

Usefulness of dual-source computed tomography for the evaluation of coronary arteries in heart transplant recipients

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Abstract

Background: Heart transplant recipients require serial assessment of coronary arteries due to a risk of cardiac allograft vasculopathy or atherosclerosis. Currently available non-invasive imaging methods are of a limited value for the detection of coronary stenoses, and thus invasive coronary angiography (ICA) is recommended.

Aim: We evaluated diagnostic accuracy and clinical usefulness of dual-source computed tomography (DSCT) as a potential alternative to ICA for the detection of coronary stenoses.

Methods: DSCT was performed in 20 consecutive heart transplant recipients (15 males, mean age 47.5 years) who were scheduled for ICA. Exclusion criteria included renal dysfunction with creatinine clearance < 45 mL/min and lack of patient consent. All examinations were performed using a first generation dual-source scanner and a retrospectively ECG-gated protocol. Data sets were routinely reconstructed in best-systolic and best-diastolic phases. We evaluated presence of a > 50% stenosis in a vessel with a diameter of > 1.0 mm, image quality of each segment, and radiation dose delivered to the patient. Sensitivity, specificity, positive and negative predictive values, and diagnostic accuracy were calculated in per segment, per vessel, and per patient analyses, with ICA considered the reference method.

Results: All DSCT and ICA examinations were diagnostic and performed without any complications. Mean heart rate was 85 bpm (range 63–114), and was stable in 85% of patients. Significant stenoses (> 50%) were diagnosed by DSCT in 4 of the 287 segments, and these findings were confirmed by ICA in 2 segments. Sensitivity, specificity, and diagnostic accuracy were: (1) in the per segment analysis, 100%, 99%, and 99%, respectively, for the left coronary artery; and 100% each for the right coronary artery; (2) 100%, 97%, and 97%, respectively, in the per vessel analysis; and (3) 100%, 94%, 95%, respectively, in the per patient analysis. In diastolic reconstructions, right coronary segments were significantly more commonly nondiagnostic than left coronary segments (25% vs. 11.5%, $p = 0.003$). In contrast, right coronary segments showed better quality than left coronary segments in systolic reconstructions (63.5% vs. 42.2%, $p < 0.001$). Mean effective radiation dose was 12.7 (range 5.4–18.7) mSv.

Conclusions: DSCT is a clinically useful alternative to invasive coronary angiography for excluding significant coronary stenoses in heart transplant recipients. The negative predictive value of this modality is very high. Sensitivity, specificity and diagnostic accuracy is acceptably high. Imaging of coronary arteries in patients with high heart rates is technically feasible, but require modifications of routine exam protocol. Using of modern prospectively ECG-triggered protocols is not recommended.

Key words: coronary computed tomography, heart transplantation

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INTRODUCTION

Cardiac allograft vasculopathy remains a major cause of long-term mortality among heart transplant recipients [1]. Diagnostic evaluation and identification of patients at-risk is difficult due to differences in the clinical characteristics of this patient group, including the occurrence of silent myocardial ischaemia. For this reason, many centres recommend periodic (annual or biennial) evaluation of coronary arteries [2]. Until now, the diagnostic method of choice was invasive coronary angiography which is, however, associated with a complication risk of up to several per cent [3]. Another significant drawback of coronary angiography is the ability to image only the coronary artery lumen, with no information on the vascular wall structure, and thus this method is of little value in the identification of patients at risk of a coronary event. Therefore, a search continues for new imaging methods that might be used in the evaluation of heart transplant recipients. Computed tomography (CT) has proven useful for the exclusion of significant atherosclerotic lesions in patients with suspected coronary artery disease (CAD) and in patients after previous revascularisation procedures [4, 5]. Technical limitations dictate, however, that even with advanced CT systems heart rate (HR) reduction below 60–65 bpm is recommended to achieve high clinical usefulness of this method. With higher resting HR and poor response to beta-blockers, imaging using 64-row CT scanners in heart transplant recipients may be technically difficult and of little value in the clinical practice. The aim of the present study was to evaluate diagnostic accuracy and clinical usefulness of dual-source computed tomography (DSCT) as a potential alternative to invasive coronary angiography in heart transplant recipients.

