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SHORT COMMUNICATION

The use of carbon dioxide angiography for renal sympathetic denervation: a technical report

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Objective: Hypertension is the leading attributable cause of cardiovascular mortality worldwide. Patients with hypertension have multiple comorbidities including high rates of concomitant renal disease. Current pharmacological approaches are inadequate in the treatment of resistant hypertension. Renal sympathetic denervation (RDN) has been shown to effectively treat resistant hypertension. The traditional use of iodinated contrast in RDN is contraindicated in patients with significant renal insufficiency. In patients with renal impairment, carbon dioxide (CO_2) can be used as an alternative contrast material for RDN. This article describes the technical aspects of RDN using CO_2 angiography.
Methods: Our centre is experienced in the innovative RDN procedure using CO_2 angiography. We describe the protocol for CO_2 angiography for RDN using a home-made CO_2 delivery system and the Symplicity™ (Minneapolis MN 55432 USA) catheter (Medtronic) device.
Results: CO_2 angiography is an excellent alternative to iodinated contrast for RDN procedures.
Conclusion: CO_2 angiography for RDN is a safe and effective alternative to iodinated contrast. RDN using CO_2 angiography is an easy and feasible procedure that can be used in patients with renal insufficiency or iodinated contrast allergies.
Advances in knowledge: There is a paucity of descriptive reports for CO_2 angiography for RDN and we provide details of the optimal protocol for the procedure. In particular, we describe the use of a Symplicity Spyral™ catheter (Medtronic), which has not been reported to date for use in this procedure.

INTRODUCTION

Hypertension poses a huge burden of disease and is estimated to affect 30–40% of the population in the developed world.[1] Patients with hypertension have multiple comorbidities including concomitant renal disease. Current pharmacological antihypertensive treatments are ineffective in patients with resistant hypertension. Resistant hypertension is defined as a blood pressure of ≥140/90 mmHg whilst on at least three maximum-dose antihypertensives, including a diuretic.

Renal sympathetic denervation (RDN) has been studied in international, multicentre randomized control trials as a potential treatment for patients with resistant hypertension.[2,3] RDN involves catheter-based denervation using radiofrequency ablation under fluoroscopic guidance. Patients with renal insufficiency are at risk of complications from conventional iodinated contrast materials and consequently their treatment options may be limited.

Carbon dioxide (CO_2) angiography provides a safe and effective alternative to iodinated contrast in patients with CKD or iodinated contrast agent allergy.[4,5] Owing to its low atomic number, CO_2 acts by displacing blood to provide a negative contrast image with digital subtraction angiography. The use of CO_2 as a contrast agent has potential serious complications such as neurotoxicity and arrhythmias and its use is therefore contraindicated above the diaphragm, in patients with an arteriovenous malformation, fistula or atrial septal defects. Reports of home-made delivery system CO_2 angiography in patients with Chronic kidney disease (CKD), from the study by Kawasaki et al,[6] show 100% technical success with only transient and minor complications, predominantly limb or abdominal pain. Complications related to CO_2 angiography are reduced by appropriate injection techniques.

We have a large centre in the UK with an established experience with the use of CO_2 angiography in renal artery intervention. The centre has extensive use of CO_2

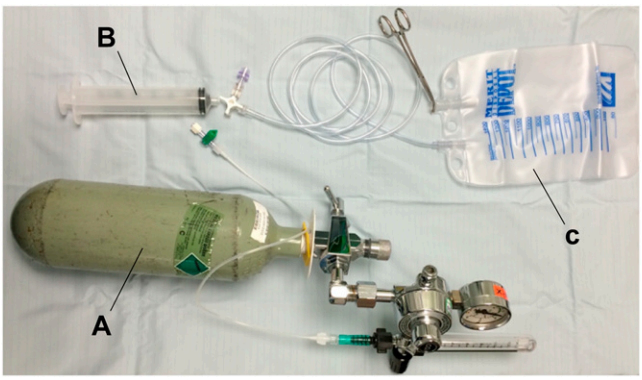
angiography for peripheral angiography and endovascular aneurysm repair over a 5-year period. Over a 12-month period, 11 patients aged 49–66 years with resistant hypertension have undergone renal artery denervation using CO_2 angiography performed by 2 consultant interventional radiologists. All of these procedures were technically successful and long-term therapeutic effects are currently being investigated. This article describes the technical aspects of performing RDN using CO_2 angiography and in particular the use of a second-generation multielectrode Symplicity Spyral™ catheter (Medtronic) for CO_2 angiography in RDN.

