Abbreviations:

CMR: Cardiovascular Magnetic Resonance imaging;

FPP: First Pass Perfusion;

LGE: Late Gadolinium Enhancement;

LV: Left Ventricular;

LVT: Left Ventricular Thrombus;

TTE: Transthoracic Echocardiography;

MI: Myocardial infarction.

**TABLE DES MATIERES**

## I] Introduction

Les maladies cardiovasculaires représentent la première cause de mortalité en Europe, et la seconde en France. L'incidence de la cardiopathie ischémique a diminué avec le développement de l'angioplastie percutanée, l'arrivée de nouvelles thérapeutiques médicamenteuses, et l'accélération des prises en charge.

Le thrombus ventriculaire gauche est une complication reconnue de l'infarctus du myocarde dont la prévention, le diagnostic, et le traitement demeurent essentiels en raison du risque embolique. La prévalence des thrombus ventriculaires gauches en post infarctus est très hétérogène selon les études. En effet l'amélioration des prises en charge a diminué la prévalence des thrombus et ceux malgré des outils diagnostiques de plus en plus sensible.

L'imagerie par résonance magnétique est considérée comme le gold standard pour la recherche de thrombus ventriculaires, notamment en comparaison à l'échographie trans thoracique. Les thrombus infra centimétriques ou muraux peuvent être détectés par IRM mais ne sont pas visualisable par Echographie de routine. La population de ces patients porteurs de petits thrombus, est une population faiblement étudiée dont il découle plusieurs interrogations. Peut-on encore améliorer le diagnostic des thrombus ? Est-ce que les facteurs de risque de thrombus ventriculaires gauche en post infarctus décrit dans les études échographiques sont les mêmes que ceux décrits dans les études imageries magnétiques ? Quel est le risque embolique des thrombus infra centimétriques ? Doit-on systématiquement les traiter par anticoagulant ?

Cette présente thèse a pour objectif de faire une mise à jour de l'actualité des thrombus ventriculaires dans la cardiopathie ischémique à travers une étude réalisée au CHU d'Angers qui a évalué l'apport de la séquence de perfusion premier passage dans le diagnostic du thrombus ventriculaire gauche à l'IRM cardiaque.

## II] Physiopathologie

L'infarctus du myocarde résulte de l'occlusion aigüe d'une artère coronaire. L'absence de flux sanguin va rapidement entrainer une ischémie, puis une nécrose myocardique dans le territoire normalement irrigué. En fonction du territoire de l'artère coronaire, de la présence d'un réseau collatéral et du temps écoulé entre l'occlusion et la revascularisation (macro et microvasculaire), l'étendue de la zone de nécrose sera variable. Plusieurs complications résultent de cette nécrose dont la formation de thrombus intraventriculaires gauches.

Le processus de thrombose est classiquement représenté par la triade de Virchow. Elle représente les 3 éléments nécessaires à la formation d'un thrombus : la stase sanguine, la dysfonction endothéliale, et l'état d'hypercoagulabilité. Chaque critère pouvant être plus ou moins présent.

Après un infarctus du myocarde, l'ensemble des éléments de la triade est représenté par :

- La **stase sanguine** : secondaire aux troubles cinétiques et à la dilatation du ventricule gauche. Un large territoire akinétique (ou dyskinétique) entraîne une stase sanguine importante. La dilatation du ventricule gauche favorise la stase sanguine, étant donné qu'elle majore le volume partiel en regard de chaque segment. La prévalence de thrombus dans les cardiomyopathies dilatées est d'ailleurs supérieure à celle des cardiopathies ischémiques. (1)

- La **dysfonction endothéliale** est facilement expliquée en post infarctus du myocarde étant donné qu'en cas de nécrose myocardique, l'endocarde est la première couche atteinte. Une altération de l'endothélium permet un contact direct entre les cellules sanguines et les facteurs tissulaires présent au niveau de la média. Cette mise en contact va permettre une activation de la voie de la coagulation.

- L'état d'**hypercoagulabilité** : L'inflammation locale, ainsi que l'état de stress adrénergique généré va favoriser la coagulation. Les cellules nécrosées sécrètent des cytokines qui vont permettre l'activation d'interleukine. La conversion de pro interleukine en interleukine mature va activer le système inflammatoire local, et donc le recrutement de macrophages et de polynucléaires neutrophiles. (2)

**III] Incidence**

La prévalence des thrombus ventriculaires en post infarctus du myocarde est très hétérogène. Selon les études, elle varie de 5.1% à 40% (1). Cette disparité s'explique notamment avec l'évolution des thérapeutiques qui a permis de diminuer la taille des infarctus et le remodelage ventriculaire. L'angioplastie per cutanée, la vitesse de prise en charge, et les nouvelles thérapies médicamenteuses ont diminué l'incidence des thrombus.

Cette diminution est d'autant plus significative que les techniques de dépistages actuelles sont plus performantes. En effet les études les plus récentes étudient la prévalence des thrombus à travers des études IRM, considérée comme le gold standard.

La majorité des thrombus surviennent dans les 15 premiers jours après un infarctus du myocarde (3) mais le risque persiste à distance notamment en raison du remodelage ventriculaire. La réalisation d'un examen de dépistage trop précoce mène au risque d'échec de diagnostic et celle d'un examen trop tardif à l'ignorance de certains thrombus. Certaines études évaluent la prévalence à 4 mois à 8.3% (1)

**IV] Facteurs favorisants**

Les principaux facteurs favorisants des thrombus ventriculaires sont la cardiopathie ischémique et la cardiomyopathie dilatée.

Au sein des cardiopathies ischémiques, les différents facteurs de risques classiquement décrits sont :

- Le temps de reperfusion qui est indirectement en lien avec l'étendue de la zone d'infarcie. Une prise en charge précoce est un facteur protecteur de thrombus. (4)
- La taille de l'infarctus (taux de Creatinine kinase, pourcentage de rehaussement tardif à l'IRM cardiaque) qui par définition augmente le volume de stase sanguine tout comme la présence de zone dyskinétique ou d'anévrisme (5)
- La dilatation du ventricule gauche (augmentation du volume télédiastolique et télésystolique) qui semble être le facteur le plus prédictif d'une apparition du thrombus (3). Le remodelage du ventricule gauche peut être très précoce après l'infarctus ou survenir jusqu'à un an (6).
- L'atteinte antérieure (7).
- L'altération de la fonction ventriculaire gauche (8).

Ces différents facteurs de risques de thrombus ont été décrits à travers des cohortes échographiques ou d'IRM en post infarctus immédiat. A notre connaissance, il n'existe qu'une seule étude qui a étudié les thrombus ventriculaires d'apparition tardive en IRM. Delewi *et. al.*a étudié l'apparition de thrombus ventriculaires en post infarctus en phase initiale et à 4 mois. Les facteurs de risques indépendants retrouvés étaient la taille de l'infarctus initiale et une atteinte antérieure. (9)

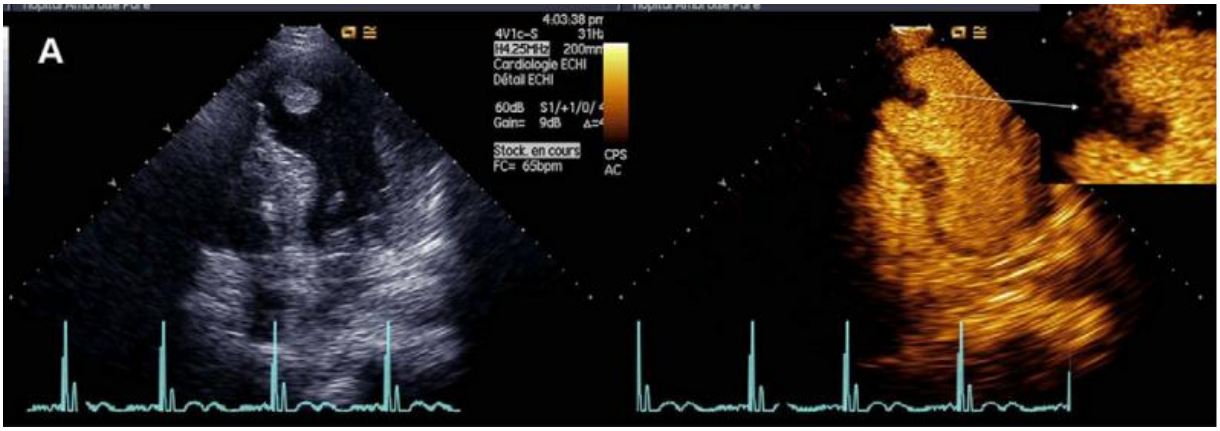
**V] Outils diagnostiques**

Les techniques d'imageries cardiovasculaires connaissent un essor considérable. L'échographie trans-thoracique reste l'imagerie dynamique la plus accessible. Sa sensibilité

diagnostique pour les thrombus peut être majorée grâce à l'injection de produit de contraste. Cependant, les techniques d'imageries en coupe tels que le scanner ou l'IRM cardiaque sont aujourd'hui des outils indispensables en cas de suspicion diagnostique.

