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# First pass perfusion imaging to improve the assessment of left ventricular thrombus following a myocardial infarction

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ABSTRACT

*Purpose:* To assess whether a first-pass perfusion sequence (FPP) improved the detection of left ventricular thrombus (LVT).
*Materials and methods:* Three hundred and twenty-nine patients with a first STEMI were prospectively included to undergo cardiac magnetic resonance (CMR) at baseline and after a 3-month follow-up. A CMR delayed analysis was performed by three blinded examiners (2 CMR experts and 1 novice) according to a two-step reading protocol. First, an analysis was performed on cine CMR and late gadolinium enhancement (routine stage). Then, the FPP stage was performed following initial protocol along with a FPP sequence.
*Results:* LVT was found in 31 out of a total of 638 (4.9%) CMR scans, affecting 30 (9.1%) individuals. All were located in the left ventricular apex. The FPP stage improved significantly the LVT diagnosis for all readers, in 10 and 13 cases (32% and 42%) of LVT suspicion for the experts and 16 cases (41%) for the novice. Respectively 1, 2 and 6 LVT were not detected during the routine stage by the CMR experts and the novice. For the novice, the FPP stage improved diagnosis sensitivity from 78.1 to 91.2%.
*Conclusions:* The prevalence of LVT following a myocardial infarction reached 9.1% and increased with the reading of FPP sequence. The FPP stage improved expert diagnostic certitude and the novice's abilities to reach expert level.



## 1. Introduction

Left ventricular thrombus (LVT) is a common complication following a large myocardial infarction. Its prevalence varies between 3.5% and 26% [1,2], with higher rates found among anterior infarction and depressed left ventricular ejection fraction (LVEF). The detection of LVT is essential to prevent embolic complication [3,4], however it seems to depend on the imaging approach used. Nowadays, cardiovascular magnetic resonance imaging (CMR) is known to present a higher accuracy than transthoracic or transesophageal echocardiography for LVT diagnosis. Prior studies have reported that sensitivity and specificity of transthoracic echocardiography were 23% to 33% respectively compared to 88% for CMR [4,5], reflecting certain echocardiography issues, such as poor acoustic window or contrast. Late gadolinium enhancement (LGE) differentiates LVT from the surrounding myocardium given that thrombus is avascular and thus characterized by an absence of contrast uptake [6]. Nevertheless, sometimes the interpretation of LGE is difficult, especially in the case of large infarct size with microvascular obstruction (MVO). First-pass perfusion (FPP) relates to the sequential transit of a contrast agent, first through the cardiac chambers and then the myocardium. It theoretically allows to identify LVT from a cavity and trabeculations, as well as LVT from a healthy or damaged myocardium. To the best of our knowledge, no study has evaluated the contribution of FPP in improving the diagnostic sensitivity for LVT [7].

This study sought to assess whether a first-pass perfusion sequence improved the detection of LVT.

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## 2. Methods

A total of 329 patients presenting a first STEMI were enrolled consecutively and prospectively between May 2006 and September 2014 in one single university hospital. All were treated successfully with primary percutaneous coronary intervention, and a final TIMI flow grade 3 was obtained. All patients gave written informed consent and underwent CMR at baseline (day 6 [IQ range 4;8]) and at a 3-month follow-up (day 98 [IQ range 93;105]). Exclusion criteria were a coronary bypass grafting, age <18 years, a major comorbidity limiting life expectancy in the year and a contraindication for CMR. The protocol was approved by the local institutional ethics committee, and the study was conducted in accordance with the declaration of Helsinki and local regulatory requirements. CMR at 3 months was not performed for various reasons: one death, one defibrillator implantation and 16 refusals. As a result, 311 patients underwent CMR at 3 months. Two uninterpretable examinations were registered at 3 months.

### 2.1. Cardiovascular magnetic resonance

CMR was performed using either a 1.5 or 3.0 T imager (Avanto or Skyra, Siemens, Erlangen, Germany) with the application of an 8-element phased-array cardiac receiver coil. Cine CMR was performed using the steady-state free precession sequence in multiple short-axis, and four-chamber long-axis views covering the entire left ventricle (LV). The typical in-plane resolution applied was 1.2 mm × 1.2 mm, with a 7 mm section thickness and no gap (matrix: 155 × 288; temporal resolution: 45–50 msec).

FPP was performed during the injection of gadolinium contrast agents at a dose of 0.2 mmol/kg (gadoterate meglumine, DOTAREM, Guerbet, Aulnay-sous-Bois, France). FPP images were acquired using saturation-recovery sequence with an acquisition time of 100 ms per section, TR 1.5 ms, TE 1.08 ms, flip angle 10°, and a typical in-plane resolution of 1.8 mm × 1.8 mm and a 7 mm section thickness. FPP series were acquired in three short-axis views covering the basal, mid-ventricular and apical segments and additionally in up to three junctive four-chamber long-axis views (depending on the individual's heart rate during the acquisition). The minimum duration of acquisition of the perfusion sequence was 35 s. Free breathing was permitted after the first passage of the contrast agent.

