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Radiology

Incidence, Outcomes, and Predictors of Ventricular Thrombus after Reperfused ST-Segment–Elevation Myocardial Infarction by Using Sequential Cardiac MR Imaging[1]

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Purpose: To characterize the incidence, outcomes, and predictors of left ventricular (LV) thrombus by using sequential cardiac magnetic resonance (MR) imaging after ST-segment–elevation myocardial infarction (STEMI).

Materials and Methods: Written informed consent was obtained from all patients, and the study protocol was approved by the committee on human research. In a cohort of 772 patients with STEMI, 392 (mean age, 58 years; range, 24–89 years) were retrospectively selected who were studied with cardiac MR imaging at 1 week and 6 months. Cardiac MR imaging guided the initiation and withdrawal of anticoagulants. Patients with LV thrombus at 6 months were restudied at 1 year. For predicting the occurrence of LV thrombus, a multiple regression model was applied.

Results: LV thrombus was detected in 27 of 392 patients (7%): 18 (5%) at 1 week and nine (2%) at 6 months. LV thrombus resolved in 22 of 25 patients (88%) restudied within the first year. During a mean follow-up of 181 weeks ± 168, patients with LV thrombus displayed a very low rate of stroke (0%), peripheral embolism (0%), and severe hemorrhage (n = 1, 3.7%). LV ejection fraction (LVEF) less than 50% ($P < .001$) and anterior infarction ($P = .008$) independently helped predict LV thrombus. The incidence of LV thrombus was as follows: *(a)* nonanterior infarction, LVEF 50% or greater (one of 135, 1%); *(b)* nonanterior infarction, LVEF less than 50% (one of 50, 2%); *(c)* anterior infarction, LVEF 50% or greater (two of 92, 2%); and *(d)* anterior infarction, LVEF less than 50% (23 of 115, 20%) ($P < .001$ for the trend).

Conclusion: Cardiac MR imaging contributes information for the diagnosis and therapy of LV thrombus after STEMI. Patients with simultaneous anterior infarction and LVEF less than 50% are at highest risk.

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A substantial number of cases with left ventricular (LV) thrombus go undetected with echocardiography (1–4). Although late gadolinium enhancement (LGE) with cardiac magnetic resonance (MR) imaging has been demonstrated to be the reference technique to detect LV thrombus soon after ST-segment–elevation myocardial infarction (STEMI) (1–7), data on the incidence and outcomes of this finding within the months following reperfusion as derived from cardiac MR imaging are scarce.

Recent recommendations consider it reasonable to use anticoagulants to treat patients with STEMI with LV thrombus (8–10). Evidence for these recommendations relies mainly on series analyzed with echocardiography. Thus, there is a need to know the outcomes of STEMI patients with LV thrombus in whom anticoagulant therapy was guided by cardiac MR imaging as well as to identify the subset that can benefit most from this technique to properly diagnose and follow up this finding.

We hypothesize that *(a)* sequential cardiac MR imaging permits an accurate definition of the incidence of LV thrombus within the first 6 months after STEMI, *(b)* a cardiac MR-guided strategy based on the initiation of anticoagulants in patients with LV thrombus and withdrawal when this finding resolves at subsequent cardiac MR imaging results in a low rate of complications, and *(c)* a simple score can be created to predict the occurrence of LV thrombus within the first 6 months after STEMI.

Our objectives were to characterize the incidence, outcomes, and predictors of LV thrombus using sequential cardiac MR imaging after STEMI.

Advances in Knowledge

- By using sequential cardiac MR imaging, left ventricular (LV) thrombus was detected in 27 of 392 patients (7%) within the first 6 months after reperfused ST-segment–elevation myocardial infarction (STEMI).
- A strategy of anticoagulation therapy guided by cardiac MR imaging solved LV thrombus in 22 of 25 patients (88%) restudied within the first year and resulted in a low incidence (one of 27, 3.7%) of stroke, peripheral embolism, and hemorrhagic events.
- Patients with simultaneous anterior STEMI and LV ejection fraction (LVEF) less than 50% at 1 week were at highest risk of LV thrombus (23 of 115, 20%).

Materials and Methods

Patients

This study stems from a large prospective ongoing registry of STEMI patients performed in a tertiary university hospital. All patients gave written informed consent. The study protocol was approved by the local ethics committee on human research and conforms to the guidelines of the 1975 Declaration of Helsinki.

Patients were considered to be included in the study group if they were admitted for a first STEMI defined by following current definitions (10), were treated with percutaneous coronary intervention, and underwent cardiac MR imaging 1 week and 6 months after infarction. Nonrevascularized patients; those revascularized more than 12 hours after the onset of chest pain; patients with a documented history of previous myocardial infarction; those who had died, had a reinfarction, or were in severe unstable condition during admission or within the first 6 months after STEMI; and patients with any contraindications to cardiac MR imaging were not considered for participation. From 2002 to 2014, we enrolled 772 patients with their first STEMI and, of them, 392 were retrospectively selected to be included in the study group. The flowchart of patients is displayed in Figure 1.

Clinical and angiographic characteristics were prospectively registered in all cases at admission. The percutaneous coronary intervention technique was left at the discretion of the interventional operator. Thrombolysis in Myocardial Infarction flow grade in the culprit artery (before and after percutaneous coronary intervention) was analyzed in all patients. Further details on patient characteristics are reflected in Table 1.