IMAGING TECHNIQUE: CARBON DIOXIDE ANGIOGRAPHY AND RENAL SYMPATHETIC DENERVATION

CO_2 requires specialist equipment to eliminate air contamination and excess compression whilst ensuring safe delivery. We use a home-made CO_2 delivery system (Figure 1), similar to Kawasaki et al.[6] Our sealed system consists of a gas cylinder, a 3-way stopcock, a CO_2 bag and a 20-ml luer lock. The source of CO_2 must be confirmed as a closed system circuit, free from air contamination. We fill the closed system with CO_2 and purge the gas four times to minimize contamination. When the CO_2 bag is sufficiently filled, we ensure we disconnect the CO_2 cylinder to control volume injection and avoid excess delivery. We then discard approximately 50 ml from the system to reduce air contamination from the connective tubing. Prior to direct injection of CO_2 contrast agent, we connect the syringe, CO_2 bag and sheath *via* a 3-way stopcock. Our RDN technique is based on that described in the Symplicity hypertension (HTN)-2 trial and previous publications.[2,4,7]

Each patient consented for the procedure and potential complications including abdominal pain, bleeding from puncture site, pseudoaneurysm, renal artery dissection, renal artery thrombosis and failure of procedure. The following procedures were conducted in accordance with the ethical standards of the responsible committee. Patient monitoring including oxygen saturation, electrocardiogram and blood pressure is necessary to identify acute deteriorations. Sedation and i.v. narcotics are routinely used.

Figure 1. A home-made carbon dioxide delivery system: (A) a pressurized CO_2 cylinder with filter, (B) a 50-ml syringe, attached to a one-way valve, and (C) a Merit disposal depot reservoir bag with removable scissor seal.

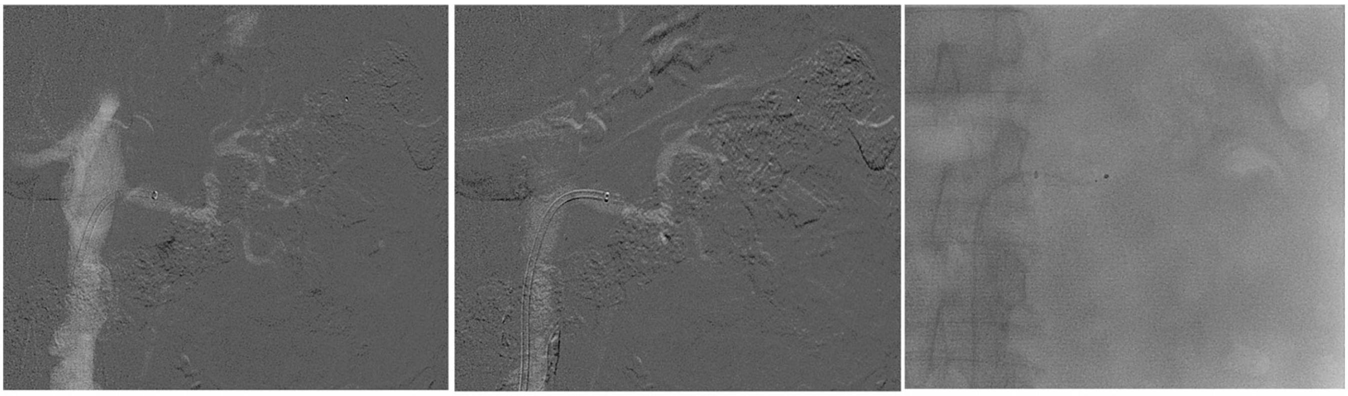


Initially, midazolam 5 mg i.v. and fentanyl 50 mcg i.v. are administered and subsequently titrated to requirement. Local anaesthetic, 1% lignocaine 10 ml, is injected into the right groin.

