PLACE

PLATFORM OF LABORATORIES FOR ADVANCES IN CARDIAC EXPERIENCE

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della Tecnica

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1 Ottobre
2022

Imaging Pre-PCI in CTO

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Outline

- Clinical background in CTO
- Key principles in CTO
- The role of CMR to select the patients
- The role of CCT to improve CTO-PCI success
- New emerging tool: FFRct and stress CTP

Clinical background and key principles in CTO

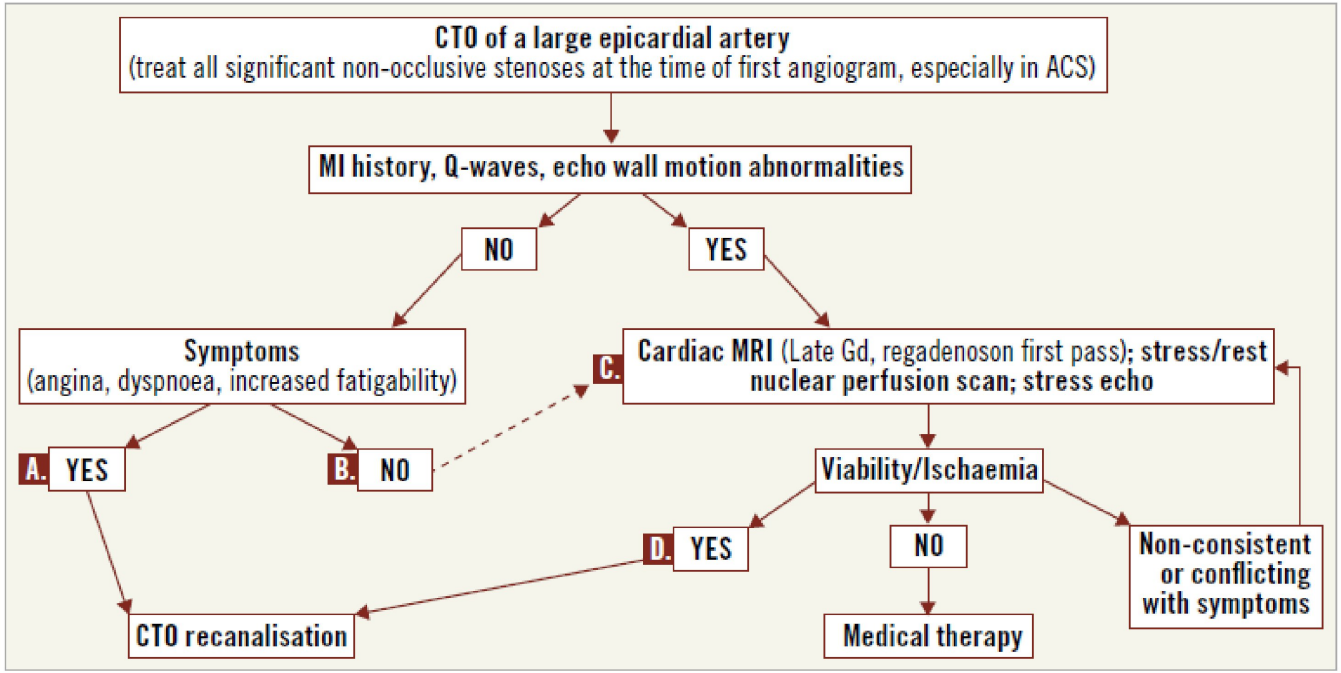

Figure 2. *Indications for CTO recanalisation: a pragmatic stepwise approach to confirmatory non-invasive tests. A) If symptoms persist after maximally tolerated anti-anginal therapy. B) The negative results of the ISCHEMIA randomised trial have challenged this practice, supported by previous guidelines and results of large multicentre registries. C) Selection based on local availability and expertise. D) Consider possible prognostic role based on size of ischaemia. ACS: acute coronary syndromes; CTO: chronic total occlusion; Gd: gadolinium; ISCHEMIA: International Study of Comparative Health Effectiveness with Medical and Invasive Approaches; MI: myocardial infarction; MRI: magnetic resonance imaging*

