PhD in Medicine – Clinical Research

Coronary microcirculation and peripheral endothelial function evaluation after acute ST elevation myocardial infarction treated with primary angioplasty

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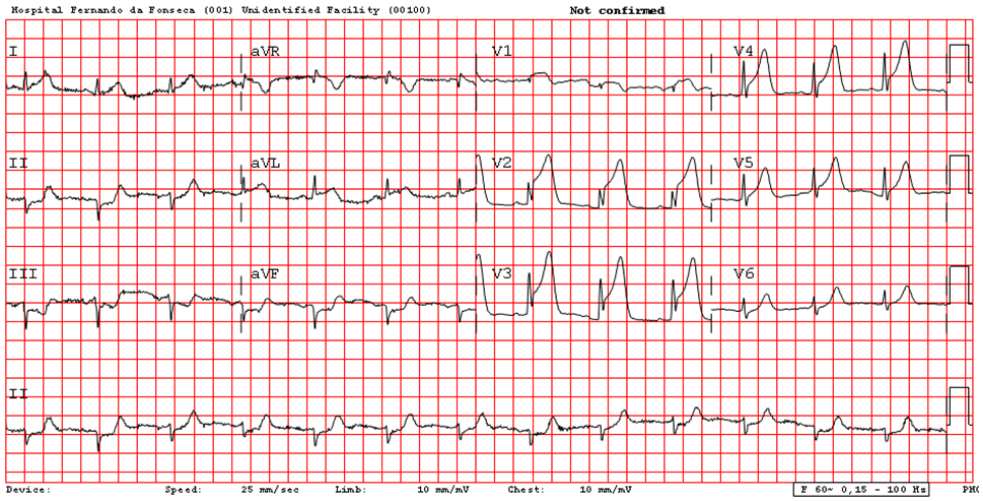
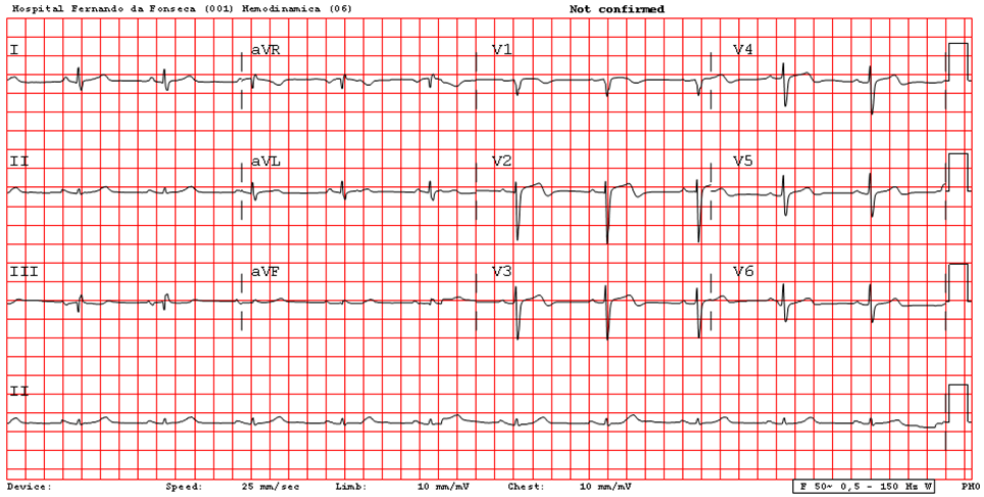
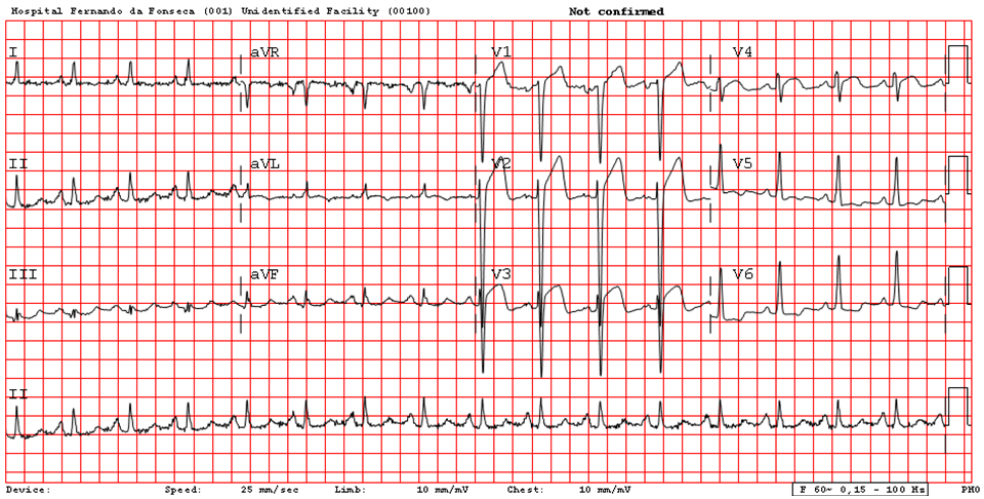
Background

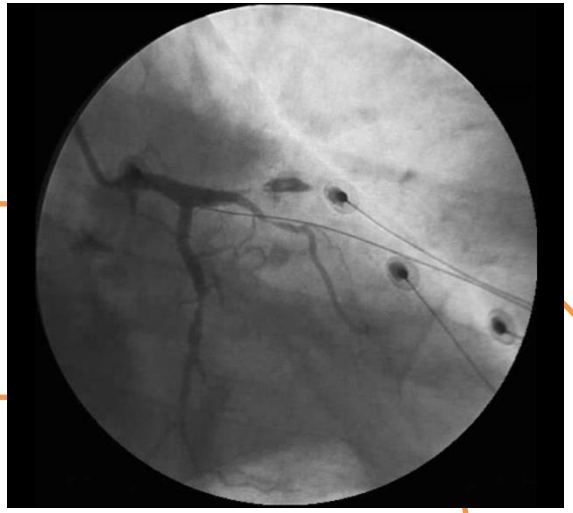
P-PCI for STEMI – Some patients do well…

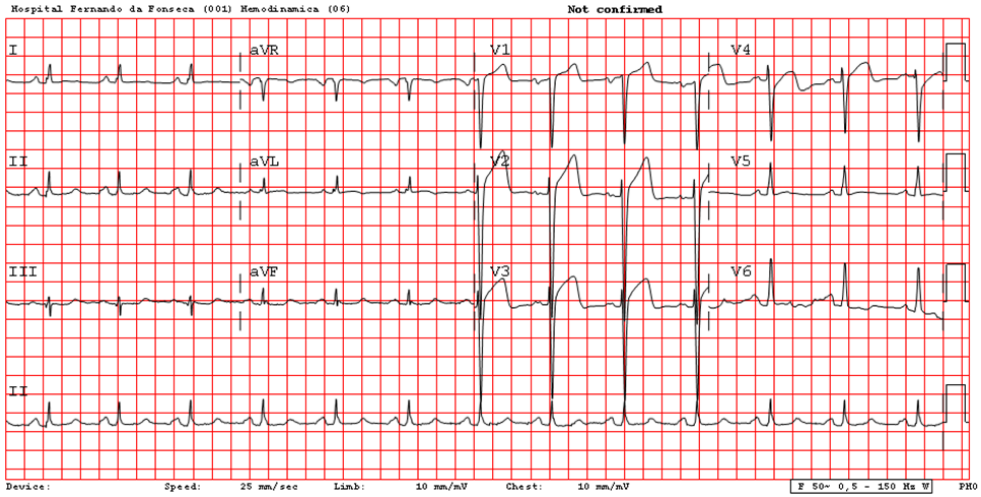




… while others don't…







Coronary microvascular damage in STEMI

A significant proportion of STEMI patients (from 20% to 60%) has a poor outcome because of microvascular coronary damage.

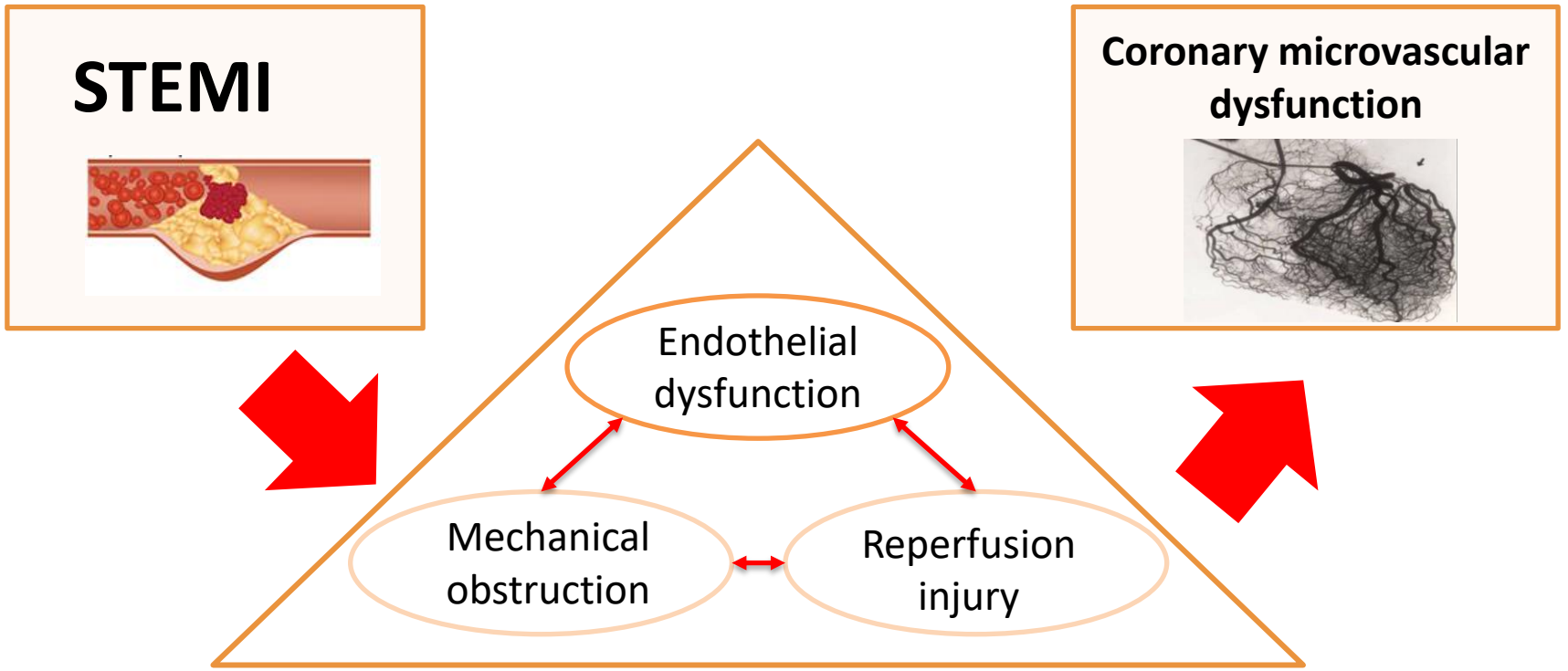
The negative prognostic implications (both on the risk of LV remodeling and on the risk of hard endpoints, including death) associated with coronary microvascular damage has been repeatedly confirmed, with several invasive and non-invasive indicators

