European Journal of Radiology 85 (2016) 830–836

Contents lists available at ScienceDirect

European Journal of Radiology

journal homepage: www.elsevier.com/locate/ejrad

Evaluation of individually body weight adapted contrast media injection in coronary CT-angiography

Casper Mihl[a,b,*,1], Madeleine Kok[a,b,1], Sibel Altintas[b,c], Bas L.J.H. Kietselaer[a,b,c], Jakub Turek[a,b], Joachim E. Wildberger[a,b], Marco Das[a,b]

[a] Department of Radiology, Maastricht University Medical Center, P. Debyelaan 25, PO Box 5800, 6202 AZ Maastricht, The Netherlands
[b] CARIM School for Cardiovascular Diseases, Maastricht University Medical Center, Maastricht, The Netherlands
[c] Department of Cardiology, Maastricht University Medical Center, P. Debyelaan 25, PO Box 5800, 6202 AZ Maastricht, The Netherlands

ARTICLE INFO

Article history:
Received 22 August 2015
Received in revised form
14 November 2015
Accepted 29 December 2015

Keywords:
Diagnostic imaging
Contrast media
Computed tomography
Cardiac imaging technique
Body weight

ABSTRACT

Objectives: Contrast media (CM) injection protocols should be customized to the individual patient. Aim of this study was to determine if software tailored CM injections result in diagnostic enhancement of the coronary arteries in computed tomography angiography (CTA) and if attenuation values were comparable between different weight categories.
Materials and methods: 265 consecutive patients referred for routine coronary CTA were scanned on a 2nd generation dual-source CT. Group 1 ($n = 141$) received an individual CM bolus based on weight categories (39–59 kg; 60–74 kg; 75–94 kg; 95–109 kg) and scan duration ('high-pitch: 1 s; "dual-step prospective triggering": 7 s), as determined by contrast injection software (Certegra^{TM} P3T, Bayer, Berlin, Germany). Group 2 ($n = 124$) received a standard fixed CM bolus; Iopromide 300mgI/ml; volume: 75 ml; flow rate: 7.2 ml/s. Contrast enhancement was measured in all proximal and distal coronary segments. Subjective and objective image quality was evaluated. Statistical analysis was performed using SPSS (IBM, version 20.0).
Results: For group 1, mean attenuation values of all segments were diagnostic (>325 HU) without statistical significant differences between different weight categories ($p > 0.17$), proximal vs. distal: 449 ± 65–373 ± 58 HU (39–59 kg); 443 ± 69–367 ± 81 HU (60–74 kg); 427 ± 59–370 ± 61 HU (75–94 kg); 427 ± 73–347 ± 61 HU (95–109 kg). Mean CM volumes were: 55 ± 6 ml (39–59 kg); 61 ± 7 ml (60–74 kg); 71 ± 8 ml (75–94 kg); 84 ± 9 ml (95–109 kg). For group 2, mean attenuation values were not all diagnostic with differences between weight categories ($p < 0.01$), proximal vs. distal: 611 ± 142–408 ± 69 HU (39–59 kg); 562 ± 135–389 ± 98 HU (60–74 kg); 481 ± 83–329 ± 81 HU (75–94 kg); 420 ± 73–305 ± 35 HU (95–109 kg). Comparable image noise and image quality were found between groups ($p \geq 0.330$).
Conclusions: Individually tailored CM injection protocols yield diagnostic attenuation and a more homogeneous enhancement pattern between different weight groups. CM volumes could be reduced for the majority of patients utilizing individualized CM bolus application.

1. Introduction

Contrast media (CM) injection parameters, CT scan technique and patient-related factors are the most important factors influencing contrast enhancement characteristics [1,2]. As current CM application protocols in coronary computed tomographic angiography (CCTA) are aimed at shorter acquisition times and reduced tube voltage (kV), CM bolus shaping necessitates adaptation and optimal synchronization with the scan protocols [3–5].

In terms of patient related factors, a correlation between intravascular attenuation and body weight has been suggested previously [6,7]. Additionally, physical factors such as cardiac output

Abbreviation: CM, contrast media; CTA, computed tomography angiography; CCTA, coronary computed tomographic angiography; CT, computed tomography; IDR, iodine delivery rate; TIL, total iodine load; HU, Hounsfield units; CAD, coronary artery disease; BPM, beats per minute; SD, standard deviation; ROI, region of interest; LAD, left anterior descending artery; Cx, circumflex artery; RCA, right coronary artery; AHA, American Heart Association; SD, standard deviation; IQR, interquartile range; BMI, body mass index.

* Corresponding author. Fax: +31 43 3877093.
E-mail address: caspermihl@mumc.nl (C. Mihl).
[1] These authors contributed equally to this work.

http://dx.doi.org/10.1016/j.ejrad.2015.12.031
0720-048X/

and muscle mass (concept of lean body weight) can differ substantially between patients with comparable body weight, which may be the cause of variability in solid organ and vascular enhancement [8–10]. A standard protocol with a standard injected CM volume, independent of weight and length of the patient, will undoubtedly lead to an over- and underestimation of the injected CM volume in certain weight categories, which potentially has consequences on image quality and attenuation of the coronary arteries [1]. Therefore, various study groups investigated solutions to overcome this non-homogeneous enhancement by usage of individually tailored injection protocols with promising results [11–16].

