IVC).

Methods: During a 6-month period (January 2000 through June 2000), 25 adult trauma patients required IVC filter placement. Bedside cavagrams using CO_2 followed by iodinated contrast were employed to determine the diameter of the IVC and the anatomy of the renal veins.

Results: Using CO_2 injection for cavography, we were able to determine the diameter of the IVC and the anatomy of the renal veins in all patients. Furthermore, when CO_2 cavography was compared with the results obtained with iodinated contrast, the difference in diameter of the IVC was within 1 mm.

Conclusions: Based on these data, it was determined that CO_2 cavagrams accurately reflect the diameter of the IVC and the anatomy of the renal veins. Additionally, CO_2 cavagrams can be safely performed in the intensive care unit during bedside placement of IVC filters.

Keywords: Carbon dioxide; Inferior vena cava filter; Cavography

The use of bedside insertion for inferior vena cava (IVC) filter placement has increased over the last 10 years as a preventive technique against pulmonary embolism. In a recent publication Sing et al [1]. from the Carolinas Medical Center in Charlotte, North Carolina, report on the safety and cost-effectiveness of bedside IVC filter insertion in the intensive care unit (ICU). Furthermore, the authors emphasize that bedside insertion avoids moving the critically ill patients outside the ICU setting minimizing the chances of adverse events, which as reported by them, can be as high as 30%.

As part of the technique prior to filter placement, a flawless cavagram must be obtained to determine (1) diameter of the IVC; (2) location and anatomy of the renal veins; (3) presence of thrombus in the IVC; and (4) identification of any anatomic anomaly. Historically, iodinated contrast material has been used for imaging of the IVC. However, over the last decade, the use of carbon dioxide (CO_2) as a contrast agent has been accepted as a good and safe alternative to iodinated contrast material [2].

The addition of carbon dioxide (CO_2) to intravascular imaging has expanded the bedside vascular imaging options. The technique originally described by Hawkins in the 1970s, was advanced with the introduction of postprocessing software, such as digital subtraction imaging in the 1980s [3]. Carbon dioxide intravascular imaging was first described in 1940 when Moore and Braselton [4] published an animal study involving the injection of air and CO_2 into the pulmonary veins of anesthetized cats. They reported that it took approximately six times the volume of CO_2 gas, rapidly injected into the pulmonary veins, to cause a fatal event when compared with room air. Intravascular CO_2 is better tolerated in larger volumes, than room air or oxygen, since it is twenty times more soluble in blood, thus mini-

* Corresponding author. Tel.: +1-954-985-5969; fax: +1-954-967-2933.

E-mail address: Trauma1ehc@aol.com

0002-9610/03/$ – see front matter
doi:10.1016/S0002-9610(02)01410-1

mizing the chances of a potentially lethal pulmonary air embolism.

Intravenous CO_2 was initially used as a nonionic agent in clinical practice since 1956 to diagnose pericardial effusions by outlining the right atrium [5,6]. In 1967, Collins and Vix [7] reported the use of CO_2 gas to visualize the hepatic veins. The use of CO_2 gas to visualize cardiac, portal and caval structures, was reported in 1977 by Bendib et al [8] in a study involving 1,600 patients without a reported complication. These data have validated the use of CO_2 as a legitimate nonionic contrast agent in diagnostic and interventional radiology.

Currently, CO_2 is used as a nonionized intravascular contrast agent; however, it is contraindicated for use in the thorax, head, and neck [9]. Carbon dioxide allows angiography to be performed in those patients with a history of allergic reactions to iodinated agents, and has been found to be less toxic to the liver or kidneys [10]. Also, it is less expensive than nonionic iodinated contrast material [11]

The purpose of this study was to determine whether CO_2 cavagrams accurately reflect IVC diameter and renal vein anatomy when compared with cavography performed with iodinated contrast material.

