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CT of the ilio-femoral arteries using direct aortic contrast injection: proof of feasibility in patients screened towards percutaneous aortic valve replacement

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Summary

Principles: Transfemoral aortic valve implantation (TAVI) is a promising treatment modality for selected patients with severe symptomatic aortic stenosis. Peripheral access via the femoral and iliac artery is an important issue, limiting this technique's applicability in patients suffering from peripheral arterial disease. Multislice computed tomography (MSCT) reliably identifies patients with suitable peripheral access. However, MSCT involves an additional contrast dye burden in patients often suffering from renal failure.

In this study, the feasibility of direct-aortic-contrast-injection for MSCT was investigated, aiming to reduce total contrast load.

Methods: Patients undergoing evaluation for TAVI underwent an aortogram including iliac and femoral arteries. In 7 selected patients with questionable peripheral access, MSCT was performed by advancing a pigtail catheter to the level of L2, followed by direct injection of 15–20 ml of contrast mixed with an equal volume of saline. This injection was followed by an injection of 40 ml of saline. Scanning was initiated 4 seconds after starting the contrast injection. All MSCT scans were obtained using a 64 slice scanner.

Results: In all 7 patients, except one, the distal aorta, iliac and femoral arteries where adequately imaged to allow reliable assessment of peripheral access for TAVI. Of the 7 patients evaluated, 2 were rejected for TAVI based on the information of the MSCT using direct-aortic-contrast-injection.

Limitations of the technique may be an underestimation of the arterial diameter due to spasms at the puncture site.

Conclusion: MSCT using direct-aortic-contrast-injection for assessment of peripheral access for TAVI is feasible and may provide good diagnostic images with a reduced volume of contrast.

Key words: transfemoral aortic valve implantation; contrast-induced nephropathy; computed tomography

Introduction

Transfemoral aortic valve implantation (TAVI) is a new, promising therapy for severe aortic stenosis in patients who are turned down for conventional open-heart surgery. However, femoral access for the large diameter valve systems is often a limiting factor and vascular injury is a major source of adverse events. Detailed assessment of the iliac and femoral arteries prior to valve implantation is therefore mandatory.

In the first series of 18 patients who underwent TAVI at our institution, 2 vascular complications occurred [1]. During the course of the initial experience, vascular access techniques, equipment and screening evolved with a reduction in vascular complications [2]. Currently at our institution, 9 (15%) out of 60 patients screened towards TAVI were turned down for a transfemoral procedure for reasons related to unsuitable peripheral access.

In our centre, patients' screening for TAVI routinely consists of selective coronary and supravalvular aortic angiography. At the same session, an abdominal aortogram is performed with imaging of both iliac and femoral arteries. Multislice computed tomography (MSCT) is helpful, if peripheral access appears questionable on aortogram, since MSCT offers detailed imaging of calcification of the arterial wall and depicts vessel tortuosity in any plane with high spatial resolution.

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Table 1

Incidence of risk factors for contrast-medium-induced nephropathy in 202 patients undergoing TAVI at Saint Paul's Hospital, Vancouver, BC, Canada.

	GFR <40 ml/min	Diabetes mellitus	Congestive heart failure	Coronary artery disease	Hypertension	Age ≥75years
Number of patients	27 (13%)	45 (22%)	100 (49%)	133 (66%)	127 (63%)	167 (83%)

However, additional "contrast-dye-burden" due to MSCT assessment of peripheral access is approximately 100 ml [3]. As aforementioned, TAVI patients typically suffer from co-morbidities, whereof renal failure is one of the most common. Given the repeat exposure of these patients to contrast-dye during TAVI work-up, and the high incidence of risk factors for contrast-medium-induced nephropathy (CIN) in this population (see table 1), these patients are at very high risk for renal complications.

An MSCT-based method using intra-aortic contrast-medium injection to the distal abdominal aorta has the potential to reduce additional contrast-dye burden dramatically yet still yield the diagnostic information required.