*Echographie cardiaque.*

L'Echographie cardiaque trans thoracique (ETT) représente l'examen d'imagerie le plus disponible. Elle est peu couteuse, non irradiante, et accessible au lit du patient. L'ETT présente l'avantage d'apporter au clinicien des critères hémodynamiques avec notamment le mode doppler. En post infarctus, l'ETT est une imagerie indispensable pour le bilan lésionnel de l'infarctus et la recherche de complication. Classiquement, un thrombus est décrit en échographie par une masse, hypoéchogène, intracavitaire, dont les berges sont distinctes de la paroi myocardique en diastole et en systole. Pour le diagnostic du thrombus intraventriculaire, on évalue la sensibilité de l'ETT à 30 % et la spécificité à 96% (8). La sensibilité peut cependant être multipliée par un facteur 2 avec l'utilisation d'un produit de contraste (4).




Archives of Cardiovascular Disease (2009) 102, 177—183

Figure 1 : A gauche, l'image d'un thrombus pédiculé de l'apex du ventricule gauche en échographie standard. A droite la même image avec injection de produit de contraste.

L'échographie trans œsophagienne est un examen utilisé surtout pour le diagnostic des thrombus atriaux. Dans le cadre du diagnostic de thrombus ventriculaire, son utilisation est peu fréquente, et souvent limité par le fait que l'apex est mal visualisé. Cependant certaines études suggèrent une sensibilité diagnostique accrue par rapport à l'ETT (8).

*Tomodensitométrie cardiaque.*

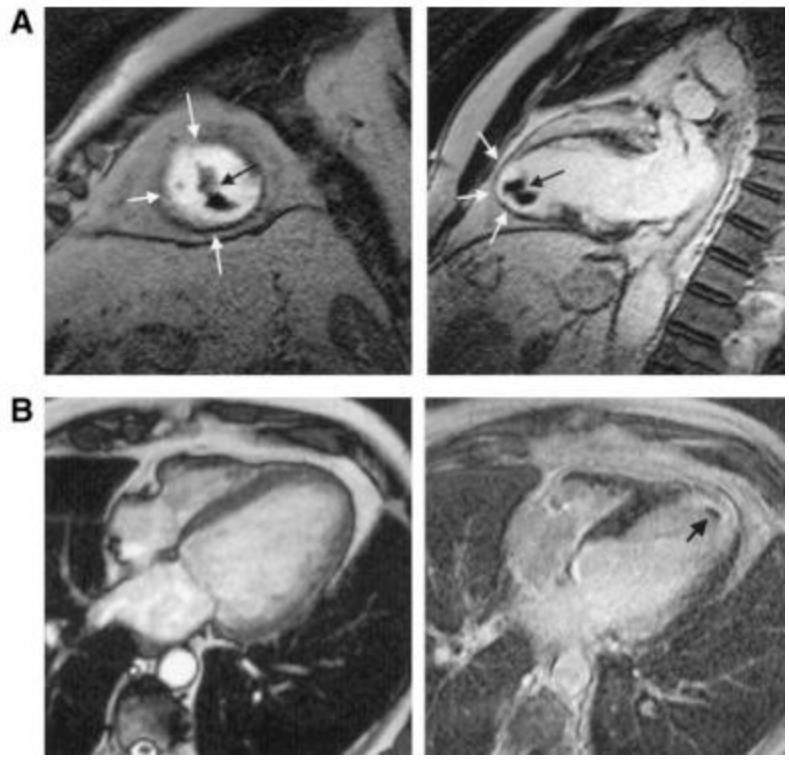
L'excellente résolution spatiale du scanner cardiaque est reconnue et fortement utilisée en pratique courante pour l'évaluation anatomique des coronaires, l'évaluation des gros vaisseaux et plus récemment pour la recherche de thrombus de l'auricule gauche (10). Au scanner, le thrombus ventriculaire est classiquement décrit comme une masse hypodense en regard d'une paroi avec trouble de la cinétique. Certaines cohortes ont comparées l'échographie au scanner sur de faibles échantillons (11), mais à notre connaissance il n'existe pas d'étude comparant la sensibilité et la spécificité pour le diagnostic du thrombus du ventricule gauche sur de grosse cohorte ayant permis de valider la technique et de l'intégrer dans l'arbre décisionnel en cas de suspicion clinique.

*Imagerie par résonnance magnétique cardiaque.*

L'imagerie par résonnance magnétique cardiaque est le gold standard pour le diagnostic des thrombus ventriculaires gauches. De nombreuses études ont montré sa supériorité diagnostique par rapport à l'échographie (4)(7). Les séquences reconnues pour avoir la meilleure accuracy sont les séquences de ciné IRM et les séquences de rehaussement tardif (5). Cette dernière est considérée comme la séquence référence. En IRM, le thrombus ventriculaire est décrit par une masse sous endocardique en hypo signal en séquence ciné IRM et en rehaussement tardif. La séquence de rehaussement tardif est reconnue comme sensible pour détecter la présence d'un thrombus étant donné que ce dernier apparait en hyposignal au milieu d'une zone myocardique nécrosée qui apparait en hypersignal.

La séquence de perfusion premier passage n'a jamais été étudiée en tant qu'outils diagnostique pour les thrombus du ventricule gauche. Cette séquence de contraste permet de mettre en évidence au sein du ventricule les parois de l'endocarde, les trabeculations et les cordages. Cette notion peut donc être fortement intéressante en cas d'importantes trabeculations ou lorsque la séquence de rehaussement tardif est mise à défaut. Par ailleurs cette séquence ne change pas le déroulement habituel de l'examen étant donné que cette injection est systématiquement réalisée pour acquérir la séquence de rehaussement tardif. L'inconvénient réside dans la nécessité de réaliser une séquence de perfusion 4 cavités, puisque la plupart des thrombus sont situés à l'apex. On suppose que l'analyse systématique de cette séquence peut augmenter accuracy de l'IRM, au même titre que l'utilisation systématique de produit de contraste dans l'échographie trans thoracique (4). La figure 5 de l'article image l'apport de la séquence de perfusion.

Les principales limites de l'IRM sont sa faible disponibilité et son coût, en comparaison notamment à l'échocardiographie. L'IRM a permis de diagnostiquer des thrombus infra centimétriques et muraux jusqu'alors méconnus des techniques conventionnelles d'imageries, dont la prise en charge est encore débattue.




Circulation. 2002;106:2873-2876

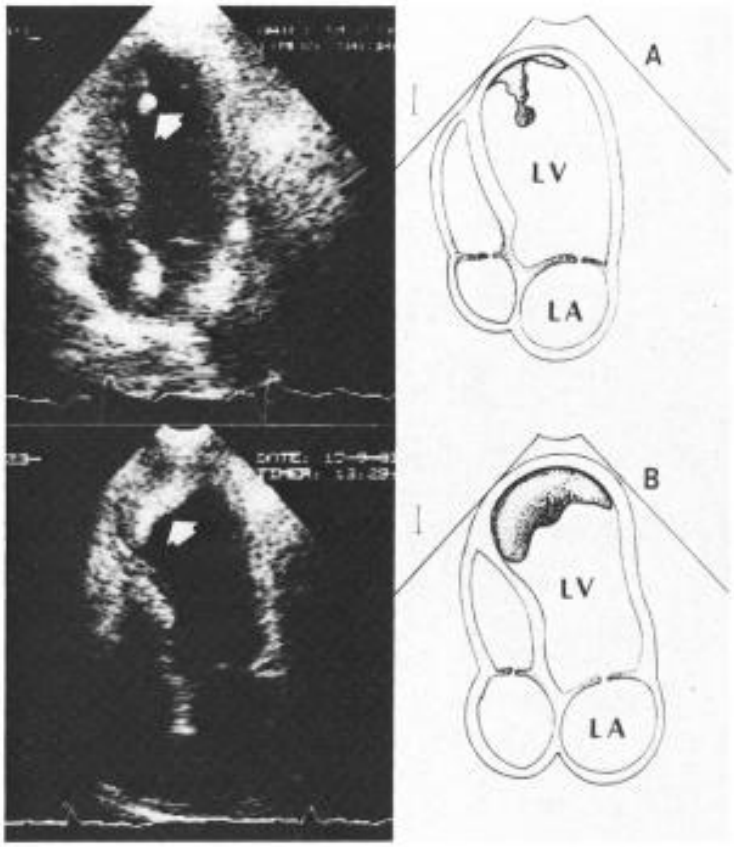
Figure 2 : A) un thrombus visible en séquence ciné et rehaussement tardif, B) thrombus visible uniquement en séquence de rehaussement tardif

**VI] Prise en charge**

*Le risque embolique.*

Les données sur le risque embolique en cas de thrombus ventriculaires sont relativement faibles. Ce risque était évalué aux alentours de 10 % (12) avant l'ère de l'angioplastie percutanée mais des données plus récentes diminuent la prévalence à moins de 5 % en cas de thrombus. (13)(14). Vaitkus *et al* estime dans une méta-analyse une augmentation du risque d'événement embolique par un facteur 5 en présence d'un thrombus ventriculaire (14).