Patients and methods

Patient selection

We conducted a prospective study of 25 adult trauma patients in the intensive care unit at Memorial Regional Hospital, a state-designated level I trauma center in Hollywood, Florida. Cavagrams with CO_2 and iodinated contrast material were used to establish the safety of the technique as well as to determine the diameter of the IVC and renal vein anatomy prior to the placement of the IVC filter. Informed consent was obtained from all patients or the next of kin. The mechanism of injury in these 25 patients were motor vehicle crash (9), falls (5), bicyclist or pedestrian struck by a motorized vehicle (3), and a combination of other injuries (8). In our unit, all trauma patients are stratified into low- or high-risk patients for the development of deep venous thrombosis (DVT) or pulmonary embolism (PE) according to Eastern Association for the Surgery of Trauma (EAST) practice guidelines [12]. Patients in the low risk group received sequential compression devices. Patients categorized in the high-risk group that could receive anticoagulation were given low molecular weight heparin as DVT prophylaxis. All patients underwent routine screening ultrasonography of the lower extremities, for surveillance of DVT, on hospital day 1 and 4. Screening continued once a week throughout their hospital stay, as per hospital protocol. The decision of IVC filter placement was determined by the attending trauma surgeon based upon the criteria listed above.

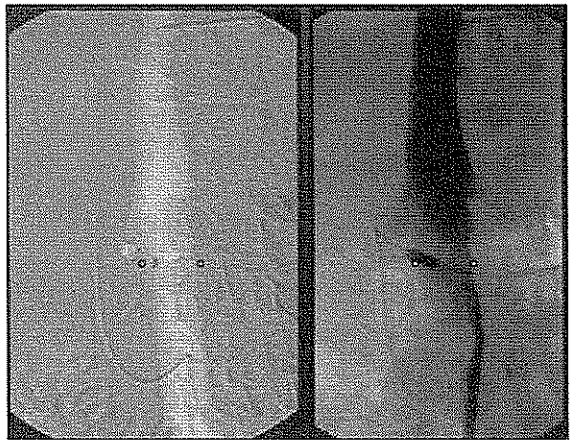

Fig. 1. (**Left**) Bedside cavagram after a forceful hand injection of 60 mL of carbon dioxide gas using an Angioflush III system. (**Right**) Cavagram performed using 50 mL of Iopamidol (ISOVUE-300) using an Angioflush III system.

Technique

On our service, all IVC filter insertions that are performed in the ICU are done on a fluoroscopic ready critical care bed. Patients are in the supine position and are sedated with morphine and midazolam as needed. Systemic heparin therapy is discontinued 2 hours prior to the beginning of the procedure. All personnel wear protective radiation garments as per hospital guidelines. During the procedure, heart rate, arterial blood pressure, and pulse oximetry are routinely monitored in all patients.

The insertion site of choice is prepared with a povidone-iodine solution and sterile drapes placed with sterile technique. Local anesthetic is infiltrated and the femoral vein cannulated using the Seldinger technique. All manipulations are performed under fluoroscopic guidance. The bedside fluoroscope has digital subtraction capabilities (OEC Medical Systems 9800 Series, Raleigh, North Carolina).

Carbon dioxide is hand injected by a rapid forceful injection of 60 mL using an Angioflush III System (Angiodynamics, Queensbury, New York) [13], with a Valsalva or breath-hold technique as previous described (Fig. 1, left) [1,2]. A reservoir bag for carbon dioxide eliminates a direct link between the patient and the cylinder filled with medical grade 99.9% pure CO_2. ISOVUE-300 (Iopamidol Injection 61%; Princeton, New Jersey) is used as the iodinated contrast agent and 50 mL is hand injected by a forceful injection (Fig. 1, right).

The x-ray field is centered just to the right of the vertebral bodies from the 12th thoracic vertebral body to the thirrd lumbar vertebral body. Each procedure is recorded on a professional quality super VHS video-cassette recorder (VCR) with editing and freeze screen features. This gives immediate play back capabilities for review of difficult to interpret cavagrams prior to filter placement. A radiopaque ruler with 1 mm markers is placed under the patient and

