Sparing the nephron: CO_2 angiography and intervention

Key words: digital subtraction angiography; carbon dioxide; arteries, transluminal angioplasty; stents and prostheses; arteries, therapeutic embolisation

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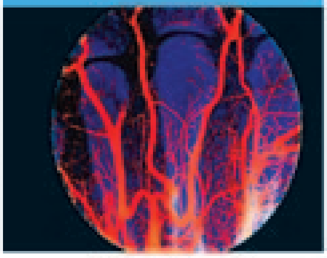

Dr Patel was appointed as Consultant Vascular Radiologist to The Leeds Teaching Hospitals NHS Trust in 1999. In conjunction with other colleagues within the vascular radiology department, Dr Patel supports the provision of a full range of vascular interventional procedures. He has a particular interest in vascular intervention for patients with liver disease and liver transplantation.

Abstract

With improvements in digital data acquisition and manipulation equipment, CO_2 has become a cheap, safe and effective alternative contrast agent in patients with contraindications to conventional iodinated contrast media. Carbon dioxide angiography may also demonstrate the site of gastrointestinal bleeding and endoleaks that are occult on conventional angiography. Unfortunately, CO_2 is not a panacea: image quality is not as reliable as with conventional contrast and it is contraindicated in the supra-diaphragmatic vessels. Intra-arterial CO_2 injection can cause intolerable pain in about 5% of patients.

Introduction

Carbon dioxide (CO_2) is an established alternative contrast agent in patients with significant renal impairment or other contraindications to iodinated contrast media. Carbon dioxide gas is highly soluble in blood. There is no limit to the total volume of CO_2 that can be injected, but volume is usually restricted to 200 mL/min to allow clearance through the lungs. Carbon dioxide reduces cerebral blood flow, causing anaesthesia and convulsions, so its intra-arterial use is restricted to sub-diaphragmatic injection.[1] The most frequent indication for using CO_2 is renal impairment. Patients should be pre-hydrated in case conventional contrast is required. Some conventional contrast is required in addition to CO_2 in about 20% of cases, particularly to visualise calf circulation in patients with critical limb ischaemia; magnetic resonance angiography should be considered in these patients.

Carbon dioxide angiography – can anyone do it?

Image quality with CO_2 angiography is variable, and early digital subtraction angiography images were inferior to those obtained with conventional contrast. Today, excellent results can be obtained on most contemporary angiographic equipment with appropriate software. Expensive pump injectors are unnecessary as the low viscosity of CO_2 gas makes hand injection simple.[2]

There are, however, several well-recognised pitfalls in the performance and interpretation of CO_2 angiography:[2–4]

Bolus fragmentation occurs as the gas passes through arterial bifurcations. Completely opacified arterial segments can be obtained by summating several images. In mainstream vessels, hand injecting the gas in one smooth, rapid bolus optimally displaces adjacent blood and reduces the effects of gas fragmentation.

Pseudostenosis results from a combination of gas fragmentation and dependency, and can be very convincing on a single image. Stenoses should be confirmed by paging through the run frame by frame; changes in the morphology of the stenosis should alert suspicion.

Failure to visualise dependent vessels results from the buoyancy of CO_2. Posterior branch vessels may not be opacified if blood within the target vessel is not completely displaced. Placing the catheter tip at the target level and increasing the volume of injected CO_2 are potential solutions.

Meticulous technique during image acquisition and processing is, therefore, invaluable in producing images that are comparable to conventional angiographic studies.

Sparing the nephron:
CO_2 angiography and intervention *continued*

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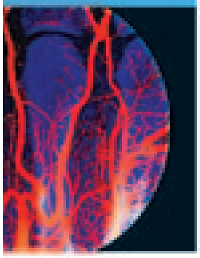

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All patients experience some sensation during intra-arterial CO_2 injection; pain may be intolerable in around 5%.[2] Complications of CO_2 angiography resulting from trapping of gas in the abdominal aorta and pulmonary artery have been reported,[5,6] but we have had no adverse events related to the injection of CO_2 gas over five years in several hundred patients.

CO_2-guided vascular intervention

There are few reports of CO_2-guided intervention.[3–4,7–10] We have found that many procedures can be successfully performed using only CO_2 angiography.[2,3,9]

Renal artery angioplasty and stenting are obvious indications for the use of CO_2, as even small volumes of non-ionic contrast can cause a significant deterioration in renal function in patients with chronic renal impairment.