Patients were treated both in hospital and after discharge by a specific STEMI unit, and current recommendations were strictly followed (8,10). Baseline characteristics and therapies prescribed in the whole study group and in patients with and without LV thrombus are listed in Table 1 and Tables E1 and E2 (online).

Patients in whom LV thrombus was detected at 1-week cardiac MR imaging

Implications for Patient Care

- Cardiac MR imaging performed sequentially after a first STEMI treated with percutaneous coronary intervention is effective to properly detect LV thrombus.
- The use of anticoagulants guided by cardiac MR imaging effectively resolves LV thrombus in patients restudied within the first year.
- Due to the high incidence of LV thrombus in patients with simultaneous anterior STEMI and LVEF less than 50% at 1 week, this is the subset that can benefit most from sequential cardiac MR imaging.

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Abbreviations:
BARC = Bleeding Academic Research Consortium
LGE = late gadolinium enhancement
LV = left ventricle
LVEF = LV ejection fraction
STEMI = ST-segment–elevation myocardial infarction

Author contributions:
Guarantor of integrity of entire study, V.B.; study concepts/study design or data acquisition or data analysis/interpretation, all authors; manuscript drafting or manuscript revision for important intellectual content, all authors; approval of final version of submitted manuscript, all authors; agrees to ensure any questions related to the work are appropriately resolved, all authors; literature research, E.C.C., C.R., D.M., V.B.; clinical studies, E.C.C., C.B., J.M., M.L.L., P.R., A.P., D.E., G.M., M.P., J.C., J.N., F.C., V.B.; experimental studies, J.G., E.d.D., C.R., N.P., G.M., V.B.; statistical analysis, E.C.C., D.M., V.B.; and manuscript editing, E.C.C., E.d.D., V.B.

Conflicts of interest are listed at the end of this article.

Figure 1

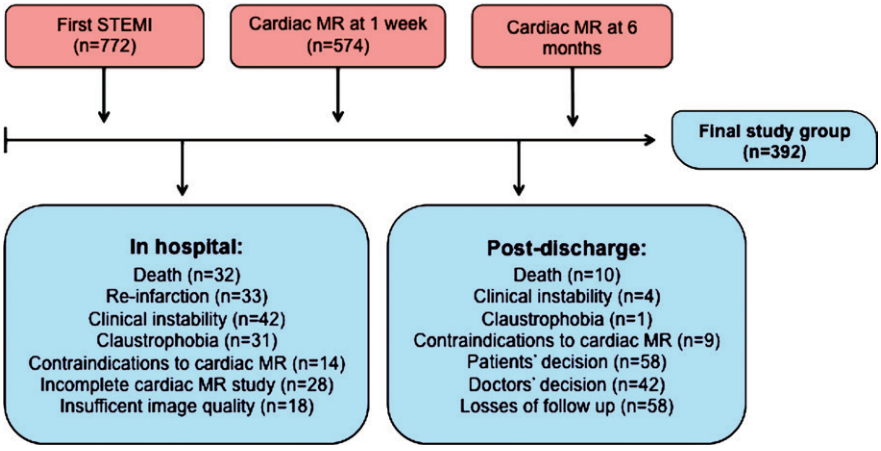

Figure 1: Flowchart of patients and reasons for exclusion.

were submitted to the hematology department, and anticoagulant therapy with the vitamin K antagonist acenocoumarol was initiated to achieve a target international normalized ratio of 2.0–3.0. At 6 months, patients were re-evaluated and oral anticoagulation was maintained (if LV thrombus persisted), suspended (if LV thrombus had vanished), or started (in patients with newly detected LV thrombus).

Cardiac MR Imaging

All patients included in the study group were examined with a 1.5-T MR System (Sonata Magnetom; Siemens, Erlangen, Germany) at 1 week (7 days ± 2 [standard deviation]) and 6 months (183 days ± 21) after STEMI according to our previously validated study protocol (11). Eleven of 13 patients with LV thrombus at 6-month cardiac MR underwent a third cardiac MR study 1 year after STEMI (371 days ± 31).

All studies were performed by two cardiologists (J.V.M. and M.P.L.L., with 15 years of experience) specialized in cardiac MR imaging and quantified offline by a third operator (J.G., with 3 years of experience) blinded to all patient data using customized software (QMASS MR, 6.1.5; Medis, Leiden, the Netherlands). Cardiac MR data were prospectively recorded and immediately included in the registry database.

LV thrombus was defined at LGE by using a segmented inversion-recovery steady-state free-precession sequence. LV thrombus characteristically had a gray etched appearance compared with black (viable) or white (infarcted) myocardium (Fig 2), with avascular tissue adherent to regions with abnormal wall motion, protruding and clearly distinguishable from cardiac structures or technical artifacts. Similar to recent data (2,3), routine nonenhanced echocardiography performed during admission yielded limited sensitivity for detection of LV thrombus at LGE (10 of 27, 37%).

LV ejection fraction (LVEF), LV end-diastolic volume index, LV end-systolic volume index, and LV mass index were calculated by means of manual planimetry of endocardial and epicardial borders in short-axis view cine images.

Areas showing LGE (> 2 standard deviations in comparison with a remote noninfarcted area in the same section) were visually revised and quantified with manual planimetry. Infarct size was assessed as the percentage of LV mass showing LGE. Microvascular obstruction was quantified by manual planimetry and defined as the percentage of LV mass showing a lack of contrast material uptake in the core of tissue showing LGE.