METHODS

Patients

We prospectively evaluated 20 consecutive patients in whom invasive coronary angiography was planned for clinical reasons. For the purpose of the present analysis, coronary CT angiography was additionally performed in these patients. We included patients regardless of their resting HR and time since cardiac transplantation. Exclusion criteria included estimated glomerular filtration rate (eGFR) < 45 mL/min and lack of patient consent. The study protocol was approved by a local ethics committee. Patient characteristics are shown in Table 1.

Coronary computed tomography angiography

All examinations were performed using a dual-source Somatom Definition CT scanner (Siemens, Germany). All patients were informed in detail regarding the purpose of the study and the need to withhold breath for several seconds. If resting HR was above 100 bpm, metoprolol was given intravenously in sequential 2.5 mg doses until HR reduced below 80 bpm or the maximum dose of 15 mg was reached.

Table 1. Study group characteristics

Number of patients	20
Age (years; mean/range)	47.5 (19–72)
Gender (women/men)	5/15
Body mass index [kg/m ²]	25.49 (19.5–37.6)
eGFR [mL/min/1.72 m ²]	67.52 (45.2–90)
Time interval between CT and invasive coronary angiography [days] (mean/range)	5.6 (2–16)
Resting heart rate [bpm] (mean/range)	85 (63–114)
Beta-blocker administration (n)	4

CT — computed tomography; eGFR — estimated glomerular filtration rate

Several minutes before image acquisition, patients were given nitroglycerin sublingually (0.8 mg) to induce maximum vasodilatation.

The initial step of the examination was determination of the coronary artery calcium score. This was performed using a standard approach, with results expressed as the Agatston score. Then, using the test bolus technique, a small amount of the contrast agent was administered to evaluate its transit time to the ascending aorta, necessary to determine acquisition initiation delay in relation to the beginning of contrast agent administration. Based on individual patient-related factors, we determined image acquisition parameters which were as follows: acquisition temporal resolution 84 ms, lamp voltage 100–120 kV, lamp current 350 mAs/rotation, lamp-detector rotation time 0.33 s, detector collimation 32 × 0.6, and pitch 0.2–0.35 (depending on HR). All examinations were performed in the craniocaudal direction during a maximal inspiration, using a retrospectively ECG-gated protocol, with maximum lamp current within 30–80% of the R-R interval. We recorded HR and its variability during image acquisition. Heart rate was considered stable if its variability was not more than ± 2 bpm.

A contrast agent with high iodine content (Iomeron 400, 400 mgI/ml, Bracco, Italy) was administered using an automatic dual-barrel syringe at the rate of 6.0 mL/s in triphasic injections (i.e., contrast agent, contrast agent mixed with saline, and saline). Effective radiation dose associated with the examination was assessed based on dose length product (DLP) and expressed in millisieverts (mSv) using the coefficient $k = 0.017$.

Computed tomography data analysis

All data were routinely reconstructed in two phases of the cardiac cycle, systolic and diastolic, using 0.6 mm thick slices (reconstruction increment 0.4, reconstruction kernel B36). If none of the routine reconstructions yielded a diagnostic image, manually programmed reconstructions were performed every 5% of the R-R interval. If none of these

additional reconstructions yielded a diagnostic image, the analysed segment was considered nondiagnostic. For the purpose of the final analysis, images from both reconstructions were used. A best quality image was used to evaluate sensitivity and specificity of the method. For each segment, we considered its diameter (< 1.0 mm; ≥ 1.0 mm), the degree of stenosis (< 50%; ≥ 50%), image quality (0 — non-diagnostic; 1 — diagnostic with significant motion artifacts; 2 — diagnostic with small motion artifacts; 3 — diagnostic without motion artifacts). We used coronary segments nomenclature (16 segments) according to the American Heart Association classification. We analysed all segments with the diameter of at least 1.0 mm. We used MPR, curved-MPR, MIP, and VRT reformatting.

Invasive coronary angiography

Invasive coronary angiography was performed using a standard approach with femoral access route. Minimum number of views was 3 for the left coronary artery and 2 for the right coronary artery. Additional views were used at the discretion of operator. In case of borderline lesions, the degree of stenosis was assessed in the view that apparently showed the most significant stenosis, using typical dedicated software run on a dedicated postprocessing station.

