Right Heart: Split-Bolus Injection of Diluted Contrast Medium for Visualization at Coronary CT Angiography

J. Matthias Kerl, James G. Ravenel, Shaun A. Nguyen et al.

(Radiology 2008; 247: 356-364)

Reviewed by Ding-Kwo Wu, M.D.

(Kaohsiung Medical University Hospital, Kaohsiung Medical University, Taiwan)

Review

Considerable effort is being directed at optimizing injection parameters for contrast material–enhanced computed tomographic (CT) applications in cardiac examinations in particular (1–4) to ensure high, homogeneous, and consistent vascular attenuation while artifacts are minimized. The introduction of dual-syringe injectors with the ability to "chase" the main contrast medium bolus with saline (4–8) has been a pivotal development for achieving this objective. It has been demonstrated that this approach can result in suppression of streak artifacts from high-attenuation contrast medium in the superior vena cava (SVC) and the right heart (6) while high and consistent attenuation in the arterial system is maintained (2). However, in many patients, use of the saline chaser technique flushes all contrast material from the right heart so effectively (4) that right cardiac anatomy and potential disease, like thrombi and tumors, although rare, can no longer be assessed.

This month's "***ASCI Choice*** " chose Kerl et al's study in which they proposed " Split-Bolus Injection " was superior to "Saline-Chaser" and conventional "Monophasic" contrast medium injection in the suppression of streak artifacts in the SVC and RA, while maintaining adequate visualization of essential structures in the RV, LV as well as coronary artery. The delay time was determined with injection of a test bolus (20mL of contrast delivered at 5mL/sce). In group 1, the actual enhancement was achieved with 50–75 mL of contrast material. In group 2, 50–75 mL of contrast material was also injected, followed by a 50-mL saline chaser bolus. In group 3, a split-bolus protocol was used, with injection of 50–75 mL of contrast material followed by a constant volume of 50 mL of a 70%:30% saline to contrast medium mixture and 30 mL of pure saline, as empirically recommended by the manufacturer. All injections were given at 5mL/sec.

Analyses for both the RA and the RV indicated that the attenuation in the split-bolus group (group 3) was significantly higher than that in the biphasic group (group 2). The attenuation in the monophasic group (group 1) was significantly higher than that in groups 2 and 3. The

attenuation measurements in the LA and LV, as well as those in the proximal and distal segments of the RCA, LAD artery, and LCX artery, were not significantly different among the monophasic, biphasic, and split-bolus groups.

In the monophasic group, the prevalence of streak artifacts was 100% in the SVC and 94% in the RA. Streak artifacts in the SVC and RA, respectively, occurred in 34% and 59% of studies in the biphasic group and in 91% and 67% of studies in the split-bolus Group. As compared with values in group 1, CT image quality in the SVC and the RA in groups 2 and 3 was significantly ($P > .05$, Duncan test) better and less affected by streak artifacts from high-attenuation contrast medium. There was no significant difference ($P > .05$, Duncan test) in the occurrence and severity of streak artifacts between groups 2 and 3.

The delineation of right heart structures (papillary muscles, moderator band, tricuspid valve, pulmonary valve, and RV myocardium respectively) received significantly lower scores ($P < .05$, Duncan test) in the monophasic group, and the biphasic group than in the split-bolus group. The scores for diagnostic visualization of left heart structures (papillary muscles, mitral valve, aortic valve, and LV myocardium, respectively) were not different among group.

The introduction of dual-syringe injectors facilitated the approach of "chasing" the main contrast medium bolus with saline (4–8). Flushing with saline solution only avoids pooling of contrast material in the injection system and in the arm veins, leading to better contrast material utilization (7) and improved bolus shaping, with more consistent and homogeneous attenuation of target vessels (2). Disturbing streak artifacts from in-flowing contrast material in the SVC and the right cardiac cavities, which may result in diagnostic pitfalls, such as artifactual stenosis of the proximal RCA due to overlying streaks (12), can be effectively avoided (2,6,10).

The absence of contrast material in the RA and RV prohibits diagnosis of right heart disease, such as cavitary thrombi or tumors. Right heart structures, such as the tricuspid valve, pulmonary valve, and papillary muscles, cannot be assessed. Pathologic thickening of the RV myocardium (eg, that secondary to pulmonary hypertension or fatty infiltration in patients with arrhythmogenic RV dysplasia) cannot be appropriately evaluated. Sufficient attenuation of the right heart is needed for more recent approaches to deriving parameters of RV function from CT scans (12, 13). Last, a prolongation of contrast medium attenuation within the pulmonary arteries along with high enhancement in the aorta and coronary arteries is a prerequisite for the assessment of all thoracic vascular territories for approaches to assessing patients with acute chest pain with a single contrast-enhanced ECG-gated study (14).

The split-bolus injection, may appear complicated in theory, provides sufficient attenuation for visualization of the right heart, while streak artifacts from high-attenuation contrast material can generally be avoided and arterial attenuation is maintained. These considerations prompted us to transition our clinical injection protocols from the biphasic saline chaser technique to the

described split-bolus protocol, as soon as the capability of moving both pistons of a dual-barrel injector simultaneously had been enabled on the injector systems.

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