MEDICAL IMAGING—TECHNICAL ARTICLE

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Carbon dioxide CT angiography during endovascular treatment of bilateral common iliac disease with angio-CT utilisation

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Summary

This paper presents the application of carbon dioxide for CT imaging during an endovascular procedure to help characterise unexpected bilateral common iliac artery stenosis utilising an angio-CT system, confirming its application in interventional radiology while maintaining sterility. A 78 year old male was referred to the Radiology Interventional Suite with left lower limb rest pain. On imaging via digital subtraction angiography and CT utilising both iodinated contrast and carbon-dioxide (CO_2), endovascular treatment of bilateral CIA stenosis was performed with good clinical result. The case presented demonstrates the advanced imaging techniques possible in suites that have ready access to angiography and conventional CT. CO_2 CT angiography is optimally performed on combined Angio-CT systems where CT and angiography system are integrated into a single room.

Key words: angiography; carbon dioxide; computed tomography; digital subtraction angiography; interventional radiology.

Introduction

The use of carbon dioxide (CO_2) is well referenced in the literature and has long been an established alternative to iodinated contrast media.[1–4] It has been utilised in situations of allergy to iodinated contrast or compromised renal function.[2–4]

Described is a novel technique of using CO_2 instead of iodinated contrast for the performance of CT angiography (CTA) during a digital subtraction angiographic (DSA) procedure to treat bilateral common iliac artery (CIA) disease due to the poor renal function of the patient. The use of CO_2 CTA allowed for the improved characterisation of the common iliac artery stenoses which were obscured during conventional DSA and CO_2 DSA acquisition by copious amounts of bowel gas within the pelvis.

Case study

A 78 year old male was referred with left lower limb rest pain (Rutherford 3) and a sonographic finding of left external iliac artery (EIA) stenosis for vascular intervention (Fig. 1). The patient's past medical history included IHD, T2DM, hypercholesterolemia, hypertension and impaired renal function (eGFR 39).

Both femoral pulses were present and an on table ultrasound for puncture revealed CFA stenosis. Micropuncture access was obtained above the CFA stenosis to characterise initially after an initial retrograde left common femoral access, angiography was performed of the left lower limb arterial system. The initial angiograms demonstrated no EIA stenosis however, it was noted that there was extensive calcification and stenosis of the common femoral artery (CFA) which extended into the proximal superficial femoral artery (SFA). Mild distal crural disease was also evident (Fig. 1).

Difficulty was encountered advancing a catheter beyond the left common iliac artery, with a stenosis suspected. A 5 french pigtail Catheter (Cordis Medical, Tipperary, Ireland) was advanced to the distal aorta. Both CO_2 and iodinated contrast media angiography was performed with sub-optimal results obtained due to obscuration by overlying artefact (Fig. 2).

On review of conventional DSA images, a decision was made to attempt to characterise the lesions better by utilising the Miyabi Angio-CT System (Siemens Medical Systems, Erlangen, Germany), and obtain a CTA of the aorta and common iliac arteries.

Due to the patient's compromised renal function and the contrast volume already used during the course of the procedure (total of 120 mL of Omnipaque 350 mg I/mL), CO_2 contrast was utilised for the CTA.

After a Topogram was acquired. A helical acquisition was planned to cover from the distal aorta to CFA. Due to the transient presence and maximum volume of CO_2, a high ratio pitch of 1.5 and a rotation time of 0.5sec was used in order to reduce the scan time to a minimum. Total scan time of 6.85 seconds.

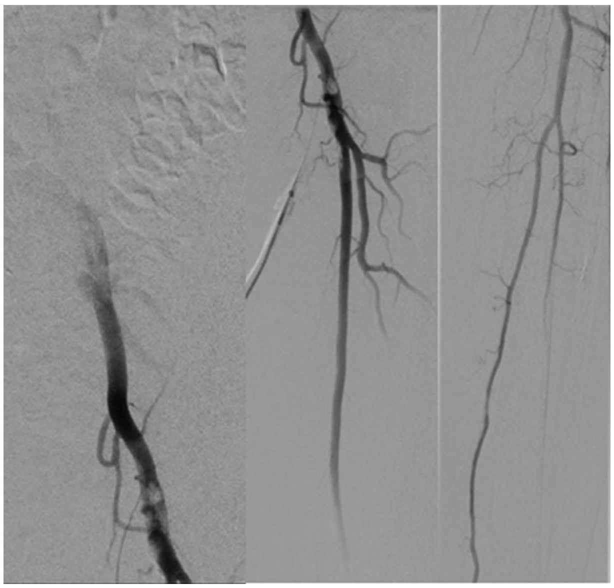

Fig. 1. Digital subtraction angiographic images of EIA (left), CFA/SFA (centre) and Tibial Arteries (right).

