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Abbreviations:
DSA = digital subtraction angiography
IVC = inferior vena cava

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Vena Cavography with CO_2 versus with Iodinated Contrast Material for Inferior Vena Cava Filter Placement: A Prospective Evaluation[1]

PURPOSE: To determine whether carbon dioxide (CO_2) vena cavography can safely guide the placement of inferior vena cava (IVC) filters.

MATERIALS AND METHODS: One hundred nineteen patients were prospectively enrolled in this study. CO_2 cavograms were obtained and evaluated for IVC diameter, location of renal veins, and presence of thrombus and venous anomalies. If CO_2 cavography was judged to be adequate, an IVC filter was deployed. After filter placement, cavography was performed with iodinated contrast material; these images were compared with the CO_2 cavograms.

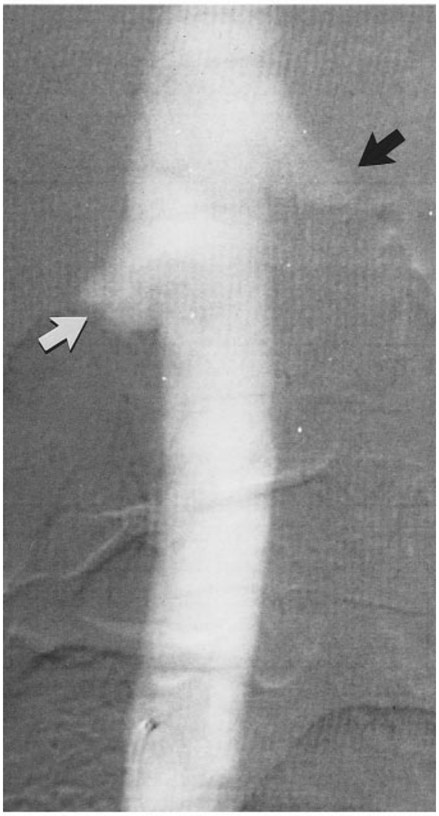
RESULTS: Two patients experienced mild side effects related to venous CO_2 injection. Comparison of cavograms obtained with CO_2 and iodinated contrast–enhanced material showed the caval size to be within 3 mm in all 119 patients. In 116 patients (97.5%), CO_2 cavography was judged to be adequate, and in 115 patients, filters were placed. In three (2.5%) patients, it was necessary to perform iodinated contrast–enhanced cavography before filter deployment. All six cases of venous anomaly and 11 (78.6%) of 14 cases of thrombosis were clearly identified with CO_2 cavography. One filter was maldeployed owing to misinterpretation of the CO_2 cavogram.

CONCLUSION: CO_2 cavography is well tolerated, safe, and adequate for identification of the parameters necessary for filter deployment. It is especially valuable in patients with a history of reaction to iodinated contrast material or renal insufficiency.

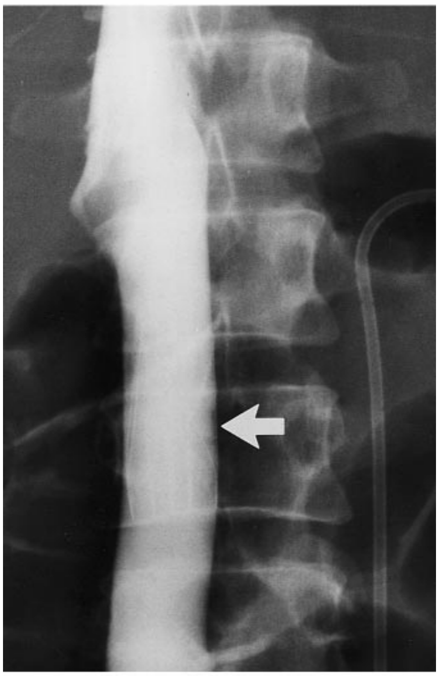
Safe placement of caval filters requires accurate determination of the anatomic characteristics of the inferior vena cava (IVC) and renal vein before deployment (1,2). Complete assessment includes caval sizing, determination of the presence or absence of anatomic anomalies, and evaluation of the patency of both the IVC and iliac veins (3). Vena cavography has been shown to provide important information affecting filter placement in up to 29% of patients (1–3).

