Discontinuation of the Plastic Bag Delivery System for Carbon Dioxide Angiography Will Increase Radiocontrast Nephropathy and Life-Threatening Complications

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Recently the plastic bag delivery system for carbon dioxide (CO_2) angiography [1] has been removed from the market by two vendors after a serious complication in which the bag was inadvertently filled with oxygen rather than CO_2. CO_2 has proven invaluable in patients with chronic renal insufficiency, renal failure, and diabetes and for many diagnostic vascular and interventional radiologic procedures [2, 3]. Over the past 40 years, we have used many types of CO_2 delivery systems, all fraught with the potential for serious complications associated with air contamination. Because a safe, reliable delivery system, such as the plastic bag system, is no longer available, many operators have, out of desperation, used techniques that are ineffective for CO_2 delivery and could even result in serious complications.

Our two institutions have used the plastic bag system for CO_2 angiography for more than 15 years in more than 10,000 patients, with an extremely low complication rate (only one case of transient bowel ischemia). If the bag system is used correctly, it can prevent air contamination and delivery of excessive volumes. Because the physics of gases are quite different from those of liquids, it is imperative that the operators understand these differences so they can assemble the bag system properly.

Several points are critical for safe delivery of the gas for CO_2 angiography: Only medical-grade CO_2 should be used, a CO_2 cylinder should never be connected directly to the patient, a completely closed system should be available, and CO_2 should not be delivered at high pressures to avoid explosive delivery. A full CO_2 cylinder contains 3,000,000 mL of CO_2 at the pressure of 820 pounds per square inch. More than 80% of the compressed gas in the cylinder is in a liquid form. Although medical-grade CO_2 is available from many vendors, previously used cylinders filled with pure CO_2 may have contaminants, such as rust, methane, and particulate matter. We recommend using a disposable aluminum or a stainless steel cylinder that has not been previously used and has been individually tested for purity. Some of the cylinders available for anesthesia may contain 80% oxygen and 20% CO_2. If CO_2 cylinders are purchased from other vendors, they should be tested for purity with a mass spectrometer (usually available in anesthesia departments) or using an inexpensive chemical reagent tube (Colorimetric Gas Detector Tube, Sensidyne).

If an excessive volume of CO_2 is injected into the venous side of the circulation, blood will be displaced from the right heart and pulmonary artery, resulting in a vapor lock phenomenon and possibly cardiac arrest. If excessive amounts are injected into the arterial system, there can be reflux into unwanted areas, such as the cerebral or coronary circulation, which might be lethal. Again, the cylinder should never be connected directly to the patient because even with the plastic bag system CO_2 could rapidly flow into the vascular circulation. If the syringe is filled directly from the cylinder, the pressurized CO_2 will expand in the vessel causing reflux into the adjacent vessel and discomfort to the patient. No system should include stopcocks, which could be inadvertently malpositioned, or additional 3-way stopcocks to fill the plastic bag system.

The 1500-mL bag contains more than enough volume for most diagnostic and interventional procedures. If the bag is filled only to atmospheric pressure (flaccid), the amount of CO_2 aspirated into the syringe is always accurate in volume. A closed airtight system is absolutely necessary because the partial pressure difference between the syringe CO_2 and room air will result in rapid diffusion of room air into the syringe if the stopcock is left open [4]. Any system with stopcocks should not be used because the stopcock could be left open

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to room air. On the venous side, we have seen bradycardia and ST-segment changes with as little as of 25 mL of room air injected.

Because CO_2 has not been approved for vascular indications by the U.S. Food and Drug Administration (FDA), physicians have been trained by published articles and hands-on training courses; however, with the plastic bag system, there have been very few complications. CO_2 has been used in millions of patients for laparoscopy, delivering several liters with extremely low complication rates [5]. CO_2 has also been injected into the hepatic artery as an ultrasonic contrast medium [6]. We have used CO_2 at the University of Florida for more than 40 years with extremely low complication rates. At both the University of Florida and the University of Michigan, we have found that CO_2 is a safe contrast agent in the arterial and venous circulation and is best performed using the plastic bag system. If iodinated contrast materials were used in these high-risk groups, many hundreds of cases of renal failure and deaths would be expected. We and other investigators have submitted an appeal for FDA approval for the use of CO_2 as an intravascular contrast agent for angiography. If approved, the plastic bag system could be preassembled and proper training instituted. We are also developing a low-cost sensor to be added to the bag system to abort the injection if there is air contamination.

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