Myocardial edema was defined in T2 sequences (half-Fourier acquisition single-shot turbo spin-echo multisection and segmented turbo spin echo) as areas with high T2 signal intensity (> 2 standard deviations in comparison with a remote noninfarcted area in the same section) and was visually revised and expressed as percentage of LV mass. Myocardial salvage index was calculated by subtracting the mass of the infarcted myocardium from myocardium showing edema and was expressed as percentage of LV mass with myocardial edema.

The operator who subsequently performed the quantification of all cardiac MR studies (J.G.) and one of the operators who acquired the cardiac MR images (J.V.M.) analyzed separately in all the studies the presence or absence of LV thrombus. Disagreement took place in three cases (0.8%) at the 1st week and in two (0.5%) cases at 6th months and was solved by consensus. The inter- and intraobserver variability for the calculation of the rest of cardiac MR indexes used in the present study in our laboratory has been previously reported and is less than 5% (11).

Further details on the technical aspects of cardiac MR acquisition and sequences can be consulted in the Appendix E1 (online).

End Points

The objective of the present study was to analyze in a prospective series of patients with a first STEMI reperfused within the first 12 hours after onset of chest pain, without any contraindications to cardiac MR imaging, and sequentially examined with cardiac MR imaging 1 week and 6 months after infarction *(a)* the incidence of LV thrombus, *(b)* the outcome of LV thrombus by using cardiac MR imaging to guide the anticoagulation therapy, and *(c)* to design a simple score to identify those patients who are at highest risk of developing LV thrombus within the first 6 months after STEMI and consequently can benefit most from a tighter follow-up.

The outcomes of patients in terms of the occurrence of stroke, peripheral embolism, and hemorrhage greater than Bleeding Academic Research Consortium (BARC) type 2 (any overt actionable sign

Table 1

Baseline Characteristics of the Whole Study Group and Patients with and without LV Thrombus within the First 6 Months after STEMI

Characteristic	All Patients	Patients with LV Thrombus	Patients without LV Thrombus	*P* Value
No. of patients	392	27	365	…
Age (y)*	58 ± 12	58 ± 13	58 ± 12	.9
Male sex	321 (82)	23 (85)	298 (82)	.6
Diabetes mellitus	73 (19)	6 (22)	67 (18)	.8
Hypertension	181 (46)	10 (37)	171 (47)	.3
Hypercholesterolemia	170 (44)	12 (44)	158 (43)	.9
Smoker	235 (60)	16 (59)	219 (60)	.9
Heart rate (beats per min)*	79 ± 20	80 ± 18	79 ± 20	.7
Systolic pressure (mm Hg)*	131 ± 29	132 ± 28	131 ± 29	.8
Killip class				.1
I	344 (88)	322 (88)	22 (82)	…
II	37 (9)	3 (11)	34 (9)	…
III	3 (1)	0 (0)	3 (1)	…
IV	8 (2)	2 (7)	6 (2)	…
Time to reperfusion (min)†	195 (134–311)	225 (130–420)	190 (135–300)	.02
ST-segment resolution (%)†	81 (59–100)	68 (42–83)	81 (60–100)	.01
Anterior infarction	207 (53)	25 (93)	182 (50)	.001
Multivessel disease	101 (26)	3 (11)	98 (27)	.3
TIMI flow grade before PCI				.2
0	177 (45)	17 (63)	160 (44)	…
1	23 (6)	0 (0)	23 (6)	…
2	42 (11)	1 (4)	41 (11)	…
3	149 (38)	9 (33)	140 (38)	…
TIMI flow grade after PCI				.1
0	8 (2)	0 (0)	8 (2)	…
1	1 (0.3)	1 (4)	0 (0)	…
2	24 (6)	5 (19)	19 (5)	…
3	358 (92)	21 (78)	337 (93)	…

Note.—Unless otherwise indicated, data are percentages with the number of patients in parentheses. PCI = percutaneous coronary intervention, TIMI = Thrombolysis in Myocardial Infarction.

* Data are means ± standard deviation.

† Data are medians with 25th and 75th percentiles in parentheses.

of hemorrhage requiring attention by a health care professional, prompting evaluation, leading to hospitalization, and fatal bleedings) (12) were recorded. To adjudicate an event, consensus between two cardiologists was required.

Statistical Analysis

Data were tested for normal distribution by using the Kolmogorov-Smirnov test. Continuous normally distributed data were expressed as the mean ± standard deviation and compared by using the unpaired samples Student *t* test. Nonparametric data were expressed as the median with the interquartile range and compared by using the Mann-Whitney *U* test. Group percentages were compared by using the χ^2 test or the Fisher exact test, where appropriate. *P* for the trend was used to compare more than two percentages. The association of LV thrombus with time to stroke, peripheral embolism, or hemorrhage greater than BARC type 2 was assessed by using Kaplan-Meier curves and the log-rank test.