Statistical analysis

Diagnostic accuracy of CT angiography in detecting significant coronary stenoses was compared with the reference invasive coronary angiography and expressed as sensitivity, specificity, positive predictive value, and negative predictive value with corresponding 95% confidence interval. Analyses were performed: (1) per segment, assessing individual segments for the presence of significant coronary lesions; (2) per vessel, assessing main coronary arteries (the left main coronary artery, the left anterior descending artery, the left circumflex artery, and the right coronary artery); and (3) per patient, assessing the presence of significant CAD in individual patients. Continuous variables were expressed as mean values

with standard deviation, and categorical variables were expressed as percentages and compared using the χ^2 test. Statistical analysis was performed using the SPSS 14.0 software (SPSS Inc., Chicago, Illinois, USA) and an interactive online calculator (<http://faculty.vassar.edu/lowry/clin1.html>).

RESULTS

All examinations were performed according to the protocol, with no direct or early complications. For each coronary segment, a diagnostic quality image was obtained in at least one view. Heart rate during acquisition ranged from 63 to 114 bpm, mean 85 bpm. Mean HR was above 80 bpm in 12 (60%) patients, ranged from 70 to 80 bpm in 7 patients, and was lower than 70 bpm in only 1 patient. Stable HR was found in 17 (85%) patients. We analysed all segments with the diameter of at least 1.0 mm (n = 287), including 191 left coronary segments and 96 right coronary segments. Diastolic reconstructions were performed within 68 to 89% (mean 74%) of the cardiac cycle length, and systolic reconstructions within 25 to 48% (mean 41%) of the cardiac cycle length.

Diagnostic accuracy of coronary computed tomography angiography

Table 2 shows data on the clinical usefulness of coronary CT angiography.

Per segment analysis. Among 287 evaluated segments, coronary CT angiography identified stenoses of more than 50% in 4 segments. These findings were confirmed by invasive coronary angiography in two segments. The two segments that were inappropriately evaluated by coronary CT angiography were located in distal segments of coronary arteries. Sensitivity, specificity, and diagnostic accuracy were 100%, 99%, and 99%, respectively, for the left coronary artery segments, and 100% each for the right coronary artery segments.

Per vessel analysis. In the per vessel analysis (the left main coronary artery, the left anterior descending artery, the left circumflex artery, and the right coronary artery), CT angiography identified stenoses in 4 vessels, and 2 of these ves-

Table 2. Diagnostic accuracy of dual-source computed tomography in the detection of significant coronary artery stenoses

	N	TP	TN	FP	FN	Sensitivity	Specificity	PPV	NPV	Accuracy
Per segment analysis:										
All coronary arteries	287	2	283	2	0	100% (20–100%)	99% (97–100%)	50% (9–91%)	100% (98–100%)	99%
Left coronary artery	191	1	188	2	0	100% (6–100%)	99% (96–100%)	33% (2–87%)	100% (98–100%)	99%
Right coronary artery	96	1	95	0	0	100% (6–100%)	100% (95–100%)	100 (6–100%)	100% (95–100%)	100%
Per vessel analysis:										
All coronary arteries	79	2	75	2	0	100% (20–100%)	97% (90–100%)	50% (9–91%)	100% (94–100%)	97%
Per patient analysis:										
All coronary arteries	20	2	17	1	0	100% (20–100%)	94% (71–100%)	67% (13–98%)	100% (77–100%)	95%

TP — true positives; TN — true negatives; FP — false positives; FN — false negatives; PPV — positive predictive value; NPV — negative predictive value; 95% confidence intervals given in parentheses



Figure 1. Computed tomography, MPR reconstructions; **A, C.** Examples of motion artifacts rendering study interpretation difficult or impossible. The ability to perform additional reconstructions (**B, D**) allows reliable evaluation of the coronary arteries