Several mechanisms proposed:

- Mechanical obstruction (due to distal embolization of atherothrombotic debris)
- Coronary endothelial dysfunction (mediated by the release of vasoactive factors, like endothelin-1 and tissue factor)
- Reperfusion injury (through several mechanisms)

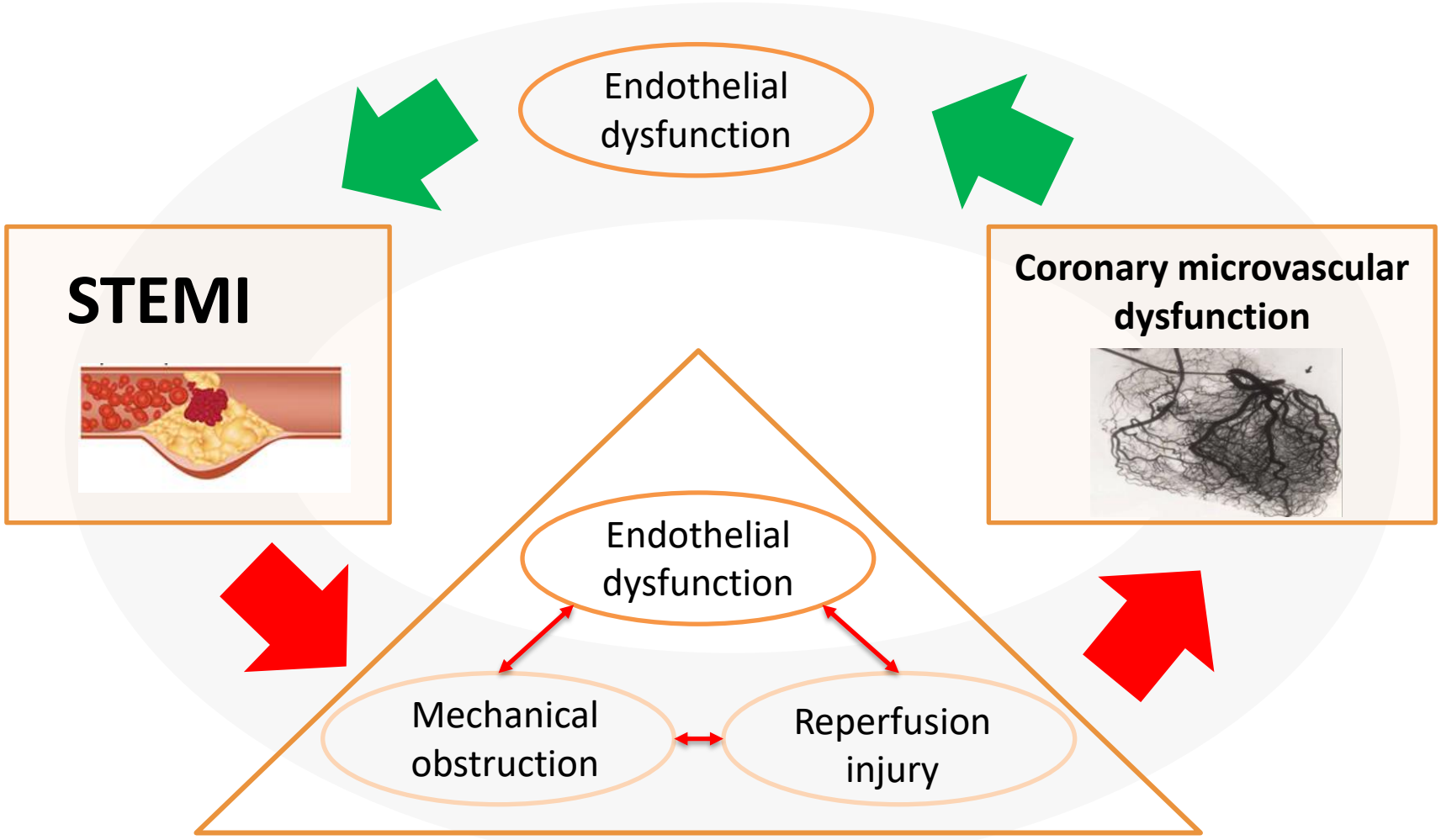
Coronary microvascular damage in STEMI

Consequence, *cause,* or both?



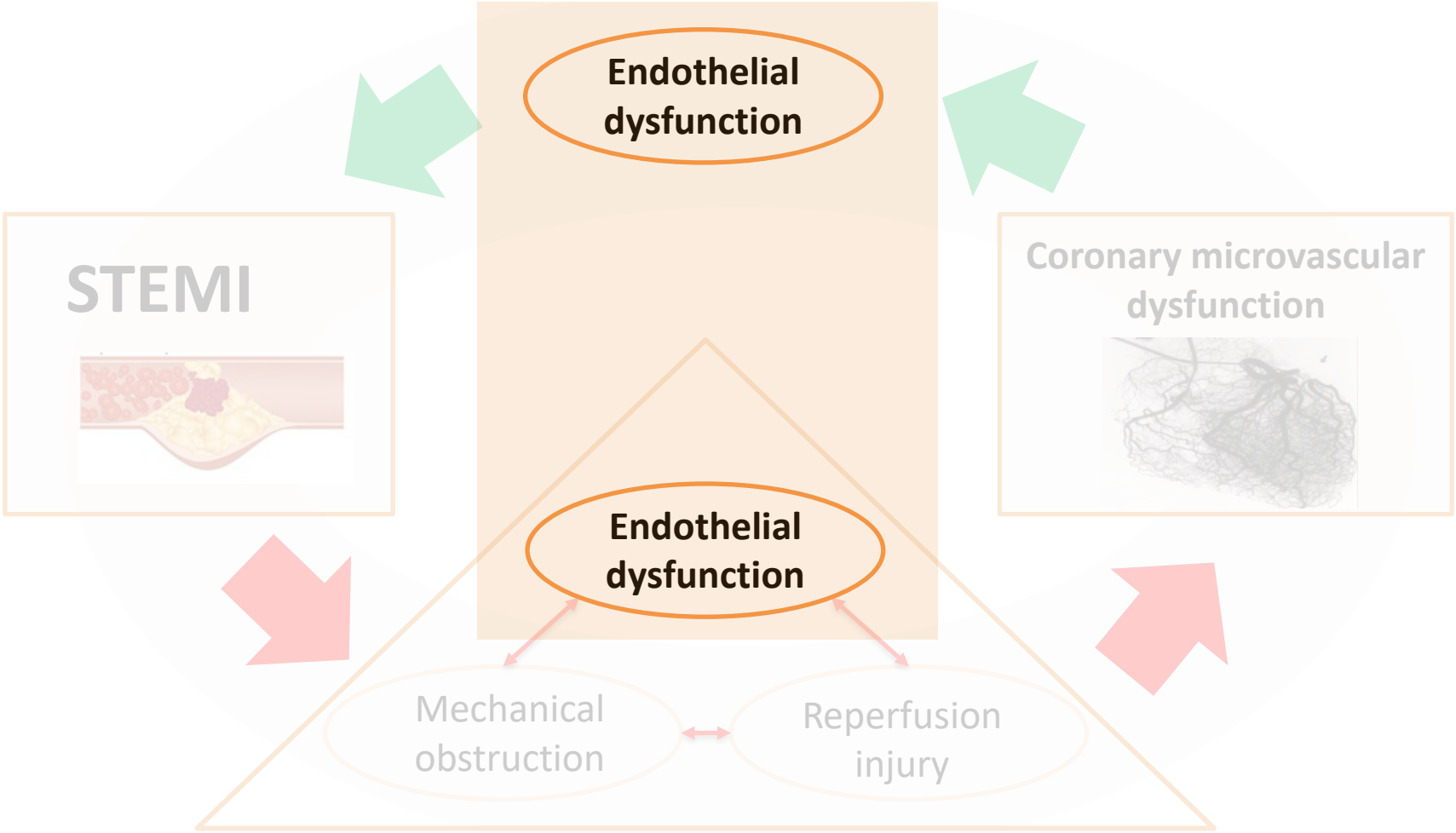
Coronary microvascular damage in STEMI

Consequence, *cause,* or both?



Coronary microvascular damage in STEMI

Consequence, *cause,* or both?



Non-invasive evaluation of endothelial function

Peripheral arterial tonometry (PAT)

- Noninvasive measurement of endothelial-dependent vasodilator function in the microcirculation of the finger.
- Pulse amplitude in the fingertip measured at rest and following the induction of reactive hyperemia.