A 1 second delay was utilised to adequately deliver the CO_2 to the region of interest for the CT acquisition. Using the Optimed CO_2 injection system (Optimed Medizinische Instrumente GmbH, Ettlingen, Germany), a total volume of 80 mL was injected.

On review of the CT images, high grade stenosis of the common iliac artery origins was demonstrated on both sides rather than just the left side seen sonographically. This allowed appropriate planning for bilateral common iliac stenting (Fig. 3). The CFA/SFA disease was also reviewed ensuring that catheter placement through the left puncture site would allow intervention to occur without a high risk of embolic events from the plaque present (See Fig. 4).

Retrograde puncture of the contralateral right CFA was performed and a 7-French sheath inserted. The left CFA sheath was also upsized to 7-French to allow stenting. Bilateral covered stents were deployed (Atrium Advanta V12, 2 10 mm × 38 mm, Maquet Getunge Group, Gothenburg, Sweden). Following the deployment another CO_2 CTA was performed which demonstrated appropriate deployment of the stents and improved vessel lumen size (Fig. 3). Distal angiography demonstrated no embolic complications.

The procedure was completed and haemostasis was achieved using manual compression for the left CFA due the pathology present and a Star Close closure device (Abbott Star Close Closure device) for the right CFA. The patient did not have any post procedural complications.

A good clinical result (Rutherford 0) was achieved with resolution in the patient's rest pain and claudication.

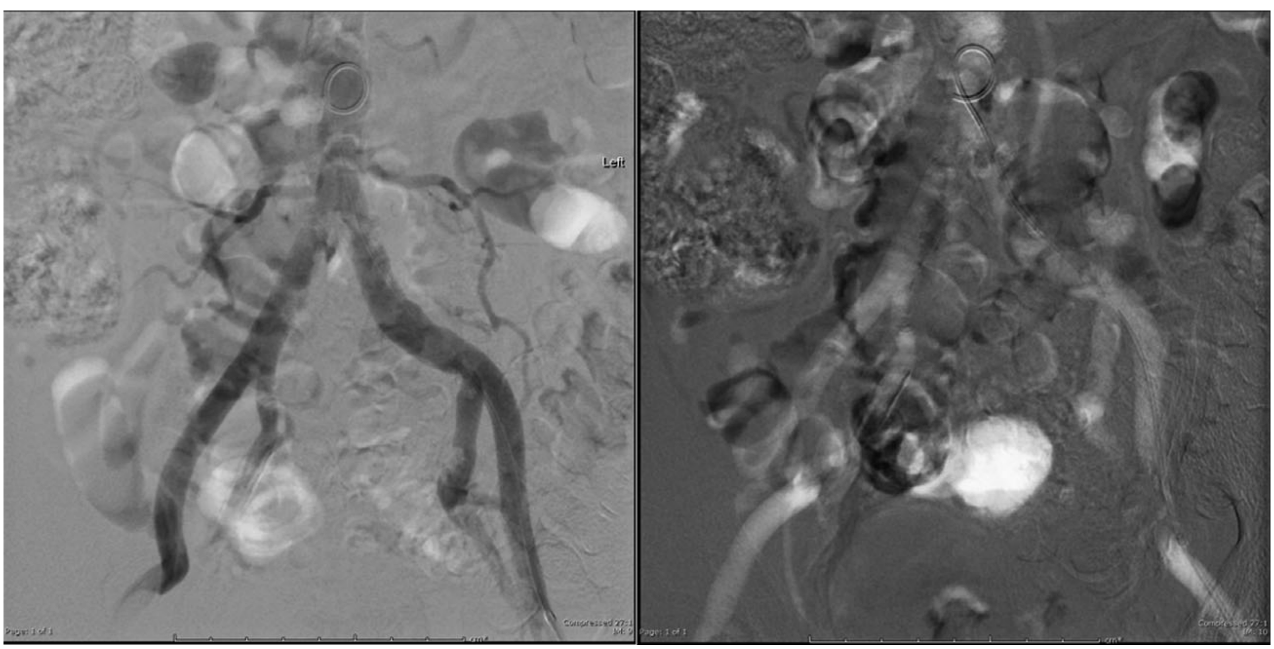

Fig. 2. Iodinated and CO_2 contrast DSA images demonstrating sub-optimal imaging of iliac stenoses – Technical Parameters for the iodinated contrast media angiograms were 14mls of contrast at 10 ml/s with an acquisition of 2 f/s. A total of 60mls of CO_2 was pre-set to be used via the Optimed CO_2 Angioset giving set (Optimed Medizinische Instrumente GmbH, Ettlingen, Germany) for the CO_2 contrast angiograms with an acquisition of 4 f/s.

