Selective Intra-arterial Dual-energy CT Angiography (s-CTA) in Lower Extremity Arterial Occlusive Disease

J. Swanberg [a], **R. Nyman** [a], **A. Magnusson** [a], **A. Wanhainen** [b,*]

[a] Department of Radiology, Oncology and Radiation Sciences, Section of Radiology, Uppsala University Hospital, Uppsala, Sweden
[b] Department of Surgical Sciences, Section of Vascular Surgery, Uppsala University Hospital, Uppsala, Sweden

WHAT THIS PAPER ADDS

Detailed preoperative imaging of the infrapopliteal arteries is crucial for patient selection and procedural planning in patients with critical limb ischemia. Sometimes, however, the use of conventional contrast enhanced imaging methods (CTA and MRA) is limited by the contraindications of the iodine and gadolinium contrast media. In this study, a novel imaging method (s-CTA) is presented that provides high-quality arterial phase images with ultra-low dose iodine contrast media, useful also for patients unsuitable for conventional contrast enhanced imaging methods because of renal insufficiency.

Objective: In patients with peripheral arterial occlusive disease, renal impairment is a common contraindication to iodine and gadolinium contrast media, which limits the utility of conventional computed tomography angiography (CTA) and magnetic resonance angiography (MRA). It is proposed that selective intra-arterial dual-energy CT-angiography (s-CTA), that is CTA with intra-arterial injection of an ultra-low dose iodine contrast media, is a feasible, safe and accurate alternative imaging method to conventional non-invasive contrast enhanced vascular imaging in this patient group. The aim of this study was to report a preliminary experience of s-CTA in patients with critical limb ischemia and renal insufficiency with respect to safety, feasibility, and diagnostic accuracy.

Materials and methods: Ten non-consecutive patients with ischemic foot ulcers underwent s-CTA of one leg. Procedure related complications were recorded and imaging results were compared with conventional digital subtraction angiography (DSA).

Results: A median 17 mL (range 10—19 mL) contrast media (400 mg I/mL) was used. The median baseline plasma creatinine was 163 μmol/L (range 105—569) pre s-CTA versus 153 μmol/L (range 105—562) post s-CTA ($p = .24$). There was no puncture site complication. Among the patients selected for intervention ($n = 6$ with 30 arterial segments) the s-CTA findings correlated well with the DSA findings; the diagnostic sensitivity was 100%, the specificity 89%, and the accuracy 93%.

Conclusion: In this pilot study, a novel imaging method (s-CTA) is presented that provides high-quality arterial phase images with ultra-low dose iodine contrast media useful also for patients unsuitable for conventional contrast enhanced imaging methods because of renal insufficiency.

Article history: Received 9 December 2013, Accepted 13 May 2014, Available online 21 June 2014

Keywords: CT-angiography, Computed tomography, Lower extremity, Ischemia, Iodine, Contrast media, Renal insufficiency, Intra-arterial

INTRODUCTION

Accurate and detailed preoperative mapping of the infrapopliteal arteries is essential in patient selection (candidate for revascularization) and pre-procedural planning (open or endovascular, target artery for bypass, antegrade/cross-over/pedal access, sizing of angioplasty balloons etc). Magnetic resonance angiography (MRA) and computed tomographic angiography (CTA) with intravenous contrast injection are two cornerstones in preoperative arterial mapping, which have been shown to be accurate and tolerable for most patients. However, in patients with peripheral arterial occlusive disease (PAOD), concomitant renal impairment may limit the use of iodine and gadolinium contrast media, and thus the utility of conventional contrast enhanced CTA and MRA.[1,2] The third cornerstone is duplex ultrasound (DUS), which is a safe and widely used alternative to contrast enhanced sectional imaging, that does not require any use of nephrotoxic contrast media. Although DUS has a high overall accuracy in detecting tibial vessel patency or occlusion, it is less reliable in subjects with

* Corresponding author. A. Wanhainen, Institution of Surgical Sciences, Department of Vascular Surgery, Uppsala University, SE-751 85 Uppsala, Sweden.
E-mail address: anders.wanhainen@surgsci.uu.se (A. Wanhainen).

1078-5884/$ — see front matter
http://dx.doi.org/10.1016/j.ejvs.2014.05.013

extensive occlusive disease, compared with digital subtraction angiography (DSA),[3] which is the gold standard.

Thus, there is a need for a minimally invasive contrast enhanced imaging technique that can reduce the amount of contrast media used while retaining high diagnostic accuracy. Ideally, such a technique should be able to visualize medium to small diameter arteries with a low blood flow, and be able to separate the vessel lumen from the vessel wall in the presence of calcification, as well as be safe and tolerable to the patient. By using CT with selective intra-arterial contrast media injection, the required injected amount can be considerably reduced, thereby reducing the risk of renal impairment.

The aim of this study was to report an initial experience with selective intra-arterial dual energy CT-angiography (s-CTA), a novel minimally invasive vascular imaging method, in patients with lower extremity arterial occlusive disease unsuitable for conventional contrast enhanced imaging.