Our initial experience using this method with direct contrast-dye injection to the abdominal aorta is presented, in a subgroup of our patient population screened towards TAVI.

Methods

In 202 selected patients conventional coronary and iliofemoral angiogram and supravalvular angiogram were performed using a 6 French arterial sheath in the right femoral artery after initial puncture using Seldinger technique. In 7 selected patients with questionable peripheral access, an MSCT of the peripheral vasculature was performed using direct aortic injections: After the angiogram, the arterial sheath was left in the right femoral artery, was sutured, covered in sterile dressing and attached to a pressure flush system to maintain patency. Arterial vascular access and peripheral pulses were repeatedly monitored. After approximately 2 hours, patients underwent MSCT. Renal function (in terms of glomerular filtration rate) of all patients was calculated using the Cockroft [4] equation prior to the interventions.

Prior to MSCT, a pigtail catheter was advanced through the arterial sheath to the distal abdominal aorta at the level of L2. Before the contrast injection, a non-contrast examination of the abdomen and pelvis was performed to evaluate for the degree of iliofemoral calcification.

15–20 ml of non-ionic iodinated contrast medium (Iodixanol (Visiopaque) 320; GE Healthcare, Princeton, NJ) was injected through the pigtail catheter (diluted with 15 ml of normal saline), followed by an injection of 40 ml of saline. The contrast saline bolus was injected at 4.5 cc/sec. Data acquisition was initiated 4 seconds after starting the contrast injection. MSCT examinations, at our institution, were performed with a GE LightSpeed VCT 64-slice scanner (GE Medical Systems, Milwaukee, Wisconsin) with the following parameters: Collimation of 64 X 0.625 mm and rotation time of 0.6s with table speed of 39.37 mm/rotation for a pitch of 0.984:1. Dose was modulated with auto mA and smart mA with a range from 100 mA to 600 mA at 120 kV and noise index of 20.00. 0.625 mm axial images were acquired from below the diaphragm to the lesser trochanters. The images were then sent to the workstation (ADW 4.4 GE Healthcare, Waukasha, WI) and the data sets were reconstructed using multiplanar reformats and volume rendering. Maximum intensity projection reformats in coronal and oblique sagittal planes of the aorta were also performed.

Image quality, thus feasibility, was assessed by a senior radiologist specialized in cardio-vascular computed tomography (CT). Comparison to conventional angiogram was done qualitatively at interdisciplinary rounds (with interventional cardiologists, MSCT radiologists and cardiovascular surgeons) and quantitatively by measuring vessel diameters at different sites (1 cm above the aortoiliac bifurcation, 1 cm below the bifurcation on the right iliac artery and as well at the puncture site).

After the procedure, the sheath was removed and the puncture site was manually compressed for 30 minutes. Thereafter patients were monitored for another 4 hours before discharge.

All patients gave informed consent to both procedures.

Statistics

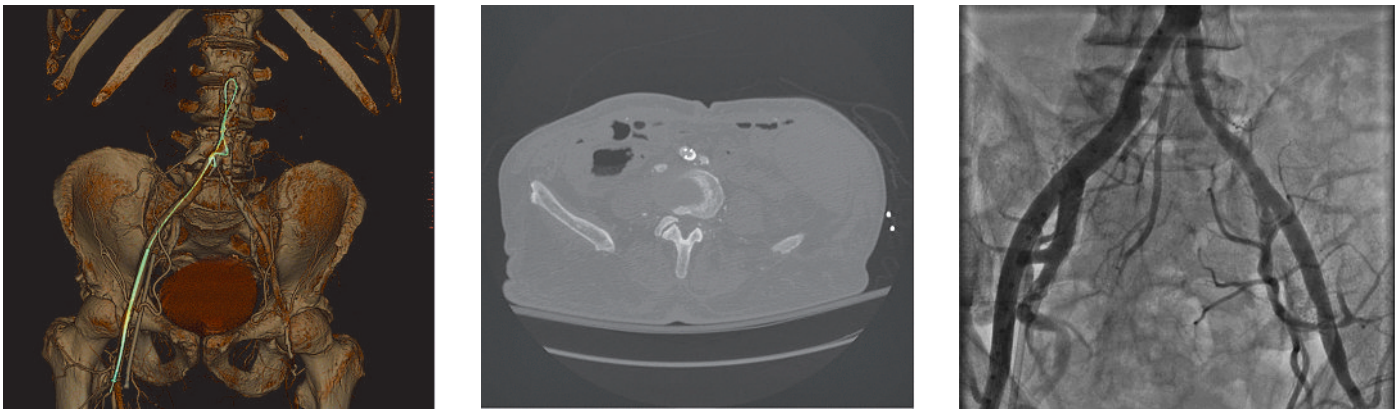
Statistical analyses were done using SPSS for Mac, Version 16.0. Data are presented as mean ± standard deviation (SD). Comparison between groups was done by 2-tailed paired t-test. A p-value of ≤0.05 was considered statistically significant.

