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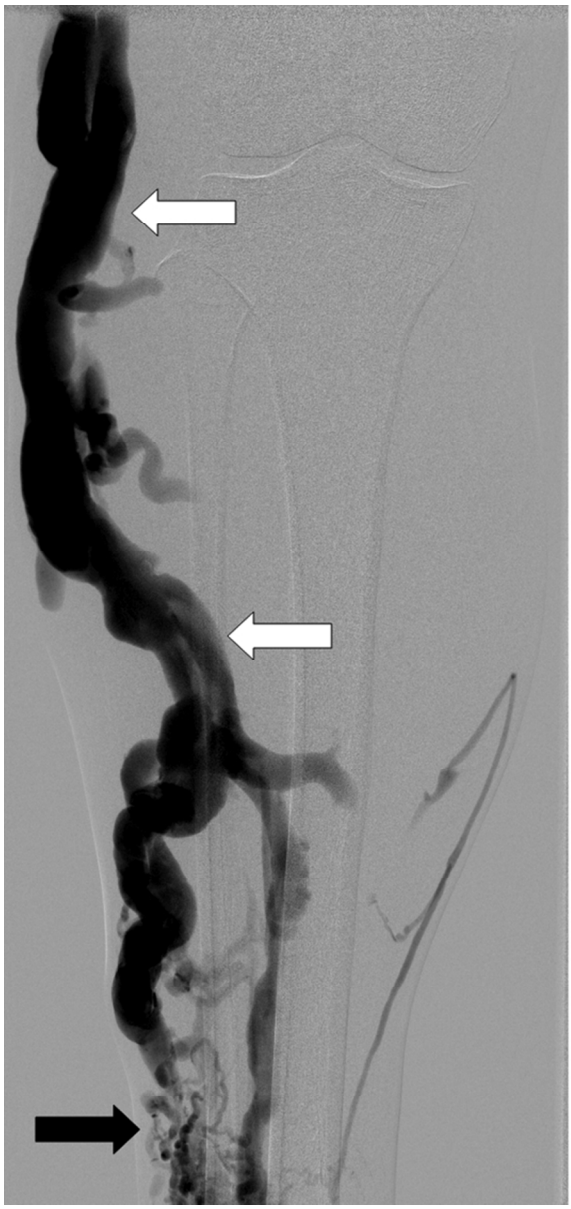

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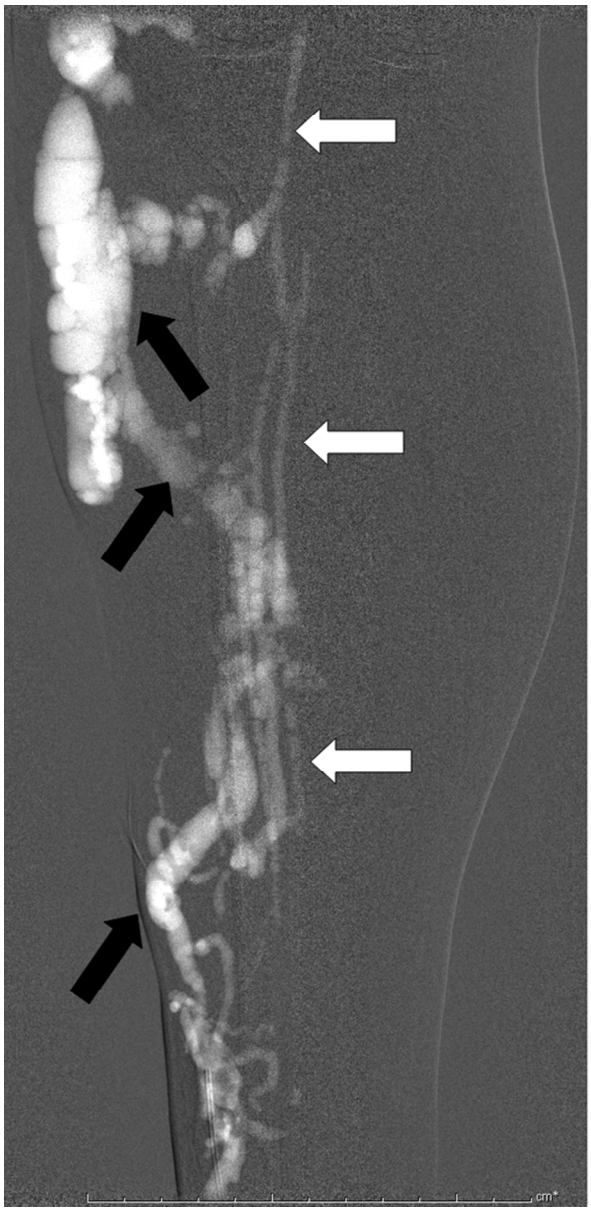