Le risque embolique varie selon la forme et la mobilité du thrombus. Il est reconnu que pour les thrombus mobiles, pédiculés et de tailles importantes (15)(16), le risque d'événement embolique augmente. Ce risque est plus controversé pour les thrombus muraux, immobiles et de petites tailles.




Circulation 75, No. 4, 737-743,1987

Figure 3 : Représentation en A) d'un thrombus ventriculaire pédiculé et en B) d'un thrombus mural.

*Le traitement.*

Les principales recommandations de prise en charge reposent sur des études anciennes datant de l'ère avant angioplastie. La prévalence des thrombus ventriculaires était plus élevée et les thrombus de tailles plus importantes. Ainsi certaines études ont montré qu'un traitement systématique préventif par héparine diminuait le taux de thrombus en post infarctus (17) mais augmentait le risque hémorragique de façon significative (18), sans pour autant diminuer le risque embolique. D'autres auteurs tels que Vecchio *et al.* n'ont pas montré de réduction du nombre de thrombus ventriculaires chez les patients traités par héparine en addition à un traitement thrombolytique (19).

A ce jour quelques soit la taille du thrombus, les recommandations préconisent un traitement anticoagulant. La durée du traitement varie selon entre les sociétés scientifiques. La société européenne de cardiologie recommande un traitement de  6 mois alors que la société américaine (20) recommande un traitement indéfini selon le risque hémorragique du patient. La question reste cependant toujours controversée pour les thrombus de petites tailles dont le risque embolique est mal défini.

On notera que certains auteurs essayèrent la thrombolyse, pour diminuer l'incidence des thrombus ventriculaires. Cette thérapie n'est pas recommandée à ce jour, étant donné qu'elle ne diminue pas l'incidence des thrombus (13) et peut entraîner une augmentation du risque embolique (21).

L'objectif de cette thèse est d'évaluer l'apport de la séquence de perfusion premier passage pour le diagnostic des thrombus en post infarctus du myocarde ; puis secondairement d'établir les facteurs favorisants de la formation de thrombus.

Cette étude monocentrique, réalisée au CHU d'Angers.

# La séquence de perfusion premier passage pour améliorer le diagnostic des thrombus du ventricule gauche en post infarctus du myocarde :

# Une étude d'imagerie par resonnance magnétique cardiaque.


**RESUME**

**Introduction**

Le thrombus ventriculaire gauche (LVT) est une complication courante et potentiellement dangereuse de l'infarctus du myocarde (MI). Plusieurs études surlignèrent l'intérêt de l'IRM cardiaque pour le diagnostic des thrombus ventriculaires gauches mais aucune d'entre elle n'a étudiée l'intérêt d'une lecture combinée des différentes séquences IRM disponibles.

Cette étude tente de savoir 1) si la séquence de perfusion premier passage (FPP) améliore le diagnostic de thrombus du ventricule gauche et 2) les facteurs prédictifs de thrombus après un infarctus du myocarde (MI).

**Méthodes et résultats**

Entre Mai 2004 et Juin 2014, 329 patients avec un MI passèrent une IRM cardiaque précocement puis à 3 mois. Les patients eurent un suivi clinique à 3, 6, 12 et 24 mois. Les IRM ont été analysées en aveugle par 2 lecteurs (1 expert et 1 novice) selon le même protocole de lecture. Une première analyse avec les séquences ciné et rehaussement tardif, puis une seconde avec le même protocole combiné à la séquence FPP. Un LVT a été retrouvé sur 31 des 640 IRM, affectant 30 (9.1 %) patients. La séquence FPP améliore significativement le diagnostic de LVT pour les 2 lecteurs. Deux LVT n'avaient pas été vus sans la séquence FPP par l'expert, contre 6 par le novice. La séquence FPP améliore la certitude diagnostique dans 32% des cas. La formation des LVT est associée à une altération de la FEVG (39.6 ± 8.0% vs. 48.0 ± 9.7%; p<0,001), une augmentation du volume télésystolique (63,6 ± 19,2 ml/m² vs. 46,0 ± 14,8 ml/m²; p<0,001), un large infarctus (24,21 ± 8,9% vs. 15,64 ± 10,96%; p=0,008), une diminution de la masse myocardique (63.6 ± 1 vs. 58.3 ± 11.9; p=0.046) et à un infarctus antérieur. En analyse multivariée l'augmentation du volume télé systolique est le meilleur facteur prédictif de LVT. Quatre patients avec LVT présentèrent un AVC au cours du suivi. La présence d'un LVT par IRM incrémentait le risque d'AVC à un OR de 22.61 [95% CI: 3.95-129.38].

**Conclusion :**

La séquence de FPP accroît la prévalence de thrombus ventriculaire gauche à 9.1% des infarctus du myocarde. Le taux de LVT augmente avec la dilatation du ventricule gauche et en cas d'infarctus antérieur. Nos résultats sont fortement en faveur d'une utilisation de FPP pour la détection des LVT.

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

# A cardiac magnetic resonance imaging study


**ABSTRACT**

**Introduction:**

Left ventricular (LV) thrombus is a current and potentially dangerous complication of myocardial infarction. Prior studies highlighted cardiovascular magnetic resonance imaging (CMR) to detect LV thrombus, but none of them evaluated the interest for a combined reading of the various CMR sequences that are available.

This study sought to assess 1) whether the first pass perfusion sequence improved the detection of LV thrombus and 2) the predictive factors of LV thrombus after myocardial infarction

**Methods and Results:**

Between May 2004 and June 2014, 329 patients with myocardial infarction underwent CMR at baseline and at 3 months follow-up. Patients underwent clinical examination at 3, 6, 12 and 24 months. CMR were analyzed by two blinded examiners (1 CMR expert and 1 novice) and according to two reading protocol. On the first hand, an analysis was performed on cine CMR and late gadolinium enhancement. On the second hand another analysis was performed following initial protocol combined to first pass perfusion sequences (FPP). A thrombus was found in 31 of 640 CMR scans, affecting 30 (9.1%) individuals. The FPP improved significantly the LVT diagnosis for both readers. Two LVT were not seen without the FPP sequence for the CMR expert and 6 for the novice. The FPP sequence improved the final diagnosis in 32% of cases. LVT formation was associated with lower LV ejection fraction (39.6 ± 8.0% vs. 48.0 ± 9.7%; $p<0.001$), greater LV end-systolic volume (63.6 ± 19.2 ml/m² vs. 46.0 ± 14.8 ml/m²; $p<0.001$), greater infarct size (24.21 ± 8.9% vs. 15.64 ± 10.96%; $p=0.008$), greater LV mass (63.6g ± 1 g/m² vs. 58.3 ± 11.9 g/m²; $p=0.046$) and anterior infarction. Multivariable analysis revealed LV end-systolic volume to be the best predictor of LVT. Four LVT patients presented a stroke during the follow-up. The presence of LVT by CMR increased the risk of stroke with an OR of 22.61 [95% CI: 3.95-129.38].

**Conclusion:**

The detection of left ventricular thrombus after myocardial infarction increased with the FPP sequences to reach 9.1% of STEMI patients. The LVT presence was related to greater LV end systolic volume, and anterior infarctions. Our results are strongly recommending the use of FPP in routine for the detection of LV thrombus.

## INTRODUCTION:

Left ventricular thrombus (LVT) is a well-known complication after a large myocardial infarction. The detection of LVT by transthoracic echocardiography (TTE) seems underestimated, yet essential to prevent embolic complication (22)(8). Nowadays, cardiovascular magnetic resonance imaging (CMR) is considered as the gold standard to diagnose LVT. Prior studies reported better sensitivity and specificity for LVT detection with Cine CMR and Late gadolinium enhancement (LGE) compared to TTE (23). LGE differentiates LVT from surrounding myocardium as thrombus is avascular and thus characterized by an absence of contrast uptake (7). Nevertheless sometime the interpretation of LGE is difficult especially in large infarct size with microvascular obstruction. The first pass perfusion (FPP) precise intracavitary borders of LVT with high contrast. In our knowledge, no study evaluated the contribution of FPP to improve the sensitivity for LVT detection (5).

Moreover, predictive factors resulted from TTE or small CMR cohorts (24)(25). CMR allow the analysis of multiple parameters encompassing anatomy, function and tissular characteristics. It should be used to refine our knowledge about LVT determinants.

This study sought to assess 1) whether the first pass perfusion sequence improved the detection of LVT and 2) the predictive factors of LVT formation after myocardial infarction in a CMR prospective cohort.