EndoPAT 2000

(Itamar Medical, Caesarea, Israel)

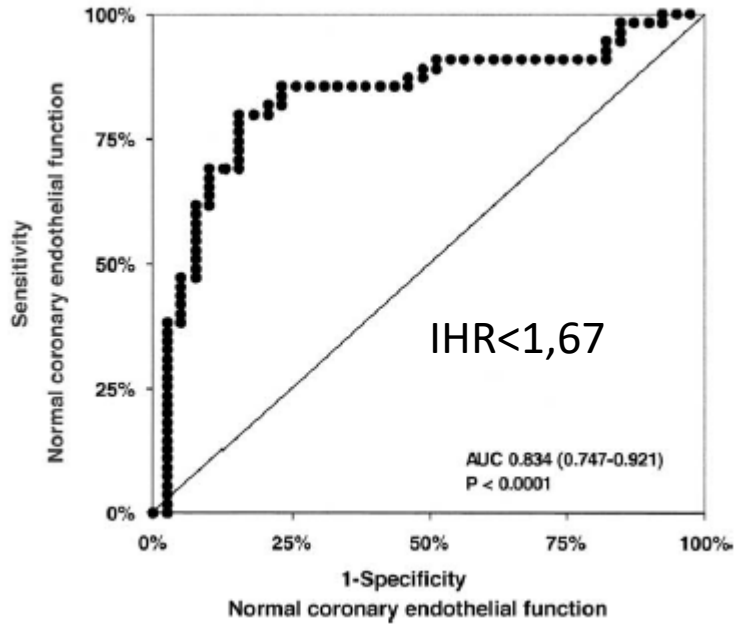
Bonetti P *et al.* J Am Coll Cardiol 2003;41(10):1761–8.

Non-invasive evaluation of endothelial function

Peripheral arterial tonometry (PAT) and coronary endothelial function

- Endothelial-dependent dysfunction evaluated by PAT is correlated with coronary microvascular dysfunction in stable patients

Sensitivity 80%
Specificity 85%



- 94 patients with non-obstrutive CAD
- Invasive evaluation of coronary endothelial function (acetylcholine)
- endoPAT evaluation

Bonetti P. *et al. J Am Coll Cardiol* 2004;44:2137

Endothelial dysfunction in CAD patients

Peripheral arterial tonometry (PAT) and extent of infarction in patients with STEMI

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Endothelial dysfunction evaluated by peripheral arterial tonometry is related with peak TnI values in patients with ST elevation myocardial infarction treated with primary angioplasty

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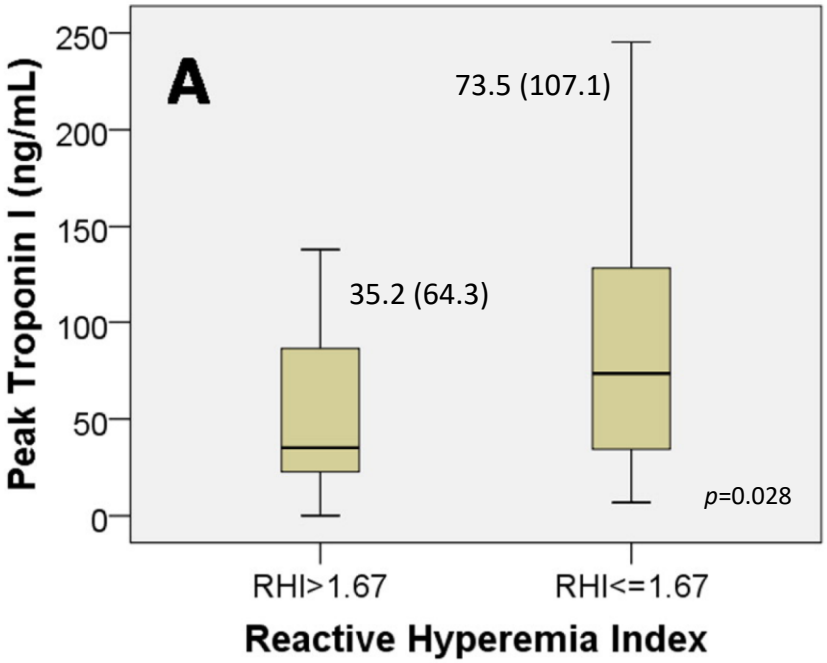
Endothelial dysfunction in CAD patients

Peripheral arterial tonometry (PAT) and extent of infarction in patients with STEMI

- Endothelial dysfunction evaluated by RHI-PAT relates with the extension of myocardial infarction (P-PCI treated) measured by peak TnI
  - 58 primary PCI patients
  - Peak TnI
  - EndoPAT evaluation

RHI-PAT <1,67 = only variable related with peak TnI on multivariate analysis



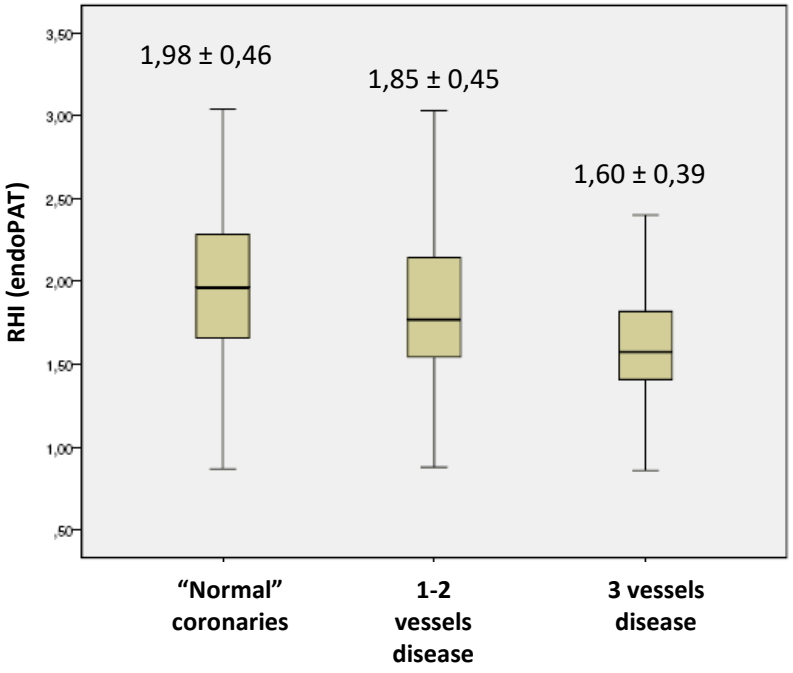
Endothelial dysfunction in CAD patients

Peripheral arterial tonometry (PAT) and severity of CAD

- Endothelial-dependent dysfunction evaluated by RHI-PAT relates it the severity of CAD disease

  - 231 CAD patients
  - Angiography performed
  - endoPAT evaluation

RHI-PAT = only predictor of 3 vessel disease on multivariate analysis



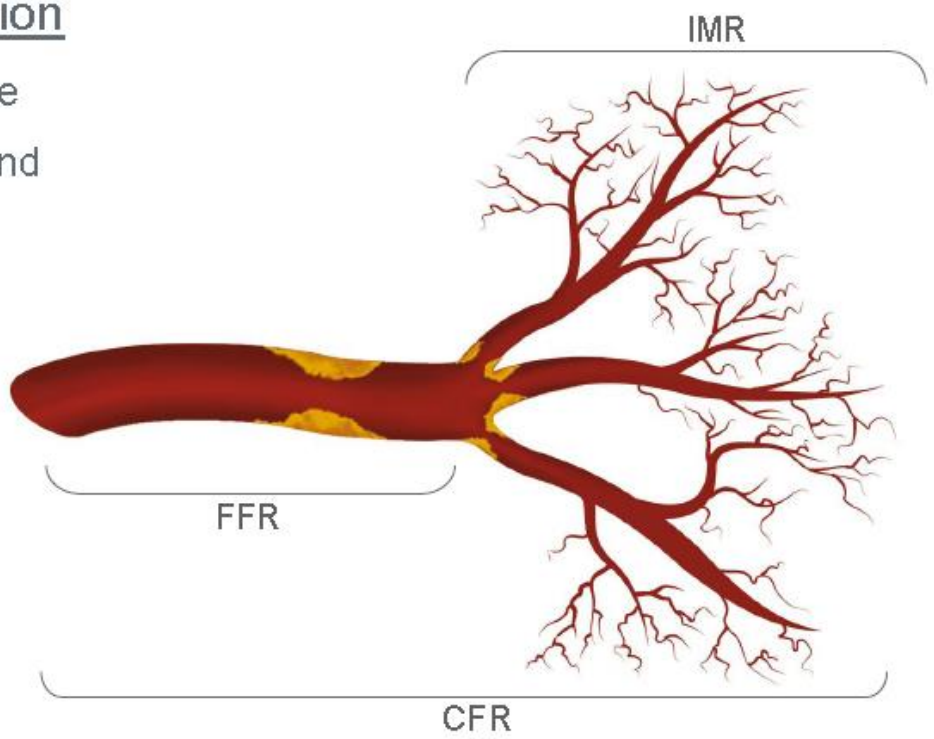
Baptista SB. J Am Coll Cardiol. 2013; 62(18_S1):B183-B183

Invasive evaluation of microvascular coronary circulation

Index of microvascular resistance (IMR)

Invasive and quantitative method for evaluating the microcirculation

- FFR: Specific for epicardial disease
- CFR: Affected by both epicardial and microcirculatory disease (cannot distinguish between the two)
- IMR: Specific for microcirculatory disease



Study Objectives

Study Hypothesis and Aims

Study hypothesis

- In patients with acute STEMI treated with primary PCI, endothelial dysfunction (evaluated by peripheral arterial tonometry) is related to the extent of microvascular damage and, consequently, to the extent of myocardial necrosis.

Study aims

- **Primary aim**: To evaluate the relation between endothelial dysfunction (evaluated with EndoPAT) and coronary microvascular dysfunction (evaluated by IMR) immediately after primary PCI.
- **Secondary aims**: *Confirming* IMR and *evaluating* endothelial dysfunction (as measured by peripheral arterial tonometry) as predictors of microvascular dysfunction and extension of the myocardial infarction.

Study outcome measures

Primary outcome measures

- IMR value in patients with endothelial dysfunction (RHI <1.67)
- IMR value according to the tertile of RHI

Secondary outcome measures

1. The relation between RHI values and:
   - The extent of myocardial necrosis
   - The extent of coronary microvascular obstruction
2. The relation between IMR values and:
   - The extent of myocardial necrosis
   - The extent of coronary microvascular obstruction

Population and Methods

Population

Type of Study

Observational, prospective, single centre, cohort study, performed in the Cardiology Department of Hospital Prof. Doutor Fernando da Fonseca (Amadora, Portugal).

