Inferior Vena Cava Filter Placement: Preinsertion Inferior Vena Cava Imaging

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Imaging of the vena vava prior to the insertion of an inferior vena vava (IVC) filter is mandatory to assess IVC diameter and patency, delineate anatomy and venous anomalies, and to direct filter placement for appropriate deployment and avoidance of complications. The standard imaging technique is vena cavography, although alternative methods to evaluate the inferior vena cava include carbon dioxide venography, transabdominal duplex ultrasound, and intravascular ultrasound. This manuscript will review the anatomical features, technique, and complications of pre-insertion inferior vena cava imaging and discuss alternative methods to evaluate the inferior vena cave prior to filter insertion.

IMAGING OF THE vena cava before the insertion of an inferior vena cava (IVC) filter is mandatory for appropriate deployment and avoidance of complications. Savin et al.[1] reported a filter misplacement rate of 2.5 per cent when preceded by vena cavography and 43 per cent when not preceded by vena cavography.[1] The *Recommended Reporting Standards for Vena Cava Filter Placement and Patient Follow-up* published by Greenfield et al.[2] in 1999 emphasized that documentation of vena cava imaging and identification of the renal veins should be recorded. Quality improvement guidelines for IVC filter placement published for the Society of Cardiovascular and Interventional Radiology Standards of Practice Committee in 2001 state that "the IVC should be assessed with imaging before placement of a filter and the current preferred imaging method is vena cavography."[3] In addition the package inserts accompanying commercially available IVC filters including the Greenfield® Filter (Boston Scientific, Natick, MA), Gianturco-Roehm Bird's Nest® Filter and Günther Tulip™ Vena Cava MReye™ Filter (Cook Inc., Bloomington, IN), TrapEase™ and OptEase Vena Cava Filters (Cordis Corp., Miami Lakes, FL), Vena Tech™-LGM and LP® vena cava filters (B. Braun Medical, Inc., Evanston, IL), and Simon Nitinol Filter® (C.R. Bard, Inc., Murray Hill, NJ) assert the necessity for preinsertion vena cava imaging. The preinsertion imaging of the IVC is critical to assess IVC diameter and patency, delineate anatomy and venous anomalies, and direct filter placement. This report discusses alternative methods to evaluate the IVC in addition to contrast vena cavography under fluoroscopic guidance; these methods include duplex transabdominal imaging and intravascular ultrasound (IVUS).

Anatomic Features of Preinsertion IVC Imaging

Before IVC filter deployment the venous anatomy inferior to and including the renal veins should be characterized as this may affect the location and particular choice of IVC filter to place. Specific anatomic features to be delineated include the infrarenal IVC length and diameter, the location and number of renal veins, the location of the iliac veins and their confluence, IVC anomalies, accessory or large lumbar veins, and pre-existing IVC thrombosis or compression. As many as 11 per cent of patients have an abnormality revealed by preinsertion IVC imaging that will require an alternative approach for placement.[4]

The anatomy of the IVC is fairly consistent. The renal veins are typically located anterior to the disc space between the first and second lumbar vertebral bodies. The confluence of the iliac veins is usually anterior to the disc space between the fourth and fifth lumbar vertebral bodies or anterior to the superior aspect of the fifth lumbar vertebral body. These anatomic relationships are important to determine after completing the preinsertion cava imaging, as the relationship of the renal veins and iliac venous confluence to the lumbar disc spaces and vertebral bodies can serve as a guide for proper anatomic placement of the filter.

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For the prevention of lower extremity and pelvic thromboembolism proper placement of a filter is in the infrarenal IVC.[2] Both renal veins are identified so the filter can be placed with its apex inferior to or immediately adjacent to the lowest renal vein. The confluence of the iliac veins is identified to prevent the placement of a filter in the iliac vein or deployment of the filter struts within the iliac venous confluence. In both instances improper placement causes unilateral filtration of venous flow and would not reduce the risk of pulmonary embolism.[5] In addition if the filter struts are placed into the renal veins, iliac veins, or a large accessory or lumbar vein the orientation of the filter may be altered. When certain filters such as the Greenfield® filter are tilted their filtering capacity is reduced even when deployed in the IVC.

Other abnormalities potentially discovered on preinsertion IVC imaging are a duplicated vena cava system or IVC thrombosis. The incidence of a duplicated system is less than 0.2 per cent.[6] If a duplicated system is found it may require placement of an IVC filter in each vena cava or a filter above the confluence of the duplicated system. If IVC thrombosis is identified on preinsertion imaging from a femoral venous approach then conversion to a supradiaphragmatic (internal jugular vein) approach will avoid manipulation of the thrombus. Obviously it is imperative to deploy the filter above the thrombus to prevent embolic events and to avoid deployment of the filter within the thrombus. If any part of the filter is deployed within the thrombus the filter will not adequately expand and may actually trigger embolization.