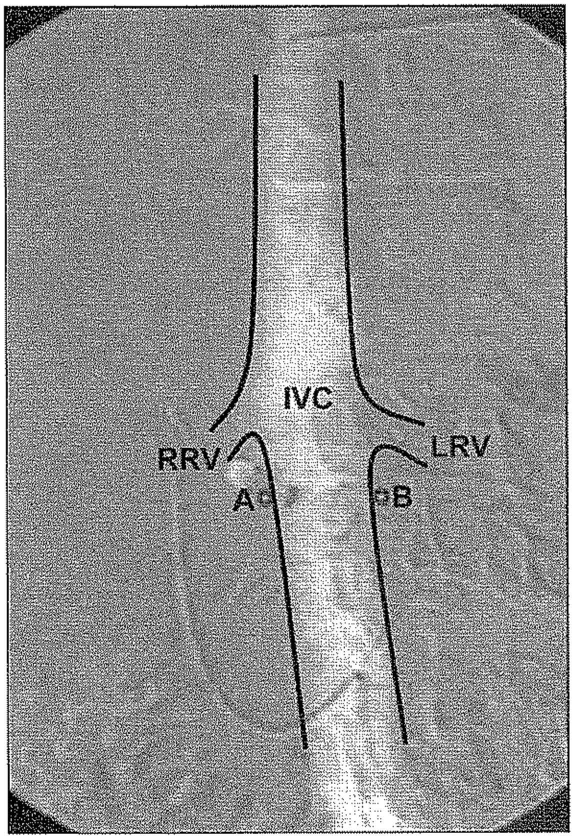

Fig. 2. Schematic representation from the actual digital substraction cavagram. IVC = inferior vena cava; RRV = right renal vein; LRV = left renal vein. Points A and B are reference points for measurement of the diameter of the IVC.

fluroscopically positioned at the level of the third lumbar vertebral body.

Cavography is obtained with the use of a 5F pigtail catheter (Angiodynamics, Queensbury, New York) with radiopaque markers 28 mm apart. These markers are placed in the center of the image instead of the periphery to avoid the effect of pincushion distortion when measuring the diameter of the vena cava.

Inferior vena cava diameters are measured using electronic calipers (Digimatic, Mitutoyo, Japan), at the same reference point for both the CO_2 and ISOVUE-300. All measurements are rounded to the nearest millimeter. The reference point is the inferior end plate of the second lumbar vertebral body, as this point will remain a constant when comparing the caval diameter from the CO_2 and ISOVUE-300 (Fig. 2).

Using this technique, each patient served as his or her own control. By using these bony points of reference, we are able to ascertain that we are measuring the vena cava at the exact same level in both CO_2 and ISOVUE-300 cavagrams. In addition, we are able to look at both infrarenal and suprarenal vena cava diameters in each individual patient. At the completion of the procedure, a plain film radiograph was obtained to document the position of the IVC filter.

Table 1
Comparison of measurements* of inferior vena cava diameter (cavography)

	Carbon dioxide (CO_2)	ISOVUE-300
Inferior vena cava (infrarenal)		
Observer # 1		
Mean	22	22
Standard deviation	4.8	4.9
Observer # 2		
Mean	22	22
Standard deviation	4.8	5.0
Inferior vena cava (suprarenal)*		
Observer # 1		
Mean	20	22
Standard deviation	8.1	9.2
Observer # 2		
Mean	20	22
Standard deviation	8.2	9.2

* All measurements are in millimeters.

Two of the authors working independently reviewed each CO_2 and ISOVUE-300 cavagrams, with measurements of the IVC taken at the reference point described above. No significant differences in the measurements by the two observers were identified (Table 1). Additionally, visualization of the renal veins was noted not only by observing the actual opacification of the veins, but also by inflow of unopacified blood from a renal vein causing a filling defect in the IVC. In this respect, analysis of the videotape is a more accurate representation of renal vein anatomy than by reviewing a single static film, this may account for our ability to delineate renal vein anatomy in a greater percentage of cases than has previously been reported [2]

Results

During the study period, IVC filters were placed by the trauma service in 25 critically injured patients. The study population included 19 men (76%) and 6 women (14%), which represents 11% of the 218 trauma patients admitted to the ICU during the 6-month study period. The mean age of the subjects was 35 years (range 18 to 85).

According to the EAST trauma practice guidelines for the management of venous thromboembolism in trauma patients, 7 patients (28%) met level I recommendations for placement of an IVC filter for proximal DVT. The remaining 18 patients (72%), underwent "prophylactic" filter insertion according to level III recommendations.

The 18 patients meeting level III recommendations were unable to receive anticoagulation and had the following high-risk injury pattern: spinal cord injury with paraplegia or tetraplegia, 9 patients (50%); complex pelvic fractures with associated long bone fractures, 5 patients (28%); multiple long bone fractures, 4 patients (22%).

Twenty-four stainless steel Greenfield filters (Medi-

Tech, Watertown, Massachusetts), and one Bird's Nest filter (Cook, Bloomington, Indiana) were placed without complications.