Population

Patients admitted to Hospital Prof. Doutor Fernando da Fonseca with a first acute ST elevation myocardial infarction, treated with primary angioplasty

Population

Inclusion Criteria

- Age > 18 years
- ST elevation (first) myocardial infarction defined as:
  - Thoracic pain with ≥ 20 min and/or
  - ST elevation ≥1 mm in two or more contiguous ECG leads
- Time pain-to-balloon < 6 hours (or between 6 and 12 horas, if pain clearly persists)
- Successful PCI of the culprit artery (no significant residual lesion, independently of the final TIMI flow) in a native coronary artery
- Informed consent obtained

Population

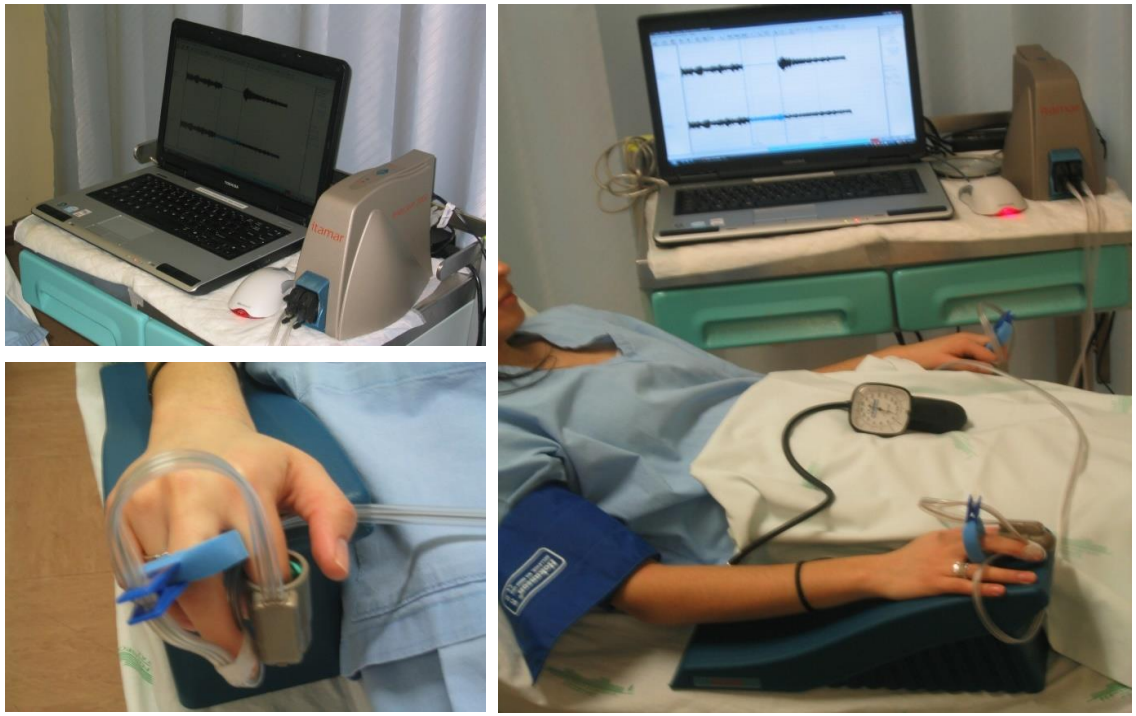
Exclusion Criteria

- LBBB or pacemaker
- Previous myocardial infarction (STEMI or nSTEMI)
- Killip class IV
- PCI in the previous 3 months or previous CABG (anytime)
- Long-QT syndrome, 2nd or 3rd degree AV block, sinus node disease
- Arrhythmias considered by the investigator to contra-indicate adenosine
- Severe asthma or COPD
- Previous severe side effects to adenosine or other contra-indication for adenosine use
- Life expectancy <12 month
- Inclusion in other trials

Non-invasive evaluation of endothelial function

Peripheral arterial tonometry (PAT)

- PAT probe positioned in one finger of each hand
- Blood pressure cuff is inflated on one arm to suprasystolic pressures for 5 minutes.



Bonetti P *et al.* J Am Coll Cardiol 2003;41(10):1761–8.

Invasive evaluation of microvascular coronary circulation

Index of microvascular resistance (IMR)

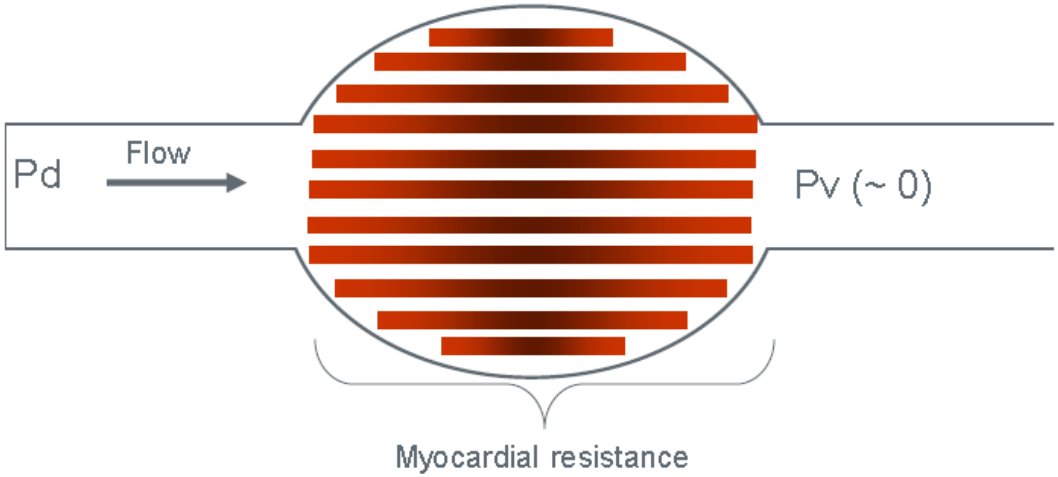
- Immediately after successful PCI of the culprit artery
- Certus Pressure-Wire® (St. Jude Medical)
- RadiAnalyzer Xpress (St. Jude Medical®)
- Maximal hyperemia obtained with adenosine (perfusion by central or large peripheral vein)

Invasive evaluation of microvascular coronary circulation

Index of microvascular resistance (IMR)

Myocardial resistance = **pressure** drop across the myocardium divided by **flow**

Myocardial resistance = Δ **pressure / flow**



Δ Pressure = Pd - Pv = Pd (assuming Pv = 0)

Flow ≅ $1 / T_{mn}$

IMR = $Pd / (1 / T_{mn})$

IMR = Pd x T_{mn} (at maximal hyperemia)

Fearon WF *et al*. J Am Coll Cardiol 2008;51(5):560–5

Infarct extension evaluation

Troponin I release

- Dimension Vista™ Intelligent Lab System, Siemens Healthcare Diagnostics™
- Blood samples collected at admission, 6, 12, 18, 24, 36 and 48h
- Peak TnI values and the area under the curve (AUC) of TnI release

Echocardiography

- Performed in the first hours after P-PCI and at 3 months
- LV volumes, LVEF, WMSI and global longitudinal strain

Contrast enhanced cardiac magnetic resonance (ceCMR)

- Performed on the 7-8th day post-MI
- 1.5-T MRI system (Avanto, Siemens Medical System, Erlangen, Germany)
- Infarct size, percent of infarct size

Coronary microvascular obstruction evaluation

ECG ST-elevation resolution

- ECGs collected before, immediately after/90 min/180 min after P-PCI
- % of total ST-elevation resolution was calculated vs. pre-PCI ECG

Angiographic indicators (measured at the end of the procedure)

- Corrected TIMI frame count (cTFC)
- TIMI myocardial perfusion grade (MPG)

Contrast enhanced cardiac magnetic resonance (ceCMR)

- Presence of microvascular obstruction (no reflow)
- Mass of microvascular obstruction

Results

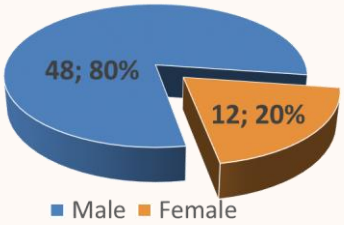
Included population

Results

Main Epidemiological characteristics

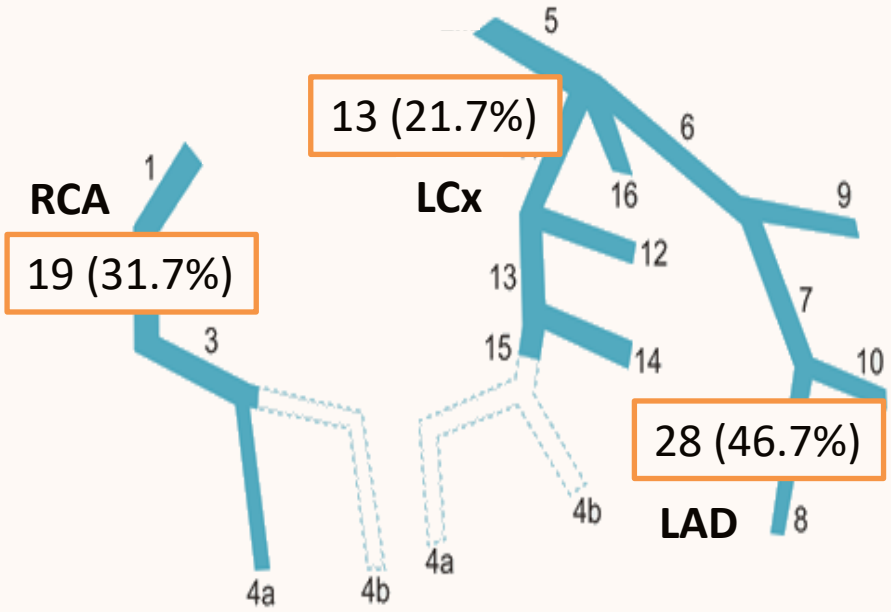
N: 60 patients

Mean age: 59.6±12.7 years



Hypertension: 43 (71.7%)
Diabetes: 15 (25.0%)
Dyslipidemia: 30 (50.0%)
Smoking habits: 26 (43.3%)