For predicting the occurrence of LV thrombus, forward stepwise multiple binary logistic regression was used after adjustment according to baseline and cardiac MR variables, yielding a *P* value < .2 at univariate analyses. Odds ratios with the respective 95% confidence intervals were computed. Variables with a two-tailed *P* value < .05 were included in the final model. Infarct location (anterior vs nonanterior) and LVEF (as a continuous variable) were the independent predictors. The predictive power of this model was determined by using the area under the receiver operating characteristics curve (estimated with the c-statist test). Then a simpler (from a clinical perspective) score was proposed by dichotomizing patients according to infarct location (anterior vs nonanterior) and the state of LVEF (preserved vs depressed). LVEF was dichotomized via univariate receiver operating characteristics techniques. Once the best cut-off value of LVEF at 1-week cardiac MR imaging (depressed if < 50%) for the prediction of LV thrombus was obtained, patients were categorized as having *(a)* nonanterior infarction, preserved LVEF; *(b)* nonanterior infarction, depressed LVEF; *(c)* anterior infarction, preserved LVEF; and *(d)* anterior infarction, depressed LVEF. The in-sample predictive value of these categories to predict LV thrombus at the univariate analysis was assessed.

Statistical significance was considered for a two-tailed $P < .05$. The SPSS statistical package (version 21.0; SPSS, Chicago, Ill) was used.

Results

Among 772 patients with STEMI consecutively admitted to our institution from January 2002 to December 2014 and reperfused within the first 12 hours after chest pain onset, the final study group comprised 392 patients. The complete flowchart of patients is displayed in Figure 1, and the baseline characteristics are listed in Table 1.

Incidence and Outcomes of LV Thrombus

Overall, LV thrombus was detected at 1 week in 28 of 574 patients (5%) who underwent 1-week cardiac MR imaging. Among 392 patients included in the final study group, LV thrombus occurred in 27 patients (7%) within the first 6 months after STEMI, 18 (67%) patients at 1 week, and nine (33%) patients at 6 months (Fig 3).

Figure 2

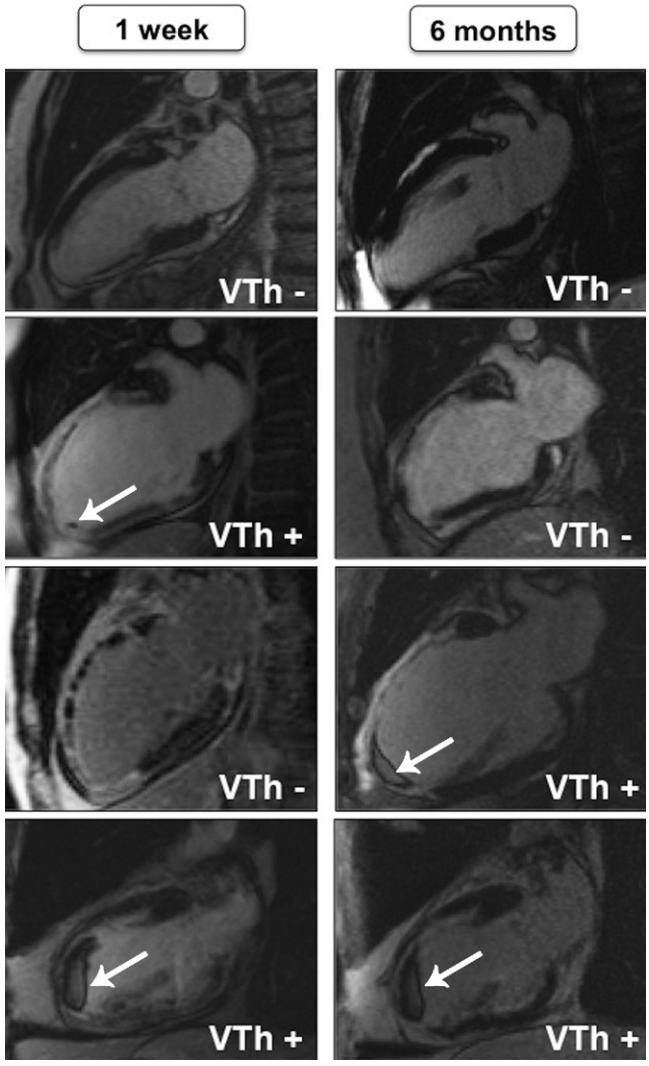

Figure 2: Possible dynamics of LV thrombus *(Vth)* within the first 6 months after STEMI. Image illustrates four possible scenarios regarding the evolution of LV thrombus. Top row: absence of LV thrombus at 1 week and 6 months. Second row: LV thrombus at 1 week that vanished at 6 months. Third row: absence of LV thrombus at 1 week, with a newly detected thrombus at 6 months. Last row: presence of LV thrombus at 1 week that persisted at 6 months. Arrow = location of thrombus.

LV thrombus occurred at 1 week in 18 patients (5%); at that moment, all of them initiated oral anticoagulation therapy. Among the 18 patients with LV thrombus at 1-week cardiac MR imaging, the LV thrombus had vanished in 14 (76%) and persisted in four (24%) at 6-month cardiac MR imaging. Oral anticoagulation was stopped in the former (Fig 3). All patients with persistent LV thrombus at 6-month cardiac MR imaging (n = 4) had anterior infarction and displayed a nonsignificant tendency toward more severe structural abnormalities at 1-week cardiac MR imaging compared with those patients (n = 14) in whom LV thrombus had vanished at 6-month cardiac MR imaging (Appendix E1 [online], Table E3 [online]).

