Clinical Radiology (2005) **60**, 123–125

TECHNICAL REPORT

Carbon dioxide angiography: a simple and safe system of delivery

P. Cronin, J.V. Patel*, D.O. Kessel, I. Robertson, S.J. McPherson

Department of Radiology, The Leeds Teaching Hospitals NHS Trust, Leeds, UK

KEYWORDS
Carbon dioxide;
Angiography

Carbon dioxide (CO_2) is an established alternate angiographic contrast agent, which can be delivered by pump or hand injection. We describe a simple, safe and inexpensive hand injection system that delivers a known volume of CO_2 at atmospheric pressure and prevents contamination with room air.

Introduction

Carbon dioxide (CO_2) has been established as a safe alternative to conventional iodinated contrast media in patients with a history of contrast reaction or renal impairment. It may also be used in cases such as aortic stent grafting where a high contrast load would be anticipated. Like conventional contrast CO_2 gas can be delivered by pump or by hand injection. We describe a simple, safe and inexpensive system that allows syringes to be filled with a known volume of CO_2 at atmospheric pressure and prevents contamination with room air. The equipment used is readily available in every hospital.

Technique

A circuit is constructed from the following components (Fig. 1)

(1) Medical grade CO_2 cylinder and regulator assembly.
(2) Connecting tubing: bladder syringe to luer lock (Merrit Medical, Coatsbridge, UK; £2.00).
(3) Particle filter (0.2 mm syringe filter) (Pall Medical, Portsmouth, UK; £1.45).
(4) Two low-pressure connector tubes (Bexter, Lessing, UK; £0.30 each).
(5) Three-way tap (Becton Dickinson, Drogheda, Ireland; £0.30).
(6) A sliding two-way tap for each injection syringe (Kimmal, Uxbridge, UK; £4.20).
(7) Sixty millilitre luer lock syringes (Becton Dickinson, Drogheda, Ireland; £0.32 each).
(8) Bowl of saline to make an underwater seal and prevent accidental aspiration of room air.

Filling syringes with CO_2 (Fig. 2)

Syringes are filled in accordance with a strict protocol, this eliminates the risk of contamination with room air.

1. The CO_2 gas is turned on and the circuit is set so that it can be heard bubbling into the underwater seal. This purges air from the tubing.
2. The three-way tap is turned to direct gas into the syringe (Fig. 2(a)). The syringe fills due to the pressure of the CO_2 gas in the cylinder. **The syringe plunger is never manually pulled back**. Aspiration is the only way that room air could enter the system. Correct use of the underwater seal ensures that inadvertent aspiration will lead to the syringe filling with water not air.
3. The three-way tap is turned and the syringe is purged through the underwater seal. Gas continues to flow from the cylinder, the cylinder pressure prevents retrograde flow (Fig. 2(b)). This filling/purging cycle is repeated three times to ensure that only CO_2 remains in the system. CO_2 gas is denser than air, the syringe is tilted

* Correspondent: J. Patel, Department of Radiology, The Leeds Teaching Hospitals NHS Trust, Beckett Street, Leeds LS9 7TF, UK. Tel.: +44 113 206 4047; fax: +44 113 206 4691.
E-mail address: jai.patel@leedsth.nhs.uk (J.V. Patel).

0009-9260/$ - see front matter
doi:10.1016/j.crad.2004.05.005

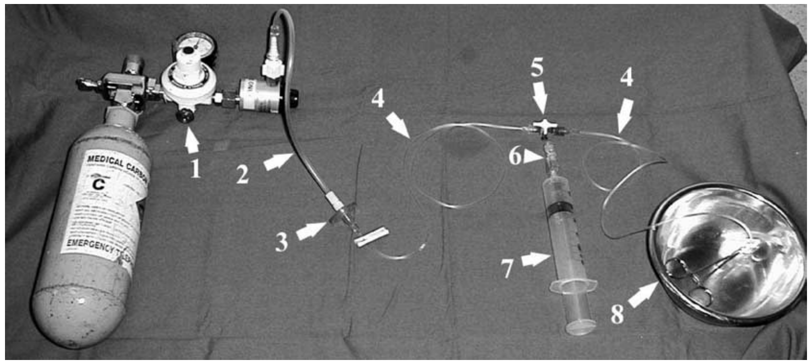

Figure 1 Simple circuit for carbon dioxide angiography (see main text for details of numbered components).

slightly upwards during the filling/purging cycle to allow the room air to rise to the tip and thus be preferentially expelled.