Culprit Artery



Time Delays

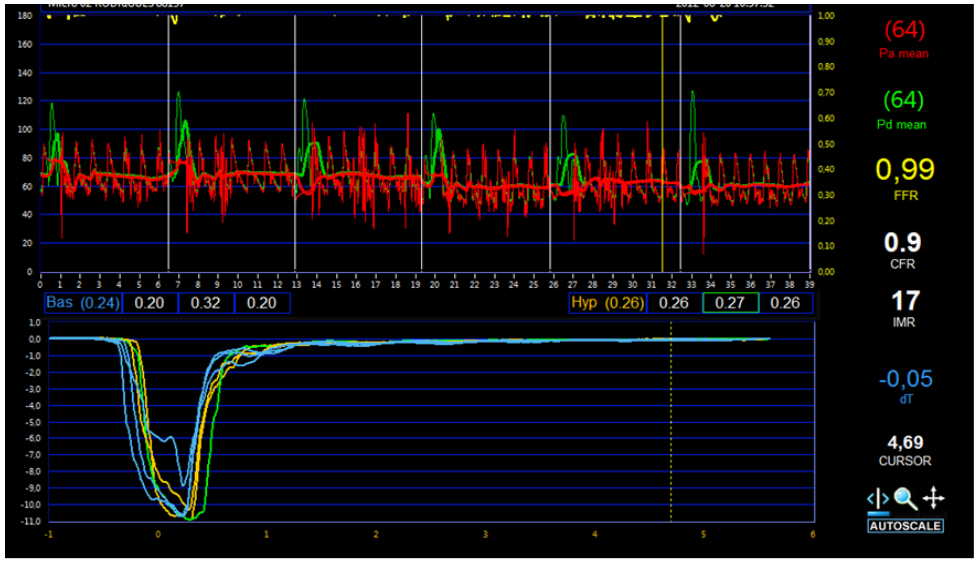
Pain-to-balloon time: 209 (IQR 148) min
Door-to-balloon time: 78 (IQR 45) min

Primary PCI

Abciximab: 14 (23.3%)
Mechanical thrombectomy: 26 (43.3%)
Stent: 57 (95.0%)
Direct stenting: 25 (41.7%)
Post-dilatation: 28 (38.3%)

Index of microvascular resistance (IMR)

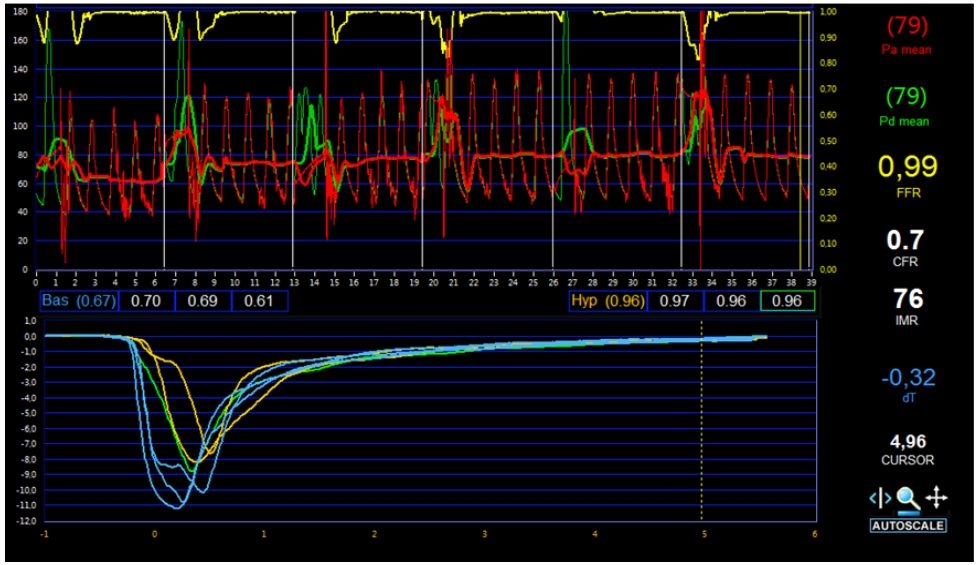
Results



Example 1

28 years ♂
Inferior STEMI
Proximal RCA occlusion
Successful P-PCI
IMR = 17

Median value:
23.9 (IQR 32.9)



Example 2

75 years ♀
Inferior STEMI
Proximal LCx occlusion
Successful P-PCI
IMR = 76

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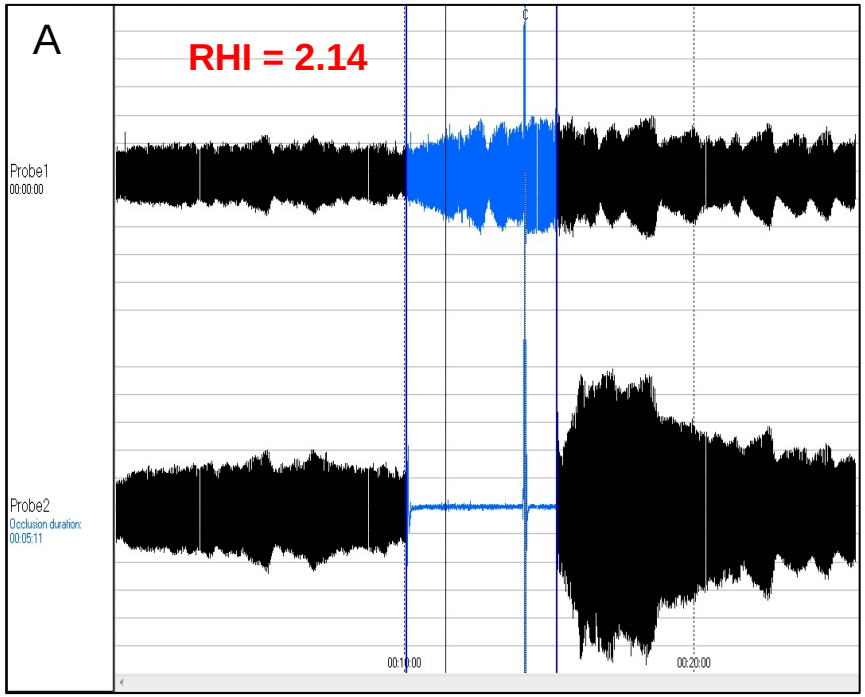
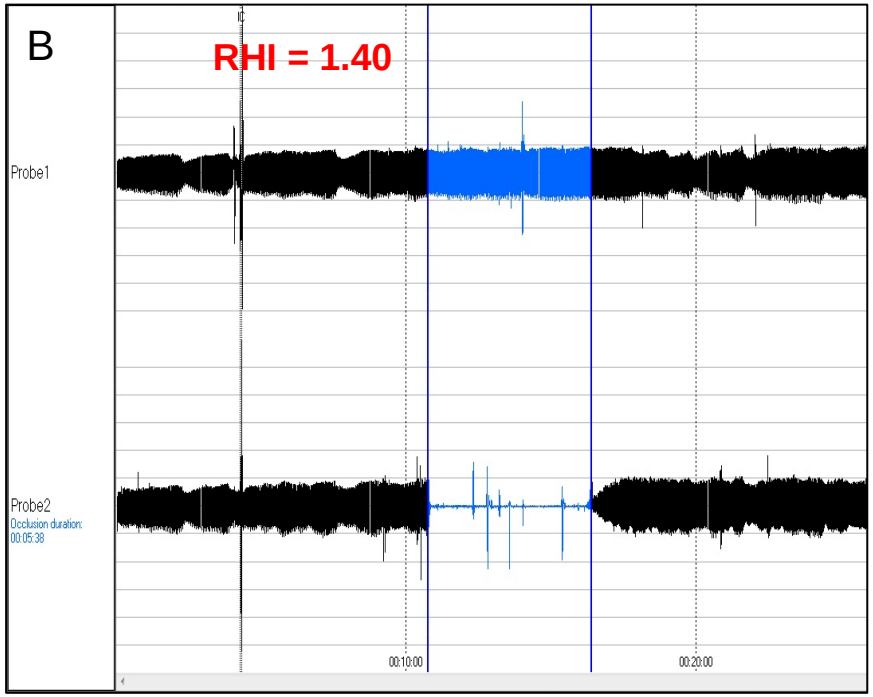
Peripheral arterial tonometry (EndoPAT)

Examples of normal and abnormal results

Example 1
Patient with normal endothelial function

Example 2
Patient with endothelial dysfunction





Peripheral arterial tonometry (EndoPAT)

Reactive hyperaemia index (RHI) values on the 1st and 2nd EndoPAT

	1st EndoPAT
N	60
RHI [a]	2.15±0.58
Endothelial dysfunction (RHI<1.67)[b]	11 (18.3)
L_RHI [a]	0.73±0.28

[a] Presented as mean±standard deviation; [b] Presented as N(%). [C] p-value for the comparison between first and second EndoPAT only in patients with 2 evaluations; paired samples T-Test for continuous variables and Chi-square test for categorical variables; RHI: reactive hyperaemia index; L_RHI: logarithmic RHI.

Outcome measures

Primary outcome measures

- IMR value in patients with endothelial dysfunction (RHI <1.67)
- IMR value according to the tertile of RHI

Secondary outcome measures

1. The relation between RHI values and:
   - The extent of myocardial necrosis
   - The extent of coronary microvascular obstruction
2. The relation between IMR values and:
   - The extent of myocardial necrosis
   - The extent of coronary microvascular obstruction

In the 1st EndoPAT (acute)

In the 2nd EndoPAT (24-h)

Outcome measures

Primary outcome measures

- IMR value in patients with endothelial dysfunction (RHI <1.67)
- IMR value according to the tertile of RHI

In the 1st EndoPAT (acute)

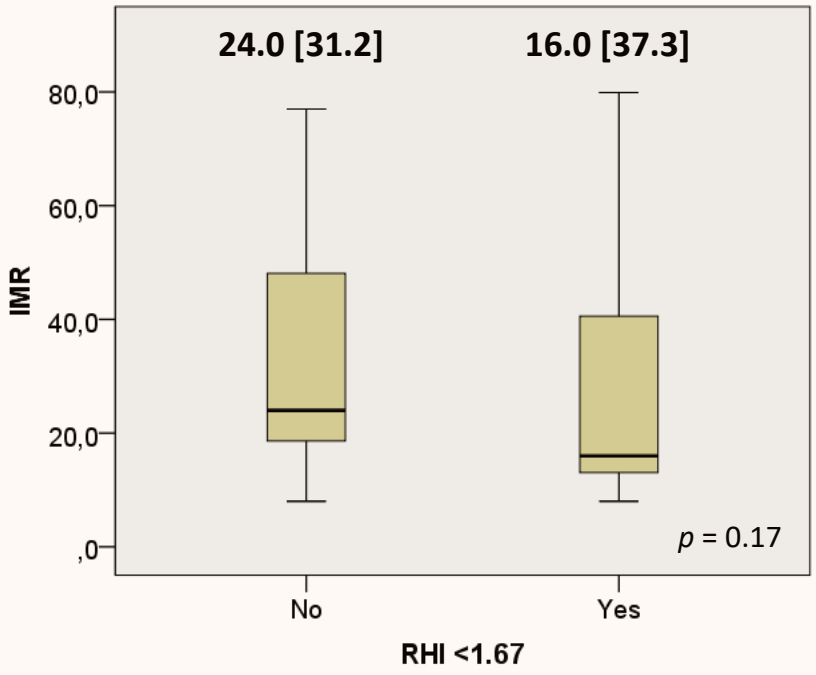
In the 2nd EndoPAT (24-h)