A newly detected LV thrombus appeared in nine of 392 patients (2%) at 6-month cardiac MR imaging. Overall, 13 of 392 patients (3%) displayed LV thrombus at 6-month cardiac MR imaging: in four of them it was already detected at 1 week and in nine it was newly identified at 6 months. Oral anticoagulation was maintained in the former and initiated in the latter (Fig 3).

Of 13 patients with LV thrombus at 6-month cardiac MR imaging, 11 were re-examined with cardiac MR at 1 year. Two patients were excluded (one died of refractory heart failure and one had implantable cardioverter defibrillator). Among 11 patients with LV thrombus at 6-month cardiac MR imaging, the thrombus vanished in eight (73%) and persisted in three (27%) at 1 year (Fig 3).

Thus, LV thrombus disappeared in 22 of 25 patients (88%) in whom this finding had been detected at cardiac MR imaging within the first 6 months after STEMI and had been re-examined at 1 year (Fig 3).

During a mean follow-up of 181 weeks ± 168, the occurrence of stroke (n = 0), peripheral embolism (n = 0), and hemorrhage greater than BARC type 2 (n = 1, 3.7%) was very low in those 27 patients with LV thrombus detected within the first 6 months and with anticoagulation therapy guided by cardiac MR results. The rates of stroke, peripheral embolism, and hemorrhage greater than BARC type 2 in patients with and without LV thrombus are shown in Table 2.

Predictors of LV Thrombus

Baseline characteristics and cardiac MR data associated with the presence of LV thrombus are depicted in Tables 1 and 3, respectively.

At the multivariate analysis, baseline variables and cardiac MR data showing an association with LV thrombus ($P <$ .2 at univariate analyses) were tested. All variables tested at the multivariate analysis and their respective odds ratios and 95% confidence intervals are displayed in Table 4. The independent predictors of LV thrombus were anterior infarction (odds ratio, 7.38 [95% confidence interval: 1.67, 32.65]; P =

Figure 3

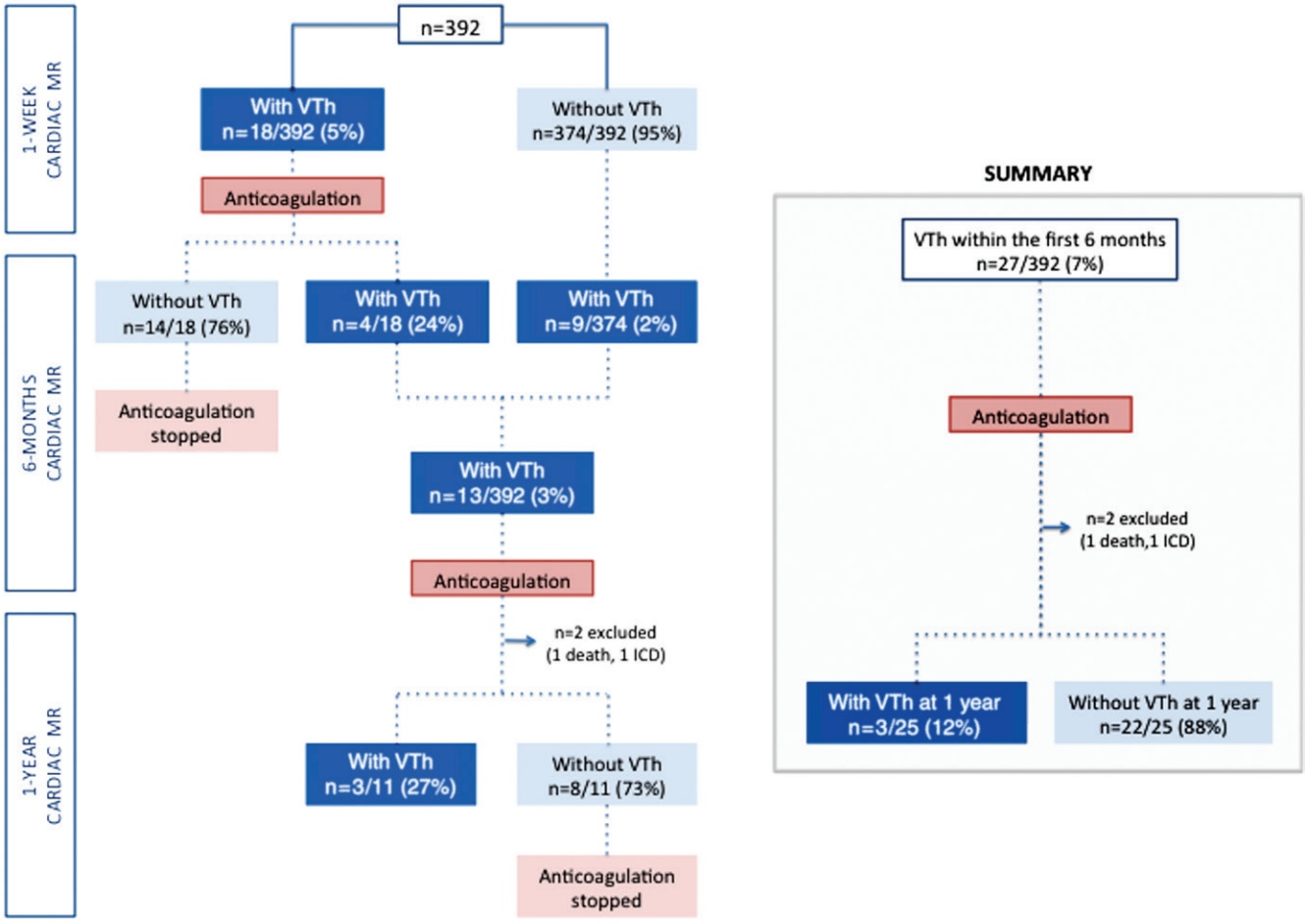

Figure 3: Outcomes of LV thrombus *(VTh)* within the first 6 months after STEMI. Schematic depicts dynamics of thrombus occurrence and use of anticoagulation: step by step *(left)* and summary *(right)*. All patients were examined with cardiac MR imaging 1 week and 6 months after STEMI. One-year cardiac MR imaging was performed only in patients with LV thrombus at 6 months. *ICD* = implantable cardioverter defibrillator.