## METHODS:

A total of 329 patients presenting a first STEMI were enrolled prospectively between May 2004 and September 2014 in the university hospital of Angers (France). All were treated successfully with primary percutaneous coronary intervention and final TIMI flow grade 3. All patients gave written informed consent and underwent CMR at baseline (6.5 days ± 4.4) and at 3 months follow-up (103 days ± 28.7). Exclusion criteria were a coronary bypass grafting, age <18 years, a major comorbidities limiting life expectancy and a contra-indications 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 French

regulatory requirements. Only 311 patients underwent CMR at 3 months for reasons explained in **Figure 1**.

2.1. Cardiovascular magnetic resonance

CMR was performed using either 1.5 or 3.0 Tesla 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 views covering the entire LV. The typical in-plane resolution applied was 1.2x1.2mm, with a 7mm section thickness and no gap (matrix: 155x288; temporal resolution: 45-50 msec).

FPP was performed during gadolinium contrast agent injections at a dose of 0.2mmol/Kg. FPP images were acquired using saturation-recovery sequence with an acquisition time of 100ms per section, TR 1.5 ms, TE 1.08 ms, flip angle 10°, typical voxel size after adapting the field of view with a resolution of 1.8 x 1.8 x 7 mm. FPP series were acquired in three short-axis views covering the basal, mid-ventricular and apical segments and additionally in a four-chamber long-axis view. The minimum duration of acquisition of the perfusion sequence was 35 seconds. Free breathing was permitted after first passage of the contrast agent.

LGE sequences were performed 12 to 15 minutes after the injection, by means of a 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 slices covered the entire ventricle. The typical in-plane resolution used was 1.6x1.6mm, with a 7mm section thickness and a matrix of 140x224.

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 2 readers: 1 novice and 1 expert. Readers were blinded to clinical history and TTE results. Readers interpreted all CMR, independently in two 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 thrombus, 2) Evidence of thrombus with high probability, and 3) Thrombus with certitude. More, uninterpretable examinations were registered.

For Cine CMR, LVT was defined as a mass within the cavity which borders are distinguishable from ventricular endothelium, trabeculation and chordae. On FPP, LVT appeared as 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. A diagnosis of LVT at baseline CMR defined as "early LVT", conversely LVT at 3 months defined as "late LVT".

Signal-to-noise ratio values were calculated as the mean signal intensity for regions of interest placed over the center of the LVT, inside the LV cavity and the myocardium, divided by the signal noise level. The contrast-to-noise ratio was calculated between the differences of mean signal intensity of each compartment divided by the noise (26).

2.3 Follow-up

All clinical characteristics were registered prospectively during the first hospitalization, and repeated at 3 months, 6 months, 12 months, 24 months for assessments of clinical status and adverse events. In case of LVT, the follow-up was longer than 2 years. Major adverse cardiac events (MACE): cardiovascular death, infarction, heart failure and stroke (ischemic or not) were recorded.

2.4 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.

Multivariate analyses assessed (1) the determinants of LVT, and (2) the predictive factors for stroke occurrence. A stepwise binomial logistic regression analysis was performed, including variables with *p* value <0.05.

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 (6.68%) and 9 late LVT (2.89%). Overall 30 (9.1%) individuals presented LVT after STEMI. Clinical, CMR, and angiographic results are described in **Table I**. All thrombus were seen in anterior infarction. There was no difference between groups for clinical characteristics, except the prevalence of dyslipidemia which was lower in early LVT group.

3.1 FPP to diagnose LVT

The comparisons of LVT diagnostic accuracy between routine and FPP stages were described in **Table II** and **Figure 2**. Expert and novice examination changed their final diagnosis from "High probability of LVT" to "LVT with certitude" for respectively 32%, and 17% of the LVT cases after FPP reading. For expert examination, FPP improved final diagnosis pertinence in 39%. Two LVT were not seen after the first reading, and were only detected due to FPP contribution. This contribution increased for the novice examination, where FPP diagnosed 6 additional LVT (20% of total LVT) to reach the expert diagnostic accuracy. With routine stage, the sensitivity for a novice reader was 78.1%, the specificity 99%, the positive predictive value 80.6%, and the negative predictive value 98.8%. With FPP stage, this value increased respectively to 91.2%, 100%, 100%, and 99.5% (**Table III)**. This contribution was higher for the novice at baseline. **Figure 3** show SNR and CNR for the detection of LVT by cine CMR, FPP and LGE imaging.

3.3 Risk factors of LVT

In univariate analysis, the risk factors of early and late LVT were: large infarct size, high peak of creatin kinase, increased LV volumes and depressed LV ejection fraction and low LV mass (**Table IV and V)**. All LVT occurred in anterior infarctions. LV volume changes between baseline and 3 months CMR revealed to be univariate predictor of late LVT.

In multivariable analysis, LV end systolic volume at baseline was the sole determinant of early and late LVT (OR: 1.056 [1.018-1.096], p0.004, and OR=1.184 [1.046-1.340], p0.007, respectively) **(Table VI)**. A threshold of 59 ml/m² of LV end systolic volume was established to predict a LVT presence **(Figure 4)**. At baseline, a LV end systolic volume over 59 ml/m² predicted early LVT with a sensitivity of 77.7%, a specificity of 82.2%, a negative predictive

value of 99.2%, and a positive predictive value of 11.0%. The same results were observed for the prediction of late LVT at 3 months, with respectively 88.9%, 84.3%, 99.6% and 14.5%.

3.4 Outcomes

Follow-up lasted a median of 724 days [25-75 percentiles: 365-1264] after initial infarction. MACE were not different between patients with or without either early or late LVT. There was 6 strokes during follow-up, including and 1 patient with early LVT and 3 patients with late LVT (OR 49.5 [8.2-297.3]; $p<0.001$) and two patients without LVT. Late LVT was independently associated with a higher risk of ischemic stroke compared to the early LVT.

DISCUSSION:

Our study demonstrates that FFP improved LVT diagnostic accuracy after a myocardial infarction. LVT prevalence reached 9.1% among a homogenous cohort of patient with early and successful revascularization after symptoms onset. We found greater LV volumes to be the best determinant of LVT. The risk of ischemic stroke increases strongly in case of late LVT.

4.1 LVT diagnosis.

This is the first report to assess FPP for LVT diagnosis after an acute myocardial infarction. CMR is known to present a better accuracy than TTE or transesophageal echocardiography for LVT diagnosis. Prior studies reported that sensitivity and specificity of TTE were 60% and 90% respectively compared to 88% and 99% for CMR (7). Among the sequences, LGE was considered as the gold standard for LVT detection (5) but all CMR studies were based only on cine CMR and LGE imaging. The criteria to differentiate an area of microvascular obstruction from mural thrombus are uncertain and may be difficult. FPP dynamically enhance intracavitary borders of LVT and can be of precious help for examiners **(Figure 5)**. In our study, the FPP stage allowed to improve LVT diagnostic accuracy in 39 % for the expert. FPP permitted to rectify LVT diagnosis in few patients. The finding may be liable to improved CNR. In fact, contrast may be still underestimated in our study because contrast

was measured between LVT and blood pool rather than on LV trabeculations, which was found technically unfeasible.

Most of LVT diagnoses, rectified with FPP stage, were situated on the apical segment, therefore the FPP sequence shall include systematically a four-chamber long-axis view. We noted no statistical difference between the imaging characteristic of LVT diagnosed by FPP stage and the LVT diagnosed by routine stage **(Table VII)**.

Despite this contribution, the perfect timing to perform CMR after an acute MI is still debatable. Most of LVT seems to be formed at 2 weeks (3), but a very early LVT formation (<48h) would be a prognosis factor (27).

4.2 LVT prevalence

LVT prevalence (total 9.1% of the cohort) was smaller than prior studies though the diagnosis techniques chose (CMR) possesses a better sensitivity (28). There were a number of possible explanations of this discrepancy. LVT incidence had decreased with the development of PCI treatment in acute myocardial infarction (29) and many studies were performed before the angioplasty era. Use of revascularization therapy and modern medical management are probably the main reasons why LVT rate is so heterogeneous (5.1% to 40%) (1). Our study excluded patients in cardiogenic shock or severe heart failure and did not include patients with late presentation. One should consider our cohort to be at low event risk that is common to most recent studies in the field (30)(31). Moreover, most of studies estimated the early LVT rate which is around 6.7% in our study, thus close to the last reports (24)(28). For example, Gueret *et al* studied in TTE trial the prevalence of mechanical complications in the early phase of MI and discovered only 2.8 % LVT (32). Delewi *et al* found prevalence of late LVT at 4 months of 8.3% (9).

4.3 LVT determinants

The main risk factors of LVT commonly described were: depressed LV ejection fraction (8), anterior infarction (7), patients that did not undergo primary percutaneous coronary intervention (28), LV changes (3), heart failure (13), presence of aneurysm and greater infarct size (5).