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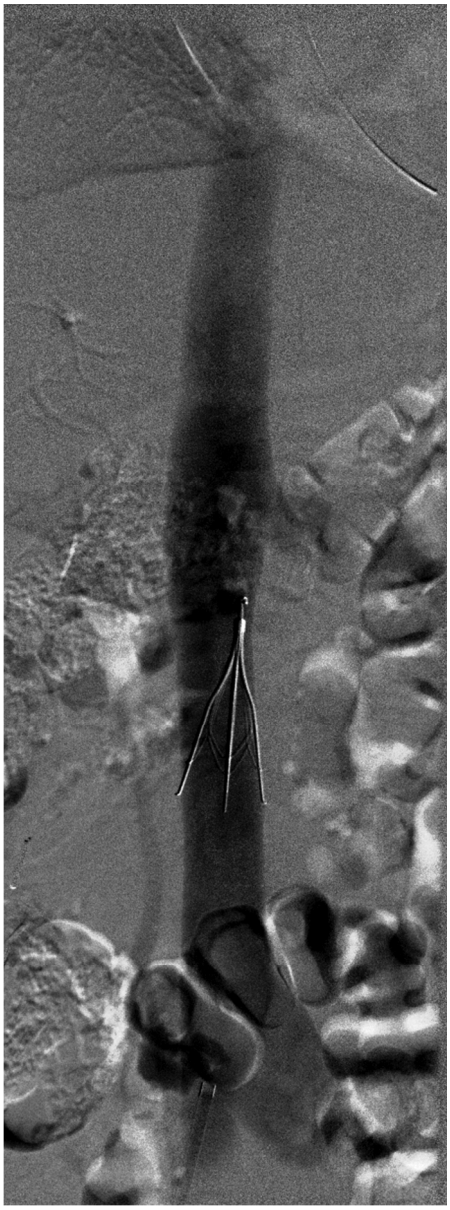