Preinsertion IVC imaging is also completed to determine cava diameter. The majority of vena cava filters have a 28- or 30-mm maximum size indication and placement of a filter greater than its approved diameter indication risks filter migration. Reed et al.[7] reported the incidence of a vena cava diameter greater than 28 mm to be 2.3 per cent, so most filters will be appropriate for the majority of patients. Nevertheless only the Gianturco-Roehm Bird's Nest® Filter (Cook Inc.) has been approved by the U.S. Food and Drug Administration for a vena cava greater than 30 mm in diameter. This filter has an indication of up to 40 mm.

Preinsertion IVC Imaging

The standard imaging technique and that recommended by the Society of Cardiovascular and Interventional Radiology Standards of Practice Committee is vena cavography. Venous access is established through a femoral or internal jugular vein using a standard Seldinger technique. A 5-French pigtail catheter is positioned over a guidewire into the IVC just superior to the iliac veins. Approximately 30 to 60 mL of nonionic iodinated contrast is injected through a pressure injector at a flow rate of 15 to 25 mL/second. Total contrast volume is dependent on the patient's age and size. For instance, a large young male may have much higher venous flow rates and require higher contrast volumes and higher rates of contrast injection to allow for adequate imaging compared with an elderly thin female. The iodinated contrast should be injected through a pigtail catheter with multiple side holes. Catheters with multiple side holes provide for adequate mixing of the iodinated contrast within the venous (cava) blood column, filling the entire vena cava to allow for accurate cava diameter measurements and identification of anomalies of thrombus. Fluoroscopic images with or without digital subtraction are obtained at three to six images per second. Radiopaque markers on the pigtail catheters (20 or 28 mm) act as a measuring guide for filter placement and correct for magnification artifact during fluoroscopy (Fig. 1). Radiopaque measuring tapes can be placed posteriorly on the patient's skin, however, but artifact may contribute to inaccurate measurements in obese patients.

Carbon dioxide cavography is an alternative to using iodinated contrast for preinsertion imaging. Venous access and catheter placement are similar to intravenous contrast vena cavography. Sixty milliliters of carbon dioxide gas is hand injected through a 5-F pigtail catheter during each angiographic run. Manual ("hand") injections can be performed with iodinated contrast and carbon dioxide using a hand injection system (AngioDynamics®, Queensbury, NY). Because carbon dioxide is a very low-resistance gas it is easier to inject manually compared with iodinated contrast. Before hand injection of the carbon dioxide bolus, medical-grade carbon dioxide (99.9% CO_2) is purged of room air and captured in a 60-mL syringe through a series of stopcocks, syringes, and intrave-

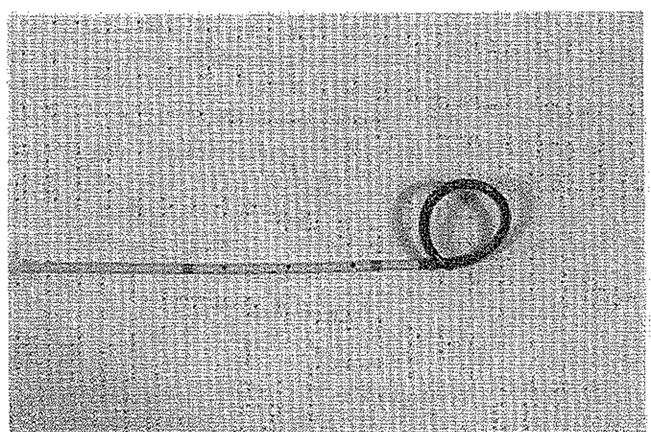

Fig. 1. Angiography catheter with multiple side holes and radio-opaque measuring guides.

nous tubing. Fluoroscopic images with digital subtraction are obtained. Digital subtraction is required for adequate imaging using CO_2. Repeat carbon dioxide cavagrams are performed as needed if images are inadequate without risk to the patient. The contrast of an iodinated contrast cavagram is shown in Fig. 2, *A* and *B*.