Di Mario C Eurointervention 2022

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The role of CMR to select the patients

Cost-effectiveness of a CMR based strategy vs invasive strategy

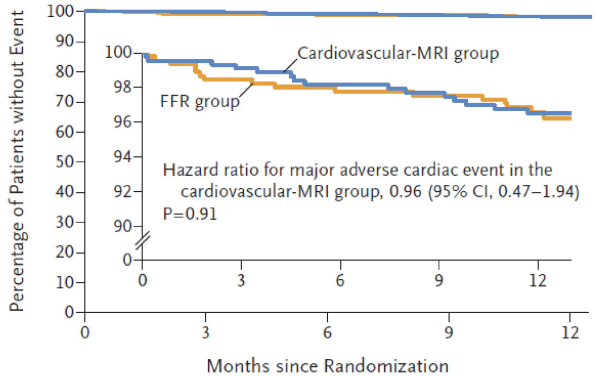

Figure 2. Kaplan–Meier Analysis of Event-free Survival.
The graph shows the unadjusted Kaplan–Meier estimates of patients surviving free from the primary composite outcome (death from any cause, nonfatal myocardial infarction, or target-vessel revascularization). The inset shows the same data on an expanded y axis.

Among patients with stable angina and risk factors for coronary artery disease, myocardial-perfusion cardiovascular MRI was associated with a lower incidence of coronary revascularization than FFR and was noninferior to FFR with respect to major adverse cardiac events.

MR INFORM Study NEJM 2019

Centro Cardiologico Monzino

The role of CMR to select the patients

JACC: CARDIOVASCULAR IMAGING
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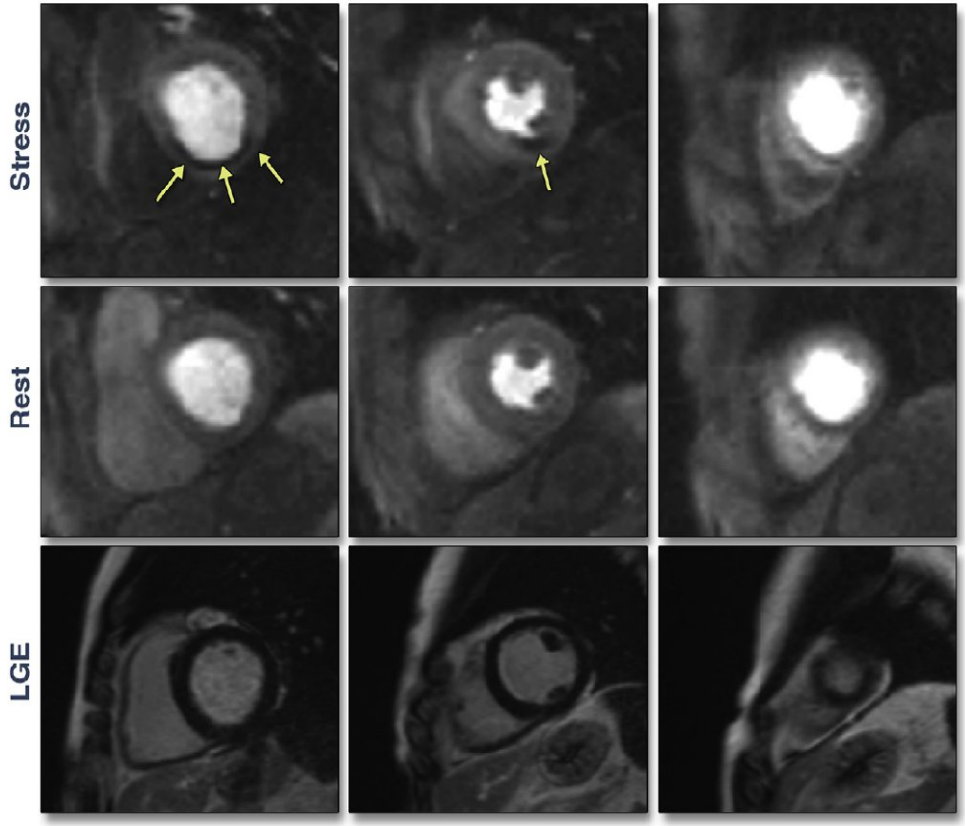
http://dx.doi.org/10.1016/j.jcmg.2015.10.025