In our study, all patients were revascularised successfully. Our multiparametric CMR study revealed an anterior infarction and greater LV volumes to be the main determinants of LVT formation. Still LVT are quite (1)(33) but not exclusive (29) to anterior infarction in the literature. The studied population may be considered at low risk of events, as it presented no aneurysm formation and low heart failure occurrence. We rather found a LV end-systolic volume less than 59ml/m² to present a negative predictive value for LVT presence over 99%. Unlike past studies, in multivariate analysis lower LV ejection fraction and larger infarct size did not appear as LVT risk factors.

Greater LV volumes reached to a blood stasis and further the LVT formation (3), as in the dilated cardiomyopathy where the rate of LVT is higher than in ischemic cardiomyopathy (34)(35). In addition, dynamic changes of LV volume is considered as one key point of LV remodeling after acute MI (36). This is consistent with both intracavitary stasis and systemic inflammatory response, two major factors of LVT formation. More, early LVT was more common than late LVT, underlining the effect of acute dynamic changes so as the potential role of acute inflammatory response and hypercoagulability early after MI (37). LV remodeling knows various definitions among authors but was specified by an excess in absolute LV dilation in the late LVT patients.

Among the 22 early LVT, only one had residual thrombus on the CMR at 3 months. Thus the patients who had early and late LVT are distinct, but shared similar determinants emphasizing LV end systolic volume and anterior infarction.

4.4 Clinical implications

Among 22 early LVT, 16 patients were treated with anticoagulation. Despite this treatment, we noted 6 ischemic strokes whose 3 were considered as an embolic complication of the LVT (**Table VIII)**. In our study, the 9.6% rate of embolic events is corroborating previous results (16). Actually, there are only few and debatable criteria to characterize the individual embolic risk of LVT, namely its mobility (16). Our results suggest late LVT to be at greater risk for stroke (affecting a third of late LVT patients) rather than early (one case). Our study is limited for the investigation of tardily events that may be related to the greater levels of LV remodeling.

Europeans guidelines (38) require after LVT diagnosis, an oral anticoagulant therapy with vitamin K antagonists for up to 6 months. However, it is specified that this management was

based on old study results (14) (17) and was not revisited in the modern stenting era with its concomitant dual anti-platelet therapy. For example, Kontny *et al* concluded in 1997 that dalteparin reduces significantly LVT formation in acute anterior myocardial infarction but was associated with increased hemorrhagic risk (18). Presently, LVT prevention with anticoagulation addition is questionable after acute MI, especially because the hemorrhagic risk with the new dual platelet (39)(40) or the triple therapy increases significantly (41). The ins and outs between bleeding risks and LVT formation are unfortunately unknown and hard to define as stroke prevalence after MI is low (42).

## CONCLUSION:

The FPP imaging improved the CMR diagnosis performance of LVT after an acute myocardial infarction. This routine sequence should be carefully considered, especially in apical views and for novice examiners.

The main predictive factor of LVT was left ventricular end-systolic volume. A threshold of 59 ml/m² of left ventricular end-systolic volume allowed excluding LVT formation in 99%.

Finally, in modern era of primary percutaneous coronary intervention, the management of LVT stays controversial and further studies should aim 1) to identify at-risk patients whether or not they have been revascularised and 2) to support the interest of serial assessment by CMR in medical management.

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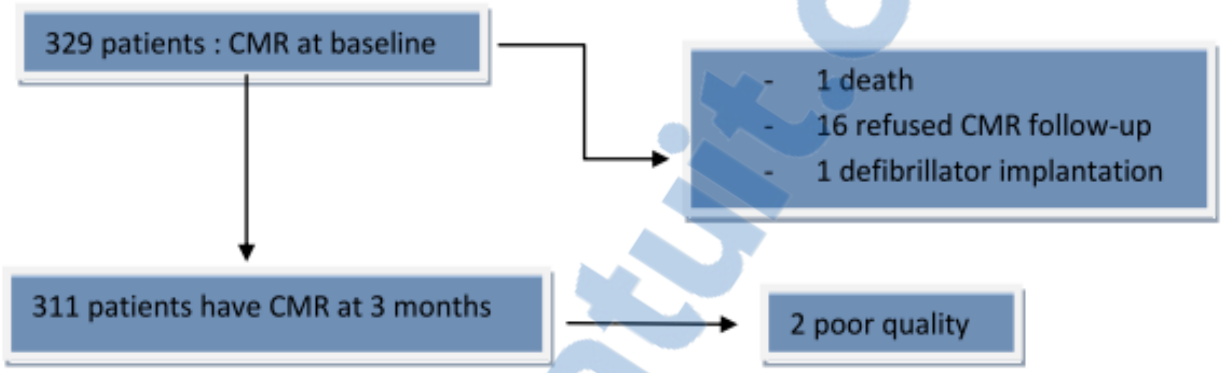



Figure 1: Flowchart of the patients.

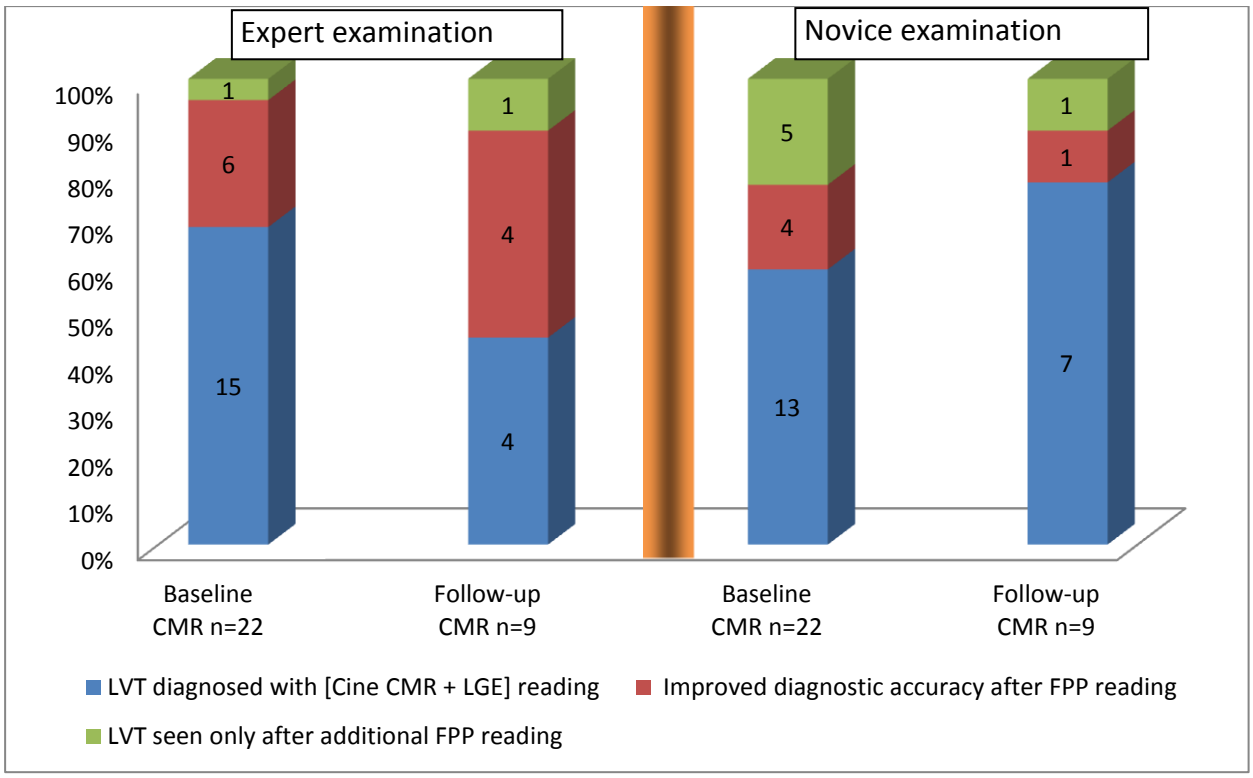
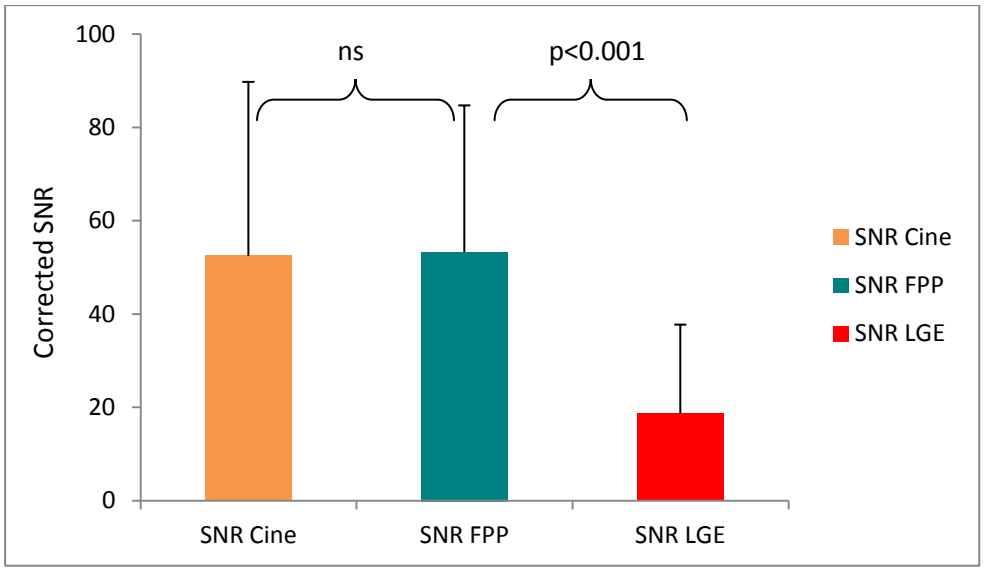



