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Technical Note

A Simple Gas Injector for Carbon Dioxide Angiography

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In 1971, Hawkins accidentally injected 70 ml of room air into the coeliac axis, and was surprised to see a reasonable negative contrast arteriogram, and no adverse effect on the patient [1]. At that time injection of carbon dioxide into the right atrium (for the detection of pericardial effusion) was known to be safe, and Hawkins then tried using carbon dioxide for arteriography. Image quality was poor, and the technique was abandoned until the advent of digital subtraction angiography nearly 10 years later. In 1982 he reported the use of carbon dioxide with digital subtraction in 20 patients [1], and since then the use of carbon dioxide in angiography has become widespread.

Carbon dioxide has many advantages as an intravascular contrast medium [2]. It is very safe if used correctly, has no risk of allergy, and no nephrotoxicity in normal doses [2]. When used with modern digital subtraction equipment, the contrast provided by intravascular gas can be enhanced into high quality angiograms. Carbon dioxide is also cheap, large volumes can be used (in divided doses with time for excretion by respiration), and its very low viscosity means that 3 French catheter systems can be used for delivery. Low viscosity also allows for passage across tight stenoses, and through capillary beds- good portal venograms can be produced by hepatic vein injections during the formation of intrahepatic portosystemic shunts [3].

Despite all these advantages, most angiographers find it much easier to obtain good images using iodinated contrast medium, and reserve the use of CO_2 for patients who are known to be allergic to iodine, or have poor renal function. Good imaging with CO_2 is often a technical challenge, and most problems arise in the delivery of gas to the vessels to be imaged. If hand injection is used, the CO_2 tends to compress within the syringe and be delivered unevenly and relatively slowly [2]. A specially designed gas injector system is available (Angiodynamics, Glens Falls, New York), and produces excellent results, but is very expensive. Most angiographers use CO_2 only a few times a year, and cannot justify the purchase of a dedicated injector.

The principles of CO_2 distribution in the vasculature are described in the reviews by Kerns *et al.* [4], and by Back *et al.* [2]. The gas produces the best angiograms when given in an adequate volume, and at a high flow rate. This is because it is required to displace blood from the vessel, rather than mixing with it, and the more complete the displacement the better the representation of the vessel lumen. Large vessels are often difficult to image because the buoyancy of the gas means it quickly forms a layer against the non-dependent wall, with blood occupying the rest of the lumen. These problems are overcome by a high injection rate, but this is difficult to achieve without a dedicated injector.

TECHNIQUE

We have devised a simple way of using standard angiographic items to deliver CO_2 in a safe, predictable way, giving a known volume at a high flow rate. The gas volume is measured out from the cylinder at ambient pressure, and then repressurised into a smaller volume using a Leveen inflator (Medi-tech (Boston Scientific Corporation), Natick, MA). The arrangement of taps and tubing is shown in Fig. 1, and diagrammatically in Fig. 2. A micron filter (Medi-Redi, Fortitude Valley, Queensland) ensures gas purity from the cylinder. After purging the system with CO_2, the end of the last tap [4] is filled with saline to exclude all room air. Tap 2 is an exhaust, to allow pressure in the 30 ml syringe to equilibrate with the atmosphere if too much gas is admitted from the cylinder. The system is then connected to the intravascular catheter. We usually compress 90 ml of CO_2 (three syringe measures of 30 ml each) at ambient pressure into a 20 ml volume in the Leveen inflator, at a pressure of approximately 2 atmospheres. Some of this 90 ml volume is lost, compressed in the dead space and passed back into the 30 ml syringe, but three 'pumps' of the system gives a volume of approximately 86 ml for injection. We use the larger 20 ml Leveen inflator, with an attached pressure gauge, with the plunger of the inflator pulled out to its maximum position. Once filling is complete the inflator is isolated from the syringe and

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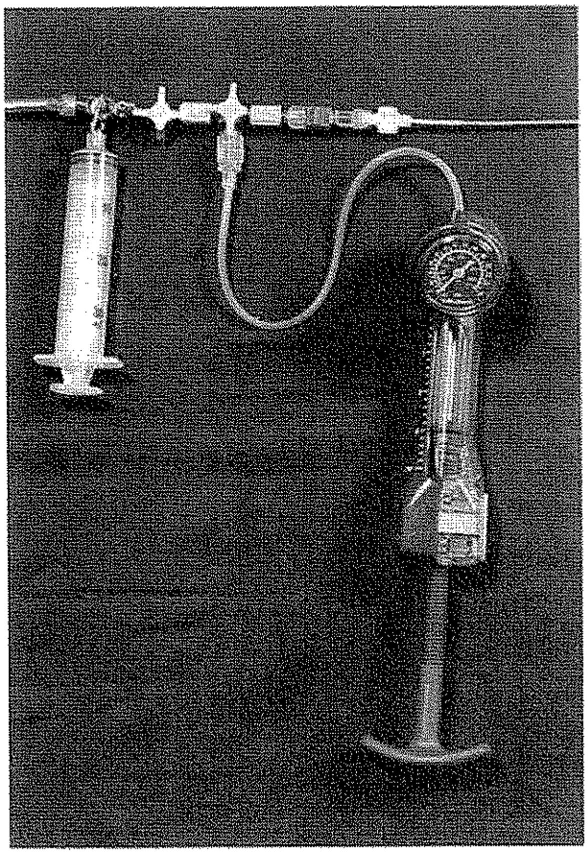

Fig. 1 – Taps and syringes as represented diagrammatically in Fig. 2.

the screw mechanism is used to compress the gas to 4 atm (well within the device's maximum rating of 28 atm) – this is in approximately 14 ml volume indicated on the syringe barrel. Gas is delivered for imaging by opening tap 4 (FloSwitch HP, Medi-tech) when the DSA masks have been acquired.