CMR Guidance for Recanalization of Coronary Chronic Total Occlusion

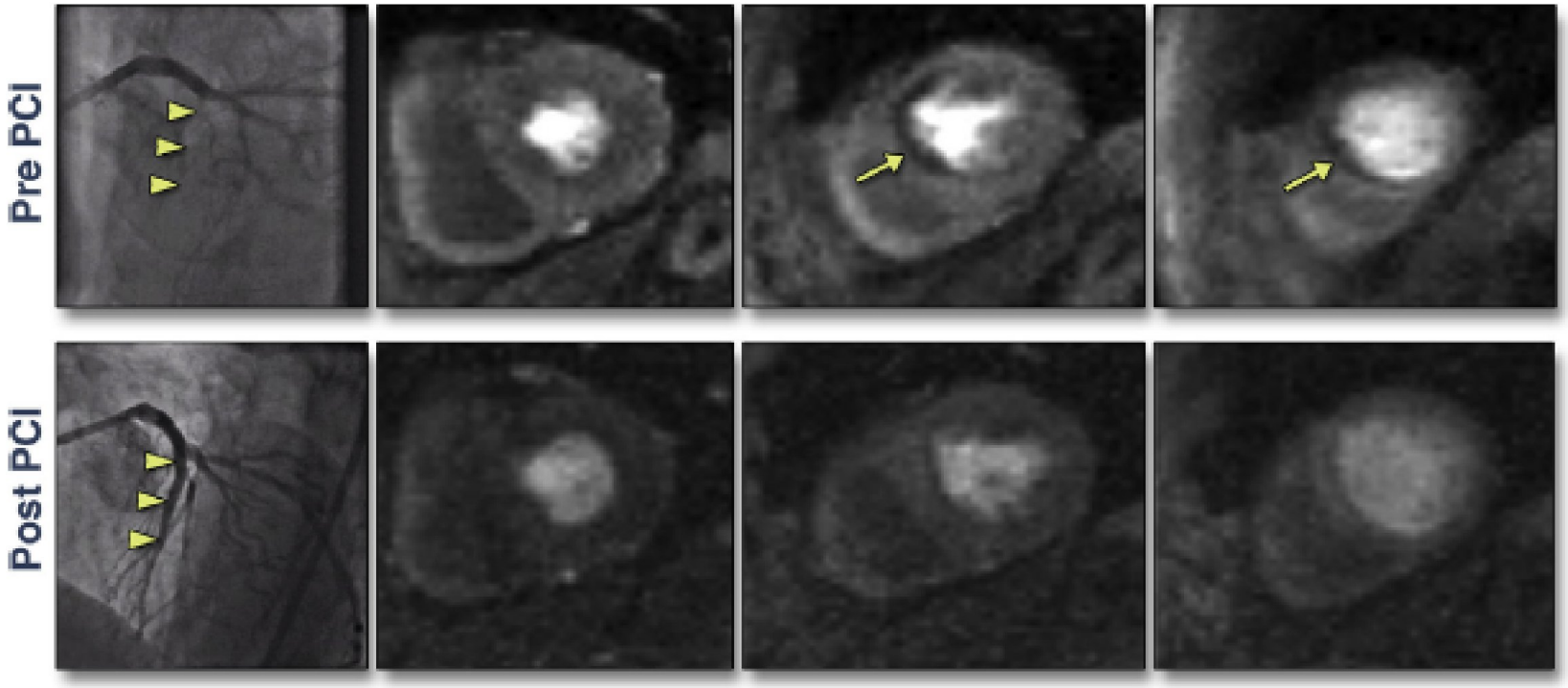
Chiara Bucciarelli-Ducci, MD, PhD,[a,b,c] Dominique Auger, MD, PhD,[a] Carlo Di Mario, MD, PhD,[b,d] Didier Locca, MD,[a] Joanna Petryka, MD,[a] Rory O'Hanlon, MD,[a] Agata Grasso, MD,[a] Christine Wright, RN,[d] Karen Symmonds, RT,[a] Ricardo Wage, RT,[a] Eleni Asimacopoulos, MB, ChB,[a] Francesca Del Furia, MD,[d] Jonathan C. Lyne, MD,[a,d] Peter D. Gatehouse, PhD,[a,b] Kim M. Fox, MD,[b,d] Dudley J. Pennell, MD[a,b]