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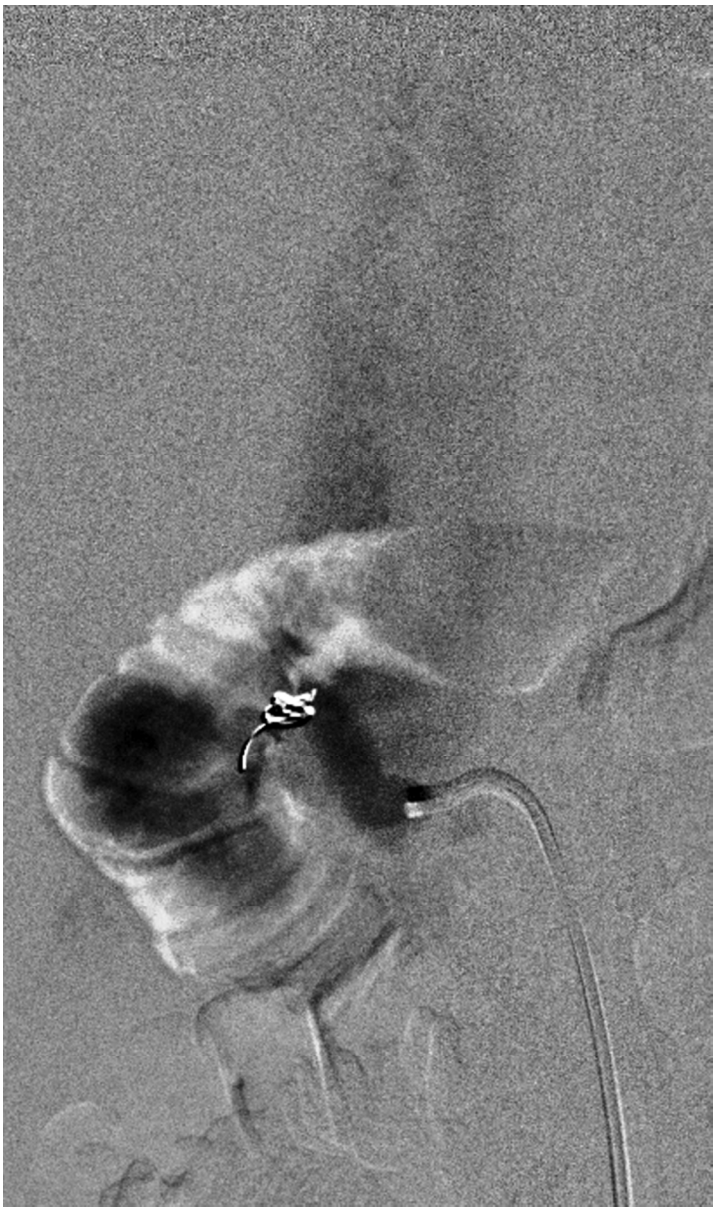

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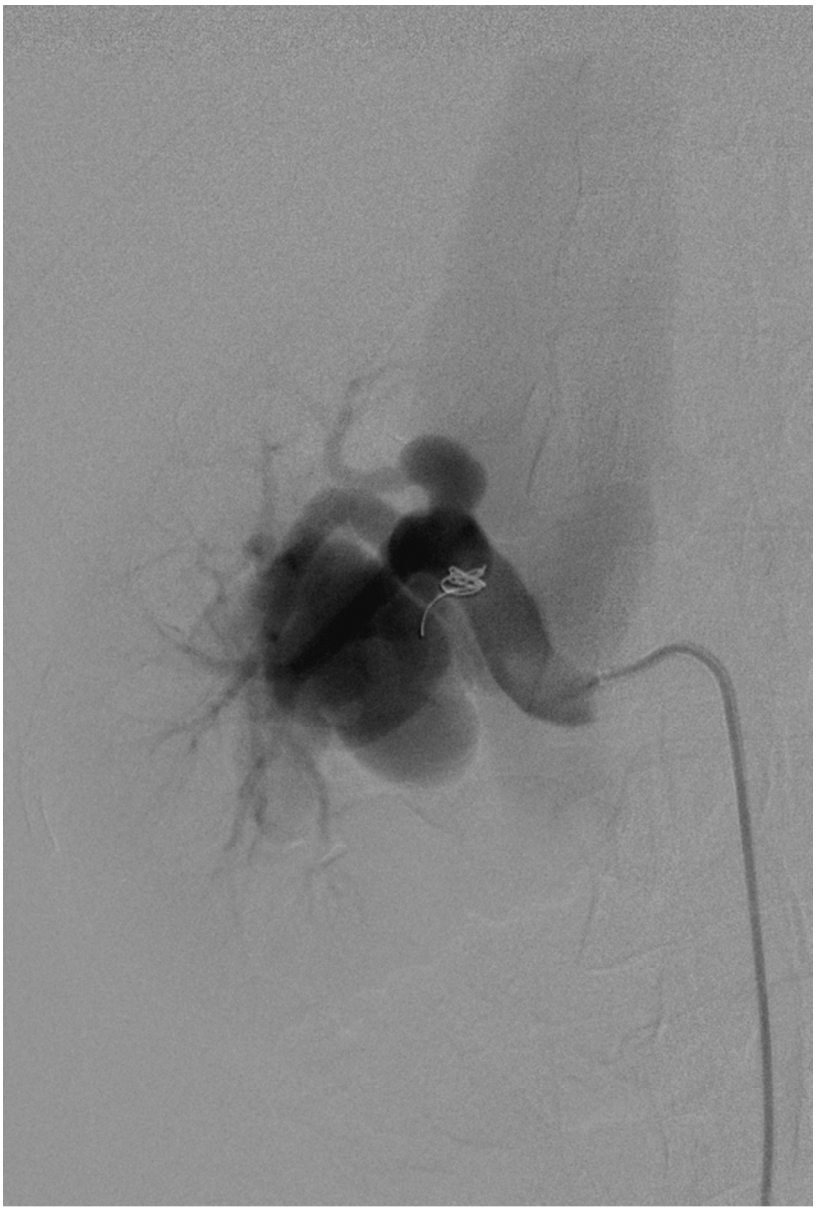