A dedicated contrast protocol software (P3T^{TM} Bayer Healthcare, Berlin, Germany) customizes a triphasic injection protocol for each patient and procedure, using patient weight, scan duration, CM concentration and timing attributes of a test bolus scan. The P3T^{TM} software adapts the iodine delivery rate (IDR, iodine delivered per second) and total iodine load (TIL) based upon a non-linear relationship between patient weight and scan duration in order to achieve diagnostic attenuation (>325 Hounsfield Units [HU]) [8,13,17].

Customized injection software might lead to diagnostic and comparable attenuation values of the coronary arteries for each individual patient and a more efficient use of injected CM volumes.

Aim of this study was to evaluate vascular attenuation of the coronary arteries as well as image quality and injection parameters within different weight classes by using software tailored body weight adapted CM bolus injection protocols and to compare this to a standardized injection protocol with fixed parameters.

2. Materials and methods

2.1. Study population

329 consecutive patients with stable symptoms of chest discomfort and suspected coronary artery disease (CAD) were referred for CCTA from the cardiology outpatient department within a period of 6 months. Patients with a calcium score >1000 were excluded from the study (n = 9). Additionally, patients weighing >109 kg were excluded as these patients were scanned with a tube voltage of 120 kV (n = 50). Patients with a heart rate >90 beats per minute (bpm) were excluded as these patients were scanned with a retrospectively gated helical protocol (n = 5). Thus, a total of 265 patients were prospectively included in this study. The included patients were divided into two groups: group 1 (n = 141) received an individually adapted injection protocol and group 2 (n = 124) received a fixed injection protocol.

Ethical approval was given and informed consent for the use of (coded) images was waived by the local ethical committee, as the data was analyzed anonymously in accordance with the Institutional Review Board guidelines (METC 14-4-049).

2.2. Injection and scan protocol

Scans were performed using a 2nd generation Dual-source CT scanner (Somatom Definition Flash; Siemens Healthcare, Forchheim, Germany) with a 128 × 0.6 mm slice collimation; gantry rotation time of 280 ms; tube voltage of 100 kV; tube current of 320 or 370 mAs_{ref} (CareDose 4D^{TM}, Siemens), depending on the scan protocol. Image reconstruction was done with individually adapted field of view (FOV) at 0.75 mm slice thickness with an increment of 0.5 mm using an I26f kernel (SAFIRE, Iterative reconstruction strength 2).

A non-contrast enhanced scan was performed to determine the calcium score (Agatston score). All patients received an oral dose of 50 mg metoprolol tartrate (Selokeen; AstraZeneca, Zoetermeer, The Netherlands), two hours before CCTA. When indicated, an additional dose of 5–20 mg metoprolol tartrate was administered intravenously to lower the heart rate to <60 bpm, if possible. A maximum dose of 0.8 mg nitroglycerine (Isordil®; Pohl-Boskamp, Hohenlockstedt, Germany) was given sublingually prior to CCTA. Heart rate and ECG were monitored during CCTA. In patients with a stable heart rate <60 bpm, a prospectively ECG-triggered "high

Table 1
Injection parameters for CCTA. Prewarmed (37°) CM was used (iopromide 300 mg/ml). CM: contrast media, TIL: total iodine load, IDR: iodine delivery rate, Adapt Seq: adaptive sequence.

Group	CM bolus (ml)	Mixed bolus (20%CM, ml)	Total volume (CM, ml)	TIL (g)	Saline flush (ml)	Flow rate (ml/s)	IDR (gI/s)	Injection time (s)
1 (P3T)								
39-59 kg								
'Adapt Seq'	**52**	**50 (10)**	**102 (62)**	**18.6**	**30**	**5.2**	**1.6**	**19.6**
'High pitch'	**41**	**50 (10)**	**91 (51)**	**15.3**	**30**	**5.2**	**1.6**	**17.5**
60-74 kg								
'Adapt Seq'	**56**	**67 (13.4)**	**123 (69.4)**	**20.8**	**30**	**5.6**	**1.7**	**22**
'High pitch'	**45**	**67 (13.4)**	**112 (58.4)**	**17.5**	**30**	**5.6**	**1.7**	**20**
75-94 kg								
'Adapt Seq'	**66**	**84 (16.8)**	**150 (82.8)**	**24.8**	**30**	**6.6**	**2.0**	**22.7**
'High pitch'	**53**	**84 (16.8)**	**137 (69.8)**	**20.9**	**30**	**6.6**	**2.0**	**20.8**
95-109 kg								
'Adapt Seq'	**74**	**102 (20.4)**	**176 (94.4)**	**28.3**	**30**	**7.4**	**2.2**	**23.8**
'High pitch'	**60**	**102 (20.4)**	**162 (80.4)**	**24.1**	**30**	**7.4**	**2.2**	**21.9**
2 (Control)	**75**	**-**	**75 (75)**	**22.5**	**50**	**7.2**	**2.2**	**10.4**