Fig. 3. Coronal CO_2CTA MPR and MINIP imaging demonstrating bilateral iliac stenosis pre (top row) and post treatment (bottom row).

Discussion

A literature review was conducted with the key words of Carbon Dioxide, Computered Tomography, and Angiography. A list of four articles between the years of 2008 and 2014, which related to the use of CO_2 and CT imaging were found. Mahnken *et al.* [5] reviewed the feasibility of using CO_2 as a contrast media in CT in porcine models and concluded it is a feasible alternative to iodinated contrast.[5] This imaging technique may also provide an alternative to iodinated contrast media in patients that have contraindications to MRI and/or compromised renal function in the setting of diagnostic catheter based imaging of the vascular system.[5] In 2013, again based on porcine models, Penzkofer *et al.*,[6] looked at optimising the imaging quality and concluded that 'high-pitch, low-delay, high-pressure CT protocols improve CO_2 angiography of the lower leg, paving the way for further testing of the method in patients',[6] thus identifying that the recommendations made were 'ready for use in human subjects'.[6]

Penzkofer *et al.* [6] was soon followed by Sonoda *et al.* [7] who attempted to define the vascularity of malignant liver tumours through the uses of CO_2 Imaging in CT. In Sonoda *et al.*'s [7] article, they attempted to identify the supply of liver tumours. Even with the limitations identified within their study, Sonoda *et al.* (2013) still concluded that 'intravascularly-injected CO_2 gas may help to identify the vascular area of human hepatic tumours and may aid in the delivery of selective TACE.[7] Of note Sonoda *et al.* [7] suggested that In patients with allergic or nephrotoxic reactions to iodinated contrast media, CT arteriography with CO_2 gas may facilitate the detection of liver tumours and their vascular area'.[7] Finally, Penzkofer *et al.*,[8] re-published on the subject, this time in humans confirming the practical application of their suggested protocol previously published.[8]

In regards to the case presented, due to the presence of bowel gas, conventional angiography sub-optimally displayed the target lesions due to artefact caused by bowel peristalsis, a known potential issue with angiography of the pelvis. Techniques traditionally performed to minimise artefact created from this inherent movement is use of an anti-peristaltic muscle-relaxant to temporarily paralyse the bowel. This is usually performed with hyoscine butylbromide (Buscopan) intra venously which acts for short periods of time, limiting the amount of imaging that can occur in this scenario. The use of CT imaging overcomes this by being able to separate out in space, anatomy which can be difficult in conventional angiography. Performing CTA with iodinated contrast media (intra-venous or intra-arterial) can contribute to contrast induced nephropathy.[8]

In renal impairment, a feasible alternative is smaller dose contrast injections for direct CT angiography. In iodine allergy alternative contrast agents such as gadolinium can also be used at lower doses in CT angiography.

An alternative to iodinated contrast that has been used in angiography extensively to date is CO_2 as a negative contrast media.[2–4] Historically this has not been investigated nor published extensively for uses with CT, as identified in the literature review. In the articles sourced and reviewed, all have described the success of utilising CO_2 contrast in imaging vascular anatomy. Within the articles reviewed, CTA studies were either performed in porcine models or as hybrid procedures where patients were moved from the angiography to CT for imaging then returned to complete the procedure. The injection of CO_2 was also been performed utilising commercially available injection systems with technical success. Of note, when using this technique, the time delay between starting the injection of CO_2 and the commencement of imaging of the CT injector is rapid. In the case described there was slight mistiming of the second injection due to the manual process involved. The change in delay was approximately 0.5 seconds which can account for the differences in arterial filling in some vessels. This did not affect the visualisation of the target lesions and the subsequent treatment performed.