.008) and LVEF (odds ratio, 0.94 [95% confidence interval: 0.90, 0.97]; $P <$ .001) (Table 4). The c-statistic of this model was 0.82 (95% confidence interval: 0.75, 0.89; $P <$ .001).

Patients were categorized according to the independent predictors: infarct location (anterior vs nonanterior) and LVEF (preserved vs depressed at 1-week cardiac MR). Based on the receiver operating characteristics curve analysis, LVEF less than 50% resulted to be the best cut-off value to predict LV thrombus.

From a clinical perspective and based on these two widely available variables, we constructed a simple score to identify patients at highest risk of developing LV thrombus within the first 6 months (at 1-week and/or 6-month cardiac MR). The percentages of patients with LV thrombus in the respective groups were *(a)* nonanterior infarction, LVEF 50% or greater: one of 135 (1%); *(b)* nonanterior infarction, LVEF less than 50%: one of 50 (2%); *(c)* anterior infarction, LVEF 50% or greater: two of 92 (2%); and *(d)* anterior infarction, LVEF less than 50%: 23 of 115 (20%) ($P <$ .001 for the trend) (Fig 4). Accordingly, the majority of patients with LV thrombus (23 of 27, 85%) displayed a simultaneous anterior infarction and LVEF less than 50%. The occurrence of LV thrombus at 1-week cardiac MR imaging in these groups was as follows: one of 87 (1%), zero of 98 (0%), one of 53 (2%), and 16 of 154 (10%), respectively ($P <$ .001 for the trend).

Discussion

The main findings of the present study were as follows: *(a)* In patients with reperfused STEMI, cardiac MR revealed the presence of LV thrombus in a considerable number of patients (7%) within the first 6 months after infarction; *(b)* a strategy of anticoagulation guided by sequential cardiac MR succeeded in resolving LV thrombus within the first year in the majority of cases and was associated with a very low rate of stroke, peripheral embolism, and significant hemorrhage; *(c)* patients with simultaneous

Table 2

Occurrence of Stroke, Hemorrhage Greater than BARC Type 2, and Peripheral Embolism in the Whole Study Group and Patients with and without LV Thrombus within the First 6 Months after STEMI

Characteristic	All Patients	Patients with LV Thrombus	Patients without LV Thrombus	*P* Value
No. of patients	392	27	365	…
Stroke	6 (1.5)	0 (0)	6 (1.6)	.6
Hemorrhage > BARC type 2	1 (0.3)	1 (3.7)	0 (0)	.07
Peripheral embolism	2 (0.5)	0 (0)	2 (0.5)	.8
Stroke/hemorrhage/embolism	9 (2.3)	1 (3.7)	8 (2.2)	.5

Note.—Data in parentheses are percentages.

anterior STEMI and LVEF less than 50% were at highest risk of LV thrombus and represent the subset of patients who deserve a tight surveillance regarding the occurrence of LV thrombus.

Incidence and Outcomes of LV Thrombus

An adequate detection of LV thrombus after STEMI brings about relevant implications on patient care. Although randomized trials addressing this topic are lacking, the common consensus in current guidelines is that the use of anticoagulant therapy in patients with LV thrombus after STEMI is reasonable (8). Failure to identify this finding, and subsequently to prescribe anticoagulants, might imply catastrophic consequences such as stroke or peripheral embolism. On the other hand, in the era of a generalized use of dual antiplatelet therapy, anticoagulants must be reserved for patients with definitive evidence of LV thrombus; an inadequate indication of anticoagulation in this context might unnecessarily boost the risk of bleeding. Consequently, the use of reliable cardiac imaging tools is mandatory to make decisions in this field (13,14).

LGE has emerged as the reference technique for the diagnosis of LV thrombus. So far, to our knowledge, only three studies (2–4) have rigorously addressed the incidence of LV thrombus in STEMI using LGE and, in only two of them (3,4), the study group was exclusively made up of STEMI patients.

Weinsaft et al (2) reported, in a mixed cohort of 121 patients, an overall 20% incidence of LV thrombus. The inclusion of patients with chronic heart failure and chronic ischemic heart disease might explain the high occurrence of LV thrombus in this series. The same group of authors (3), in a more recent series of 201 STEMI patients studied with LGE, detected 17 cases with LV thrombus (8%) a mean of 28 days after infarction. Finally, in a group of 194 STEMI patients treated with percutaneous coronary intervention and examined with cardiac MR imaging, Delewi et al (4) reported a 9% rate of LV thrombus 1 week after infarction.