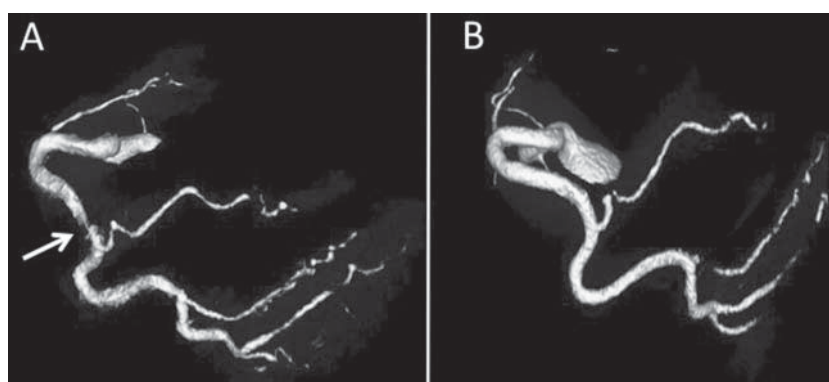


Figure 2. Computed tomography, volume reconstructions (VRT); **A.** A motion artifact imitating a significant stenosis in the right coronary artery is seen (arrow); **B.** Actual image obtained in another phase of the cardiac cycle, showing no significant stenosis

sels were inappropriately identified as stenosed. Sensitivity in the per vessel analysis was 100%, specificity 97%, and diagnostic accuracy 97%. A separate origin of a left coronary artery branch from the aorta was identified in 1 patient.

Per patient analysis. Among 20 evaluated patients, coronary CT angiography showed significant stenoses in 3 patients. Of these 2 patients were found to have significant ste-

noses in invasive coronary angiography. Sensitivity was 100%, specificity 94%, and diagnostic accuracy 95%.

Data quality analysis — nondiagnostic images

We found a relation between the proportion of nondiagnostic images (due to motion artifacts) and the phase of the cardiac cycle during which these images were obtained. In dias-

Table 3. Image quality in different reconstructions obtained from coronary computed tomography: systolic vs. diastolic reconstructions. Coronary segments numbers according to ACC/AHA

Segment number	N	Nondiagnostic in systolic reconstruction	Nondiagnostic in diastolic reconstruction
Right coronary artery			
1	20	0	6
2	20	0	6
3	20	2	4
4	20	1	5
16	15	0	3
Total	95	3	24
Left coronary artery			
5	19	1	1
6	20	1	1
7	20	2	2
8	20	3	3
9	19	2	3
10	12	1	1
11	20	0	3
12	20	0	3
13	19	1	3
14	16	0	2
15	7	0	0
Total	192	9	22

tolic reconstructions (the only available if the examination would be performed using protocols allowing significant reduction of the radiation dose), image quality was insufficient for analysis in 46 (16%) out of 287 evaluated segments. Non-diagnostic images were obtained significantly more commonly for right coronary segments (24/95, 25.3%), than left coronary segments (22/170, 11.5%, $p = 0.003$). Detailed data are shown in Table 3.

Data quality analysis

— diastolic versus systolic reconstructions

Data quality differed significantly depending on the phase of the cardiac cycle during which reconstruction was performed. Among left coronary segments ($n = 192$), better quality was noted for systolic reconstructions in 42.2% of the evaluated segments ($n = 81$), while diastolic reconstructions showed better image quality in the remaining cases ($n = 111$). An opposite proportion was found for right coronary segments ($n = 95$) as in most segments (65.3%, $n = 62$), image quality was better in systolic reconstructions. We found that compared to left coronary segments, right coronary segment images were significantly more commonly of better quality in systolic reconstructions (65.3% vs. 42.2%,

$p < 0.001$). Examples of motion artifacts are shown in Figures 1 and 2. The examinations with diagnostic quality in single reconstruction are shown in Figures 3 and 4.

Radiation dose

The need to obtain both diastolic and systolic reconstructions necessitated the use of a retrospectively ECG-gated acquisition protocol. Among patients with the body mass of up to 80 kg, lamp voltage was routinely reduced from 120 kV to 100 kV. In the overall study population, effective radiation dose per patient ranged 5.4–18.7 mSv, mean 12.7 mSv (DLP 318–1104, respectively, mean 747.3). The use of lower lamp voltage (100 kV) was associated with an exposure to a significantly lower radiation dose as compared to those patients in whom 120 kV lamp voltage was used (5.4–9.6 mSv, mean 7.4 mSv, vs. 11.8–18.7 mSv, mean 5.6 mSv, respectively, $p < 0.001$).

Amount of the contrast agent

Mean total volume of the contrast agent administered during CT examination was 67.5 mL (range 52–86 mL) and did not differ significantly from the mean volume administered during invasive coronary angiography, which was 64.5 mL (range 50–100 mL; $p = \text{NS}$).

