Technical Note

Plastic Bag Delivery System for Hand Injection of Carbon Dioxide

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Digital subtraction angiography with carbon dioxide as a contrast agent provides images useful in making a diagnosis and occasionally gives information not obtainable with use of iodinated contrast material. However, delivery of the gas is difficult because carbon dioxide is compressible and invisible [1, 2]. Over the past 10 years, we have developed a reliable, user-friendly, computer-controlled injector, which is not yet approved by the Food and Drug Administration. We describe a hand-delivery system designed on the basis of principles learned from the development of the computer-controlled injector system.

Materials and Methods

The system has two major components (Fig. 1): a plastic bag (AngioFill Bag Collection System; AngioDynamics, Queensbury, NY) that is used as a reservoir for the carbon dioxide and a closed fluid (or gas) delivery system (AngioFlush II, AngioDynamics) consisting of multiple check valves, stopcocks, and a connecting tube. The reservoir is a 1500-ml plastic bag with a 100-cm connecting tube. In order to remove residual air from the connecting tubing and the bag, a special female-to-female adaptor is connected to the one-way stopcock. After air is removed from the bag, the stopcock is closed and connected to a disposable cylinder of carbon dioxide (Custom Medical Devices, Gainesville, FL). The cylinder, which contains 99.7% pure medical grade carbon dioxide, is equipped with a two-stage gas regulator, a Luer-Lok fitting to which the connecting tube is attached, and a filter to remove submicron particles.

The reservoir bag connects directly to the side arm of a dual check-valve three-port fitting. The valves allow rapid filling and emptying of the delivery syringe without manipulation of the stopcock. The two valves prevent reflux into the reservoir bag during injection of carbon dioxide and prevent reflux of blood in the delivery syringe. Any size Luer-Lok syringe or mechanical injector syringe can be

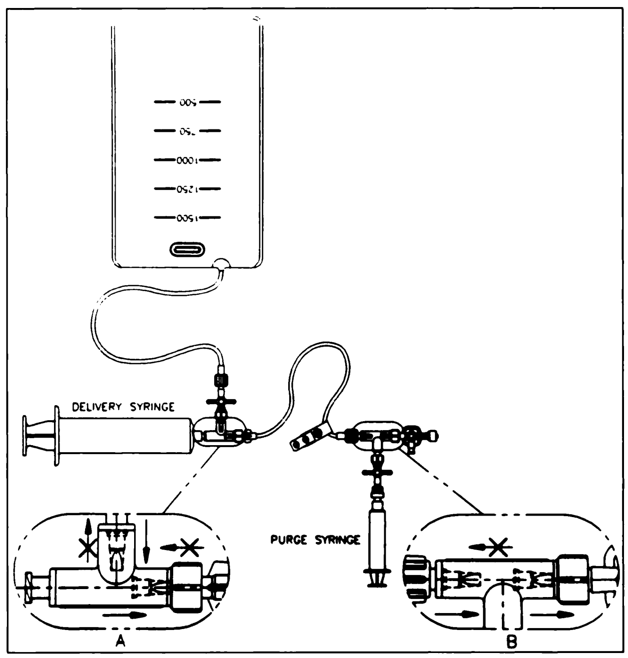

Fig. 1.—Plastic bag delivery system for delivery of carbon dioxide as contrast agent in angiography. A 1500-ml plastic bag is connected to three-port fitting with two one-way check valves. Any size Luer-Lok delivery syringe can be used. Three-port fitting is connected via 100-cm connecting tube to second fitting (two in-line check valves) with 3-ml purge syringe. Standard three-way stopcock is interposed between this fitting and angiographic catheter.

attached to the injection port. Connecting tubing 100 cm long is attached to the distal port of the check valve, which increases the distance from the X-ray beam and thus decreases the operator's

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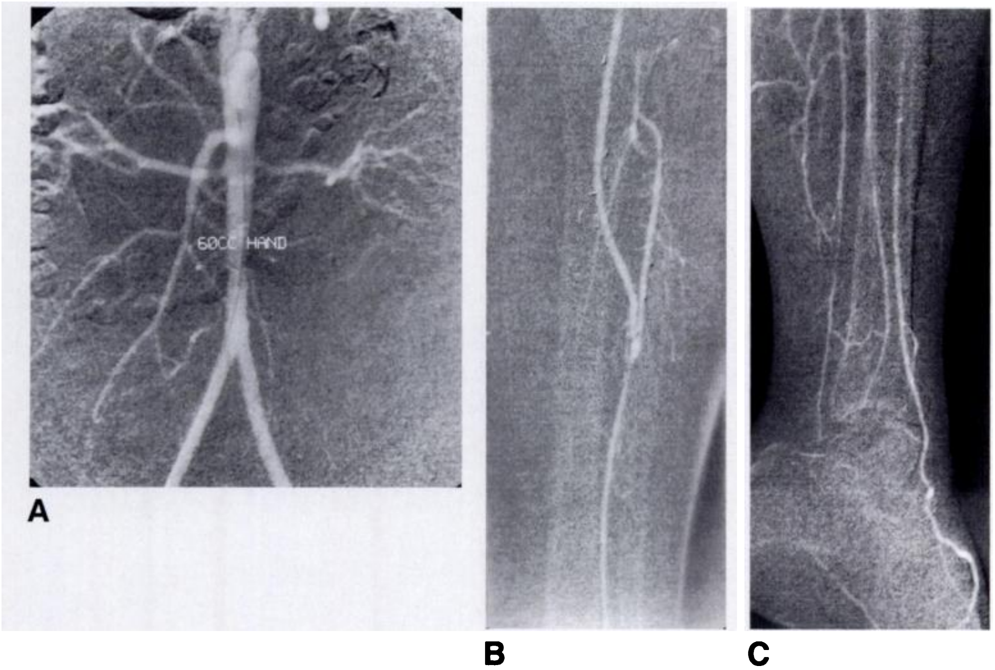

Fig. 2.—Digital subtraction angiographs obtained with carbon dioxide as a contrast agent.