The patient is positioned to elevate the target site, ideally by 45°, to utilize gaseous reflux to reduce incomplete vasculature filling. The common femoral artery (CFA) is punctured using ultrasound guidance and a 6-Fr guide sheath introduced using a standard Seldinger technique. After the initial puncture, a 5-Fr pigtail catheter over a standard J-wire is introduced. Using the first lumbar vertebra as the central anatomical landmark, a digital subtraction aortogram is taken using CO_2 as the contrast agent. To reduce air contamination, a small volume, approximately 5 ml, is initially expelled when the sheath is attached to the closed CO_2 circuit. CO_2 is slowly injected by hand *via* the delivery syringe. The rate of CO_2 injection should be faster than the rate of blood flow to facilitate complete filling; we aim for an injection rate of 10–20 $ml\,s^{-1}$. To allow for full elimination, injections of CO_2 contrast are separated by 2–3 min. Theoretically, owing to rapid first-pass elimination in the lungs, there is no limit to the volume of CO_2 used. However, 100 ml is reported as the maximum recommended amount.[8] High-rate frames and image stacking improve the quality of the digital subtraction angiography as they reduce the effects of gas diffusion. The renal artery is accessed using a 5-Fr Cobra catheter™ (Boston Scientific, Malborough MA 01752). We perform a selective angiogram using CO_2 to demarcate the renal artery, ostia, bifurcation and accessory arteries.

To manage coagulation, we administer 100 iU/kg of heparin. To prevent vasospasm, we administer an intra-arterial vasodilator, Isoket 100 mcg i.v., *via* the guide catheter. The Symplicity Flex™ catheter (Medtronic) is inserted at an initial position of 5 mm proximal to bifurcation of the renal artery at a posteroinferior angle. We have also used the new multielectrode 4-Fr Symplicity Spyral catheter (Medtronic) that allows for simultaneous ablations, thus reducing ablation time as only one burn cycle is required. The vessel resistance is checked to ensure it is $>300\,\Omega$. Additional analgesia, fentanyl 50 mcg i.v., is administered at this stage to pre-empt pain related to radiofrequency ablation delivery. The foot pedal is used for a 2-min burn cycle when radiofrequency ablation occurs *via* the Symplicity Flex catheter (Medtronic) tip electrode. The second burn is completed 5 mm proximal with a rotation of 45°. Repeating this burn cycle will treat the full circumference of the artery, effectively targeting the sympathetic nerve fibres. This helical burn cycle technique is continued up to 5 mm from the renal ostium at the superior surface of the renal artery. The above process is simplified when using the Symplicity Spyral catheter (Medtronic), as the helical shape simultaneously provides four-quadrant burns in a 1-min burn cycle. The Symplicity™ catheter (Medtronic) is removed and cleaned; the guide catheter is aspirated and discarded. A repeat selective right renal arteriogram is taken to ensure patency post-ablation. A selective left renal arteriogram is performed and the process is repeated for the left-hand side. Figure 2 demonstrates images obtained from the above protocol. We routinely and safely complete simultaneous bilateral RDN. Following successful completion of the procedure, a 6-Fr Angioseal™ St Jude Medical Minnetonka MN 55345-2126 USA vascular closure device is deployed.

Figure 2. (a) Baseline selective left renal artery carbon dioxide (CO_2) angiogram to assess dimensions of the main renal artery segment prior to renal sympathetic denervation (RDN); (b) post-RDN selective renal artery CO_2 angiogram; (c) a Simplicity™ (Medtronic) device within the left renal artery during RDN procedure.



(a) (b) (c)

CONCLUSION

CO_2 angiography in RDN is a relatively straightforward and feasible procedure, which could facilitate treatment of resistant hypertension in patients with renal insufficiency or iodinated contrast allergy. In our experience, images from CO_2 angiography are of adequate quality to facilitate accurate RDN. We have found that the procedure is more efficient with the use of the multielectrode Symplicity Spyral system (Medtronic) and predict further technological advancements integrating CO_2 angiography equipment will enhance the procedure significantly. We are conducting a clinical trial to investigate the clinical efficacy and safety of CO_2 angiography for RDN in patients with moderate to severe renal impairment.

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