Although vena cavography has traditionally been performed with use of iodinated contrast material, carbon dioxide (CO_2) has been substituted as an intravascular contrast material in patients who are allergic to iodinated contrast material and in those with renal insufficiency (4–7). The use of CO_2 has been described in both the arterial and the venous systems. Venographic examples include performing CO_2 wedged hepatic portography to guide and follow up transjugular intrahepatic portosystemic shunt placement (8), venography of subclavian and brachiocephalic veins for venous occlusion (4) or for venous catheter placement (9), and fistulography of dialysis grafts (10). With specific reference to vena cavography, Sullivan et al (4) reported that IVC filters were successfully deployed by using CO_2 alone in seven of nine patients; however, it was unclear whether CO_2 cavography enabled an accurate assessment of IVC diameter.

The purpose of this study was to determine the safety and adequacy of CO_2 as a contrast material for inferior vena cavography before IVC filter deployment. We also performed



a.



b.

Figure 1. **(a)** Posteroanterior DSA CO_2 cavogram demonstrates both renal vein origins (arrows). **(b)** Posteroanterior cut-film cavogram obtained with iodinated contrast material after CO_2 cavography–guided IVC filter placement confirms appropriate infrarenal position of the filter (arrow).

vena cavography with iodinated contrast material to provide a standard of reference for caval size and the presence of anomalies or thrombus.

MATERIALS AND METHODS

All 316 patients referred for IVC filter placement between August 1994 and May 1997 were eligible for this study. Patients were excluded from the study if they (*a*) were unable to give consent, (*b*) were known to have intracardiac shunts, (*c*) had severe pulmonary compromise, (*d*) had non–dialysis-dependent renal failure (creatinine level, ≥1.6 mg/dL [141.4 μmol/L]), and (*e*) had a history of major reaction to intravascular iodinated contrast material. We obtained approval for the study from our institutional review board and written informed consent from all patients.

A total of 119 patients (65 male, 54 female; mean age, 48.7 years; age range, 17–89 years) were prospectively included in this study. One hundred nineteen (38%) of 316 IVC filters placed at our institution during the 33-month study period were placed in these patients. The two main indications for filter placement were contraindication to anticoagulation in patients with deep venous thrombosis or pulmonary emboli (n = 57 [47.9%]) and prophylactic treatment of patients deemed to be at high risk for the development of deep venous thrombosis (n = 38 [31.9%]). Other indications for filter placement included the failure of conventional anticoagulation agents—that is, the progression of deep venous thrombosis or recurrent pulmonary emboli (n = 10 [8.4%]), complications from anticoagulatives (n = 9 [7.6%]), and patient noncompliance while receiving anticoagulant regimens (n = 5 [4.2%]).

Standard venous access was obtained through either a common femoral vein or internal jugular vein by using the Seldinger technique. After a 5-F pigtail or similar catheter was positioned in the IVC just superior to the iliac veins, posteroanterior vena cavography was performed after hand injection of approximately 60 mL of CO_2 per angiographic run. Medical-grade (99.99% pure) CO_2 (Altair Medical Gases, San Ramon, Calif) was used. A 60-mL syringe was purged of room air three times to prevent air contamination and was then allowed to fill with CO_2 at low pressure. Rapid injection was then performed after the angiographic catheter was primed with CO_2.

Images were obtained with digital subtraction angiography (DSA) at a rate of three to six images per second. If needed, multiple runs were performed to obtain a cavogram that was adequate for IVC filter placement. Occasionally, the patient was placed in the ipsilateral anterior oblique position to help identify renal venous inflow. When needed, additional tube angulation was used to displace bowel gas with respect to the IVC. When CO_2 cavography was deemed adequate, radiographic landmarks were noted and the caval filter was deployed (Fig 1). If CO_2 cavography was considered to be inadequate for safe filter deployment, iodinated contrast material–enhanced cavography was performed. The filter was then placed, and the study was recorded as a CO_2 cavography failure.