The single Bird's Nest filter was inserted in 1 patient who was found to have an IVC larger than 28 mm. Upon injection of CO_2 the infrarenal caval diameter of the patient was 29 mm, and was found to measure 30 mm in diameter after injection with iodinated contrast. There were no cases where CO_2 venography overestimated caval size.

When injecting CO_2 via a pigtail catheter at the L_1 to L_2 level, the measurements of the suprarenal caval diameter were equal to or within 1 mm of the measurements taken using ISOVUE-300. In a vessel the size of the IVC the CO_2 injection performed within one or two vertebral bodies of the level at which the cava was measured, enhanced the gas to effectively displace the entire blood volume. For CO_2 to be an effective contrast agent, it must displace the entire volume to accurately reflect the imaged vessel [14]. For example, after an inadequate injection the uppermost quarter of the cava may be filled with CO_2; however, the greatest diameter will be halfway through the cava, leading to an underestimated caval diameter. Fortunately, CO_2 injections can be repeated without cumulative toxicity, until the best image is obtained.

In 4 of the 25 patients, renal vein anatomy could not be determined on flush injection and selective renal vein catheterization was required. This was easily performed at the bedside using a 5F Omni selective tipped catheter (Angiodynamics, Queensbury, New York) and injecting 10 cc of CO_2 into the renal veins. Adequate visualization of the IVC and renal veins was obtained with a single 60 cc injection of Iopamidol (ISOVUE-300) through the delivery sheath of the filter in the majority of cases. Neither iodinated contrast nor CO_2 injection resulted in a complication.

Comments

Intravascular CO_2 allows for injections into the vena cava of up to 100 mL at a time. When injected CO_2 displaces blood rather than mixing with it like iodinated contrast, CO_2 rises to the most nondependent position in the vessel. It is this displacement of CO_2 thatcan make the vessel appear smaller than its true diameter. Furthermore, displacing all the blood from the imaged vessel can negate this effect. Carbon dioxide ultimately pools in the right atrium and can be visualized by performing fluoroscopy over the heart [14–16]. Owing to the ability for CO_2 to dissolve into the blood, it will pass into the pulmonary circulation where it rapidly diffuses across the pulmonary capillary membrane into the alveoli and is cleared from the lungs during normal ventilation.

The best technique when performing repeated injections into the inferior vena cava is to wait 1 to 2 minutes between injections, to allow the above noted process to occur [17–19]. The described technique would prevent a precipitous drop in cardiac output, as in theory intravenous injection of CO_2 could lead to "vapor lock" in the pulmonary veins as is seen in air embolism [3]. Fluoroscopic examination of the chest using digital subtraction after a CO_2 injection reveals the gas collection in the right heart. This gas collection can be seen getting smaller with each beat as the CO_2 dissolves.

It has been shown, that with experience and good technique CO_2 cavography can be as accurate as iodinated contrast material. The availability of good quality portable fluoroscopic equipment, with digital subtraction capabilities, allows for the safe bedside application of this technique [20]. Patient safety is further improved owing to the decreased hazards involved in transporting critically ill patients.

The use of CO_2 as a vascular imaging tool will undoubtedly find more applications in the future [21]. It has been reported, that CO_2 wedged portography during hepatic vein catheterization is superior to iodine in visualization of the venous portal system, and revealed portal systemic collaterals not seen with iodinated contrast [7, 22]. Most recently, CO_2 has been used during endovascular stent placement in a case requiring treatment of an abdominal aortic aneurysm [23]. During this procedure, repeated imaging is required for accurate stent placement, CO_2 with its lack of cumulative toxicity may make it the ideal contrast agent.

In summary, CO_2 safely and accurately defines caval diameter and renal vein anatomy. The low incidence of renal toxicity makes CO_2 an ideal contrast agent in the multiply injured trauma patient. In those select cases where the IVC is found to be larger than 28 mm, placement of a Bird's Nest filter, or TrapEase (Cordis Endovascular, Warren, New Jersey) filter as opposed to the Greenfield filter may be a better treatment modality. These data also show that during bedside placement of IVC filters, CO_2 cavagrams are safely performed in the ICU with availability of good quality portable fluoroscopic equipment. The use of CO_2 cavography in these patients will ultimately optimize the placement of IVC filters, with minimal or no morbidity added to the critically injured trauma patient.