Primary Outcome – IMR and RHI values

IMR values according to the presence of ED (RHI<1.67)

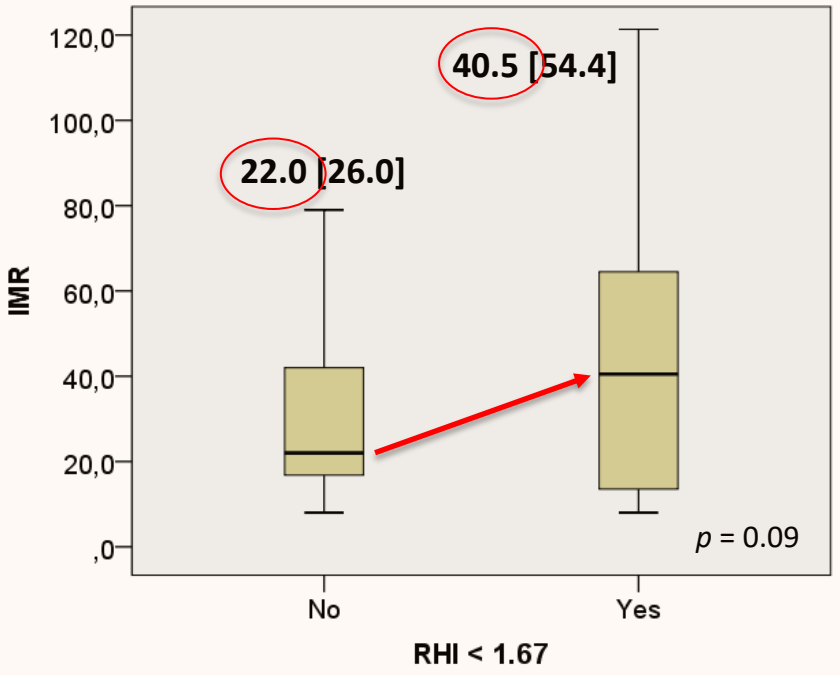
1st EndoPAT

Endothelial dysfunction present in 11/60 patients **(18.3%)**



2nd EndoPAT

Endothelial dysfunction present in 16/38 patients **(42.1%)**

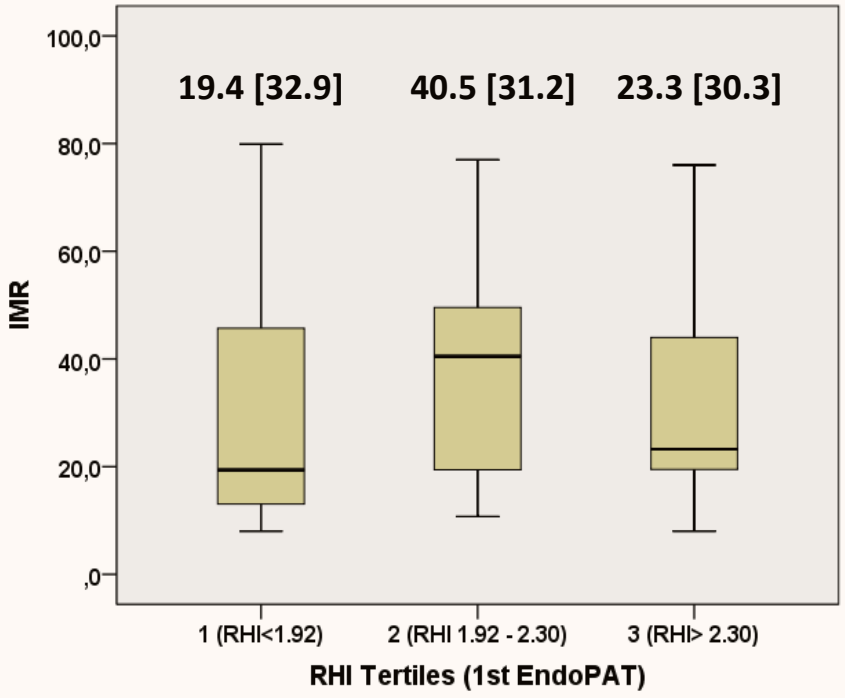


Presented as Median [Interquartile Range]
Mann-Whitney test

Primary Outcome – IMR and RHI values

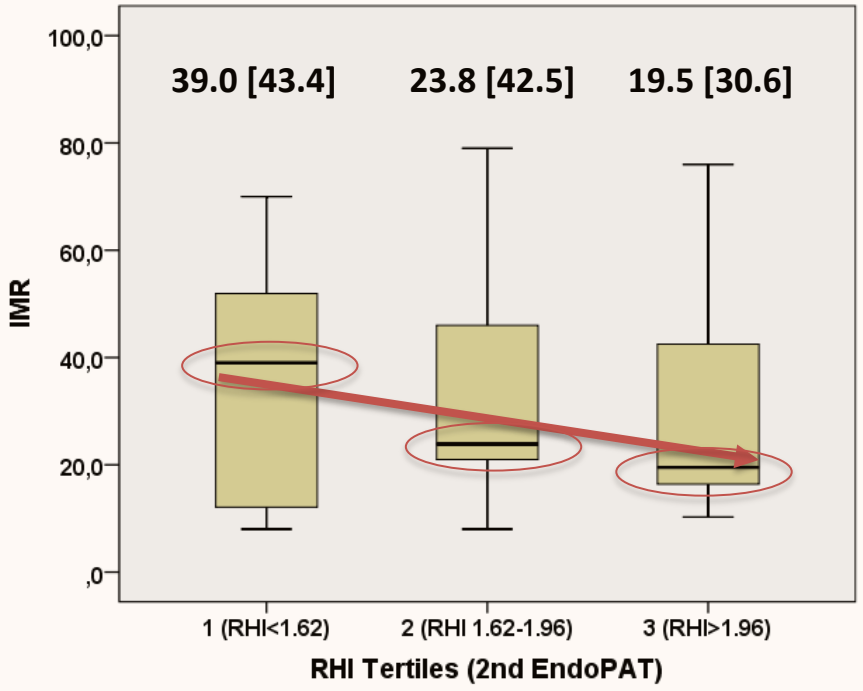
IMR values according to tertiles of RHI

1st EndoPAT



p = 0.26

2nd EndoPAT



p = 0.64

Presented as Median [Interquartile Range]
Kruskal-Wallis test

Outcome measures

Primary outcome measures

- IMR value in patients with endothelial dysfunction (RHI <1.67)
- IMR value according to the tertile of RHI

Secondary outcome measures

1. The relation between RHI values and:
   - The extent of myocardial necrosis

In the 1st EndoPAT (acute)

In the 2nd EndoPAT (24-h)

Secondary Outcomes (1st EndoPAT)

Endothelial dysfunction and extent of myocardial infarction

Variable	Total Population	Endothelial Dysfunction (RHI<1.67)		p value
		No (n=49)	Yes (n=11)	
Troponin Release				
TnI_{peak} [a]	117±82	117±87	115±55	0.96
TnI_{AUC} [a]	1938±1283	1951±1376	1883±787	0.88
Echocardiography (n=40 for GLS)				
LVEF (%)[a]	47.9±6.7	47.9±6.8	47.8±5.9	0.96
Wall motion score index [b]	1.41 (0.35)	1.41 (0.35)	1.53 (0.18)	0.78
Global longitudinal strain [a]	-13.54±2.28	-13.38±2.30	-14.7±1.96	0.23
ceCMR (n=49)				
LVEF (%)[a]	53.6±8.7	53.9±8.7	52.4±9.3	0.62
Wall motion score index [a]	1.42±0.29	1.41±00.30	1.46±0.23	0.64
Transmural necrosis [c]	23 (46.9)	18 (46.2)	5 (50.0)	0.89
Infarct mass [b]	14.7 (12.6)	11.7 (9.8)	19.9 (11.9)	0.11
Percent infarct mass [b]	12.6 (14.4)	11.6 (12.9)	20.3 (14.5)	0.08
Indexed to BARI score [b]	3.8 (4.3)	3.0 (3.6)	5.5 (5.1)	0.07

[a] Presented as mean±standard deviation; [b] Presented as median (interquartile range); [c] Presented as number (%);

Secondary Outcomes (2nd EndoPAT)

Endothelial dysfunction and extent of myocardial infarction

Variable	Total Population	Endothelial Dysfunction (RHI<1.67)		p value
		No (n=22)	Yes (n=16)	
Troponin Release				
TnI_{peak} [b]	95 (96)	67 (81)	118 (186)	0.024
TnI_{AUC} [b]	1293 (1580)	1076 (1042)	2305 (2486)	0.012
Echocardiography (n=21 for GLS)				
LVEF (%)[a]	48.6±7.1	51.4±4.7	45.3±8.3	0.045
Wall motion score index [b]	1.44 (0.41)	1.35 (0.47)	1.77 (0.47)	0.006
Global longitudinal strain [a]	-13.16±2.35	-14.32±1.72	-11.89±2.35	0.014
ceCMR (n=29)				
LVEF (%)[a]	53.9±8.4	56.6±8.1	49.5±7.2	0.025
Wall motion score index [a]	1.37±0.33	1.28±0.31	1.53±0.32	0.05
Transmural necrosis [c]	12 (38.7%)	4 (22.2%)	7 (63.6%)	0.06
Infarct mass [b]	11.6 (9.3)	10.1 (10.3)	17.5 (15.4)	0.08
Percent infarct mass [b]	11.5 (13.7)	10.2 (7.6)	17.5 (21.8)	0.10
Indexed to BARI score [b]	3.4 (5.8)	2.3 (2.7)	5.1 (11.5)	0.09