The present study constitutes the largest series so far focused on the occurrence and outcomes of LV thrombus after STEMI, using cardiac MR imaging to diagnose this finding and to guide anticoagulant therapy. In our large cohort of 392 patients treated according to contemporary clinical practice, the overall incidence of LV thrombus within the first 6 months after STEMI was 7%. Substantial dynamic changes took place. At 1 week, 18 patients (5% of the whole study group) displayed LV thrombus; this finding vanished at 6 months in three-quarters of them. Moreover, LV thrombus was newly detected in nine patients (2%) at 6 months. Overall, LV thrombus vanished in 22 of 25 patients (88%) with thrombus detected within the first 6 months and re-examined within the first year after STEMI.

This dynamic behavior mandates immediate modification in patient care, namely prescription or interruption of anticoagulant therapy at the moment of detection or resolution of LV thrombus, respectively. Thus, in this scenario, cardiac MR becomes decisive not only for diagnosis but also for decision making. In fact, in our series with LV thrombus, the rate of potential complications derived from lack of proper anticoagulation or of potential substantial side effects of anticoagulants was very low: only one case (3.7%) of hemorrhage greater than BARC type 2 was registered. It should be emphasized, however, that these results were derived from a short series of 27 patients with LV thrombus treated with anticoagulant therapy. In this setting, safety of anticoagulation therapy itself should be determined in a large randomized study.

The presented data suggest that a cardiac MR-guided strategy based on the use of anticoagulants when LV thrombus is detected after STEMI and maintenance or withdrawal of this therapy depending on the persistence or disappearance of LV thrombus during follow-up is *(a)* effective for solving the majority of LV thrombus and *(b)* safe in terms of a very low occurrence of stroke, peripheral embolism, and substantial hemorrhage.

Predictors of LV Thrombus after STEMI

Attending to its wide availability and excellent cost-effectiveness balance, echocardiography represents the first choice for assessing the structural consequences of myocardial infarction (10). Unfortunately, the accuracy of this technique for detecting LV thrombus is insufficient. When compared with LGE, transthoracic echocardiography performed by expert operators barely detected one-third of cases with LV thrombus (2,4). Furthermore, in a recent study that compared contrast-enhanced echocardiography and LGE in STEMI, almost 40% of LV thrombus went undetected by the former (3). Thus, current evidence suggests that, for a correct diagnosis of LV thrombus, cardiac MR imaging should be used. Unfortunately, this technique is not available at all institutions, and indiscriminate use may unnecessarily increase costs of health systems. There is a need to identify in a simple manner those patients who are at highest risk of developing LV thrombus and in turn can

Table 3

Cardiac MR Characteristics at 1 Week in the Whole Study Group and Patients with and without LV Thrombus within the First 6 Months after STEMI

Characteristic	All Patients	Patients with LV Thrombus	Patients without LV Thrombus	*P* Value
No. of patients	392	27	365	…
LVEF (%)*	52 ± 13	40 ± 11	53 ± 13	.001
LVEDVI (mL/m^2)*	79 ± 24	90 ± 25	78 ± 24	.001
LVESVI (mL/m^2)*	39 ± 21	55 ± 22	38 ± 20	.001
LV mass (g/m^2)*	74 ± 18	80 ± 14	74 ± 18	.001
Edema (% of LV mass)†	28 (17–39)	39 (32–53)	27 (16–37)	.001
MVO (% of LV mass)†	0 (0–2)	4.6 (0.3–11)	0 (0–1.6)	.001
Infarct size (% of LV mass)†	19 (10–30)	33 (22–47)	18 (9–29)	.001
Myocardial salvage index (%)†	23 (3–42)	13 (2–35)	23 (3–44)	.001

Note.—LVEDVI = LV end-diastolic volume index, LVESVI = LV end-systolic volume index, MVO = microvascular obstruction. The correlation coefficients among the eight cardiac MR characteristics are reported in Table E4 (online).

* Data are means ± standard deviation

† Data are medians with 25th and 75th percentiles in parentheses.

Table 4

Multivariate Analysis of Potential Predictors of LV Thrombus within the First 6 Months after STEMI

Variable	Odds Ratio*	*P* Value
Killip class 1	…	…
Killip class 2 versus 1	1.29 (0.37, 4.53)	.7
Killip class 3 versus 1	0.88 (0.23, 56.32)	.9
Killip class 4 versus 1	4.89 (0.93, 25.61)	.1
Anterior infarction	7.38 (1.67, 32.65)	.008
Time to reperfusion	0.99 (0.97, 1.01)	.5
ST-segment resolution	1.00 (0.99, 1.01)	.5
TIMI flow grade 3 after PCI	…	…
TIMI flow grade 2 versus 3 after PCI	2.0 (0.62, 6.37)	.2
TIMI flow grade 1 versus 3 after PCI	0.99 (0.63, 59.32)	.9
TIMI flow grade 0 versus 3 after PCI	5.69 (0.91, 27.62)	.1
LVEF (%)	0.94 (0.90, 0.97)	<.001
LVEDVI (mL/m^2)	1.01 (0.92, 1.11)	.8
LVESVI (mL/m^2)	0.99 (0.87, 1.13)	.9
LV mass index (g/m^2)	0.98 (0.95, 1.01)	.3
LV mass with edema (mL/m^2)	1.04 (0.99, 1.10)	.1
MVO (% of LV mass)	1.08 (0.99, 1.18)	.07
Infarct size (% of LV mass)	0.96 (0.91, 1.02)	.2
Myocardial salvage index	0.99 (0.96, 1.04)	.9

Note.—LVEDVI = LV end-diastolic volume index, LVESVI = LV end-systolic volume index, MVO = microvascular obstruction, TIMI = Thrombolysis in Myocardial Infarction, PCI = percutaneous coronary intervention. For the categorical variables, Killip class 1 and TIMI flow grade 3 after PCI were considered as the normal reference values (8). Variables yielding $P < .2$ at univariate analyses (Tables 1 and 3) were tested.