4. The syringe is filled to 50 ml and the sliding tap closed. The three-way tap is immediately set to allow CO_2 from the cylinder to bubble into the underwater seal. Failure to do this will pressurize the tubing and result in "audible disconnection" from the gas cylinder.
5. The syringe now contains CO_2 gas at greater than atmospheric pressure. As the pressure of the gas in the syringe is not known, according to Boyle's law neither is its volume at atmospheric pressure.

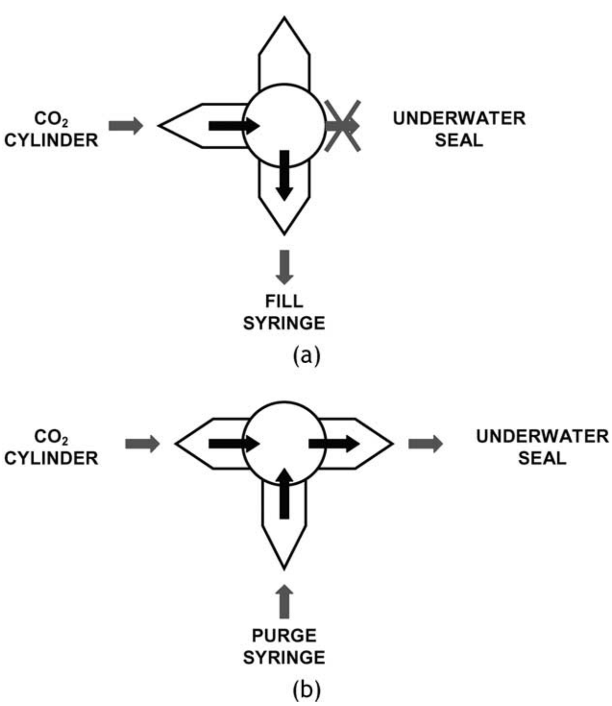

Figure 2 Sequence of three-way tap positions during (a) filling of syringe and (b) purging syringe (solid arrows indicate direction of CO_2 flow).

6. Keep the sliding tap closed until the gas is needed for angiography. Diffusion will replace the CO_2 gas in an open syringe with room air in about 30 min. **Discard any syringe that is partially filled, has the tap open or if you are uncertain whether it contains CO_2 or air**. Just before connecting the syringe to the catheter open the sliding tap. The pressure in the syringe will immediately fall to atmospheric pressure hence the volume of the CO_2 gas is now 50 ml. Connect the CO_2 syringe promptly to the end of the angiographic high-pressure connector and close the sliding tap. The gas is ready to inject.
7. Catheters and connecting tubes are flushed with saline as in conventional angiography. However, before performing angiography the catheter should be purged with CO_2 at atmospheric pressure. Connect the CO_2 syringe to the connecting tube, pressurize the CO_2 syringe and open the sliding tap. A fall in resistance is noted when the CO_2 has displaced the saline from the catheter. Close the sliding tap and the system is ready to perform an angiographic run.
8. Pressurize the CO_2 syringe again. When ready to inject open the sliding tap. Controlled compression of the syringe prevents explosive delivery of CO_2.

Discussion

Recent advances in angiographic equipment have markedly improved the quality of CO_2 digital subtraction angiography (DSA) images and have led to renewed interest in CO_2 angiography. Although CO_2 angiography takes a little more effort than conventional angiography, it becomes straightforward with familiarity. Medical grade CO_2 is contained in cylinders at high pressure and must not be connected directly to an angiography catheter. The delivery system must reduce this to near atmospheric pressure to allow safe controlled injection of a known volume of gas.