After caval filter placement, an iodinated contrast–enhanced cavogram was obtained after injection of nonionic contrast material (Optiray 320; Mallinckrodt Chemical, St Louis, Mo) at 10–20 mL/sec for 2 seconds. Imaging was performed with conventional cut-film angiography (n = 109) or DSA (n = 10). We compared the CO_2 cavograms with the contrast-enhanced cavograms, and any differences were noted. The radiologist performing the study completed a data sheet that included the following: (*a*) number of CO_2 runs and amount of CO_2 injected, (*b*) location and type of venous anomaly, (*c*) presence of IVC thrombosis, (*d*) maximum IVC diameter with both contrast media, (*e*) complications related to filter deployment, and (*f*) patient response to CO_2 injection. In addition, the diagnostic quality of each CO_2 cavogram was subjectively classified as superior to, inferior to, or equal to that of the corresponding iodinated contrast–enhanced cavogram. Measurements of the IVC diameter were made with the assistance of a known standard of reference. Early in our study, this standard was provided by using either metallic coins taped above and below the patient (n = 32) or a radiopaque marker placed beneath the patient (n = 25). Later, 20- and 28-mm calibrated intracaval pigtail catheters (n = 62) (Cook, Bloomington, Ind) were used. In each patient, the same standard of reference was used for both CO_2 and contrast–enhanced cavographic measurements of the IVC.

Routine noninvasive monitoring of the patient's vital signs included electrocardiographic tracing, intermittent blood pressure monitoring, and pulse oximetry. Sedation and/or anesthesia was achieved with a local anesthetic at the entry site, with the addition of conscious sedation

TABLE 1
Comparison of IVC Diameters Obtained with CO_2 Cavography and Iodinated Contrast Cavography

	Diameter (mm)			
Technique	Mean	Median	Range	SD
CO_2 cavography	19.6	19.0	10–29	4.1
Iodinated contrast cavography	19.9	20.0	10–31	4.1

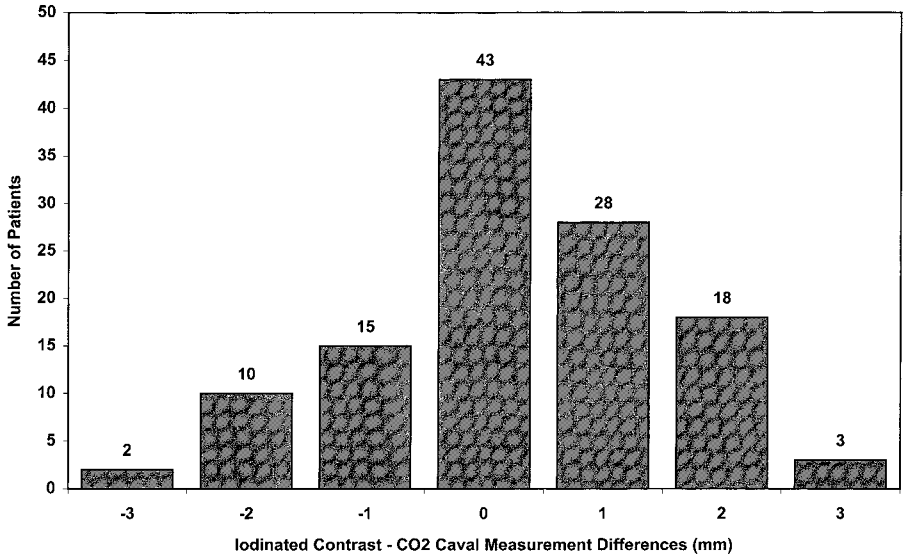


Figure 2. Histogram shows the differences in caval measurements obtained with iodinated contrast-enhanced cavography and CO_2 cavography. Note that all differences were within ±3 mm. Note the tendency for the IVC diameter to be underestimated with CO_2 cavography compared with the diameter estimated with iodinated contrast–enhanced cavography (bell curve skewed to the right).

in most instances. The patient signs and symptoms related specifically to CO_2 cavography were recorded. Those sought included nausea, vomiting, pain, dyspnea, light-headedness, hypotension or hypertension, and dysrhythmias.