Figure 2: FFP contribution by readers for LVT diagnosis



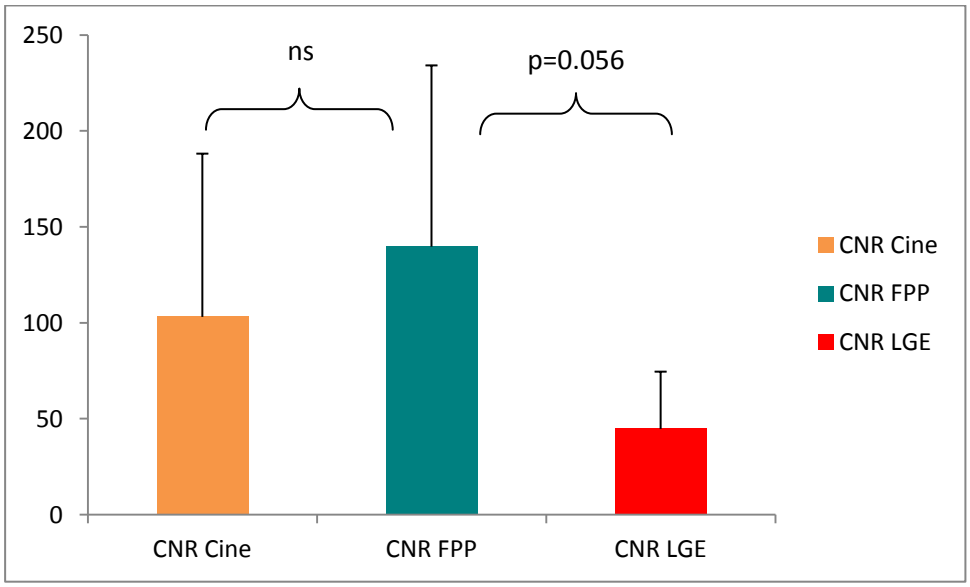
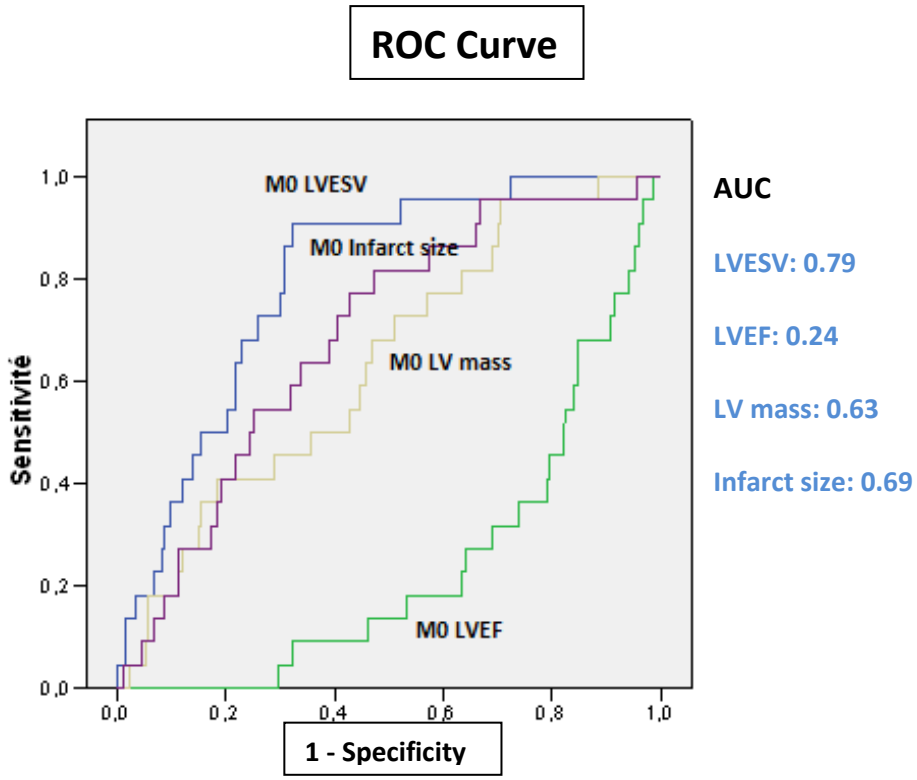




Figure 3: Comparison of Signal-to-noise ratio and Contrast-to-noise ratio for the detection of LVT by cine CMR, FPP and LGE imaging.

A




**AUC**

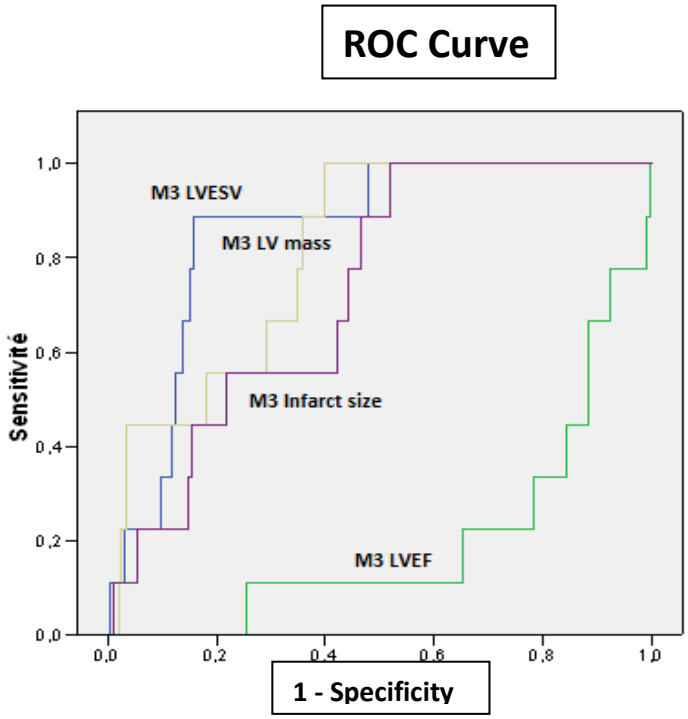
**LVESV: 0.79**

**LVEF: 0.24**

**LV mass: 0.63**

**Infarct size: 0.69**

B




**AUC**

**LVESV: 0.85**

**LVEF: 0.24**

**LV mass: 0.63**

**Infarct size: 0.73**

Figure 4: The ROC curve studying imaging characteristic on CMR for early (A) and late (B) LVT formation