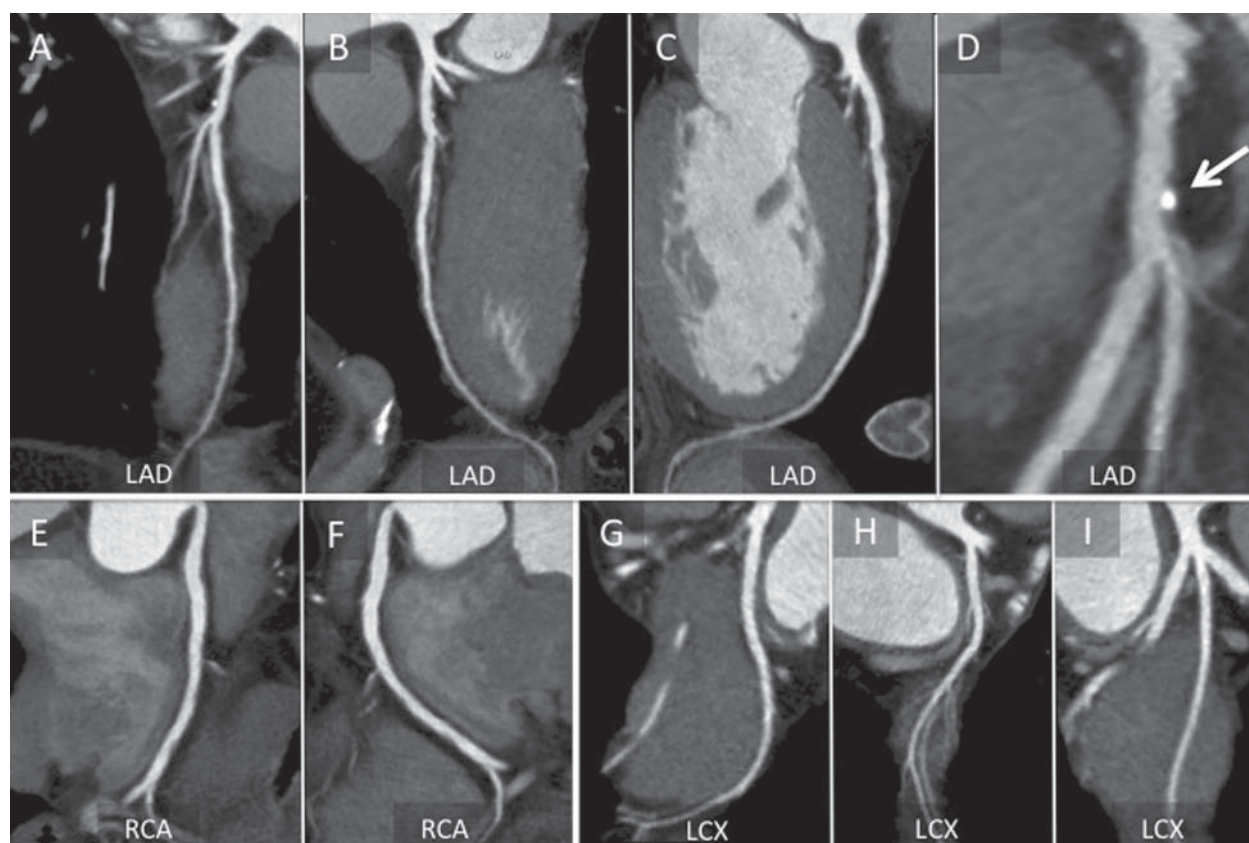


Figure 3. A–I. Computed tomography. Images of the coronary arteries obtained at heart rate above 80 bpm. Diagnostic images obtained from diastolic reconstructions. A stenotic atherosclerotic lesion is seen in the left anterior descending coronary artery (arrow); LAD — left anterior descending coronary artery; RCA — right coronary artery; LCX — left circumflex artery

DISCUSSION

Heart transplant recipients are a diagnostically difficult group, with coronary artery stenoses due to either vasculopathy or atherosclerosis. Their clinical course is often asymptomatic for a long time and as a result, it may lead to heart failure or even death [2]. As development and complications of vasculopathy are the most common cause of late mortality following heart transplantation, periodic evaluation of coronary arteries with invasive coronary angiography, sometimes combined with intravascular ultrasound (IVUS), has become routine in many centres [2]. Due to altered anatomy, invasive coronary angiography may be technically difficult and associated with an increased risk of complications related, among other, to difficulties in selective cannulation of coronary arteries and the need to administer a larger volume of a contrast agent. Another important limitation of invasive coronary angiography is its low (< 20%) sensitivity in detecting vasculopathy as compared to IVUS [6].