The images were evaluated for the location and type of venous anomaly, presence of IVC thrombus, maximum IVC diameter with both contrast media, and complications related to filter deployment. The images were reviewed by two interventional radiology attending staff members (M.D.K., C.C.J.) together by means of consensus.

Statistical analysis was performed by using the paired, two-tailed Student *t* test and an array correlation coefficient.

RESULTS

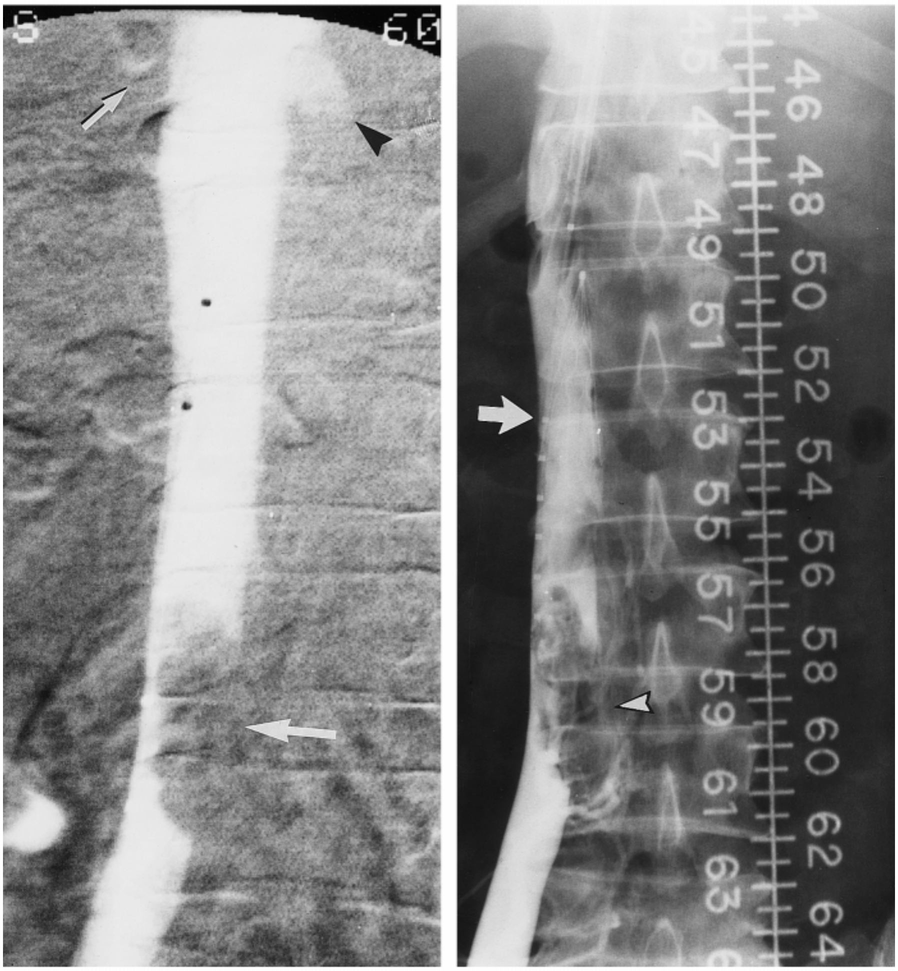
The access site for vena cavography and filter deployment was most commonly through the right common femoral vein (n = 72 [60.5%]) or right internal jugular vein (n = 38 [31.9%]). The left common femoral vein (n = 8 [6.7%]) and left internal jugular vein (n = 1 [0.8%]) were used less frequently. In three (2.5%) patients, the pathway from the initial entry site to the IVC was either completely or partially thrombosed, and in each of these patients, an alternate access site was chosen without further complication.