Discussion

Iodinated contrast for vena cavography provides an element of risk to filter placement; however, these risks are minimal compared with the risks of insertion without identifying the entrance of the renal veins, noting any venous anomalies, and measuring the vena cava diameter. The two major potential complications of iodinated contrast are allergic reactions and contrast nephropathy. In a study of 1004 patients receiving intravenous contrast for cardiac angiography or CT scans the adverse reaction rate was 19 per cent.[8] The adverse event rate from intravenous contrast is higher in this group of patients because these procedures require a larger contrast exposure than the typical 60 mL or less used for vena cavography.[8] Adverse reactions can be significantly reduced with the use of nonionic contrast. Cochran et al.[9] examined 391 adverse reactions to iodinated contrast after a total of 90,473 administrations. During the time period when only ionic contrast was in use they observed a 6 to 8 per cent incidence of adverse events. Selective use of nonionic contrast reduced the incidence of adverse events to 0.6 to 0.7 per cent, and universal use of nonionic contrast reduced the incidence even further to 0.02 per cent.[9] Currently we use nonionic contrast exclusively, unless the patient has a contraindication to intravenous contrast. The reported incidence of contrast nephropathy is highly variable, but recent studies suggest an incidence in patients with some renal compromise below 10 per cent. A retrospective review by Sterner et al.[10] reported an 8 per cent incidence of creatinine elevation of 25 per cent or greater in patients with renal insufficiency receiving iodinated contrast for angiography. Additionally, Lufft et al.[11] found a 9 per cent incidence of contrast nephropathy after CT angiography for renal artery stenosis.

In patients with a contraindication to intravenous contrast (impaired renal function/allergy) we perform carbon dioxide with digital subtraction fluoroscopy.[12]