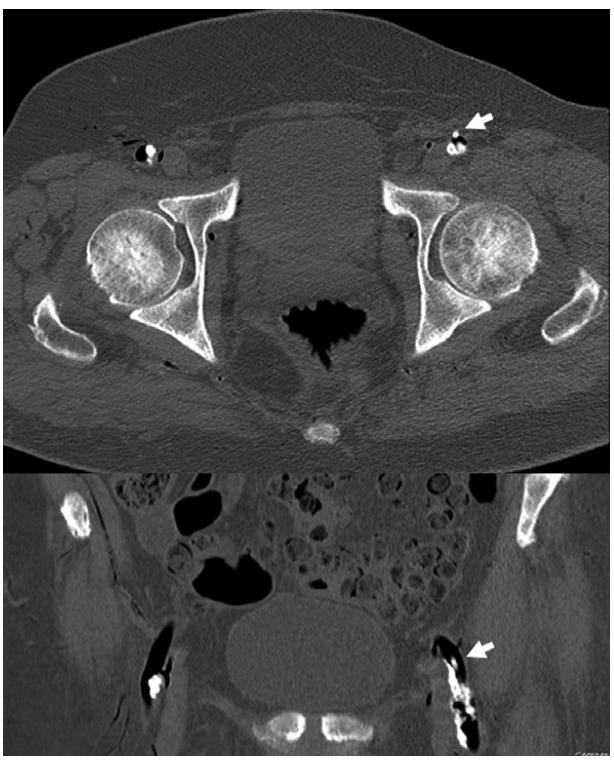

Fig. 4. Catheter Position confirmed near CFA plaque, axial image (top) shows catheter entering into vessel immediately anterior to plaque (white arrow), coronal image (bottom) shows catheter entering vessel immediately superior to plaque (white arrow).

This technique may be possible with current angiography systems with rotational acquisition capabilities however, due to the method of capturing images (entire volume is acquired in a single rotation) artefact may be present due to movement of bowel gas which will affect image quality. Further investigation into this technique would be recommended before using this imaging technique. As conventional CT acquisition is performed in a helical fashion, it is less affected by bowel movement because each voxel is only imaged in a fraction of the time that occurs in Cone beam CT and thus shows its temporal resolution superiority.

One of the limitations of CO_2 CTA is its transient presence within the vasculature. As the bolus is smaller and the gas displaces rather than mixes with blood, the temporal window for imaging is smaller. Layering of gas and blood can also occur,[4] as was encountered on the second acquisition (Fig. 5).

Due to this, a rapid acquisition is necessary, such as is possible with conventional-CT with its high temporal resolution. Whilst a short duration cone beam CT may be a feasible alternative, currently these extend over a rotation of at least 4-6 seconds, making accurate timing difficult in addition to the extended injection duration to maintain the CO_2 bolus in the volume of interest.

Finally, the uses of pressure measurement to determine if a gradient was present in the setting of vascular stenosis has been a technique used within the field of Interventional radiology for a long time. It has been demonstrated that catheter directed pressure measurements and determination of a pressure gradient can determine the significance of a stenosis with relative ease and at minimal cost.[9] This provides instantaneous diagnostic information about the stenosis in question allowing prompt treatment to occur.[9] The case presented

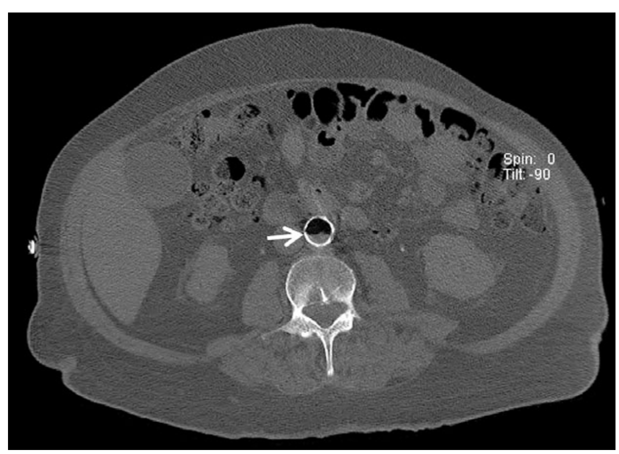

Fig. 5. Axial CO_2CTA imaging demonstrating layering of CO_2 gas and blood within the aorta (white arrow).

unfortunately, the ability to perform such measurements could not occur due to technical issues with measurement equipment however it is recognised that catheter based pressure measurements is a valid alternative in procedures as previously described.

In conclusion, the case presented demonstrates the advanced imaging techniques possible in suites that have ready access to both Angiography and Conventional CT. Although it is possible to do this at sites that have both Angiography and CT suites, due to practicality concerns, CO_2 CTA is optimally performed on combined Angio-CT systems.

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