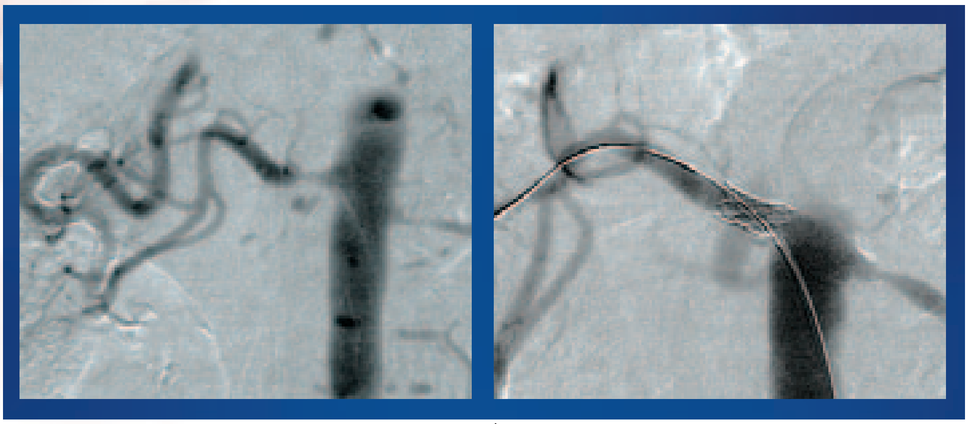
Technical improvements have increased our ability to perform these procedures without conventional contrast. In 1999, both Kan *et al*. and Caridi *et al*. described CO_2-guided renal artery angioplasty; additional contrast was required in 9 of 11 angioplasties (82%) and in 6 out of 29 patients (29%), respectively.[7,8] Caridi *et al*. also found decubitus views were frequently necessary. In our experience, the majority of renal interventions can be performed with CO_2 alone (Figure 1).[9]

Endovascular stent grafting using CO_2 guidance has been reported.[10] We have found stent grafting surprisingly easy to perform with CO_2 alone: the mean volume of conventional iodinated contrast used has fallen from about 200 mL to 15 mL (range 0–120 mL) in our department since we started using CO_2 as our preferred contrast for all patients undergoing aortic stent grafting.[3,4]

We have found that endoleaks are often more easily demonstrated than with conventional angiography.[11] Similarly, CO_2 can readily demonstrate the source of gastrointestinal bleeding; this probably relates to the compressed gas expanding and rapidly passing through are tiny defects (Figure 2).

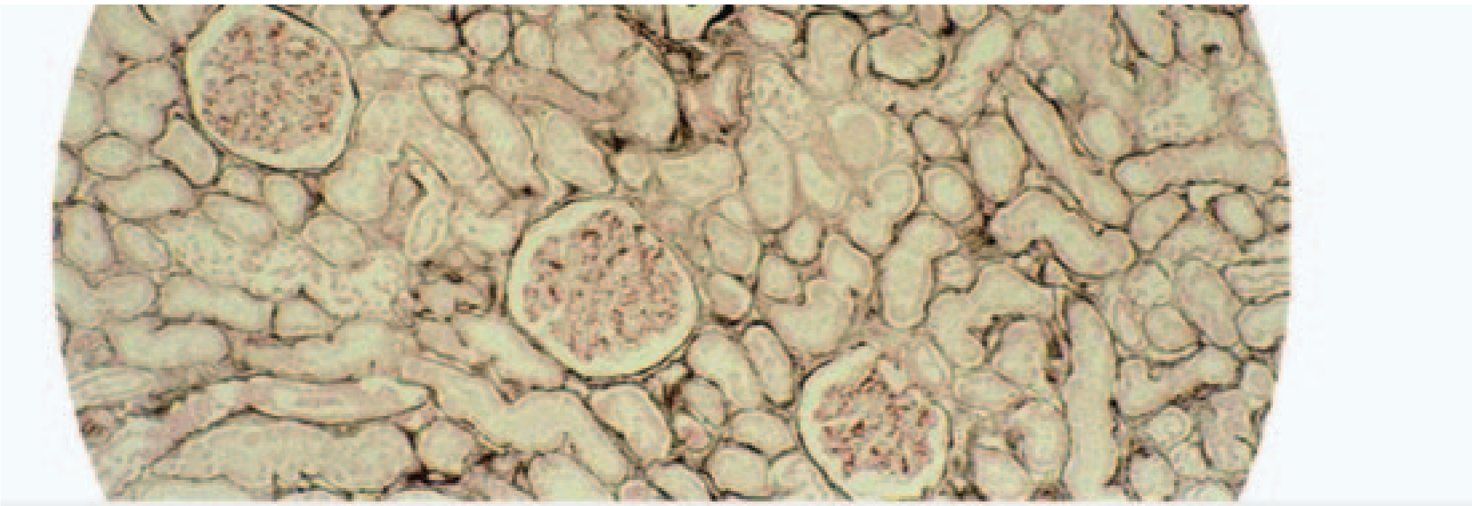
Carbon dioxide also simplifies transjugular intrahepatic portosystemic shunt (TIPS) procedures as it readily passes through the hepatic sinusoids into the portal vein, thus obviating the need for other imaging to guide portal vein puncture.[12,13]