Adenosine stress perfusion images (top) show the presence of subendocardial inducible defect in the basal and mid-cavity inferior wall (arrows), not present at rest (middle). Late gadolinium enhancement (LGE) images demonstrate a viable inferior wall with absent myocardial enhancement (no infarction) (bottom). RCA ¼ right coronary artery.

Bucciarelli Ducci C JACC CI 2016

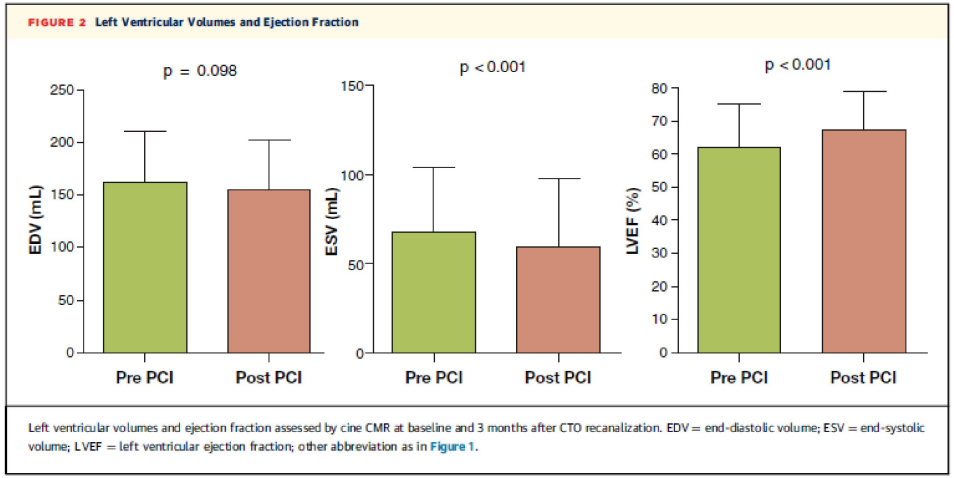
The role of CMR to select the patients

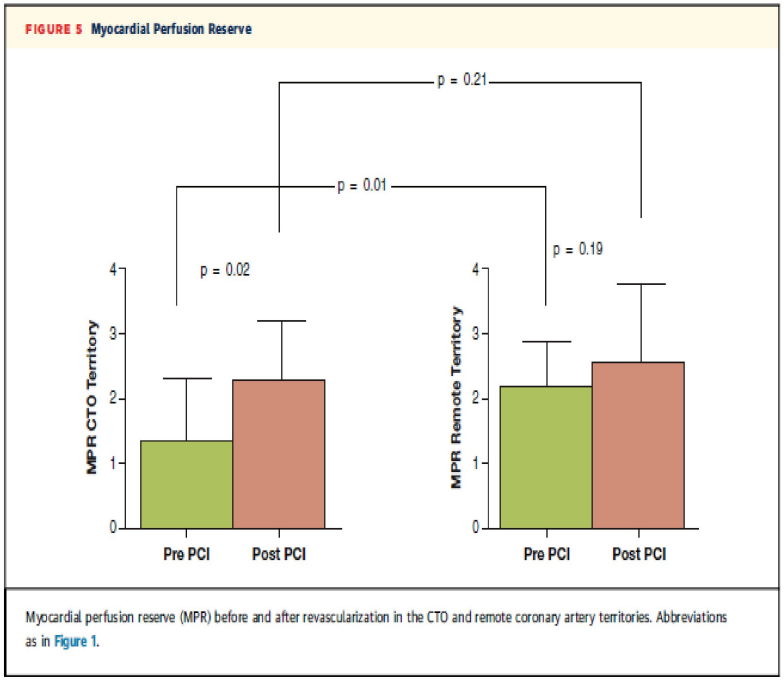


The left anterior descending artery (LAD) is proximally occluded (top, arrowheads) and adenosine stress perfusion demonstrated inducible perfusion defect in the mid-cavity and apical septum (top, arrows). After recanalization, adenosine stress perfusion showed near-complete resolution of the inducible perfusion defect previously observed (bottom)

Bucciarelli Ducci C JACC CI 2016

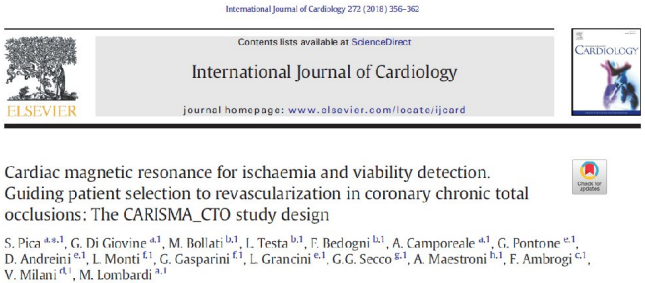
The role of CMR to select the patients