[a] Presented as mean±standard deviation; [b] Presented as median (interquartile range); [c] Presented as number (%);

Outcome measures

Primary outcome measures

- IMR value in patients with endothelial dysfunction (RHI <1.67)
- IMR value according to the tertile of RHI

Secondary outcome measures

1. The relation between RHI values and:
   - The extent of myocardial necrosis
   - The extent of coronary microvascular obstruction

In the 1st EndoPAT (acute)

In the 2nd EndoPAT (24-h)

Secondary Outcomes (1st EndoPAT)

Endothelial dysfunction and microvascular obstruction

Variable	Total Population	Endothelial Dysfunction (RHI<1.67)		p value
		No (n=49)	Yes (n=11)	
ECG				
% ST resolution				
Immediately after P-PCI [b]	74.5 (39.0)	74.0 (42.0)	77.0 (37.0)	0.83
90 min after P-PCI [b]	79.5 (32.0)	78.0 (34.0)	86.0 (25.0)	0.70
Residual total ST elevation				
Immediately after P-PCI [b]	3.3 (6.0)	3.5 (6.0)	2.5 (6.0)	0.96
90 min after P-PCI [b]	1.5 (4.0)	1.5 (5.0)	1.5 (4.0)	0.77
ceCMR				
MVO present [c]	13 (26.5)	10 (25.6)	3 (30.0)	0.90
Angiography				
Corrected TIMI frame count[b]	17.0 (7.0)	18.0 (8.0)	14.0 (8.0)	0.27
TIMI myocardial perfusion grade 2-3[c]	49 (81.7)	38 (77.6)	11 (100.0)	0.24
Index of microvascular resistance [b]	23.9 (32.9)	24.0 (31.2)	16.0 (37.3)	0.17

[a] Presented as mean±standard deviation; [b] Presented as median (interquartile range); [c] Presented as number (%);

Secondary Outcomes (2nd EndoPAT)

Endothelial dysfunction and microvascular obstruction

Variable	Total Population	Endothelial Dysfunction (RHI<1.67)		p value
		No (n=22)	Yes (n=16)	
ECG				
% ST resolution				
Immediately after P-PCI [b]	74.5 (39.0)	76.5 (41.0)	60.5 (72.0)	0.23
90 min after P-PCI [b]	77.0 (29.0)	78.5 (28.0)	69.0 (53.0)	0.07
Residual total ST elevation				
Immediately after P-PCI [b]	3.0 (6.0)	2.5 (5.0)	5.0 (12.0)	0.048
90 min after P-PCI [b]	1.8 (4.0)	1.3 (4.0)	3.0 (7.0)	0.036
ceCMR (n=29)				
MVO present [c]	8 (27.6%)	2 (11.1%)	6 (54.5%)	0.03
Angiography				
Corrected TIMI frame count [b]	17.0 (7.0)	16.4 (7.0)	19.5 (12.0)	0.07
TIMI myocardial perfusion grade 2-3[c]	28 (73.7%)	19 (86.4%)	9 (56.3%)	0.09
Index of microvascular resistance [b]	23.4 (35.2)	22.0 (26.0)	40.5 (54.4)	0.09

[a] Presented as mean±standard deviation; [b] Presented as median (interquartile range); [c] Presented as number (%);

Secondary Outcomes (2nd EndoPAT)

Endothelial dysfunction, microvascular obstruction and infarct extension

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ORIGINAL ARTICLE

Early peripheral endothelial dysfunction predicts myocardial infarct extension and microvascular obstruction in patients with ST-elevation myocardial infarction

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Outcome measures

Primary outcome measures

- IMR value in patients with endothelial dysfunction (RHI <1.67)
- IMR value according to the tertile of RHI

Secondary outcome measures

1. The relation between RHI values and:
   - The extent of myocardial necrosis
   - The extent of coronary microvascular obstruction
2. The relation between IMR values and:
   - The extent of myocardial necrosis
   - The extent of coronary microvascular obstruction

Secondary Outcomes (IMR)

IMR and infarct extension

Variable	Total Population	IMR > 24		p value
		No (n=30)	Yes (n=30)	
Troponin Release				
TnI_{peak} [a]	117±82	91±59	142±93	0.013
TnI_{AUC} [a]	1938±1283	1459±898	2418±1438	0.003
Echocardiography 3 months				
LVEF (%)[a]	52.6±7.1	54.6±6.5	50.1±7.1	0.024
Wall motion score index [b]	1.24 (0.35)	1.21±0.18	1.43±0.25	<0.001
Global longitudinal strain [a]	-15.77±3.11	-16.81±1.86	-14.50±3.83	0.007
ceCMR (n=49)				
LVEF (%)[a]	53.6±8.7	54.2±9.0	52.8±9.0	0.59
Wall motion score index [a]	1.42±0.29	1.34±0.31	1.53±0.23	0.026
Transmural necrosis [c]	23 (46.9)	8 (27.6)	15 (75.0)	0.001
Infarct mass [b]	14.7 (12.6)	11.4 (10.9)	17.6 (15.0)	0.031
Percent infarct mass [b]	12.6 (14.4)	11.6 (12.1)	17.0 (15.4)	0.035

[a] mean±standard deviation; [b] median (interquartile range); [d] number (%);

Secondary Outcomes (IMR)

IMR and left ventricular remodelling

Difference between initial (acute) and follow up (3 months) Echo parameters according to median IMR

	IMR < 24			IMR > 24		
Echo parameters	**Echo1**	**Echo2**	**P value[c]**	**Echo1**	**Echo2**	**P value[c]**
2D measurements		n=22			n=23	
LVEdV (ml) [a]	102.5±23.9	101.2±20.3	0.78	108.3±26.0	118.3±32.1	0.043
LVEsV (ml) [a]	51.5±12.0	45.3±11.5	0.01	56.8±12.8	60.7±23.0	0.29
LVEF (%)[a]	49.4±6.6	55.4±5.1	0.001	47.3±5.2	49.7±6.8	0.13
WMSI [b]	1.41 (0.32)	1.12 (0.12)	<0.001	1.41 (0.35)	1.35 (0.41)	0.010
Left atria (ml/m2) [a]	34.7±13.6	37.9±16.8	0.08	34.0±10.3	41.4±16.6	0.026
Doppler measurements		n=18			n=19	
E/A' ratio [a]	1.01±0.34	1.14±0.33	0.08	0.97±0.35	1.14±0.64	0.13
E/e' ratio [a]	9.0±3.3	7.3±2.7	0.005	9.0±2.3	10.6±3.7	0.03
2D speckle tracking imaging		n=16			n=19	
Global longitudinal strain [a]	-14.6±1.4	-17.2±1.3	<0.001	-13.3±2.4	-14.4±3.6	0.10

[a] mean±standard deviation; [b] median (interquartile range); [c] p-value for the comparison between the 2 echos

Secondary Outcomes (IMR)

IMR and left ventricular remodelling

Difference between initial (acute) and follow up (3 months) Echo parameters according to median IMR

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ORIGINAL INVESTIGATION

The Index of Microcirculatory Resistance as a Predictor of Echocardiographic Left Ventricular Performance Recovery in Patients With ST-Elevation Acute Myocardial Infarction Undergoing Successful Primary Angioplasty

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From the Department of Cardiology, Hospital Professor Doutor Fernando da Fonseca, Amadora, Portugal

Secondary Outcomes (IMR)

IMR and microvascular obstruction

Variable	Total Population	IMR > 24		p value
		No (n=30)	Yes (n=30)	
ECG – ST resolution (%)				
Immediately after P-PCI [b]	74.5 (39.0)	79.0 (33.0)	52.5 (79.0)	0.02
90 min [b]	79.5 (32.0)	86.5 (29.0)	75.5 (36.0)	0.014
180 min [b]	84.5 (23.0)	90.0 (23.0)	81.5 (40.0)	0.048
Angiographic indicators				
cTFC [a]	17.0 (7.0)	14.0 (7.0)	20.0 (10.0)	<0.001 [a]
TMPG 2-3 [b]	49 (81.7)	28 (93.3)	21 (70.0)	0.019 [b]
ceCMR (n=49)				
MVO present [b]	13 (26.5)	4 (13.8)	9 (45.0)	0.015
Mass of MVO [a]	5.7 (4.0)	2.9 (2.9)	6.4 (11.5)	0.006

[a] median (interquartile range); [b] number (%);

Conclusions

Main findings of the study

Conclusions

- RHI measurement with EndoPAT immediately after primary PCI in ST elevation myocardial infarction patients **probably cannot be performed**, due to the serious unavoidable technical pitfalls in the acute phase.
- RHI measurement with EndoPAT 24 hours after primary PCI in STEMI patients **is feasible and related both to the extension of the infarct and to microvascular obstruction** (including a tendency for lower IMR values in patients with higher RHI values).
- IMR measured immediately after primary PCI in STEMI patients **predicts MVO and infarct extension - remodelling**

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PhD in Medicine – Clinical Research