***A,* Image of abdominal aorta obtained after injecting 60 ml of carbon dioxide.**

***B,* Image of patent femoral tibial bypass graft.**

***C,* Image obtained after intraarterial infusion of 150 mg of nitroglycerin followed by injection, by hand, of 45 ml carbon dioxide shows good filling of anterior tibial artery and collateral filling of peroneal and occluded posterior tibial artery.**

exposure to radiation. The connecting tubing is coupled to a second three-port fitting that has two in-line one-way check valves. A one-way stopcock is attached to the side arm of the second fitting to which a 3-ml syringe is connected. The syringe is used to clear the catheter of saline before the bolus of carbon dioxide is delivered. The two check valves also prevent reflux of blood into the catheter after the catheter is purged of carbon dioxide. A standard three-way stopcock is attached distally to allow aspiration of the catheter and flushing with saline.

After the reservoir bag is filled with carbon dioxide, the stopcock to the bag is opened, and both the delivery syringe and the 3-ml syringe are used to purge the air from the system. After the entire system is purged, the catheter is attached, the 3-ml syringe is filled, and the carbon dioxide is injected forcefully, clearing the catheter of saline. The delivery syringe is filled to whatever volume is desired, and the carbon dioxide is injected into the patient in a controlled, nonexplosive manner. If injections are made every 3 min, repurging the catheter is unnecessary, because the one-way valve prevents reflux.

Discussion

We have shown that the gas carbon dioxide is quite safe. It has no renal or hepatic toxic effects and is not allergenic. We do not know if it can be used safely in the cerebral circulation, and we do not use carbon dioxide in any situation in which the cerebral circulation might be exposed to the gas. The potential danger of using carbon dioxide is in its delivery, because the cylinder of gas contains 3300 l (3.3 million ml) of gas at high pressure. If there is a direct connection between the gas and any delivery system, if the regulator malfunctions, or if a valve is inadvertently opened, the patient can be exposed to tremendous volumes of carbon dioxide in a short time.

The idea of using a plastic bag originated from an experience in which a nearly fatal complication occurred during establishment of a transjugular intrahepatic portosystemic shunt: A 10-French catheter was connected directly to the cylinder of carbon dioxide, and an excessive amount of carbon dioxide was inadvertently injected into a hepatic vein.

Because carbon dioxide is absorbed readily and is eliminated by the lungs in a single pass, many doses of small volumes of the gas can be injected over a long period [3]. However, if large volumes are delivered rapidly, the right side of the heart can be flooded with carbon dioxide, resulting in a "vapor lock" and possibly death. Arterial injections can also cause a cardiac vapor lock; we have found that if large volumes of carbon dioxide are injected into the aorta in dogs, the large volumes of gas return to the inferior vena cava and the right side of the heart.

If the 1500-ml plastic bag is not completely filled (to a point before it becomes distended), it contains a maximum volume of only 1500 ml, because it is subjected only to 1 atm (1.01×10^5 Pa) of pressure. Because aspiration is required to fill the syringe, the syringe never contains more than the indicated volume. The plastic bag provides a truly closed system. However, in order to avoid inadvertent aspiration of room air, three-way stopcocks should not be used. The described system has no three-way stopcocks proximal to the check valves.

The second problem in using carbon dioxide as a contrast agent is explosive delivery of the gas. If a catheter is filled with fluid, considerable force is required to push the fluid through the catheter. During delivery, the carbon dioxide is initially markedly compressed against the resistance of the fluid–catheter interface, and when the fluid is finally expelled, the gas expands rapidly, resulting in an explosive delivery. If the fluid is removed from the catheter before the carbon dioxide is delivered, there is virtually no resistance, because of the low viscosity of the gas. Forceful purging of the system with a 3-ml syringe coupled with a one-way check valve completely clears the catheter of saline, permitting controlled delivery of carbon dioxide with the larger syringe. The multiple check valves enable the operator to rapidly fill the delivery syringe and inject the gas without manipulating multiple stopcocks.

This system has been used in more than 50 patients with excellent results (Fig. 2). However, use of this system can be more labor-intensive and somewhat less reliable than use of the computer-controlled injector. In our experience, the injection rates of the two systems are similar. For aortograms, a 60-ml Luer-Lok syringe should be used, and the gas should be injected within 0.5 sec. For pelvic studies, 20–40 ml should be injected over 1–2 sec. For studies of the extremities in which a catheter is inserted in the common femoral artery or in the contralateral common femoral artery, 20 ml injected over 2 sec is usually adequate. If filling is inadequate, a longer (3–4 sec) injection is recommended. Intraarterial infusion of 100 mg of nitroglycerin also improves filling in most instances.

The system described here uses two syringes and two check-valve systems. We recently found that using only one check valve is sufficient to prevent reflux of blood into the catheter and that only one syringe is required to purge the catheter and deliver the definitive bolus of carbon dioxide. With this variation, the single delivery-purge syringe is initially filled with 3–5 ml of carbon dioxide, and the gas is injected forcefully, completely clearing the catheter of saline. The same syringe is quickly refilled via the check valves, and the desired bolus of carbon dioxide is easily injected. If the operator chooses not to use the 3-ml syringe with the previously described system, this port can be used for a constant saline flush or injection of iodinated contrast material.

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