The principle concern of CO_2 angiography is that room air might be injected in error and lead to air embolism or thrombosis. Dedicated gas injectors[1] are available, but they are expensive to buy and have costly consumables. Gas injectors offer sophisticated functions such as programs to deliver different volumes of CO_2 at preset rates, allowing extremely controlled delivery. However, there is no evidence that these improve image quality. As CO_2 gas is highly compressible, even at atmospheric pressure, potentially explosive delivery of the gas can result with hand injection. To avoid this, we gently purge the catheter and connecting tubing with CO_2 to remove saline from them immediately before image acquisition. The CO_2 is then delivered in a more controlled fashion by injecting it over 1-2 s.

The low viscosity of the gas makes hand injection simple even through small catheters. Several "homemade" systems have been described for filling syringes with CO_2.[2-4] Snow and Rice[2] described a hand injection system comprising a Leveen inflator and a modified metal three-way tap. The need to modify the tap and sterilize it after each use makes this system undesirable. Caridi and Hawkins[3] and Hawkins et al.[4] described systems using multiple one-way check valves in which a 1500 ml plastic bag is filled with CO_2 at atmospheric pressure. The bag serves as a reservoir for filling syringes. Some operators have found this system complex and confusing to use, this has resulted in injection of room air or large volumes of CO_2 at high pressure. Despite modification[4] their system remains relatively complex. The reservoir may need to be refilled, syringes are still filled by aspiration and the catheter cannot be readily aspirated.

We report our initial experience performing CO_2 angiography and intervention in over 250 patients (Table 1). The system used to fill syringes is simple to learn and straightforward to use. The "circuit" is quick and easy to assemble from inexpensive equipment readily available in any angiography suite. There is a constant supply of carbon dioxide with no need to refill the system during a procedure.

It has been suggested that "homemade" CO_2 delivery systems are potentially dangerous.[5] In our experience extending to 5 years there have been no complications directly related to the use of our system. It is, however, essential to follow a few simple safety rules.

Table 1 Summary of cases performed

Case type	Number
Angiography: peripheral	62
Angiography: renal	35
Angiography: mesenteric	22
Angiography: hepatic	3
Angiography: arm	2
Angioplasty: renal	52
Stent insertion: renal	39
Endoleak	4
Stent-graft	41
TIPPS	7
Embolization	11

To avoid injection of large volumes of CO_2. Only use CO_2 at atmospheric pressure. Never connect the pressurized gas cylinder to the angiographic catheter. Always open the sliding tap on syringe immediately before connection to the catheter.

To avoid contamination with room air. Never aspirate the syringe whilst filling it with CO_2. Discard any syringe of uncertain provenance, i.e. if it is partially filled, has the tap open or if there is uncertainty whether it contains CO_2 or air.

In conclusion the system we describe has proved not only safe and effective but also simple to learn and inexpensive with consumables of about £10, €15.70 or $15. No alteration and/or re-sterilization of equipment is required. By adhering to simple safeguards complications of CO_2 angiography are readily avoided.

References

1. Bees NR, Beese RC, Belli AM, Buckenham TM. Carbon dioxide angiography of the lower limbs: initial experience with an automated carbon dioxide injector. *Clin Radiol* 1999;**54**:833—8.
2. Snow TM, Rice HA. A simple gas injector for carbon dioxide angiography. *Clin Radiol* 1999;**54**:842—4.
3. Caridi JG, Hawkins IF. CO_2 digital subtraction angiography: potential complications and their prevention. *J Vasc Interv Radiol* 1997;**8**:383—91.
4. Hawkins IF, Caridi JG, Klioze SD, Mladinich CRJ. Modified plastic bag system with o-ring fitting connection for carbon dioxide angiography. *AJR Am J Roentgenol* 2001;**176**:229—32.
5. Nicholson T, Downes M. Contrast nephrotoxicity and iso-osmolar contrast agents: implications of NEPHRIC. *Clin Radiol* 2003;**58**:659—60.