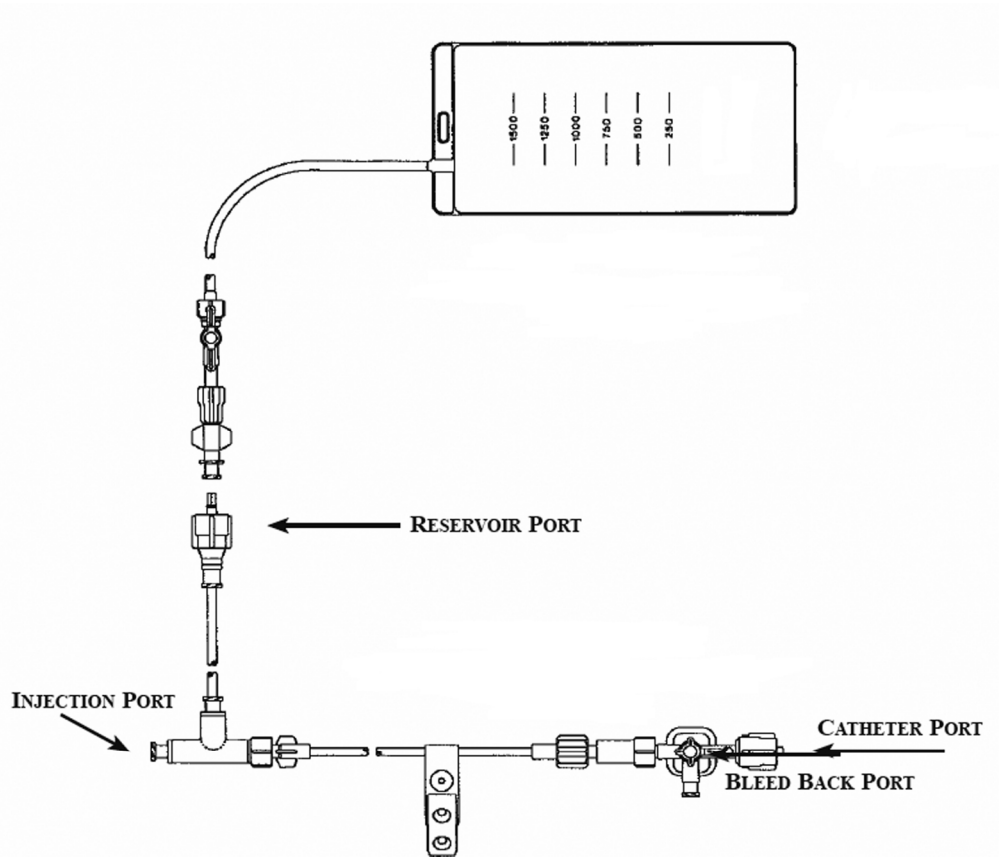

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ABSTRACT

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Materials and Methods

The clinical and demographic data, diagnostic images, technical success and complications in children and young patients who underwent angiography using carbon dioxide as a contrast agent between March 2005 and March 2011were retrospectively analyzed. A simple system for the delivery of carbon dioxide from the gas cylinder into the syringe was assembled from sterile tubes, air filter, stopcock and a bowl of saline.