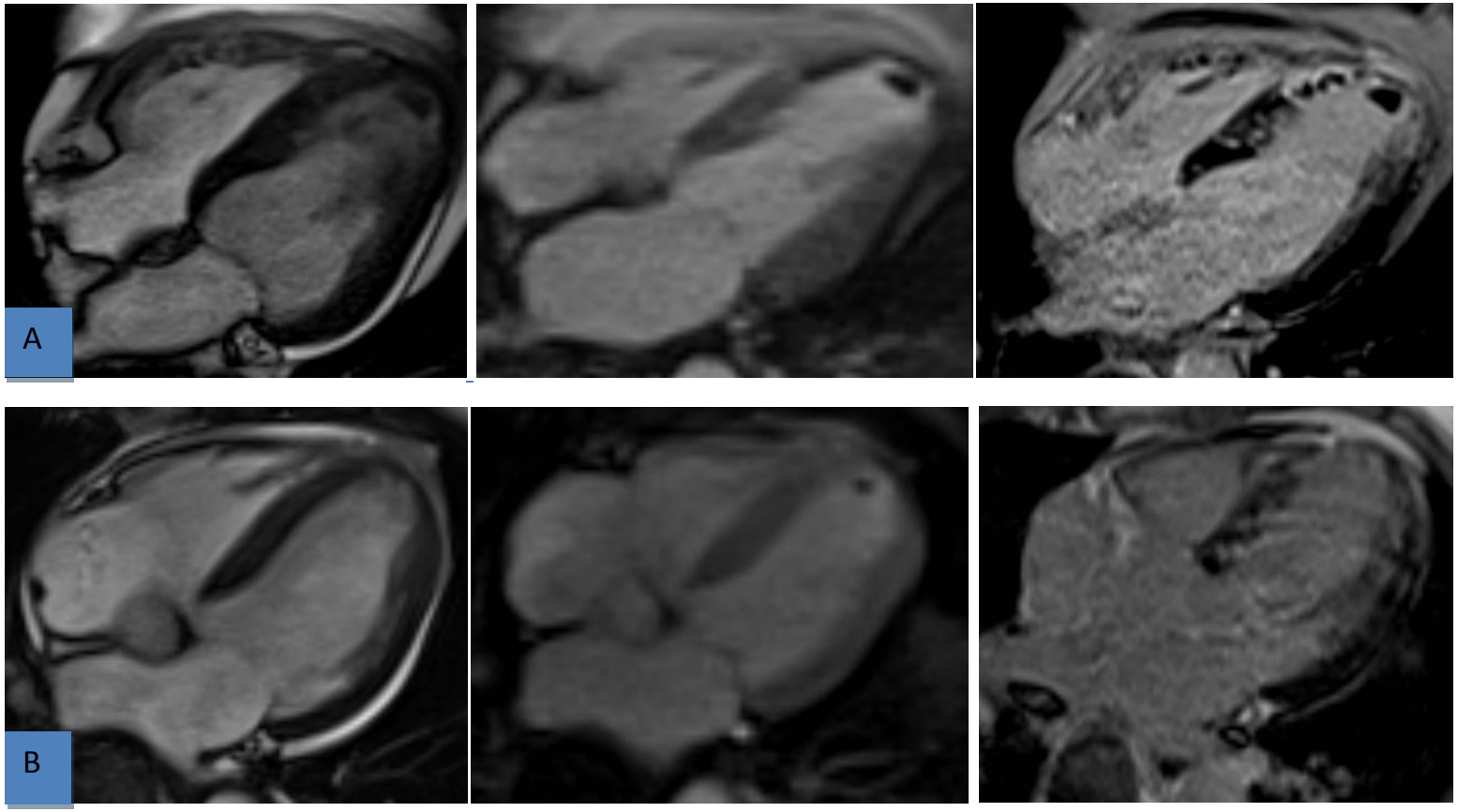



Figure 5: Demonstrative imaging of the contribution of the first pass perfusion sequence in LVT diagnosis.

Slice A: Case with large LVT already documented at the routine stage. Slice B: Case where the FFP was necessary for the LVT diagnosis, for both readers.

Table I: Baseline patient characteristics stratified according to the early or late LVT at CMR after acute myocardial infarction

| | **No early LVT (n= 305)** | **Early LVT (n= 22)** | **p value** | **No late LVT (n= 302)** | **Late LVT (n= 9)** | **p value** |
|---|---|---|---|---|---|---|
| Baseline characteristics | | | | | | |
| Age, yr | 58.5 ± 11.3 | 57.3 ± 9.5 | 0.67 | 58.2 ± 11.3 | 65.3 ± 8.7 | 0.05 |
| BMI kg/m² | 27.1 ± 4.0 | 25.3 ± 3.2 | 0.21 | 27.0 ± 4.0 | 26.4 ± 3.4 | 0.74 |
| Systolic blood pressure, mmHg | 119.1 ± 17.8 | 117.1 ± 16.2 | 0.63 | 118.8 ± 17.7 | 114.1 ± 16 | 0.42 |
| Heart rate, bpm | 70.3 ± 11.9 | 63.8 ± 7.7 | 0.36 | 70.3 ± 11.8 | 74.7 ± 8.6 | 0.29 |
| Risk factors, no. (%) | | | | | | |
| Male gender | 252 **(82%)** | 19 **(86%)** | 0.88 | 222 **(73%)** | 9 **(100%)** | 0.39 |
| Hypertension | 102 **(33%)** | 4 **(18%)** | 0.10 | 101 **(33%)** | 1 **(11%)** | 0.14 |
| Diabete mellitus | 40 **(13%)** | 1 **(4%)** | 0.20 | 42 **(13%)** | 0 **(0%)** | 0.29 |
| Dyslipidemia | 156 **(51%)** | 5 **(23%)** | <0.01 | 163 **(54%)** | 6 **(66%)** | 0.23 |
| Heredity | 75 **(24%)** | 6 **(27%)** | 0.47 | 77 **(25%)** | 3 **(33%)** | 0.42 |
| Active smoker | 134 **(44%)** | 8 **(36%)** | 0.74 | 130 **(43%)** | 3 **(33%)** | 0.68 |
| Time to reperfusion, min | 280 ± 181.1 | 314.3 ± 147.4 | 0.58 | 282.6 ± 182.8 | 291.1 ± 155.2 | 0.89 |
| Creatinine, µmol/L | 82.5 ± 24.4 | 82.6 ± 22.4 | 0.65 | 82.4 ± 24.5 | 87.8 ± 18.9 | 0.24 |
| Creatin kinase peak, UI/L | 2888.2 ± 2125 | 4133.5 ± 2544 | <0.01 | 2916.8 ± 2157 | 5221.4 ± 2586 | <0.01 |
| HbA1c, % | 6.0 ± 1.1 | 5.7 ± 0.3 | 0.28 | 6.0 ± 1.1 | 5.6 ± 0.2 | 0.19 |
| CRP peak, g/L | 17.7 ± 31.5 | 30.8 ± 32.5 | 0.06 | 13.9 ± 27.0 | 29.3 ± 57.3 | 0.81 |
| Preinfarction angina | 116 **(38%)** | 8 **(36%)** | 0.82 | 119 **(39%)** | 2 **(22%)** | 0.57 |
| Anterior infarction | 161 **(52%)** | 22 **(100%)** | <0.001 | 167 **(55%)** | **9 (100%)** | <0.01 |
| Medication at baseline, no. (%) | | | | | | |
| Aspirin | 22 **(7%)** | 1 **(4%)** | 0.05 | 22 **(7.%)** | 1 **(11%)** | 0.50 |
| VKA | 0 **(0%)** | 0 **(0%)** | 0.06 | 1 **(0.3%)** | 0 **(0%)** | 0.97 |
| Medication at discharge, no. (%) | | | | | | |
| Aspirin | 302 **(99%)** | 22 **(100%)** | 0.93 | 299 **(99%)** | 9 **(100%)** | 0.97 |
| VKA | 13 **(4%)** | 16 **(72%)** | 0.26 | 13 **(4.3%)** | 1 **(11%)** | 0.34 |
| Beta blocker | 303 **(99%)** | 22 **(100%)** | 0.56 | 302 **(100%)** | 8 **(88%)** | 0.07 |
| ACE inhibitor | 294 **(96%)** | 22 **(100%)** | 0.57 | 293 **(97%)** | 9 **(100%)** | 0.94 |
| Clopidogrel | 185 **(60%)** | 14 **(63%)** | 0.50 | 190 **(62%)** | 4 **(44%)** | 0.21 |
| Prasugrel | 104 **(34%)** | 8 **(36%)** | 0.50 | 96 **(31%)** | 5 **(55%)** | 0.65 |
| Events | | | | | | |
| MACE | 39 **(12.79%)** | 5 **(22.73%)** | p=0,75 | 39 **(12.91%)** | 3 **(33.3%)** | p=0.32 |
| CV death | 5 **(1.64%)** | 0 | p=0.70 | 3 **(0.99%)** | 1 **(11.1%)** | p=0.11 |
| Heart failure | 18 **(5.90%)** | 1 **(4.55%)** | p=0.62 | 18 **(5.96%)** | 1 **(11.1%)** | p=0.43 |
| CVA | 5 **(1.64%)** | 1 **(4.55%)** | p=0.34 | 3 **(0.99%)** | 3 **(33.3%)** | p<0.001 |
| LVT size (cm) | - | 10.99 | - | - | 10.28 | ns |
| % of pedicle LVT | - | 10 **(45.4%)** | - | - | 1 **(11.1%)** | |

Data are mean ± SD or number (percentage). VKA: Vitamin K Antagonist. ACEI: Angiotensin-converting enzyme inhibitor, CRP: C reactive protein; MACE: major cardiovascular events, CV: cardiovascular, LVT: Left ventricular thrombus

Table II: Final diagnosis with and without the FPP sequence by reader

| | EXPERT EXAMINATION | | | NOVICE EXAMINATION | | |
|---|---|---|---|---|---|---|
| Thrombus (n=31) | Cine CMR + LGE n=638 | | Cine CMR + LGE + FPP n=638 | Cine CMR + LGE n=638 | | Cine CMR + LGE + FPP n=638 |
| No thrombus | 608 | 1 | 607 | 605 | 5 | 604 |
| High probability of LVT : | 14 | 2 | 5 | 15 (4 FP) | 6 | 11 (2 FP) |
| LVT with certitude : | 16 | 10 | 26 | 18 | 5 | 23 (1 FP) |

FP: False positive

Table III: Sensitivity, specificity, positive predictive value, negative predictive value by readers.