In contrast to invasive coronary angiography, CT angiography allows evaluating not only the vessel lumen but also quality and structure of the vessel wall. This method proved useful in symptomatic patients at moderate risk of CAD and

is currently recommended in the European Society of Cardiology guidelines [7]. Regarding evaluation of coronary arteries in heart transplant recipients, indications for CT angiography were considered uncertain in the joint statement of the American societies published in 2010 [4]. Difficulties with noninvasive imaging of coronary arteries in this patient group are related to rapid resting HR that usually responds poorly to HR-lowering drug therapy. In heart transplant recipients, resting HR usually ranges between 80 and 100 bpm and only rarely it is possible to lower it to about 60 bpm. Performing a diagnostic examination thus requires availability of a technically advanced CT scanner and appropriately experienced personnel. Evaluation of the clinical usefulness of CT angiography is even more difficult due to a limited number of published studies on this issue that have usually reported small patient groups [8–13]. This is clearly related to the fact that heart transplant recipients constitute a small minority of all patients undergoing coronary CT angiography, and experience is limited to a few centres (usually those performing heart transplantation or closely collaborating with such centres).

In the present study, we reported our experience with DSCT as an alternative to invasive coronary angiography in

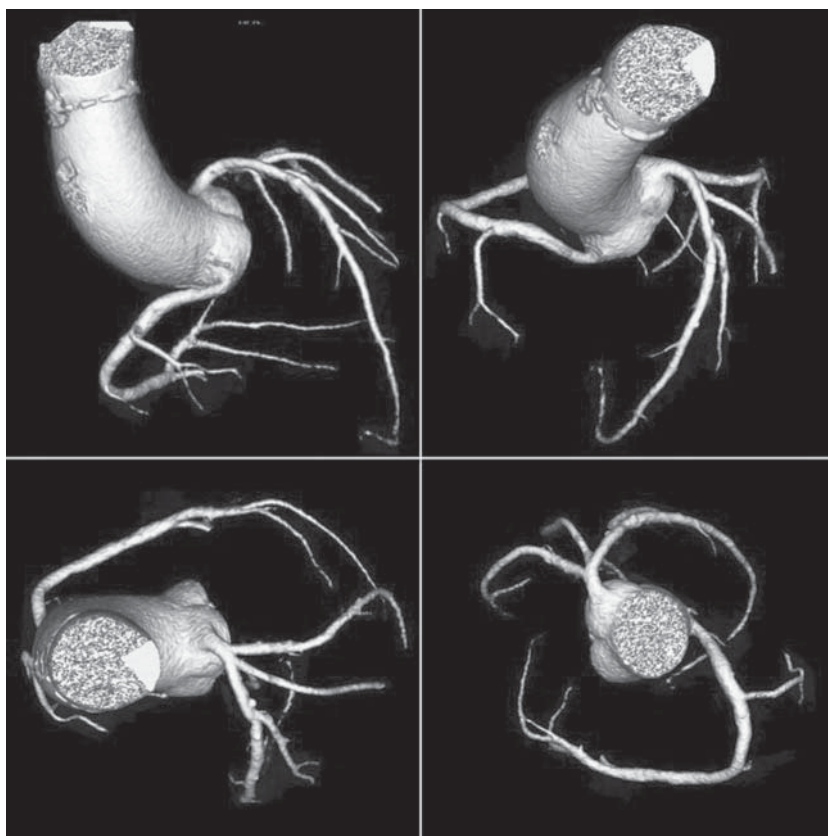


Figure 4. Computed tomography, volume reconstructions (VRT). An image of the ascending aorta and coronary arteries