One hundred eighteen caval filters were placed in the 119 patients. A Vena Tech or LGM filter (B. Braun Medical, Bethlehem, Pa) was placed in 58 patients (49.2%), and a titanium Greenfield filter (Boston Scientific/Meditech, Natick, Mass) was placed in 56 (47.5%). In two patients (1.7%), stainless steel "over-the-wire" Greenfield filters (Boston Scientific/Meditech), which became available toward the end of our study period, were placed. In two patients (1.7%), Bird's Nest filters (Cook) were placed because the CO_2 IVC diameter was greater than or equal to 28 mm. In one patient, an 89-year-old man, CO_2 and iodinated contrast cavographic studies revealed IVC clot extending to near the right atrium, and an IVC filter was not placed.

The IVC diameter measurements obtained with CO_2 and iodinated contrast–enhanced cavography are detailed in Table 1; a histogram of the differences is presented in Figure 2. Overall, the size of the IVC was underestimated with CO_2 cavography compared with iodinated contrast–enhanced cavography, with an average difference of 0.27 mm. When analyzed by using a paired, two-tailed Student *t* test, this difference in diameter measurement was statistically significant ($P \leq .05$). In 43 patients (36.1%), there was no difference in IVC diameters obtained with CO_2 and iodinated contrast–enhanced cavography. In 86 patients (72.3%), the diameters obtained with CO_2 and iodinated contrast–enhanced cavography were within 1 mm of each other. In three patients, CO_2 cavography demonstrated an IVC diameter of 28 mm or less, whereas iodinated contrast–enhanced cavography demonstrated an IVC diameter of more than 28 mm. In two of these three patients, an LGM or titanium Greenfield filter was placed and no clinical sequelae were noted.

Partial or complete IVC thrombus was identified at CO_2 cavography in 11 patients; all of these clots were confirmed with iodinated contrast–enhanced cavography (Fig 3). In addition, iodinated contrast–enhanced cavography revealed three additional instances of IVC thrombus that were not fully appreciated with CO_2 cavography. In two of these patients, a small thrombus was located just superior to the IVC bifurcation on the iodinated contrast–enhanced cavogram obtained after uncomplicated CO_2 cavography and caval filter deployment. Of note, the IVC just superior to the iliac veins was not included on either CO_2 study because the catheter was positioned just above the IVC bifurcation and there was no substantial CO_2 reflux. In the third patient, the CO_2 study showed a small filling defect involving the lateral wall of the IVC. After infrarenal IVC filter deployment, the iodinated contrast–enhanced images revealed the presence of a large clot trapped within the deployed filter. Although this case was categorized as a CO_2 failure, the origin of the IVC clot was never determined. It may have originated from the right common femoral vein introducer sheath or, more likely, may have been a dislodged lower extremity venous embolus appropriately captured by the filter.

Anatomic IVC anomalies were demonstrated in six patients (5.0%) and included circumaortic and/or retroaortic left renal veins and accessory renal veins in two patients each (1.7%). One patient (0.8%) had a partially duplicated IVC, and one patient (0.8%) had an anomaly that was compatible with a previously



a. b.

Figure 3. (a) Posteroanterior DSA CO_2 cavogram obtained with a right internal jugular venous approach demonstrates a large filling defect (large arrow) in the IVC just superior to the iliac veins. This finding is compatible with IVC thrombus. The central left renal vein (arrowhead) is well filled on this image. The right renal vein inflow (small arrow) is barely perceptible but was well seen on sequential CO_2 images. **(b)** Final posteroanterior cut-film iodinated contrast–enhanced cavogram obtained after CO_2 cavography–guided IVC filter placement helps confirm the appropriate location of the filter (arrow) in the infrarenal IVC above the IVC thrombus (arrowhead). A radiopaque ruler (scale in centimeters) was placed below the patient for position reference while an intravascular sizing catheter (Cook) was used to measure the IVC diameter.

performed right nephrectomy. All six anomalies were demonstrated with both CO_2 and iodinated contrast–enhanced cavography.

Cavography with CO_2 was prospectively judged to be a failure in three patients (2.5%): In two patients (1.7%), CO_2 cavography inadequately demonstrated the renal vein anatomy, and in one (0.8%), iodinated contrast–enhanced cavography was necessary to further define a small suprarenal IVC. In all three patients, an IVC filter was safely placed after iodinated contrast–enhanced cavography was performed.

