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

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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 (CO₂) makes it an ideal contrast agent for cavography. However, the use of CO₂ 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 CO₂ followed by iodinated contrast were employed to determine the diameter of the IVC and the anatomy of the renal veins.

Results: Using CO₂ 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 CO₂ 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 CO₂ cavagrams accurately reflect the diameter of the IVC and the anatomy of the renal veins. Additionally, CO₂ 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 preventative 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 (CO₂) as a contrast agent has been accepted as a good and safe alternative to iodinated contrast material [2].

The addition of carbon dioxide (CO₂) 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 CO₂ into the pulmonary veins of anesthetized cats. They reported that it took approximately six times the volume of CO₂ gas, rapidly injected into the pulmonary veins, to cause a fatal event when compared with room air. Intravascular CO₂ is better tolerated in larger volumes, than room air or oxygen, since it is twenty times more soluble in blood, thus mini-
mizing the chances of a potentially lethal pulmonary air
embolism.

Intravenous CO₂ 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 CO₂ gas to visualize the hepatic
veins. The use of CO₂ 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 compli-
cation. These data have validated the use of CO₂ as a
legitimate nonionic contrast agent in diagnostic and inter-
ventional radiology.

Currently, CO₂ is used as a nonionized intravascular
contrast agent; however, it is contraindicated for use in the
thorax, head, and neck [9]. Carbon dioxide allows angiog-
raphy 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 CO₂
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 Holly-
wood, Florida. Cavagrams with CO₂ 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 catego-
rized in the high-risk group that could receive anticoagula-
tion were given low molecular weight heparin as DVT
prophylaxis. All patients underwent routine screening ultra-
sonography 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 per-
formed 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 povi-
don-iodine solution and sterile drapes placed with sterile tec-
nique. Local anesthetic is infiltrated and the femoral vein
cannulated using the Seldinger technique. All manipula-
tions 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 (Angio-
dynamics, Queensbury, New York) [13], with a Valsalva or
breath-hold technique as previously 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 CO₂. ISOVUE-300 (Iopamidol Injection
61%; Princeton, New Jersey) is used as the iodinated con-
trast agent and 50 mL is hand injected by a forceful injec-
tion (Fig. 1, right).

The x-ray field is centered just to the right of the verte-
bral bodies from the 12th thoracic vertebral body to the
third 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
Two of the authors working independently reviewed each CO\textsubscript{2} and ISOVUE-300 cavigrams, 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 CO₂ 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 CO₂ venography overestimated caval size.

When injecting CO₂ via a pigtail catheter at the L₁ to L₂ 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 CO₂ 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 CO₂ 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 CO₂; however, the greatest diameter will be halfway through the cava, leading to an underestimated caval diameter. Fortunately, CO₂ 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 CO₂ 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 CO₂ injection resulted in a complication.

**Comments**

Intravascular CO₂ allows for injections into the vena cava of up to 100 mL at a time. When injected CO₂ displaces blood rather than mixing with it like iodinated contrast, CO₂ rises to the most nondependent position in the vessel. It is this displacement of CO₂ that can 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 CO₂ 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 CO₂ 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 CO₂ injection reveals the gas collection in the right heart. This gas collection can be seen getting smaller with each beat as the CO₂ dissolves.

It has been shown, that with experience and good technique CO₂ 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 CO₂ as a vascular imaging tool will undoubtedly find more applications in the future [21]. It has been reported, that CO₂ 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, CO₂ 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, CO₂ with its lack of cumulative toxicity may make it the ideal contrast agent.

In summary, CO₂ safely and accurately defines caval diameter and renal vein anatomy. The low incidence of renal toxicity makes CO₂ 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, CO₂ cava- grams are safely performed in the ICU with availability of good quality portable fluoroscopic equipment. The use of CO₂ cavography in these patients will ultimately optimize the placement of IVC filters, with minimal or no morbidity added to the critically injured trauma patient.

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