the evaluation of coronary arteries in heart transplant recipients. As far as we know, this is the first report on this issue published in Poland. An appropriately designed exam protocol resulted in high sensitivity and specificity in the identification of coronary stenoses and provided diagnostic information about all segments with the lumen diameter above 1.0 mm. As compared to invasive coronary angiography, sensitivity of CT angiography in per segment, per vessel, and per patient analyses was 100%, and specificity was 99–100%, 97%, and 94%, respectively. Based on CT angiography, > 50% stenoses were diagnosed in 2 segments of the left coronary artery in 1 patient which were not confirmed by invasive coronary angiography. Both stenoses were located in distal segments with the lumen diameter ranging from 1.0 mm to 1.5 mm, and their diagnosis did not lead to consideration of coronary revascularisation. Our findings also confirm a very high negative predictive value of CT angiography, up to 100%, and a very good diagnostic accuracy of this modality (95–100%). Our experience indicates that data quality is clearly related to the phase of the cardiac cycle in which reconstruction is performed. In practice, this requires that both systolic and diastolic reconstructions are available and thus dictates the choice of acquisition protocol. Among available protocols, only retrospectively ECG-gated acquisition allows later

reconstructions in various phases of the cardiac cycle between 25% and 80% of the R-R interval. A significant limitation of this approach is patient exposure to a high radiation dose. Other available acquisition protocols (e.g., prospective ECG-gating) usually allow significant reduction of radiation dose compared to our protocol but do not allow to obtain data from several phases of the cardiac cycle [14] and thus their use would increase the proportion of nondiagnostic segments. The most important approach to reduce radiation dose in case of a retrospectively ECG-gated protocol involved reducing lamp voltage from 120 kV to 100 kV. Effective radiation dose in the overall study population was below 13 mSv and was significantly lower in those patients in whom lamp voltage could be reduced (i.e., patients with body mass < 80–85 kg). Of note, mean radiation dose related to the examination has been high and may be a significant limitation of this method despite use of available approaches aiming at its reduction (including maximum reduction of the scope of the examination, reducing lamp voltage, and using ECG-dependent modulation of the lamp current). Recently, early reports have been published on coronary CT angiography performed using a modified prospectively ECG-gated protocol which allowed reduction of the radiation dose but simultaneously maintained high sensitivity and specificity of the method [15].

The number of publications evaluating usefulness of coronary CT angiography in heart transplant recipients has been small, and such studies usually report on small patient groups [8–13]. The most important conclusions from the available reports include the following: (1) evaluation of coronary arteries is performed with the use of newest generation scanners, i.e. at least 64-row CT detectors; (2) diagnostic images are often obtained in the systolic phase, which is related to shortening of the end-diastolic phase at rapid HR; (3) narrow segments (diameter 1.0–1.5 mm) are excluded from the analysis due to poor image quality; (4) the proportion of nondiagnostic segments ranges from 1.0% to 2.2%; (5) radiation dose is usually higher compared to examinations currently performed to exclude significant CAD in other patients. These conclusions have clear clinical implications: (1) coronary CT angiography in heart transplant recipients usually requires an acquisition protocol that differs from the one that is typically used; (2) inability to evaluate narrow segment precludes definite exclusion of early vasculopathy; (3) if images of a given segment are nondiagnostic, atherosclerotic lesions cannot be excluded and the patient may require referral for invasive coronary angiography; (4) in heart transplant recipients, exposure to a high radiation dose may be required.

Administration of a contrast agent in heart transplant recipients is associated with a greater than usual risk of contrast-induced nephropathy, which may be related to baseline renal dysfunction and/or immunosuppressive therapy. Mean volume of the contrast agent administered during coronary CT angiography in the analysed patient group was similar to the volume administered during invasive coronary angiography. Noninvasive imaging was not associated with an increased risk of renal complications.

Limitations of the study

In our study, we did not analyse vasculopathy that did not result in a significant vessel stenosis. Reliable assessment of the presence and severity of vasculopathy requires verification using IVUS. At the time when this study was performed, intravenous ivabradine was not available in Poland. It is possible that the use of this drug might result in a more effective HR reduction in heart transplant recipients. Administration of oral ivabradine would be logistically difficult in the routine clinical practice. Due to lack of data allowing direct comparisons, we did not analyse the radiation dose the patients were exposed for during invasive coronary angiography.

