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# Which concentration to choose in dual flow cardiac CT? Dual flow cardiac CT

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ABSTRACT

*Purpose:* An extensive number of protocols have been suggested to allow for functional diagnostics; however, no data is available about the minimal amount of contrast medium to achieve reliable imaging properties. None of the plethora of existing studies report a rational why the specific concentration was chosen.

*Materials and methods:* A total of 40 patients were included in this prospective, controlled study. They were divided up into four equal groups getting a different concentration (10%, 20%, 30% or 40%) of a second contrast medium bolus. Corresponding septal and right ventricular ROIs were compared. A visual score was established. Coronary attenuation was measured in the right and left coronary artery. Streak artifacts in the right atrium/ventricle were assessed.

*Results:* In the 10% contrast medium (CM) group only in 5/10 (50%) patients full septal delineation was reached. In all other groups full septal visualization was obtained.

No group showed a relevant difference of mean density measured in HU units of the left ventricle or the coronary arteries. All study groups except of group 1 (10% CM) showed streak artifacts in the right atrium.

*Conclusion:* The dual flow protocol with a minimum concentration of 20% improves septal visualization as basis for left ventricular functional assessment, however, does not allow for reliable right ventricular or atrial visualization.

There is no significant difference between the different concentration protocols in terms of coronary attenuation.



## 1. Introduction

Several studies have shown the ability of multidetector computed tomography (MDCT) to assess comprehensive left ventricular function, not only assessing ejection fraction, endiastolic volume, endsystolic volume or stroke volume but also left ventricular mass [1]. For many cardiovascular diseases left ventricular function is a predictive factor for long-term survival [2]. While the assessment of the global cardiac function such as ejection fraction requires only the delineation of the left ventricular endocardial border in systole and diastole by definition, left ventricular mass determination or reliable motion wall analysis requires a full septal delineation. Many studies assume that the contrast injection protocol used for coronary imaging automatically allows for functional analysis [3]. Most contrast medium (CM) injection protocols for cardiac CT include a saline chaser bolus to facilitate the delivery of a compact CM bolus and have been extensively reported in a multitude of studies [4]. However, the geometry of the chaser bolus displays a wide variety of strategies. Either they do not take right ventricular opacification into account and use pure saline [6], which in our experience causes an early outwash of CM in the right ventricle in many patients and thus delineation of the septum diminishes or becomes impossible and precludes e.g. from left ventricular mass assessment. Some authors deliberately contrast only the left side of the heart to reduce CM influx artifacts [5]. Another strategy is the

*Abbreviations:* AHA, American Heart Association; ARVD, arrythmogenic right ventricular dysplasia; CAD, coronary artery disease; CM, contrast medium; ECG, electro-cardio-graphy; HU, hounsfield units; IRB, institutional review board; MDCT, multidetector spiral computed tomography; MPR, multi planar reformatted image; ROI (s), region(s) of interest.

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use of simultaneous injection of contrast and saline (dual flow protocols) allowing for good right ventricular opacification, which also has been reported extensively in many studies. Kerl et al. [6] could show that a chaser bolus containing 30% concentrated CM significantly improves evaluation of the cardiac septum and consequently assessing left ventricular hypertrophy. Other authors suggest the use of a saline chaser containing 60% CM in the saline chaser [7]. The smallest concentration of CM in the saline chaser reported is 20% [8]. However, none of the plethora of existing studies report a rational why the specific concentration was chosen, let alone a systematical evaluation examining which mixing ratio of the chaser bolus is the least necessary to achieve reliable results to opacify the right atrium and ventricle. Also claims are made that these dual flow protocols even allow for global right ventricular analysis [6]. The aim of this prospective study was to evaluate which dual flow concept and which minimum concentration improves septal visualization and provides reliable delineation of the cardiac septum allowing for comprehensive left ventricular functional analysis including left ventricular mass delineation. The second aim was to evaluate whether this protocol is able to opacify the right atrium/ventricle in such a way that principally right heart diagnostic would be possible as previously claimed. The aim of this study was not to analyze sensitivity or specificity in comparison to other imaging modalities such as echocardiography or MRI but to establish a reliable contrast protocol allowing for such studies.

## 2. Materials and methods

### 2.1. Study population

A total of 40 patients were included in this study. All patients participating in this study underwent diagnostic CT coronary angiography in our institution. Only patients in stable clinical condition, in sinus rhythm, without implanted pacemakers or valve prostheses, and without contraindications to the administration of iodinated contrast agent were included in the study. Patients with a possible pregnancy or an acute coronary syndrome were excluded. All patients gave written informed consent, and the protocol was approved by the institution review board.

