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Predictors of disagreement between prospectively ECG-triggered dual-source coronary computed tomography angiography and conventional coronary angiography

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ABSTRACT

Aims: To identify causes of misinterpretation in second generation, dual-source coronary computed tomography angiography (CCTA).

Methods: A retrospective re-interpretation was performed on 100 consecutive CCTA studies, previously performed with a 2 × 128 slice dual-source CT. Results were compared with coronary angiography (CA). CCTA and CA images were interpreted by 2 independent readers. At CCTA vessel diameter, image quality, plaque characteristics and localization (bifurcation vs. non) were described for all segments. Finally, aortic contrast-to-noise ratio (CNR) and the total Agatston calcium score were quantified. Agreement between CCTA and CA was assessed with the Kappa statistic after categorizing the stenosis severity at significant (≥50%) and critical (≥70%) cut-offs, and independent predictors of disagreement were determined by multivariable logistic regression, including patient characteristics such as body mass index (BMI), heart rate (HR), age and gender.

Results: Per-segment sensitivity and specificity at ≥50% and ≥70% stenosis was of 83–95%, and 73–97%, respectively. There was a substantial agreement between CCTA and CA (kappa-50% = 0.78, SE = 0.03; kappa-70% = 0.72, SE = 0.03). Worse motion-related quality score, smaller vessel diameter, calcification within the segment of interest and LAD location were independent predictors of disagreement at 50% stenosis. The same factors, excluded LAD location, in addition to bifurcation-location of the coronary lesion predicted misdiagnosis at 70% stenosis. HR per se and BMI did not predict disagreement.

Conclusion: According to the literature a substantial agreement between CCTA and CA was found. However, discrepancies exist and are mainly related with motion-related degradation of image quality, specific vessel anatomy and plaque characteristics. Awareness of such potential limitations may help guiding interpretation of CCTA.

1. Introduction

Coronary computed tomography angiography (CCTA) has become a very robust imaging modality for the non-invasive evaluation of coronary artery disease (CAD). The excellent diagnostic accuracy was confirmed by several multi-center trials [1–3]. Accordingly, CCTA is widely used in clinical practice. Recently, second-generation dual-source CCTA technology has been made available for clinical use, allowing for excellent image quality with a low radiation exposure [4,5]. However, also second-generation low-dose technology CCTA is subject to some limitations that may compromise image quality [6–8]. Even though some factors, such as excessive coronary calcification or motion-related artifacts are well known to limit accurate evaluation of CAD by CCTA, little data comprehensively addressing the impact of multiple image- and patient-related characteristics on diagnostic accuracy of CCTA are available. This is particularly true for dual-source CCTA, where utilization of specific acquisition protocols such as prospective

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ECG-gated acquisition ("step-and-shoot") or high-pitch spiral ("flash"), that may be subject to other limitations as compared with retrospective acquisition, is encouraged for further reduction of radiation exposure. This study was therefore aimed to identify causes/predictors of misinterpretation of CAD evaluation by second-generation dual-source CCTA.

2. Material and methods

2.1. Study design and population

This was a retrospective, observational, single center study. One hundred consecutive patients undergoing invasive coronary angiography (CA) following CCTA at the Cardiocentro Ticino between January 2011 and September 2012 were included in this analysis. Both procedures, performed based on clinical indication, were retrospectively re-interpreted by 2 independent observers (1 for CCTA, S.M., and 1 for CA, D.S.), who were blinded for clinical indication, patient characteristics, and results of the CCTA and CA study, respectively. To test the inter-observer variability of CCTA imaging interpretation, a second reader (R.M.) performed an independent reading of 20 out of 100 randomly selected CCTA cases, blinded for the results of the first reader and for the CA results.