MATERIALS AND METHODS

Patients

Ten non-consecutive patients (nine males and one female; median age 73 years; age range 48—95 years) with chronic ischemic foot ulcers were examined with s-CTA between December 2010 and March 2012. The study was approved by the ethics committee of the Uppsala/Örebro Region. All subjects gave informed consent prior to the investigation.

Patients with a detected arterial lesion of clinical significance were scheduled for conventional angiography and attempted revascularization. The intraoperative angiograms were used to validate the s-CTA images. Pre and post s-CTA plasma creatinine levels were compared and puncture related complications were recorded.

CT technique

Nine examinations were performed on a Somatom Definition 64-slice Dual Source CT-scanner (Siemens Healthcare, Forchheim, Germany). Tube voltages were set to 140 kV (tube A) and 80 kV (tube B). Tube A was operated with a quality reference milliampere-seconds (QRmAs) of 55, and the QRmAs of tube B was automatically adjusted according to tube A and scout image parameters. Automatic tube current modulation (CARE Dose 4D) was used. Tube rotation time (TR) was 0.5 s. The detector collimation was 64 × 0.6; pitch was 0.6 in five examinations, and 0.7 in the remaining five cases. Separate datasets were calculated for each tube voltage with a soft kernel specific for dual energy (D30), with slice thickness 1.5 mm and a reconstruction increment of 1.0 mm. The scan delay varied between 3 and 6 seconds after the beginning of the contrast injection. The median scan time required to cover the entire leg with this technique was 45 seconds (range 37—55).

One study was performed on a Somatom Definition Flash 128-slice Dual Source CT-scanner (Siemens Healthcare, Forchheim, Germany). Tube voltages were 80 kV (Tube A) and 140 kVSn (Tube B). The QRmAs of tube A was set to 300, and that of tube B was automatically adjusted according to tube A and scout image parameters. CARE Dose 4D was used. TR was 0.33 s. The detector collimation was 64 × 0.6; pitch was 0.7. Separate 80 kV and 140 kV datasets were calculated using kernel D30 with a slice thickness of 1.5 mm and a reconstruction increment of 1.0 mm. The resulting scan time was 27 seconds with these settings.

Arterial puncture and contrast injection

After sterile preparation and draping of the ipsilateral groin, the common femoral artery was punctured using a 4 French micro-puncture set (Cook Medical, Bloomington, IN, USA) (Fig. 1). After administration of local anaesthetic, the coaxial catheter was introduced into the external iliac artery over a 0.018 inch Nitinol wire, using the Seldinger technique.[4] The catheter was connected to a Stellant DualFlow dual-headed CT contrast injector (Medrad Inc, Warrendale, PA, USA) via a 150 cm long extension tube, with an intrinsic volume of 10 mL, and simultaneous injection of the iodine contrast media (CM) iomeprol 400 mg I/mL (Iomeron, Bracco, Milan, Italy) and normal saline 0.9% (NS) was performed in three phases. The injection duration, and thereby also the total contrast volume, was tailored to match the scan time, so that adequate contrast density would be maintained throughout the scan. Typically, 7 mL of CM along with 13 mL of NS was injected during 10 seconds, immediately followed by 10.5 mL of CM and 19.5 mL of NS during 30 seconds, and finally 40 mL of NS bolus to clear the extension tube of contrast. In this way, a total of 17.5 mL of iomeprol 400 mg I/mL was injected during 50 seconds. The contrast/saline ratio was 35%, equalling an iodine concentration of 140 mg I/mL.

In the examination that was performed on the Somatom Definition Flash 128-slice Dual Source CT-scanner, 5 mL of CM along with 15 mL NS was injected during 10 seconds, followed by 5 mL CM and 15 mL NS injected during 20 seconds, resulting in an injection duration of 30 seconds. In this case an immediate repeat scan from the knee joint to the foot was obtained to make sure that sufficient time had elapsed to opacify arterial segments with slow flow.

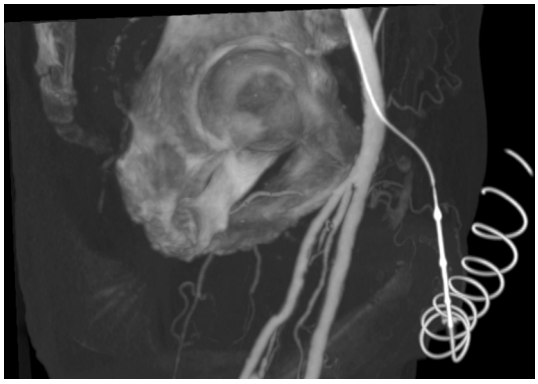

Figure 1. MPR-reformat showing the contrast injection site at s-CTA. A 4 French × 7 cm micro-puncture catheter has been inserted into the common femoral artery, and is connected to the contrast injector extension tube.