Bucciarelli Ducci C JACC CI 2016

The role of CMR to select the patients


International Journal of Cardiology 272 (2018) 356–362

Contents lists available at ScienceDirect

International Journal of Cardiology

journal homepage: www.elsevier.com/locate/ijcard

Cardiac magnetic resonance for ischaemia and viability detection. Guiding patient selection to revascularization in coronary chronic total occlusions: The CARISMA_CTO study design

S. Pica [a,*,1], G. Di Giovine [a,1], M. Bollati [b,1], L. Testa [b,1], F. Bedogni [b,1], A. Camporeale [a,1], G. Pontone [c,1], D. Andreini [c,1], L. Monti [f,1], G. Gasparini [f,1], L. Grancini [e,1], G.G. Secco [g,1], A. Maestroni [h,1], F. Ambrogi [c,1], V. Milani [d,1], M. Lombardi [a,1]

Viability:

- LGE < 50% myocardial thickness
- Kinesis improvement during dobutamine infusion

Ischemia:

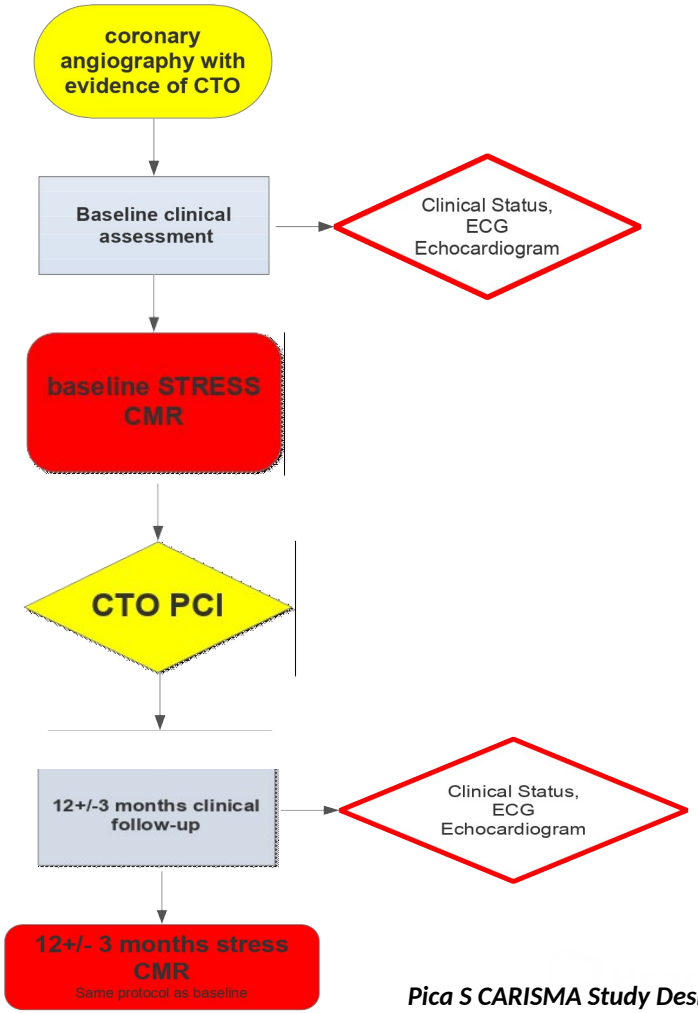
- Perfusion defect ≥ 1,5 segmenti (~10% miocardio)
- Wall motion abnormalities during stress