References

[1] Sing RF, Stackhouse DJ, Jacobs DG, Heniford BT. Safety and accuracy of bedside carbon dioxide cavography for insertion of inferior vena cava filters in the intensive care unit. J Am Coll Surg 2001;192:168–71.

[2] Boyd-Kranis R, Sullivan KL, Eschelmann D. Accuracy and safety of carbon dioxide inferior vena cavography. J Vasc Intervent Rad 1999;10:1183–9.

[3] Hawkins IF. Carbon dioxide digital subtraction arteriography. AJR Am J Roentgenol 1982;139:19–24.

[4] Moore RM, Braselton CW. Injections of air and carbon dioxide into a pulmonary vein. Ann Surg 1940;112:212–16.

[5] Oppenheimer MJ, Durant TM, Stauffer HM. In vivo visualization of intracardiac structures with gaseous carbon dioxide. Am J Physiol 1956;186:325–34.

[6] Scatliff JH, Kummer AJ, Janzen AH. The diagnosis of pericardial effusion with intracardiac carbon dioxide. Radiology 1959;73:871–83.

[7] Coolins JR, Vix VA. Hepatic vein visualization by intravenous carbon dioxide injection. Radiology 1967;89:864–7.
[8] Bendid M, Toumi M, Boudjellab A. Carboxyangiographic et carvoxyangiographic enlargie en dardiologe. Ann Radiol (France) 1977; 20:673–5.
[9] Back MR, Caridi JG, Hawkins IF, Seeger JM. Angiography with carbon dioxide. Surg Clin North Am 1998;78:575–91.
[10] Weaver FA, Pentecost MJ, Yellin AE. Clinical applications of carbon dioxide/digital subtraction arteriography. J Vasc Surg 1991;13:266–73.
[11] Yusuf SW, Whitaker SC, Hinwood D. Carbon dioxide: an alternative to iodinated contrast media. Eur J Vasc Endovasc Surg 1995;10:156–61.
[12] Eastern Association for the Surgery of Trauma (EAST). Practice parameter workgroup for DVT prophylaxis. Practice management guidelines for the management of venous thromboembolism in trauma patients. EAST trauma practice guidelines, 1998. Available at: http/www.east.org/tpg.html. Accessed April 19, 2002.
[13] Hawkins IF, Caridi JG, Kerns SR. Plastic bag delivery system for hand injection of carbon dioxide. AJR Am J Roentgenol 1995;165: 1487–9.
[14] Sabatelli FW, Current Kerns SR, Hawkins I. Status of carbon dioxide angiography. Radiol Clin North Am 1995;33:15–19.
[15] Kerns SR, Hawkins IF. Carbon dioxide digital subtraction angiography: expanding application and technical evolution. Am J Radiol 1995;164:735–41.
[16] Sing RF, Cicci CK, LeQuire MH, Stackhouse DJ. Bedside carbon dioxide cavagrams for inferior vena cava filters: Preliminary results. J Vasc Surg 2000;32:144–7.
[17] Greenfield LJ, Proctor MS. Current status of inferior vena cava filters. Ann Vasc Surg 2000;14:525–7.
[18] Tola JC, Holtzman R, Lottenberg L. Bedside placement of inferior vena cava filters in the intensive care unit. Am Surg 1999;65:833–8.
[19] Sullivan KL, Bonn J, Shapiro MJ, Gardiner GA. Venography with carbon dioxide as a contrast agent. Cardiovasc Intervent Radiol 1995; 18:141–5.
[20] Hawkins IF, Wilcox CS, Kerns SR, Sabatelli FW. CO_2 digital angiography: a safer contrast agent for renal vascular imaging? Am J Kidney Dis 1994;24:685–9.
[21] Schreier DZ, Weaver FA, Frankhouse J. A prospective study of carbon dioxide-digital subtraction vs standard contrast arteriography in the evaluation of renal arteries. Arch Surg 1996;131: 503–8.
[22] Debernardi-Venon W, Bandi JC, Garcia-Pagan JC. CO_2 wedged hepatic venography in the evaluation of portal hypertension. Gut 2000;46:856–60.
[23] Gahlen J, Hansmann J, Shumacher H. Carbon dioxide angiography for endovascular grafting in high-risk patients with infrarenal abdominal aortic aneurysms. J Vasc Surg 2001;33:646–9.