Results

Feasibility

A total of 7 patients (3 male, age 79 ± 10) underwent MSCT using direct aortic contrast injection after coronary, aortic and iliofemoral angiogram. The total amount of contrast used for percutaneous heart valve work-up was 140 (±12) ml. Thereof, approximately 50 ml were used for assessment of the iliac and femoral arteries (15–20 ml for MSCT and 34 ml for the iliofemoral angiogram). Mean creatinine was 109 (±37) µmol/l and GRF 54 (±18) ml/min/m^2. All patients were discharged the day of the procedure.

In all patients image acquisition was feasible and no complication occurred. Mainly no clotting



A B C

Figure 1

A: Coronal VR image showing the pigtail catheter coiled back in the right common iliac artery.
B: Underestimation of luminal diameter in an axial plane in the same patient.
C: Angiogram of the femoral arteries in the same patient confirming the overestimation of disease in the left iliofemoral system.

of the sheath, no dissection of the artery and no allergic reaction to contrast dye occurred.

Image quality was good in all except one patient (see below). Mean vessel diameters 1 cm above the aortoiliac bifurcation, 1 cm below the aortoiliac bifurcation and at the puncture site were 13.95 (±2.4), 9.3 (±2.7) and 6.5 (±0.9) on angiogram and 14.7 (±1.88), 9.9 (±2) and 6.6 (±1.4) mm on MSCT, respectively. These differences were statistically not significant ($p = 0.4$).

Of the 7 patients, 3 patients (43%) underwent TAVI with suitable peripheral access and no vascular complication. 4 patients (29%) were turned down for TAVI, for 2 patients the reason being non-suitable peripheral access (the other 2 patients were accepted for conventional valve surgery).

Limitations of the technique

Technical problems: In 1 patient disease burden and stenosis severity were overestimated when compared to catheter angiography. After reviewing the CT, the pigtail was found to be coiled back into the right iliac artery with resultant selective injection of the right iliofemoral system. Given the moderate atherosclerotic changes in the left iliac artery area, the degree of stenosis in the left femoral artery was overestimated (fig. 1).

Discussion

MSCT using direct-aortic-contrast-injection for assessment of peripheral access for TAVI is feasible and appears to provide valuable information in the screening process of patients towards TAVI. The main advantage of the technique, over standard MSCT with systemic intravenous contrast, is the low amount of contrast needed.

The acquired CT images were particularly helpful to assess the extent of atherosclerotic changes, as well as the structure of atherosclerosis (calcification versus soft plaque). The main additional value, however, was in evaluating tortuosity of the arteries (fig. 2) and in the assessment of calcification (fig. 3).

Difficulties in evaluating heavily calcified vessels apply for MSCT in general: calcification results in "blooming" or partial volume artefact as the highest density structure calcium essentially overwhelms the remaining contents of the voxel. If part of a voxel of data is comprised from calcification, typically the entire voxel is assigned a high attenuation value resulting in overestimation of plaque size and stenosis severity, id est overestimation of the size of the calcification and therefore limiting assessment of luminal diameter [5].