Figure 1



a b

Renal artery stenting. (a) CO_2 angiogram demonstrating a significant renal artery stenosis in a single functioning right kidney. (b) Completion CO_2 angiogram following stent insertion confirming satisfactory stent placement.



Conclusions

Carbon dioxide angiography is simple to perform and does not require special equipment, though image quality is dependent on good techniques in image acquisition and processing. Carbon dioxide gas can be used for diagnostic angiography and complex endovascular intervention in the infra-diaphragmatic arteries. Conventional contrast will still be required in those patients who do not tolerate CO_2 and in whom image quality is unsatisfactory.

What we knew before and what this tells us

- Conventional iodinated contrast agents can cause acute renal dysfunction in patients with pre-existing renal impairment
- Modern digital equipment has increased the utility of CO_2 as a contrast agent
- The use of CO_2 in at-risk patients can eliminate the need for conventional iodinated contrast or greatly reduce the amount required for angiography and vascular intervention
- Intra-arterial CO_2 injection can cause abdominal and leg pain and is not tolerated in about 5% of patients

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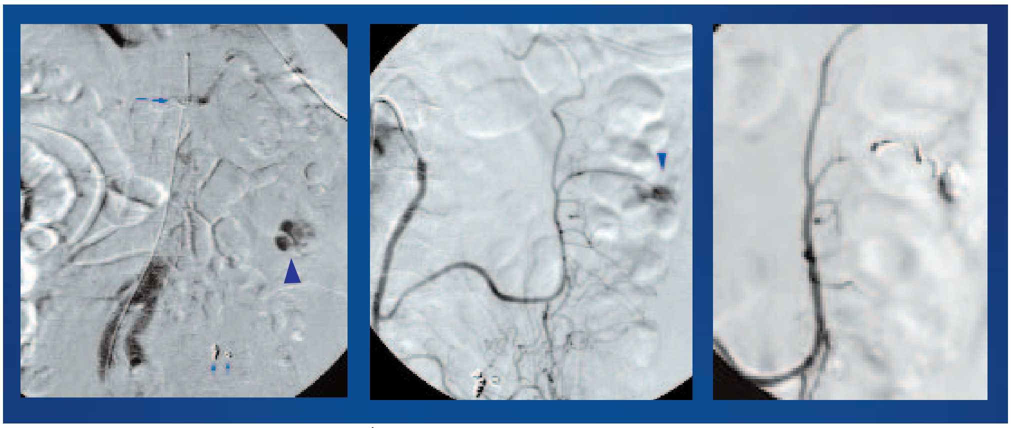
Figure 2



a b c

Localising the source of gastrointestinal bleeding. (a) CO_2 angiogram with a catheter in the coeliac axis (long arrow) instantly localises the site of bleeding, as a prominent 'CO_2 blush', in the mid descending colon (arrowhead). Note coils from a previous embolisation procedure (short arrows). (b) Selective inferior mesenteric angiogram with conventional contrast confirms bleeding into a diverticulum (arrowhead). (c) Thrombosis of the bleeding vessel confirmed following selective microcoil embolisation.