SAFETY ASPECTS

Gas can be delivered more quickly by increasing in the pressure in the Leveen inflator, but we are reluctant to go higher than 4 atm, for fear of damaging the arterial wall: 4 atm is the maximum pressure that can be generated by hand in a 50 ml syringe, and this is the usual way of performing CO_2 angiography without a dedicated injector. To our knowledge arterial damage has not occurred with hand injection of CO_2.

We do not perform CO_2 angiography above the diaphragm, because of the theoretical risk of neurological damage [2].

The system is almost closed, so there is minimal risk of room air being injected. This is a very important consideration, and we flood the apparatus with CO_2 at all stages of assembly. Once set up and connected to the intravascular catheter, the exhaust port (tap 2) is kept closed to the atmosphere, except if the 30 ml syringe is overfilled (the plunger comes up against the internal bevel of the syringe). It is known that air contamination of CO_2 in an open syringe occurs at an appreciable rate [2], the CO_2 in a 20 ml syringe being replaced with room air by diffusion in about 14 min. We therefore keep the system closed to the atmosphere whenever possible.

CO_2 from cylinders is frequently contaminated with rust, water, and oil (A.Ward, Cook Australia, personal communication, and ref. 2) – we therefore use a micron filter to ensure the purity of injected gas.

The CO_2 cylinder valve is used to pass gas in a controlled way into the 30 ml syringe, the plunger being free to move against atmospheric pressure. The gas is therefore measured out at very close to ambient pressure, and the volume of gas is thus known without relying on the accuracy of the pressure gauge.

The internal configuration of tap 1 makes it impossible for CO_2 to be delivered directly from the CO_2 cylinder to the patient. This is important because the gas in the cylinder is at very high pressure (approximately 360 000 mm Hg), and would expand to an enormous volume (800 l) if allowed to equilibrate with the arterial tree.

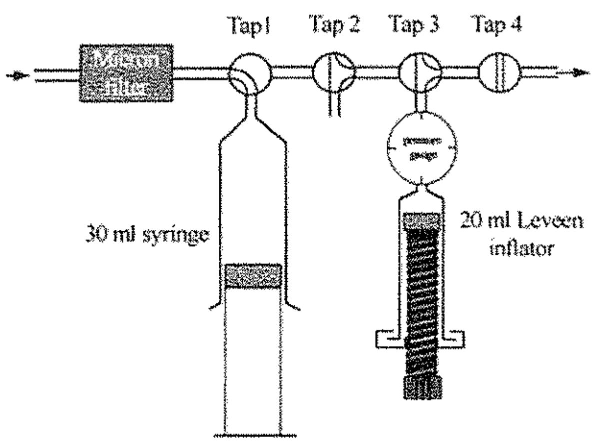

Fig. 2 – Diagram of set up. Taps are set for filling from the CO_2 cylinder.

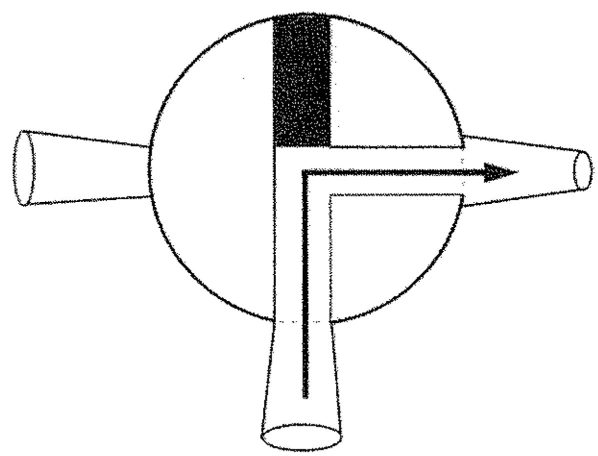

Fig. 3 – Internal configuration of tap 1. The third exit has been blocked off using a metal pin (black bar).

DISCUSSION

We have found this technique gives excellent imaging, with a rapid bolus of gas delivered. Most of our CO_2 angiography is performed to demonstrate aorta and renal arteries (84 ml produces an adequate aortogram). Selective injections, for example into the renal arteries, can also be performed using smaller volumes (30 ml compressed to 4 atm). The system is easy to set up and use; although the sequence of tap turns initially seems complicated, the sequence is repetitive and easily mastered.

All the components are readily available in our angiography suite, except for tap 1 which was modified from a metal three way tap by blocking one internal channel (Fig. 3), and this tap is resterilised and reused. The most costly item, the Leveen inflator, costs only about $80 in Australia.

This technique may be of use to other radiologists and surgeons who wish to improve their experience of CO_2 angiography.

REFERENCES

1 Hawkins IF. Carbon dioxide digital subtraction arteriography. *American Journal of Roentgenology* 1982;139:19–24.
2 Back MR, Caridi JG, Hawkins IF, Seeger JM. Angiography with carbon dioxide. *Surj Clin North Am* 1998;78:575–91.
3 Hawkins IF, Johnson AW, Caridi JG *et al.* CO_2 fine needle TIPS. *Journal of Vascular Interventional Radiology* 1997;8:235.
4 Kerns SR, Hawkins IF, Sabatelli FW. Current status of carbon dioxide angiography. *Radiol Clin North Am* 1995;33:15–28.