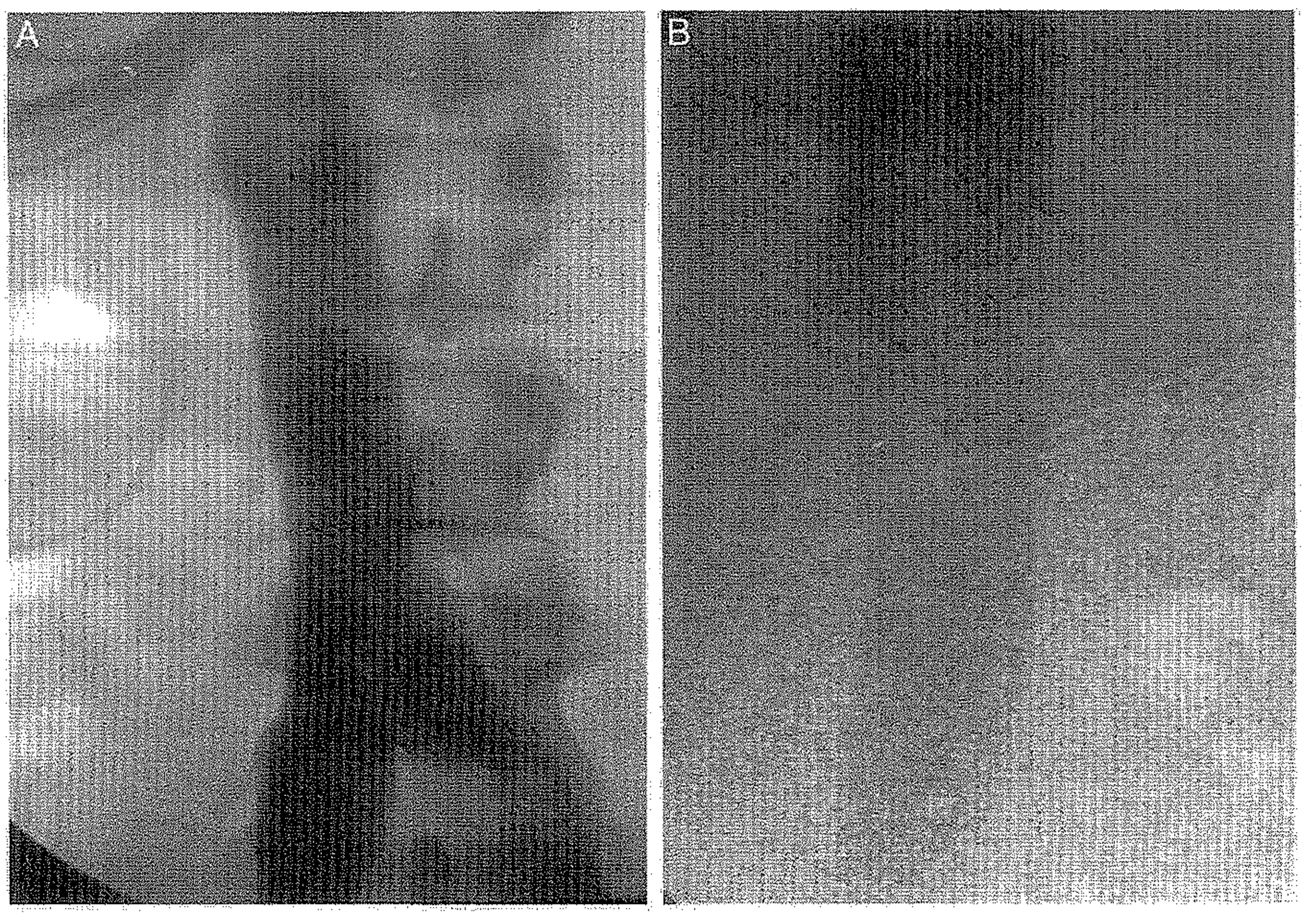

FIG. 2. *A:* Iodinated contrast cavagram. *B:* Carbon dioxide cavagram using digital subtraction.

A study from our institution prospectively compared carbon dioxide cavography with iodinated contrast cavography in 23 bedside filter placements.[12] There were no adverse reactions (hypertension, tachycardia, hypoxia, hypercarbia, or intracranial pressure elevation) to the intravenous carbon dioxide. With regard to measuring cava diameter the difference between carbon dioxide and intravenous contrast was a clinically insignificant 0.4 ± 0.1 mm with the largest measured difference only 1.7 mm.[12] Additional studies have shown carbon dioxide cavography to be a safe and accurate method of imaging the vena cava and measuring caval diameter; however, complications including underestimation of cava size, difficulty identifying the renal veins, not identifying intravenous thrombosis, and a single incidence of filter misplacement due to a misinterpretation of the carbon dioxide cavagram have been reported.[13, 14] Careful evaluation of the cavagram and the use of digital subtraction are critical when carbon dioxide cavography is used. Given the benign nature and rapid elimination of carbon dioxide in the bloodstream additional cavagrams can be performed until adequate visualization of the anatomy is achieved.

In an effort to reduce the need for intravenous contrast both transabdominal and intravenous ultrasound have been used to guide placement of vena cava filters. Conners et al.[15] reported on 325 attempts at transabdominal ultrasound-guided placement with a 12 per cent failure rate and a 2 per cent incidence of filter misplacement. Additional studies have documented technically inadequate duplex scans preventing transabdominal ultrasound-guided placement in 10 to 13 per cent of attempts and complication rates (suprarenal misplacement, iliac vein placement, etc) as high as 8.2 per cent.[16–19] IVUS has been used in an attempt to reduce complications from intravenous contrast and to overcome the technical difficulties and imaging limitations with transabdominal duplex ultrasound. In study by Bonn et al.[20] IVUS effectively determined vessel patency, renal vein location, and cava diameter in 30 of 30 patients and replaced contrast venography in 73 per cent of these patients. It should be noted that fluoroscopy was used in all cases.[20] An additional study of 26 patients found IVUS-guided placement to be successful in all but two patients.[21] IVUS appears to be promising in reducing the need for intravenous contrast when compared with transabdominal ultrasound. Nevertheless fluoroscopy and intravenous contrast is required when technical difficulties are encountered. A limitation to IVUS and duplex transabdominal ultrasonography is the requirement of training in vascular imaging. This expertise is not universal. Intravascular ultrasound is significantly more expensive than other modalities because disposable probes cost approximately $600 compared with iodinated contrast and pigtail catheters for contrast cavography ($200) and carbon dioxide cavagraphy ($100), which are less expensive.

Routine postinsertion cavagrams remain somewhat controversial. Postinsertion cavography should be completed when there is concern of excessive filter tilt or questions regarding the actual deployment site or expansion of the filter. We have misplaced two vena cava filters in a series of 350 patients. Both of these filters were likely placed in a gonadal vein. The orientation and expansion of the vena cava filters appeared abnormal on fluoroscopic examination, and a postinsertion cavagram was completed. Identification of this problem on the postinsertion cavagram allowed for the immediate placement of a second filter in the appropriate location reducing the risk of venous embolism.

Preinsertion vena cava imaging is a critical step in the proper placement of an IVC filter. Preinsertion imaging not only determines vena cava diameter but also identifies the location of the renal veins, iliac venous confluence, venous anomalies, and intraluminal thrombosis. Alternatives to iodinated contrast include carbon dioxide venography, transabdominal duplex ultrasound, and intravenous ultrasound. The feasibility of using real-time magnetic resonance imaging for IVC filter placement has been confirmed in animal models and should expand to the clinical arena in the near future.[22, 23]

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