Results

Nine patients (4 male, 5 female; age range 5-29 years) underwent angiography with carbon dioxide gas as a contrast agent using a simplified delivery circuit. The indications were venography in venous malformation (n=3), venous thrombosis related to anatomical compression (n-3), Klippel-Trenaunay syndrome (n=1), splenoportogram for portal hypertension (n=1) and arteriography for large renal arteriovenous fistula (n=1). The total volume of carbon dioxide injected was 20-650 ml per procedure. Adequate imaging quality was obtained in 8 patients (venography and splenoportography) while the quality of the arteriogram in the renal arteriovenous fistula was inadequate to identify the feeding and draining vessels. No complications were encountered.

Conclusion

The use of this simplified circuit for the delivery of carbon dioxide in children and young patients is safe and may obviate the need for a specialized delivery system.

INTRODUCTION

Carbon dioxide (CO2) is a non-toxic gas which can be used as an alternative angiographic contrast agent. CO2 is widely used in adult angiography and opacification of body cavities (1, 2-5). Though the experience in children is relatively limited, the use of CO2 in children is generally considered safe and may substitute iodinated contrast in renal insufficiency or allergy to iodine (6).

Cronin et al. (2) reported their extensive experience performing CO2 angiography in adult patients using a simple "homemade circuit" assembled from inexpensive equipment. In this communication, we reviewed variable applications and indications of CO2 angiography using a simple delivery system in children and young patients.

MATERIALS AND METHODS

This study was approved by our Committee on Clinical Investigation at Children's Hospital Boston. We retrospectively reviewed the medical records and imaging studies of patients who underwent CO2 angiography utilizing a simple system in the past 6 years (March 2005- March 2011). Data on the patient's demographics, clinical indictions, diagnostic quality, technical success and complications were collected. The delivery of CO2 from the cylinder into the syringe was assembled from sterile tubes, air filter, stopcock, flow switch and a bowl of saline.

Technique

All the procedures were done under general anesthesia and sterile conditions. CO2 angiography was performed as a diagnostic test prior to a therapeutic procedure (e.g. sclerotherapy, embolization, and thrombolysis) or in combination with other procedures. The contrast type in the angiography machine was changed to CO2. The gas was obtained from a medical grade CO2 cylinder via a simple, underwater seal circuit [Figure 1]. The regulator of the CO2 cylinder is fitted to the female funnel end of a standard gas tube (Argyle universal green bubble tubing, Tyco, Mansfield, MA). A double male Luer lock (Medex, Dublin, OH) adapter connects the taper end of the gas tube to a 0.2 μm particle filter (Posidyne intravenous filter, Pall Medical, East Hills, NY). The filter then connects to a standard connecting tube (30 inch Macrobore extension set, Hospira, Lake Forest, IL), three-way stopcock and finally another connecting tube. The female end of the latter is immersed in a bowl of saline. A syringe is connected via a flow switch (Boston Scientific, Natick, MA) to the female end of the stopcock. The assembly of the parts is made as tight as possible to prevent air entry to the system. The patient, diagnostic catheter/needle, shields and fluoroscopy are appropriately positioned for the angiogram. The CO2 regulator is turned on delivering 1 L/min or less. The flow of gas is allowed to purge the tubes as indicated by bubbling in the bowel of saline. The stopcock is opened into to the syringe while the plunger is controlled with the thumb to prevent inadvertent expulsion of the plunger due to the pressurized gas. Attention was made not aspirate CO2. When the syringe is filled with CO2, the stopcock is opened to the saline and the syringe is emptied. This step is repeated three times in order to purge the syringe from air. After filling the syringe with pure CO2, the flow switch is closed, the syringe is disconnected from the stopcock and connected to the diagnostic catheter or needle via the

flow switch. After the diagnostic catheter is purged with CO2 and under digital subtraction angiography, the manually pressurized CO2 syringe is opened and the appropriate run is obtained. The catheter is flushed with saline. The images are viewed as acquired or in an inversed display [Figure 2]. To avoid gas diffusion, CO2 was sealed in the syringe with a flow switch and the run was preformed immediately after obtaining the gas from the circuit. The study was repeated as needed after a waiting time of > 2 minutes. To minimize the artifact from bowel motion, glucagon was administered intravenously prior to the angiogram whenever needed. The volume of CO2 per injection was determined based on the volume of iodinated contrast needed for such a study.