The patients were randomly distributed into four groups with $n = 10$ each. The study groups received apart from the main contrast bolus a different saline chaser bolus, which contained different amounts of contrast medium (10%, 20%, 30% or 40% contrast medium). Note that no pure saline chaser group was analysed as reference standard since it is known from previous studies that a CM saline mixture is beneficial compared to a pure saline chaser.

### 2.2. MDCT Protocol

All patients received 100 mg atenolol (Tenormin, AstraZeneca, Wedel, Germany) orally. Additionally up to 20 mg metoprolol (Beloc, AstraZeneca, Wedel, Germany) was administrated intravenously if the heart rate was ≥70 beats per minute (bpm). All patients received 0.8 mg isosorbide dinitrate sublingually 3–5 min prior to scanning. The average heart rate was 58 ± 10 bpm. Scan parameters were: acquisition of 64 slices per rotation (SOMATOM Sensation 64, Siemens Healthcare, Forchheim, Germany), slice collimation 0.6 mm, rotation time 330 ms, table feed 3.8 mm per rotation, tube voltage 120 kV, and tube current 750 mAs. ECG-gated tube current modulation was used in all patients.

### 2.3. Dual flow concept

The contrast agent transit time was determined with a bolus injection of 10 ml contrast agent, followed by 50 ml saline solution.

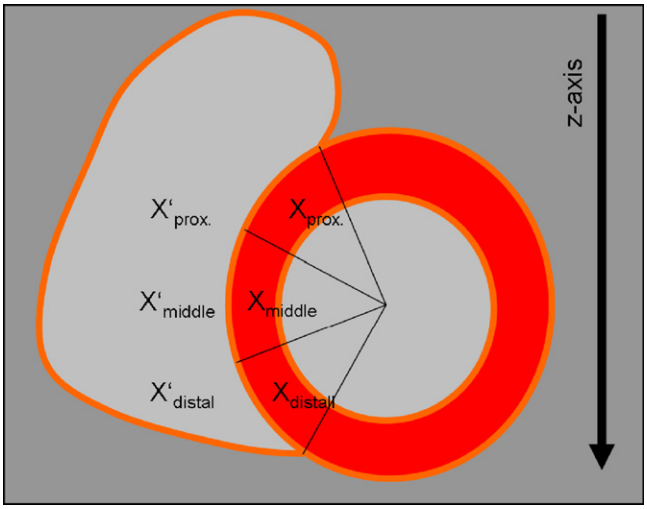


**Fig. 1.** Scheme for evaluation of interventricular septum and right ventricle in a modified short axis view in the *yz*-plane
To obtain this view only the *x*-axis was aligned septum parallel. The *y*-axis was aligned orthogonal to *x*-axis. The *xy*-plane, however, was not aligned through the mitral valve and the apex of the heart. Since equal position on *z*-axis corresponds to equal scantime it was chosen to guarantee that corresponding ROIs in the interventricular septum and the right ventricle were scanned at the same time. The septum was divided into three segments, proximal, middle and distal by three equiangular radial segments with the center point being the middle of the left ventricle.

For acquisition of the volume data set the patients received the following amounts of additional contrast:

Group 1: 10% CM saline chaser bolus: 5 ml CM/45 ml saline.
Group 2: 20% CM saline chaser bolus: 10 ml CM/40 ml saline.
Group 3: 30% CM saline chaser bolus: 15 ml CM/35 ml saline.
Group 4: 40% CM saline chaser bolus: 20 ml CM/30 ml saline.

All injections were performed using a dual head injector pump (Stellant CT, Medrad Inc., Warrendale, PA, USA).

## 3. Data analysis

The best dataset was used for evaluation on an offline workstation (syngo workplace, Siemens Healthcare, Forchheim, Germany). Coronary segments were defined according to a modified AHA 13-segment model [9]. MDCT data sets in a modified short heart axis view parallel to the *z*-axis were evaluated by two experienced blinded observers in a joint reading. The modified short axis assured that corresponding evaluated ROIs in the septum and the right ventricle were scanned at the same time. For evaluation, window and center levels were kept constant for all patients (width 600, center 200). Since the modified short axis view does not fully correspond to the established 17 segment AHA classification, the terms "basal", "middle" and "apical" as well as "septal", "anteroseptal" and "inferoseptal" were replaced by the term proximal, middle and distal septum (Fig. 1).

For semi quantitative evaluation, a visual score was established to assess septal delineation (0 = no visual difference between septum and right ventricle, 1 = septum partially delineated, 2 = septum fully delineated).

For quantitative evaluation, ROIs with at least an area of 2 $mm^2$ were measured. One ROI in the center of the left ventricle served as standard. The interventricular septum was divided into three segments of equal size. In each sector a ROI was measured in the septum as well as in the right ventricle (Fig. 1).