Overall, the average number of CO_2 cavography DSA runs performed was 2.3 per patient (mean, two; range, one to eight). The maximum amount of CO_2 administered to any one individual in this study group was approximately 500 mL.

When the two cavographic examinations were compared for overall quality and information, the CO_2 cavograms were judged to be equal to the iodinated contrast–enhanced cavograms in 84 patients (70.6%). In 24 patients (20.2%), the iodinated contrast–enhanced cavogram was judged to be superior, and in 11 patients (9.2%), the CO_2 study was judged to superior.

A complication of filter deployment occurred in one patient (0.8%). A titanium Greenfield filter originally placed in the immediate infrarenal IVC after the CO_2 study was found to have one leg protruding into the right renal vein at iodinated contrast–enhanced cavography. Because this renal vein was not clearly identified with CO_2 cavography alone, the filter positioning was believed to represent a failure of the CO_2 study.

Finally, there was a surprising lack of side effects related to CO_2 injection among our study patients. One patient had nausea with both CO_2 and iodinated contrast material, but it resolved spontaneously. One patient vomited several minutes after the administration of CO_2. This also resolved without further treatment, and it is unclear whether this episode was truly related to the CO_2 or whether it was due to the recent intravenous administration of meperidine hydrochloride. No episodes of dyspnea, light-headedness, induced hypotension or hypertension, or cardiac dysrhythmias were observed.

DISCUSSION

Iodinated contrast–enhanced cavography is the standard of reference for diagnostic vena cavography as well as for vena cavography before IVC filter placement. Although iodinated contrast material is safe and well tolerated in most patients, serious reactions have been reported to occur in up to 0.1%–0.2% of patients (11), with idiosyncratic (ie, allergic) reactions complicating approximately 3% of intravascular procedures (12). In addition, there is much controversy regarding the prevalence and severity of renal insufficiency that develops after the intravascular administration of iodinated contrast material (13–18). For these reasons, attention has been directed toward alternatives for individuals who have had a reaction to iodinated contrast material or those with renal insufficiency. One of these alternatives is CO_2.

Because CO_2 is a normal constituent of the human body, there is no possibility of an allergic reaction (7). Although the use of CO_2 in the arterial system has been deemed safe (4,19–24), more strict attention has been recommended for venous CO_2 injection (7). Concerns regarding CO_2 flooding of the right ventricle necessitate careful administration with respect to the injected volume of CO_2 and the interval between CO_2 injections. Kerns et al (7) performed vena cavography in humans using up to 70 mL of CO_2 per injection and reported that it was well tolerated, with dissolution or elimination of CO_2 in a matter of seconds. A more recent animal study revealed that although there was an immediate and reversible increase in the pulmonary arterial pressure after CO_2 cavography, diagnostic doses of CO_2 had no substantial effect on cardiopulmonary function regardless of patient positioning (25). In addition, Bendib et al (26) reported 1,600 cases without major complication in which 200 mL of CO_2 was injected intravenously for the detection of pericardial effusion. We agree with the recommendation of Kerns et al (7) that no more than 200 mL should be administered in any one injection and suggest the use of substantially less in the case of vena cavography. Under usual conditions, diagnostic images are obtained with 60 mL or less of CO_2.

TABLE 2
CO_2 Cavography Failures

Patient No./Age (y)/Sex	Failure Type	Explanation
1/60/F	Inadequate CO_2 cavogram	Iodinated contrast cavography of IVC needed to evaluate a small suprarenal IVC
2/31/F	Inadequate CO_2 cavogram	Iodinated contrast cavography needed to fully evaluate the renal veins
3/53/M	Inadequate CO_2 cavogram	Iodinated contrast cavography needed to fully evaluate the renal veins
4/65/M	Missed thrombus	The small IVC clot was located just superior to the iliac veins at cavography
5/35/F	Missed thrombus	Thrombus was underappreciated at CO_2 cavography; iodinated contrast cavography revealed intrafilter thrombus
6/59/F	Missed thrombus	Incomplete CO_2 cavographic evaluation of IVC just superior to the iliac veins; IVC clot was seen with iodinated contrast cavography
7/34/M	Complication	Right renal vein not well seen with CO_2 cavography; one filter leg was seen in the right renal vein with iodinated contrast cavography