Unlike standard MSCT, spasms at the sheath puncture site can occur with MSCT using direct-aortic-contrast-injection, thereby creating a false low luminal diameter. Therefore, the puncture site often cannot be assessed reliably with this technique.

Technical problems with the placement of the pigtail catheter, as described in one case, are probably part of the learning curve and can be overcome easily.

Contrast-medium-induced nephropathy (CIN) is one of the most common causes of hospital acquired renal insufficiency [6]. The risk of CIN is related to the amount of contrast used [7–11]. In a study by Nikolsky et al. [12] on diabetic patients undergoing percutaneous coronary intervention, there was a stepwise increase in the incidence of CIN with increasing contrast: from 16% in patients receiving <200 ml to 21%, 27% and 48% in patients receiving 200 to 400 ml, 400 to 600 ml and >600 ml of contrast, respectively. There was a 69% increase in the likelihood of dialysis with each 100 ml increment in contrast. Therefore, reducing the total amount of contrast by 85 ml is, most likely, clinically relevant in such a high-risk population.

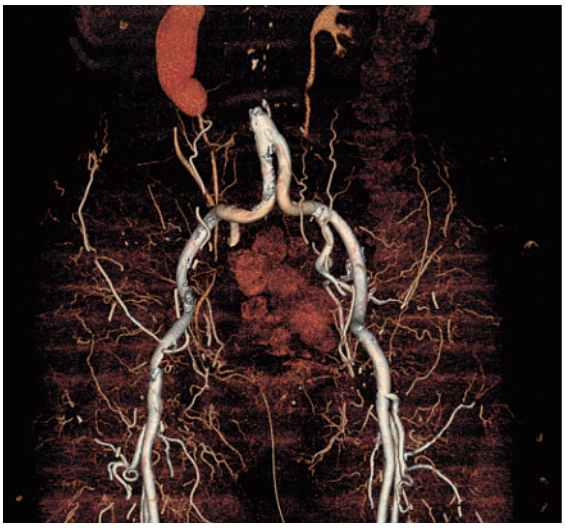


Figure 2

Coronal Volume Rendered (VR) image displaying very tortuous iliofemoral systems bilaterally, complicating TAVI.

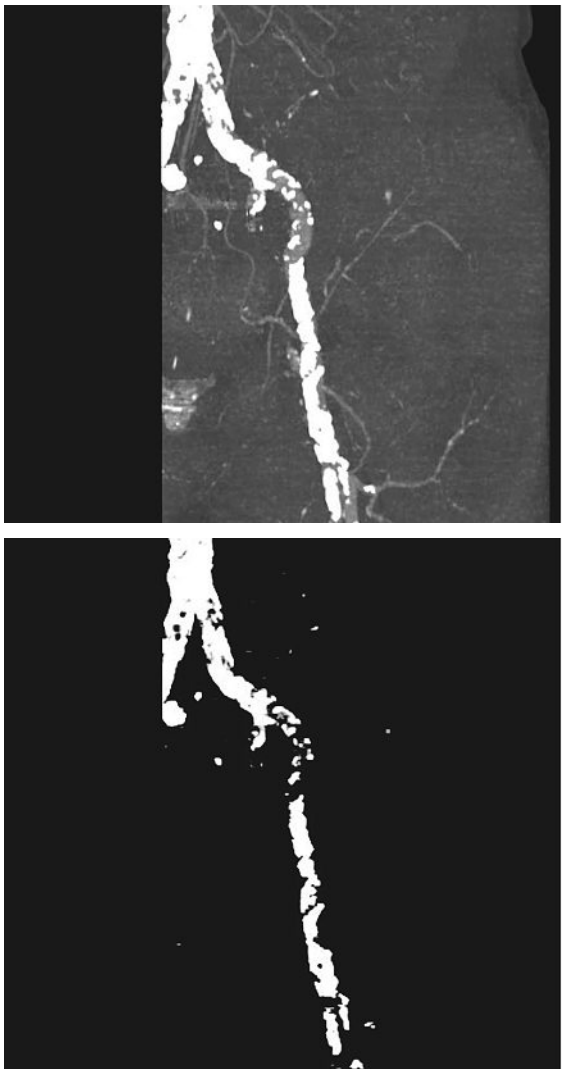


Figure 3

Top: A Coronal Maximum Intensity Projection Image (MIP) displaying heavy calcified left femoral and iliac artery – prohibitive for TAVI.
Bottom: MIP image displaying only the burden of calcification in the left iliofemoral system.