2.2. CCTA protocol

All CCTA-scans were performed on a 2 × 128-slice dual-source CT (Somatom, Definition Flash, Siemens, Erlangen, Germany) by using a prospective ECG-gated (n = 78) or high-pitch spiral (n = 22) protocol. Non-contrast-enhanced, ECG-triggered acquisition was initially performed for calcium-scoring in 90 patients (90%). High-pitch spiral protocol (tube potential = 100 kV if BMI < 30 kg/m^2, 120 kV if ≥30 kg/m^2, pitch = 3.4, tube current time product was adjusted according to CARE Dose4D with a reference value of 320 mAs) was applied in case of imaging of native vessels and regular heart rate (HR) < 60 b.p.m. Prospective, ECG-triggered acquisition at a single diastolic phase (tube potential = 100 kV if BMI < 30 kg/m^2, 120 KV if ≥30 kg/m^2, tube current time product adjusted according to CARE Dose4D with a reference value of 296 mAs) was implemented if HR was between 60 and 70 b.p.m., and at multiple phases (40–80% of the RR-interval) if >70 b.p.m. or irregular HR. Further dose reduction with "ECG pulsing" in systolic phases was adopted in patients with BMI ≤ 25 kg/m^2. Detector collimation was 128 × 0.6 mm. The typical field of view was of 200 mm with a fix matrix of 512 × 512, generating a pixel size of 0.39 mm. Patients were treated with oral beta-blockers from the day before CCTA scan and, if necessary, additional intravenous Metoprolol was administered before CCTA to achieve a target HR < 60 b.p.m. (all patients were on sinus rhythm). All patients received 2.5 mg of sublingual isosorbide dinitrate 3–5 min before scanning. Contrast transit time was determined after injection of 10 ml of contrast agent and saline flush. Contrast agent (Iomeron, Bracco, 75 ml) followed by 40 ml saline was then injected both at a rate of 6 ml/second for CCTA. Images were reconstructed at 0.6 mm slice thickness with both, standard-soft-tissue (B26) and sharp-tissue (B46) convolution kernel for the best diastolic phase. Sharp convolution kernel reconstruction was also performed for other phases of the cardiac cycle at discretion of the reading physician. For the current analysis sharp convolution kernel images were used in case of important calcification of the vessel at discretion of the reader. The final HR achieved during CCTA, body height and weight were registered.

2.3. CCTA interpretation

One single observer, who was blinded for clinical and CA information, interpreted the CCTA scans by using an 18-coronary-segment model [9]. The most relevant lesion within the segment of interest was graded in terms of luminal stenosis by visual assessment into 4 categories: (1) disease-free segment; (2) lesion with <50% stenosis; (3) 50–69% stenosis; (4) ≥70% stenosis [9]. Transaxial images, manual multi-planar reconstructions and curved, centerline-based, multi-planar reconstructed images were used for evaluation on a dedicated workstation (Syngo, Circulation, Siemens). In case of multiple-phase acquisition the best phase for every vessel was identified and used. Regardless of the image quality every segment was evaluated. On the other hand, exclusion criteria for segments were defined a priori, including: (1) anatomically missing segments, (2) stented segments, (3) segments downstream to a total occlusion, (4) segments being insufficiently represented by CA for QCA analysis. Segments were analyzed for luminal diameter (measured at the widest and possibly disease-free part of the segment of interest) and motion-related image quality using a previously validated semi-quantitative 4-point score: 1 = excellent image quality (clear segment delineation); 2 = good (minor artifacts/mild blurring); 3 = adequate (moderated artifacts/blurring) and 4 = non-evaluative (doubling or discontinuity of the vessel) [10]. In presence of a coronary lesion, the type of plaque was described as: (1) non-calcified, (2) calcified, or (3) mixed. Furthermore, the localization of the plaque within the segment was described as bifurcation- or non-bifurcation lesion. The aortic contrast-to-noise ratio (CNR) was calculated as previously described [11] and the Agatston-calcium-score was calculated in patients with available non-contrast images (Syngo, CaScoring, Siemens).

Table 1
Segmental diagnostic accuracy and level of agreement between CCTA and CA.

	Total number of evaluated segments = 1265	
	≥50% stenosis	≥70% stenosis
AUC, mean (95%-CI)	0.89 (0.87–0.91)	0.85 (0.81–0.89)
Stenosis by CCTA, no. (%)	261 (21%)	133 (11%)
Stenosis by CA, no. (%)	259 (20%)	143 (11%)
False positive, no. (%)	47 (4%)	29 (2%)
False negative, no. (%)	45 (4%)	39 (3%)
Sensitivity, % (95%-CI)	83 (78–87)	73 (65–80)
Specificity, % (95%-CI)	95 (94–97)	97 (96–98)
Positive predictive value, % (95%-CI)	82 (77–87)	78 (70–85)
Negative predictive value, % (95%-CI)	96 (94–97)	97 (95–98)
Kappa-statistic (standard-error)	0.78 (0.03)	0.72 (0.03)

CCTA: coronary computed tomography angiography; CA: coronary angiography; AUC: area under the receiver operator characteristic curve; CI: confidence interval; Kappa: Coehen's Kappa statistic of agreement.

2.4. CA protocol and image interpretation

Following the CCTA examination, all patients underwent CA using a standard technique. Angiograms were analyzed using quantitative coronary analysis (QCA) by an independent blinded reviewer (Xcelera 1.2 L4SP1, Philips Medical System, Best, The Netherlands). To define coronary segments analogous to the CCTA reviewer, the same 18-coronary-segment model was used as for CCTA. Coronary lesions were analyzed in several projections. The outer diameter of the contrast-filled guiding catheter was used for calibration. For every segment, the presence of a coronary lesion was established. In case of positive finding, the severity of the most relevant lesion within the segment of interest was evaluated measuring per-cent diameter stenosis in several angiographic views. The severity of any coronary lesion was then graded into 4 categories as for CCTA.