* Data in parentheses are 95% confidence intervals.

benefit most from undergoing sequential cardiac MR imaging.

In our study, two factors emerged as simple and potent predictors of LV thrombus: anterior infarction and the presence of a depressed (< 50%) LVEF. The majority of cases with LV thrombus (85%) took place in patients with simultaneous anterior infarction and depressed LVEF. Moreover, whereas patients with these two characteristics displayed a considerable risk (20%) of LV thrombus, the risk in the remaining categories (when only one or when none of these variables were present) was 1%–2%.

The presence of simultaneous depressed LVEF and anterior location imply a larger infarct size, more blood stasis, and a higher risk of thrombosis. The pathophysiologic basis underlying this association is obvious, but this simplicity might be helpful in routine practice. It would be recommendable to keep in mind that this specific subgroup of patients (115 of 392, 29% in our series) is at significant risk (around 20%) of LV thrombus within the weeks and months following STEMI. A generalized use of anticoagulants in all patients with simultaneous anterior infarction and depressed LVEF would be inappropriate: 80% of them do not have LV thrombus. Thus, the use of sequential cardiac MR imaging in these cases seems reasonable.

Study Limitations

Nowadays, most patients do not undergo cardiac MR imaging in the first week after STEMI. Consequently, it is unclear how many patients with unknown LV thrombus not treated with anticoagulants do or do not have stroke or embolism. Presumably the use of early reperfusion and dual antiplatelet therapy is markedly changing the natural history of this process. To know the exact benefit derived from the use of anticoagulants in STEMI patients with LV thrombus detected at cardiac MR imaging and managed according to current recommendations, a large randomized multicenter study would be needed.

Due to the inherent limitations in the use of sequential cardiac MR imaging after STEMI, our series does not include the whole spectrum of post-STEMI patients. Moreover, 182 of 574 patients examined with cardiac MR imaging at 1 week did not undergo cardiac MR imaging at 6 months. Lack of inclusion of all consecutive patients 1 week and 6 months after STEMI could exert an influence on the incidence of

Figure 4

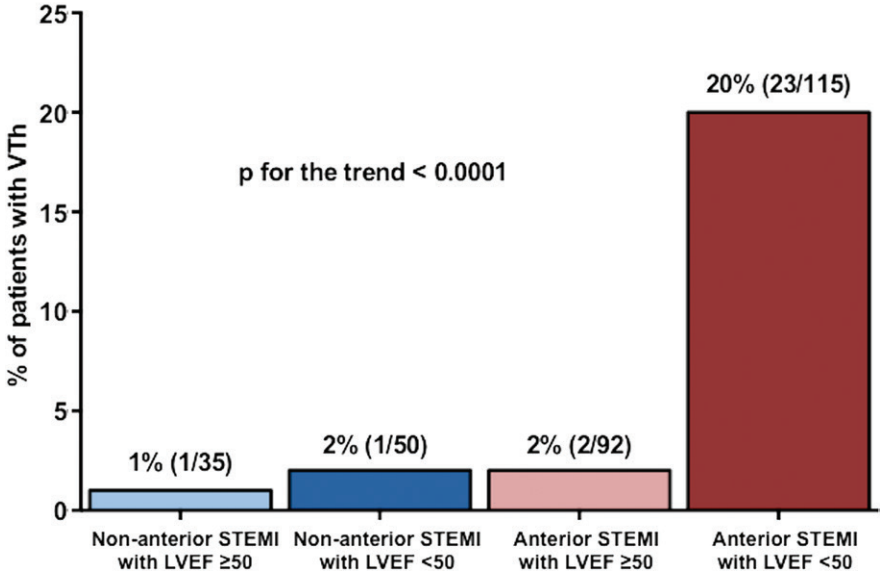

Figure 4: Graph shows incidence of LV thrombus *(VTh)* depending on infarct location and the state of ejection fraction at 1-week cardiac MR imaging. The majority of cases with LV thrombus took place in the subset of patients with anterior infarction and LVEF less than 50% at 1-week cardiac MR imaging.

LV thrombus and on the occurrence of stroke, embolism, and hemorrhage.

For the purpose of this study, we used cardiac MR imaging 1 week and 6 months after STEMI; in patients with persistent or newly detected LV thrombus at 6 months, cardiac MR imaging was repeated at 1 year. Although this strategy was effective and safe, the ideal timing for sequential cardiac MR imaging in this context is uncertain.

Conclusions

Cardiac MR imaging allows for an excellent characterization of the incidence and dynamics of LV thrombus after STEMI and, in this scenario, a strategy of anticoagulation therapy guided by means of cardiac MR imaging appears effective and safe. Patients with simultaneous anterior infarction and LVEF less than 50% are at highest risk of developing LV thrombus and, if available, the use of sequential cardiac MR imaging in this context seems reasonable.

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