The reported incidence of CIN, after CT, ranges from 4 to 21% in patients with prior reduced renal function [13–15].

In a meta-analysis of outcome data after aortic valve replacement [16], renal failure was (albeit only weakly) predicting early postoperative mortality, whereas in another study exclusively including elderly patients, renal insufficiency was a strong predictor of operative mortality [17]. The odds ratio for in-hospital mortality was about 7, if the glomerular filtration rate (GFR) was below 60 ml/min as compared to patients with a GFR of >60 ml/min [18]. Further, an abnormal renal function was a factor of long-term outcome after cardiac-surgery [19, 20]. Gummert et al. [21], looking at heart surgery in general, found preoperative renal disease to be an independent predictor of postoperative dialysis. Whether surgical data may be copied to TAVI is questionable. Procedural worsening of renal function can be expected to be less severe, since with TAVI there is no need for a heart lung machine, a shorter procedure time and the level of inflammation, an important pathophysiological factor [22] in the development of CIN, can be expected to be lower. On the other hand, there is additional exposure to contrast-medium in TAVI when compared to surgery, which might counterbalance its aforementioned advantages. From percutaneous coronary interventions it was found, that CIN correlates with longer hospital stays and is one of the most powerful predictors of 1 year mortality in patients with pre-existing chronic kidney disease [23]. Taken together, pre-interventional renal failure which may worsen the outcome of the procedure, is therefore an important issue [24–26] and should be optimized whenever possible.

It is concluded from this study, that MSCT using direct-aortic-contrast-injection is an excellent technique in combination with femoral angiogram. The conventional angiogram is, in the opinion and experience of the authors, superior in assessing true luminal diameter, especially in vessels with high calcium burden. CT on the other hand, is superior in assessing total calcium burden as well as tortuousity of the vessel.

Given the limitations of the MSCT using direct-aortic-contrast-injection and of MSCT in general, standard angiogram is still found to be mandatory in the assessment of patients.

Limitations

A postprocedural creatinine was not measured in order to compare the impact on renal function of the MSCT using direct-aortic-contrast-injection with conventional MSCT's. However, given the minimal additional contrast dye burden of 15 ml, a significant impact of the new method on renal function is not expected.

Feasibility was assessed qualitatively by a senior radiologist and by measuring diameters at various vessel sites. This is not as robust as if MSCT was compared using direct-aortic-contrast-injection with conventional MSCT. However, the fact that the image quality was considered good (except for the one case where the pigtail was

coiled back) and the measured vessel diameters did not differ between angiogram and MSCT using direct-aortic-contrast-injection is reassuring. A reliable decision for the TAVI procedure was made in all patients during the screening process. A comparative study between standard MSCT and the method described would not only cause additional radiation burden, but as outlined additional contrast dye exposure. This might cause ethical concerns in a patient collective as the one screened for TAVI.

The small number of patients included in the present study has to be considered a further limitation. Furthermore, given the "proof-of-feasibility"-nature of this study, patients were included with normal renal function, therefore being on lower risk for CIN. However, this paper does not intend to evaluate the impact of the new method on renal function. Given the feasibility of the method, the technique and its impact on renal function should be further evaluated in the future.

Conclusions

MSCT using direct-aortic-contrast-injection is feasible with little additional contrast dye administration. It revealed important additional information concerning peripheral access for transfemoral percutaneous valve replacement.

In patients with renal impairment and at high risk for CIN this technique might therefore be a good alternative to standard MSCT.

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