Adequate use of CO2 was defined as satisfactory imaging of the target vessels allowing for establishing the diagnosis or opacifying the target channels or components of the lesions.

RESULTS

Nine patients (4 male, 5 female; age range 5-29 years) underwent angiography using CO2 as a contrast agent via a simplified delivery circuit. The types of contrast study were venography (n=7), splenoportography (n=1) and arteriography (n=1). The clinical indications were venous malformation of the head and neck area (intralesional venography, n=3), venous thrombosis related to anatomical compression (central venous catheter, Paget-Schroetter and May-Thurner syndromes) (ascending venography, n-3), Klippel-Trenaunay syndrome (ascending venography, n=1), portal hypertension (splenoportography, n=1) and renal arteriovenous fistula (arteriography, n=1). CO2 was

used a sole (n=2) or supplemental (n=7) contrast medium. The clinical and procedural details are summarized in Table 1.

The total volume of CO2 used ranged from 20-650 ml per procedure.

No complications were noted during or following the injection of CO2; namely there were no changes in the vital signs, PCO2, or PO2.

Adequate imaging quality was obtained in 8 patients. Due to the very fast flow through the large renal arteriovenous fistula, the arterial and venous phases of the CO2 arteriogram overlapped precluding accurate analysis of the angioarchitecture. In this patient, non-ionic Iodine-based contrast (Ioversol 51%, Optiray 240, Tyco Healthcare/Mallinckrodt - Hazelwood, MO) provided superior opacification of the feeding arteries and draining veins [Figure 3].

DISCUSSION

As a contrast agent, carbon dioxide has many advantages including lack of toxicity, non-viscosity, compressibility, and rapid absorption and elimination (7). Because CO2 is invisible and buoyant, it requires meticulous handling and delivery to avoid inadvertent contamination with air.

The use of simplified system for CO2 angiography, described by Connin (2) and used by others (3,6, 8), has several advantages over the special fluid management systems.

The use of fluid management systems (such as AngioFlush III Fluid Management System (AngioDynamics, Queensbury, NY) [Figure 4] for delivery of CO2 is neither intuitive nor eliminates the risk of inadvertent contamination of air. Though this closed-delivery system is considered almost completely fail-safe by some (7), the need to aspirate from a

reservoir increases the risk of air contamination; which has led to fatal air embolization (9). The manufacturer has recently discontinued this product and with the lack of any FDA-approved gas management systems, the need for an alternative arises.

Under digital subtraction imaging (DSA), CO2 can be distinguished from air by demonstrating rapid absorption of the former; air contamination is suspected if the gas trapped in the right atrium remains visible 90 sec after the injection (10). Cho et al (10) found that in an open syringe, CO2 quickly diffuse into the air regardless of the syringes positions (7). For a 20 ml-syringe, the diffusion rate was 0.2 ml/sec with air replacement of 13% at 5 min and 60% at 60 min (11).

Like iodinated contrast, CO2 can be delivered via an injector. However, a dedicated CO2 delivery system for DSA (Coject, Angiodynamics, Glens Falls, NY and CO2-Angioset, OptiMed, Ettingen, Germany) is relatively expensive (8) and not-FDA approved. The use of standard computerized injectors intended to iodinated contrast has potentially dangerous disadvantages (12).