| | Sensitivity | specificity | PPV | NPV |
|---|---|---|---|---|
| Expert “LGE + Cine” | 96.7 | 99.7 | 93.5 | 99.8 |
| Expert “LGE + Cine + FPP” | 96.9 | 100.0 | 100.0 | 99.8 |
| Novice “LGE + Cine” | 78.1 | 99.0 | 80.6 | 98.8 |
| Novice “LGE + Cine + FPP” | 91.2 | 100.0 | 100.0 | 99.5 |

PPV: Positive predictive value, NPV: Negative predictive value, LGE: Late Gadolinium Enhancement, FPP: First Pass Perfusion

Table IV: Univariate predictors of LVT

| | **Early LVT** | | **Late LVT** | |
|---|---|---|---|---|
| CMR initial assessment | OR [95% Conf. Interval] | p value | OR [95% Conf. Interval] | p value |
| LVEDV index, ml/m² | 1.048 [1.02-1.07] | <0.001 | 1.038 [1.00-1.07] | 0.02 |
| LVESV index, ml/m² | 1.057 [1.03-1.08] | <0.001 | 1.048 [1.01-0.08] | <0.01 |
| LVEF, % | 0.920 [0.88-0.96] | <0.001 | 0.909 [0.85-0.97] | <0.01 |
| LV mass index, g/m² | 1.037 [1.00-1.07] | 0.04 | 1.063 [1.01-1.12] | 0.02 |
| Infarct size, **%** | 1.042 [1.01-1.07] | <0.01 | 1.062 [1.01-1.11] | 0.01 |
| MVO presence | 1.970 [0.80-4.83] | ns | 1.866 [0.43-7.94] | ns |
| LVEDV index change, ml/m² | - | - | 1.041 [1.00-1.08] | 0.05 |
| LVESV index change, ml/m² | - | - | 1.028 [1.00-1.05] | 0.04 |
| Other criteria | | | | |
| Time to reperfusion, min | 1.001 [0.99-1.00] | ns | 1.000 [0.99-1.00] | ns |
| Dyslipidemia | 0.277 [0.10-0.77] | 0.01 | 1.003 [0.99-1.00] | ns |
| Monotroncular | 0.827 [0.69-5.68] | ns | 2.500 [0.51-12.3] | ns |

LVEDV: left ventricular end-diastolic volume; LVESV: left ventricular end-systolic volume; MVO: microvascular obstruction; LVEF: left ventricular ejection fraction; LV: left ventricle

Table V Imaging characteristics of CMR initial assessment and CMR follow-up assessment stratified according to the early or late LVT

| | **No early LVT (n= 305)** | **Early LVT (n= 22)** | **p value** | **No late LVT (n= 302)** | **Late LVT (n= 9)** | **p value** |
|---|---|---|---|---|---|---|
| CMR initial assessment | | | | | | |
| LVEDV index, ml/m² | 87.7 ± 17.0 | 104.0 ± 19.2 | <0.001 | 88.5 ± 17.8 | 102.6 ± 11,7 | 0.02 |
| LVESV index, ml/m² | 46.0 ± 14.9 | 63.6 ± 19.2 | <0.001 | 46.9 ± 15.5 | 63.7 ± 11.3 | <0.001 |
| LVEF, % | 48.0 ± 9.7 | 39.6 ± 8.0 | <0.001 | 47.7 ± 9.6 | 37.8 ± 9.7 | <0.01 |
| LV mass index, g/m² | 58.3 ± 11.9 | 63.6 ± 10.0 | 0.33 | 58.5 ± 11.3 | 67.6 ± 10.0 | 0.19 |
| Infarct size, **%** | 19.5 ± 13.0 | 27.5 ± 12.5 | <0.01 | 19.9 ± 13.1 | 32.1 ± 12.7 | <0.01 |
| CMR follow-up assessment | | | | | | |
| LVEDV index, ml/m² | 85.5 ± 25.8 | 96.0 ± 37.1 | <0.001 | 89.0 ± 20.3 | 113.5 ± 15.9 | <0.001 |
| LVESV index, ml/m² | 42.3 ± 19.3 | 56.4 ± 26.9 | <0.001 | 44.3 ± 17.8 | 69.6 ± 22.7 | <0.001 |
| LVEF, % | 51.7 ± 10.0 | 42.4 ± 8.2 | <0.001 | 51.4 ± 9.9 | 38.7 ± 12.6 | <0.001 |
| LV mass index, g/m² | 51.4 ± 12.3 | 48.9 ± 21.6 | 0.09 | 52.5 ± 9.3 | 63.7 ± 8.9 | <0.001 |
| Infarct size, **%** | 15.6 ± 10.9 | 24.2 ± 8.9 | <0.001 | 16.0 ± 10.9 | 24.6 ± 10.9 | 0.02 |
| LVEF variation, % | - | - | 0.83 | 8.6 ± 17.6 | 1.9 ± 15.4 | 0.26 |
| LVEDV index change, ml/m² | - | - | 0.81 | 1.3 ± 14.3 | 10.9 ± 12.9 | 0.05 |
| LVESV index change, ml/m² | - | - | 0.33 | -5.1 ± 19.1 | 7.9 ± 20.4 | 0.04 |
| LV mass index change g/m² | - | - | 0.15 | -8.8 ± 13.1 | -5.3 ± 8.0 | 0.74 |

LVEDV: left ventricular end-diastolic volume; LVESV: left ventricular end-systolic volume; LVEF: left ventricular ejection fraction; LV: left ventricle; LVT: Left ventricular thrombus.

Table VI: Multivariable predictors of LVT

| | Early LVT | | Late LVT | |
|---|---|---|---|---|
| | OR [95% Conf. Interval] | P | OR [95% Conf. Interval] | P |
| LVESV index, ml/m² | 1.056 [1.018-1.096] | 0.004 | 1.184 [1.046-1.340] | 0.007 |
| Time to reperfusion, min | 1.000 [0.997-1.002] | ns | 1.002 [0.998-1.007] | ns |
| Infarct size, **%** | 0.972 [0.928-1.017] | ns | 1.027 [0.960-1.099] | ns |
| Dyslipidemia | 0.336 [0.114-0.990] | ns | 0.961 [0.147-6.266] | ns |

LVESV: left ventricular end-systolic volume; LAD: left artery descending

Table VII: The imaging characteristics of the heart disease between LVT discovered with and without FPP.

| | Cine and CMR diagnosis | FFP diagnosis | p value |
|---|---|---|---|
| LVEDV index, ml/m² | 105.3 ± 17.2 | 92.2 ± 10.9 | 0.43 |
| LVESV index, ml/m² | 65.4 ± 16.9 | 51.5 ± 12.7 | 0.85 |
| LVEF, % | 38.2 ± 8.1 | 44.7 ± 8.0 | 0.43 |
| LV mass index, g/m² | 65.4 ± 9.3 | 59.9 ± 12.8 | 0.39 |
| Infarct size, **%** | 30.5 ± 12 | 17.0 ± 4.1 | 0.43 |
| MVO | 4.1 ± 5.2 | 0.7 ± 1.4 | 0.33 |
| LVT size | 10.9 ±4.4 | 10.6 ± 4.6 | 0.82 |

LVEDV: left ventricular end-diastolic volume; LVESV: left ventricular end-systolic volume; MVO: microvascular obstruction; LVEF: left ventricular ejection fraction; LV: left ventricle; LVT: Left ventricular thrombus

Table VIII: Clinical characteristics and medical history of the 6 patients who had ischemic stroke

| Number of patient | Time from MI to stroke days | Stroke type | LVT morphology and size | Coronary arteries culpable | VKA treatment at discharge | Presence of LVT | | Final etiology of stroke | Others precisions |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | baseline | 3M | | |
| #019 | 1304 | Ischemic | Segment 17, pedicle, 9.8 mm. | LAD | Yes | 0 | + | unknown | Apical thrombus at M3 with VKA treatment. VKA treatment was stop at 1 year. Stroke at 3 years after MI. No LVT on CMR at one year and on TTE at 3 years. |
| #071 | 15 | Ischemic | Segment 17, pedicle, 10 mm | LAD | Yes | + | 0 | LVT | LVT on initial TTE (third days after MI). VKA treatment but stroke on 15$^{th}$ days. INR: 2.0. |
| #077 | 2 | Ischemic | Segment 17, mural, 11.9 mm | LAD | No | 0 | + | LVT | Early stroke but no LVT seen on TTE and CMR at baseline and LVT present at M3. |
| #122 | 30 | Lacunar | 0 | RCA | No | 0 | 0 | unknown | All etiologic examines were normal |
| #121 | 899 | Ischemic | 0 | LAD | Yes | 0 | 0 | AF | Very late stroke. AF discovered. |
| #217 | 150 | Ischemic | Segment 17, walled, 13.5 mm | LAD | Yes | 0 | + | LVT | Late stroke with late LVT despite an effective treatment. |

LAD: left artery descending, RCA: Right coronary artery, VKA: Vitamin K Antagonist, AF: Atrial fibrillation, TTE: Transthoracic Echocardiography, AMI: Acute myocardial infarction

**TABLE DES MATIERES**