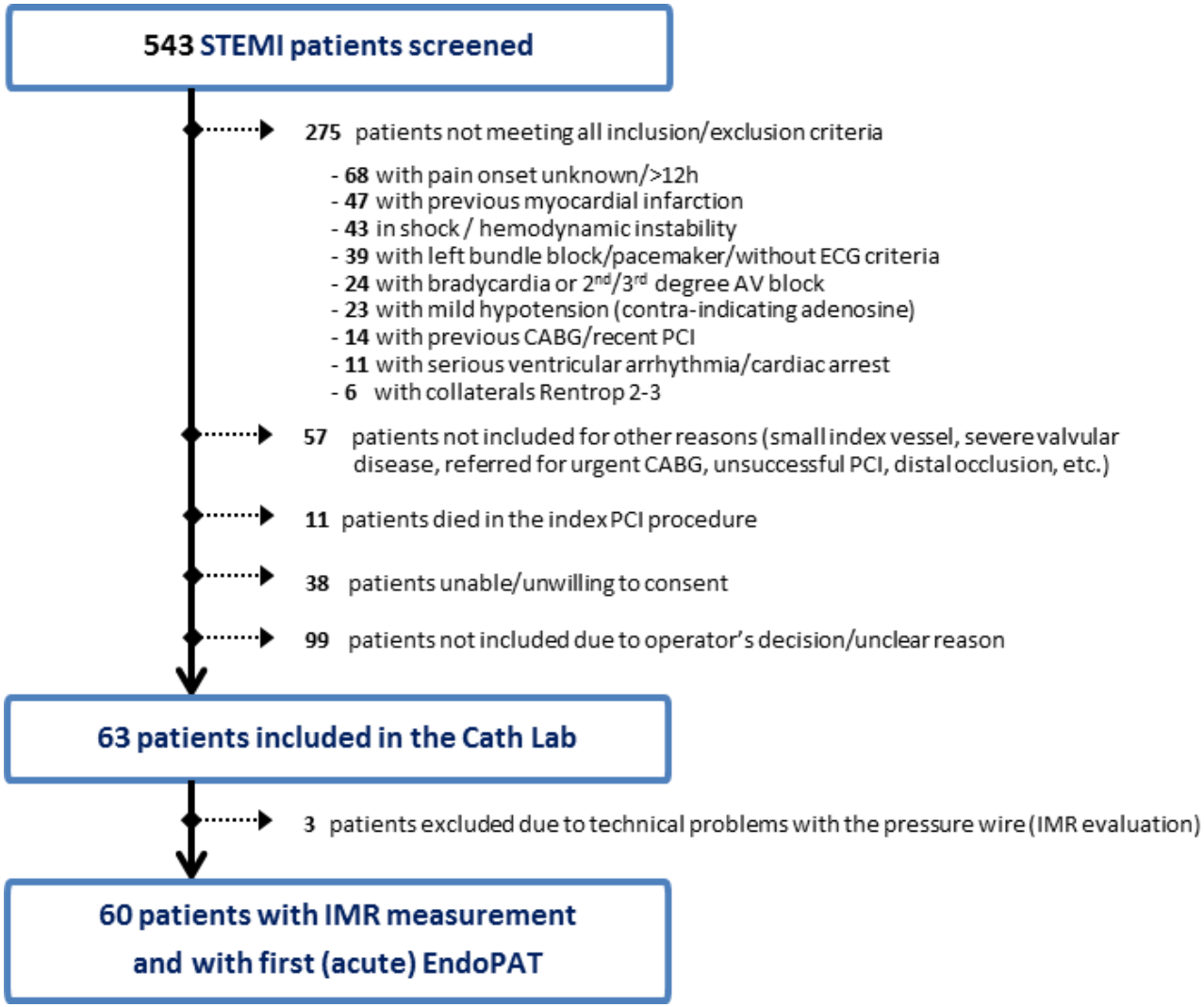
Coronary microcirculation and peripheral endothelial function evaluation after acute ST elevation myocardial infarction treated with primary angioplasty

Sérgio Bravo Baptista, MD, FESC

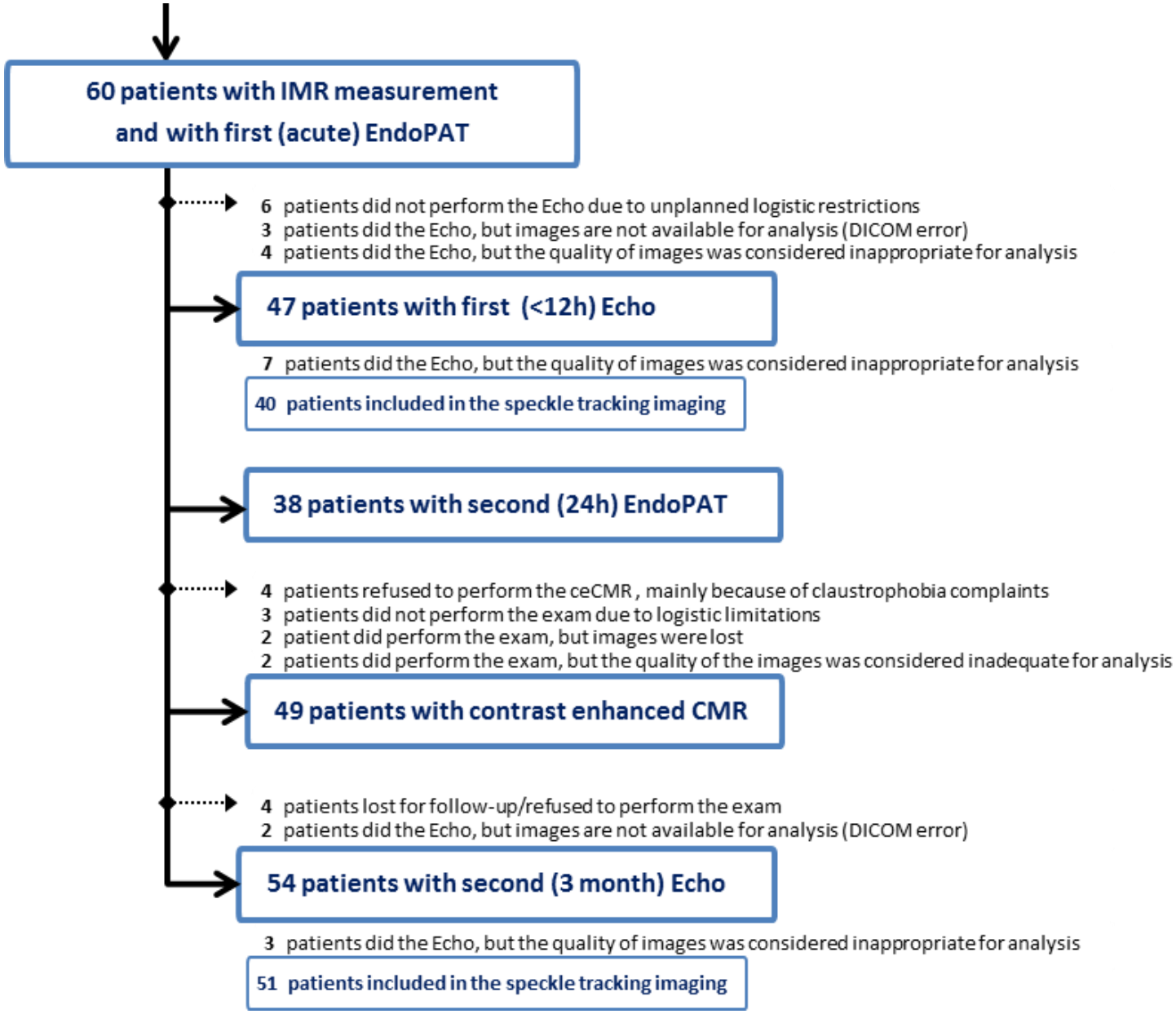
Ph.D. Supervisor: Prof. Doutor Victor Gil
Ph.D. Co-supervisor: Prof. Doutor José Fragata

Backup Slides

Flow chart of patient inclusion

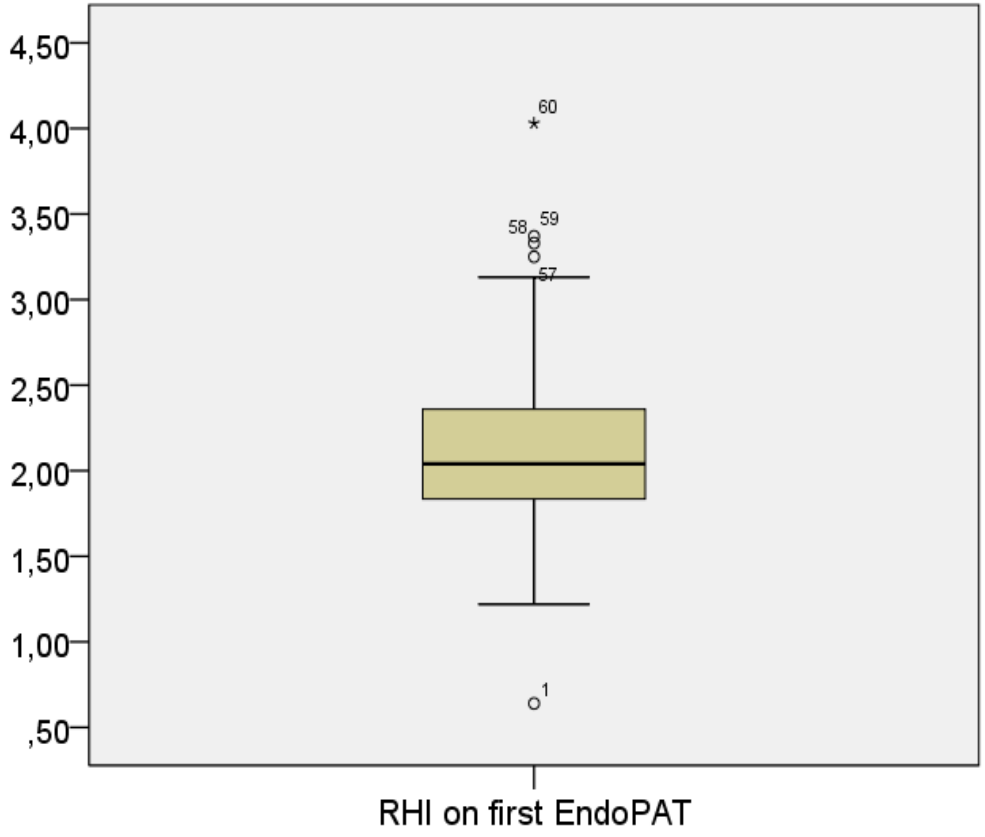


Flow chart of patient inclusion



Peripheral arterial tonometry (EndoPAT)

Reactive hyperaemia index (RHI) values on the 1st EndoPAT (complete cohort)



Limitations and Strengths

Limitations

- Inclusion rate was very low and the cohort included represents only 11% of the population of patients with STEMI
- EndoPAT exams were not performed according to the recommendations for endothelial function evaluation
- The number of patients with the second EndoPAT evaluation is small
- Imaging exams (both ceCMR and echocardiograms) are not available for all patients.

Strengths

- One of the world's largest single-centre databases in IMR evaluation in STEMI patient.
- Systematically evaluating all indirect indicators of microvascular reperfusion.
- Evaluation of myocardial infarction by troponin release was also much more comprehensive
- Echo evaluation both acutely and at follow-up and using all available modes, including speckle-tracking analysis