The use of CO2 as a contrast agent in children is safe and well tolerated (8), though this experience is relatively limited. (2, 6, 13-15). Puppala et al. (14) reported the use of CO2 for preoperative wedged hepatic venography in 10 children (3-14 years) with a mesentericoportal (Rex) shunt. Their findings correlated with the operative ones in all patients. Caridi et al. (15) successfully performed CO2 splenoportography with ultrafine needle in eight patients; five of them were children (5 months-12 years) without any complication. CO2 angiography on a small series of five patients, including children, with high flow vascular malformations concluded that CO2 improves characterization of

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Madhusudhan et al. (8) used a simple circuit for CO2 angiography composed of a sterile plastic bag connected to a laparoflator and CO2 cylinder. The bag is filled, tied securely with a wire or silk thread, transferred to the IR suite then suspended on a regular drip stand and connected under water seal to a tube. However, the system appears to be labor intensive and not practical. Cherian et al. (17) devised a simple system consisted of a standard blood bag connected to a CO2. Neither of these systems eliminates the aspiration step.

In conclusion, the delivery of CO2 gas for angiography via a simple assembly appears to be practical and safe for use in children and young patients and may obviate the need for a sophisticated delivery system.

CONFLICT OF INTEREST

No conflict of interest.

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TABLES

Table 1. Summary of patients and procedures.

Patient #	Age	Procedure	Indication	CO2 volume

	(year)/Gender			injected (ml)
1	19/Male	Venography	Large venous malformation	60
2	10/Male	Venography	Large venous malformation	30
3	12/Male	Venography	Large venous malformation	NA
4	29/Female	Arteriography	Renal arteriovenous fistula	60
5	5/Female	Splenoportography	Portal hypertension, GI bleeding, cystic fibrosis.	20
6	14/Female	Venography	Subclavian vein thrombosis.	30
7	31/Male	Venography	Klippel-Trenaunay syndrome	650
8	17/Female	Venography	Paget-Schroetter syndrome	100
9	20/Female	Venography	May-Thurner syndrome	200

CAPTIONS FOR FIGURES

Figure 1. The simple CO2 delivery system with labeled components.

Figure 2. (A) Ascending venogram in a patient with Klippel-Trenaunay syndrome using iodinated contrast medium. There is preferential opacification of the anomalous marginal venous system (white arrows) without visualization of the deep venous system. Note clots in the lower segment of the marginal vein (black arrow). (B) CO2 venography demonstrates both the deep (white arrows) and the marginal (black arrows) venous systems. C. Inferior cavogram (inverted display) demonstrated proper position of the filter with patent IVC.

Figure 3. Right renal arteriography. The complex arteriovenous fistula of the right renal vasculature is poorly visualized with CO2 angiography (A, inverted display), compared to angiography with non-ionic iodine contrast (B).

Figure 4. AngioFlush III Fluid Management System.

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2	10/Male	Venography	Large venous malformation	30
3	12/Male	Venography	Large venous malformation	NA
4	29/Female	Arteriography	Renal arteriovenous fistula	60
5	5/Female	Splenoportography	Portal hypertension, GI bleeding, cystic fibrosis.	20
6	14/Female	Venography	Subclavian vein thrombosis.	30
7	31/Male	Venography	Klippel-Trenaunay syndrome	650
8	17/Female	Venography	Paget-Schroetter syndrome	100
9	20/Female	Venography	May-Thurner syndrome	200

CAPTIONS FOR FIGURES

Figure 1. The simple CO2 delivery system with labeled components.

Figure 2. (A) Ascending venogram in a patient with Klippel-Trenaunay syndrome using iodinated contrast medium. There is preferential opacification of the anomalous marginal venous system (white arrows) without visualization of the deep venous system. Note clots in the lower segment of the marginal vein (black arrow). (B) CO2 venography demonstrates both the deep (white arrows) and the marginal (black arrows) venous systems. C. Inferior cavogram (inverted display) demonstrated proper position of the filter with patent IVC.

Figure 3. Right renal arteriography. The complex arteriovenous fistula of the right renal vasculature is poorly visualized with CO2 angiography (A, inverted display), compared to angiography with non-ionic iodine contrast (B).

Figure 4. AngioFlush III Fluid Management System.