CONCLUSIONS

Dual-source CT is a clinically useful alternative to invasive coronary angiography for excluding significant coronary stenoses in heart transplant recipients. A high negative predictive value of this method is particularly important. High sensitivity, specificity, and diagnostic accuracy make DSCT a useful clinical tool. Effective imaging of coronary arteries is technically feasible even at rapid HR but requires modification of

typically used data acquisition protocols. With the current technology, technical limitations practically preclude performing these examinations under exposure to a very low radiation dose.

Conflict of interest: none declared

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Przydatność dwuźródłowej tomografii komputerowej w ocenie tętnic wieńcowych u pacjentów po przeszczepieniu serca

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Streszczenie

Wstęp: Pacjenci po przeszczepieniu serca wymagają okresowej oceny tętnic wieńcowych w celu wykluczenia istotnych zwężeń spowodowanych waskulopatią lub zmianami miażdżycowymi. Dotychczas metodą referencyjną w tej grupie pacjentów pozostaje inwazyjna koronarografia. W niniejszej pracy przedstawiono własne doświadczenia z dwuźródłową tomografią komputerową (DSCT) jako techniką alternatywną dla koronarografii.

Cel: Celem pracy była ocena dokładności diagnostycznej i przydatności klinicznej DSCT w ocenie tętnic wieńcowych u pacjentów po przeszczepieniu serca.

Metody: Prospektywnie przeanalizowano dane 20 kolejnych pacjentów po przeszczepieniu serca, u których zaplanowano koronarografię ze wskazań klinicznych, a dodatkowo wykonano DSCT. Kryteriami wyłączenia były: brak zgody i klirens kreatyniny < 45 ml/min. Za zmiany istotne uznawano te, które zawężyły światło naczynia o co najmniej 50%. Oceniano obecność istotnych zwężeń w tętnicach wieńcowych, jakość otrzymanych obrazów, liczbę segmentów niediagnostycznych, wpływ fazy cyklu pracy serca na jakość uzyskanych danych, dawkę promieniowania związaną z badaniem. Analizowano czułość, swoistość i trafność diagnostyczną DSCT w porównaniu z koronarografią.

Wyniki: Wszystkie wyniki DSCT były diagnostyczne, a badania wykonane bez powikłań. Częstość rytmu serca wynosiła 63–114/min (śr. 85/min) i była stabilna u 85% pacjentów. Spośród 287 analizowanych segmentów 4 oceniono jako zwężone > 50%, w koronarografii obecność zwężenia potwierdzono w 2 segmentach. Czułość, swoistość i dokładność diagnostyczna DSCT wyniosła odpowiednio: (1) w analizie *per segment* dla lewej tętnicy wieńcowej (LTW): 100%, 99%, 99%, dla prawej tętnicy wieńcowej (PTW) po 100%; (2) w analizie *per vessel* 100%, 97%, 97%; (3) w analizie *per patient* 100%, 94%, 95%. Obraz niediagnostyczny w rekonstrukcjach rozkurczowych stwierdzano istotnie częściej w segmentach należących do PTW (25%) niż do LTW (11,5%); $p = 0.003$. Segmenty PTW były istotnie lepszej niż LTW jakości w rekonstrukcjach skurczowych (63,5% vs. 42,2%; $p < 0,001$). Średnia efektywna dawka promieniowania wynosiła 5,4–18,7 mSv (śr. 12,7 mSv).

Wnioski: DSCT jest przydatną klinicznie alternatywą dla koronarografii w wykluczaniu istotnych zwężeń tętnic wieńcowych u pacjentów po przeszczepieniu serca. Szczególnie ważna jest bardzo wysoka negatywna wartość predykcyjna metody. Wysoka czułość, swoistość i dokładność diagnostyczna czynią z DSCT technikę przydatną w praktyce klinicznej. Skuteczne obrazowanie tętnic wieńcowych przy szybkiej czynności serca jest technicznie możliwe, lecz wymaga modyfikacji typowo stosowanych protokołów akwizycyjnych. Przy obecnym rozwoju technologii ograniczenia techniczne praktycznie uniemożliwiają wykonywanie badań z narażeniem pacjenta na bardzo niską dawkę promieniowania.

Słowa kluczowe: tomografia komputerowa, tętnice wieńcowe, przeszczep serca

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