Our experience suggests that CO_2 cavography is a safe procedure when performed appropriately. Episodes of transient tingling, abdominal pain, and bowel ischemia and infarction have been reported with CO_2 use in the arterial system (7,27), and two fatalities have been reported (28,29), although causality was unproved, though suggestive, in both cases (27). As to venous injections, few adverse reports have been described in the literature. We noted two mild reactions (nausea and/or vomiting) in our series, one of which occurred with iodinated contrast material administration as well. The other was mild and self-limited and may have been caused by concomitantly administered narcotic medications.

In this series, CO_2 cavography adequately depicted all anatomic parameters necessary for IVC filter placement in 94% of patients. All of the anatomic caval anomalies were identified with CO_2 imaging.

IVC thrombus was clearly delineated with CO_2 cavography in 11 of 14 patients. The three instances of incomplete thrombus delineation with CO_2 cavography occurred early in our study. Although two of these cases were clearly related to an incomplete IVC CO_2 study, the filter positioning and approach was correct. The third was not clearly a failure of the CO_2 study, because the initial thrombus was found and filter positioning appeared to be appropriate.

Overall, there were seven (5.9%) CO_2 cavography failures (Table 2). This number could likely have been minimized with stricter attention to careful positioning of the catheter and patient. Specific attention to the IVC just superior to the iliac veins is recommended with CO_2 cavography because incomplete evaluation of this region led to nearly one-third of our cavography failures. Patients with incomplete IVC evaluation at CO_2 cavography should undergo iodinated contrast–enhanced cavography or selective venous imaging.

The diameter of the IVC tended to be slightly underestimated with CO_2 cavography, although in approximately three-fourths of cases, the IVC diameters at CO_2 and iodinated contrast–enhanced cavography were within 1 mm of each other. In no instance was a size discrepancy of greater than 3 mm discovered. This undersizing can be explained by insufficient blood displacement owing to the buoyancy effect of CO_2, with only the anterior or non–gravity-dependent portion of the vessel being visualized (22). Similarly, as reported by other authors, CO_2 arteriography has a slight tendency toward overestimation of stenoses (30). Although no clinically apparent sequela of this undersizing was found in our study, three instances were noted in which the IVC diameter at CO_2 cavography was 28 mm or less but iodinated contrast–enhanced cavography revealed the IVC diameter to be greater than 28 mm. Because manufacturers of only one of the five filters with U.S. Food and Drug Administration approval recommend placement in instances of IVC diameters greater than 28 mm (31), caution should be used with caval measurements approaching this size. On the basis of our experience, we recommend caution when caval measurements are greater than 25 mm at CO_2 cavography. In these instances, consideration of iodinated contrast–enhanced cavography or placement of an appropriate filter for the possible large IVC is recommended. In our study, eight patients (6.7%) were found to have an IVC diameter of greater than 25 mm at CO_2 cavography.

Finally, the overall quality of the CO_2 cavograms in our study was rated as good to excellent, with nearly 80% of CO_2 cavograms having a diagnostic quality equal or superior to that of iodinated contrast–enhanced cavograms. Essentially all of the remaining CO_2 cavograms, even though judged to be of lesser quality, were believed to contain sufficient diagnostic information to allow safe caval filter placement.

Overall, we believe that CO_2 is a safe contrast material for radiography of the vena cava, is well tolerated, and provides sufficient diagnostic information for vena cavography and for guiding IVC filter placement. Although appropriate for use in almost any patient, CO_2 appears to be clearly advantageous in those with a history of iodinated contrast material reaction or renal insufficiency. Because IVC diameter tends to be slightly underestimated with CO_2 cavography, caution is recommended in filter selection when the diameter of the IVC is greater than 25 mm at CO_2 cavography.

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