LGE sequences were performed 12–15 min after the injection, by means of a standard 2D segmented inversion recovery gradient-echo pulse sequence. An initial inversion time scout sequence was conducted to determine the optimal inversion time. Contiguous short axis and four-chamber long-axis slices covered the entire ventricle. Typical parameters used were: in-plane resolution of 1.6 mm × 1.6 mm, with a 7 mm section thickness; TE 4.66 ms; flip angle 30°; image acquisition triggered at every other heartbeat.

### 2.2. Image analysis

The CMR images were transferred to a workstation for analysis and calculation (Qmass 7.1, Medis, Leiden, The Netherlands). All images were interpreted independently by 3 readers: 1 novice (a resident with 1 years' experience in cardiovascular magnetic resonance imaging) and 2 experts (one senior with 7 years' experience, up to 500 CMRs a year, another with 5 years' experience, up to 300 CMRs a year). Readers were blinded to clinical history and transthoracic echocardiography results, as well as to each other's results. Readers interpreted all CMRs, consecutively (first the complete baseline set, then the 3-month), and independently in two separate stages: first examination with cine CMR and LGE (routine stage), and a second examination associating cine CMR and LGE with FPP (FPP stage). They estimated the presence or absence of LVT in 3 grades: 1) No LVT, 2) Evidence of LVT with high probability, and 3) LVT with absolute certitude. Expert senior readings both resulted in the diagnosis of the same 31 LVT cases. Hence expert results following the FPP stage constituted the gold standard for diagnosis of LVT.

For cine CMR, LVT was defined as a mass within the cavity, with borders distinguishable from ventricular endothelium, trabeculation and chordae. On FPP, LVT appeared as an intracavitary low signal mass. Finally, on LGE sequence, it appeared as a low signal intensity mass surrounded by high signal intensity structures such as cavity blood or enhanced myocardium. LVT were cautiously distinguished from areas of MVO [8]. A diagnosis of LVT at baseline CMR was defined as "early LVT", while LVT at 3-month was defined as "late LVT".

To avoid overestimation from partial volume effects, LVT long axis rather than volume was measured in order to define LVT size as an order of magnitude. Signal-to-noise ratio (SNR) values were calculated as the mean signal intensity for regions of interest placed over the center of the LVT as well as the inside the LV cavity, divided by the signal noise level. The contrast-to-noise ratio (CNR) was calculated as the difference of mean signal intensities of each compartment divided by the noise [9]. We differentiated protruding LVT when projecting into the LV cavity from mural LVT which appeared flat and parallel to the myocardial wall [10].

LV end-systolic and end-diastolic volumes, LV ejection fraction and LV myocardial mass were calculated after manual contouring of cine imaging in a standard manner and indexed to the body surface area. The LGE area was defined on each segment by using the full-width at half-maximum method, with its total mass defining infarct size (as a percentage of total LV mass). MVO was identified by the presence of a central hypoenhancement within the bright signal.

### 2.3. Statistical analysis

All statistical tests were generated by SPSS 15.0 software (IBM Inc., Chicago, IL). Calculations were 2-tailed, and p value < 0.05 was considered statistically significant. The data has been presented as mean ± standard deviation, with categorical data expressed as frequencies and percentages. Comparisons of variables were performed using unpaired Student's *t*-test or the chi-squared test, where appropriate. Non parametric variables were compared with the Wilcoxon rank-sum test (including signal-to-noise ratios).

We calculated the specificity, sensitivity, as well as positive and negative values of the different CMR reading protocol for diagnosing LVT.

## 3. Results

Among the 329 patients, 82.6% were men with a mean age of 59 ± 11 years. Mean baseline LV ejection fraction was 47.4 ± 9.8%. Twenty-two early LVT were found (6.7%) and 9 late LVT (2.9%). Overall, 30 (9.1%) individuals presented a LVT after STEMI. Clinical, CMR, and angiographic results are described in Table 1. All thrombi were seen in anterior infarction. We found 4 mural LVT (including 2 early LVT and 2 late LVT). Overall, the mean LVT long axis size was 10.3 ± 4.7 mm. There was no difference between groups for clinical characteristics, except the prevalence of dyslipidemia which was lower in the early LVT group. Early and late LVT were associated with greater LV volumes and infarct size (Table 2).

### 3.1. FPP to diagnose LVT

The comparisons of LVT diagnostic accuracy between routine and FPP stages are described in Figs. 1 and 4. For expert examination, FPP improved final diagnosis pertinence in 10 and 13 cases