Primary Endpoint

LV function improvement: a) LVEF improvement ≥5%; LV kinesis improvement ≥1 grade; LV-EDV improvement ≥10%; LV-ESV improvemente ≥10%

Secondary Endpoint

a) Seattle Angina Questionnaire improvement; b) MACE reduction

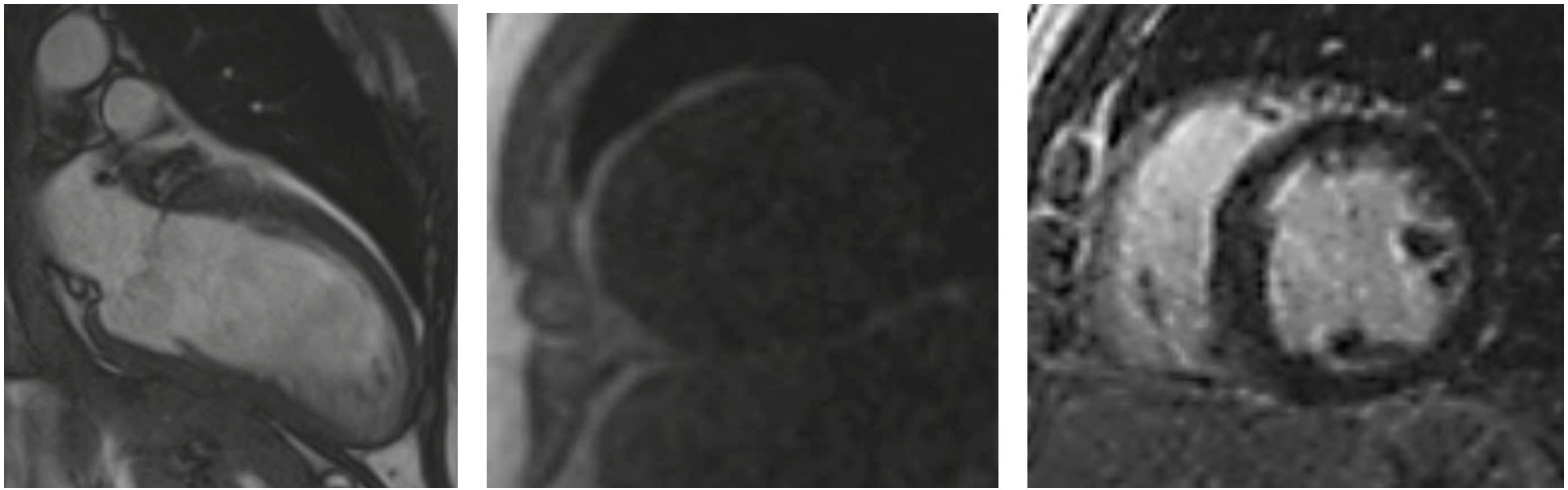


Pica S CARISMA Study Design IJC 2018

The role of CMR to select the patients

CARISMA STUDY

 # CASE 1: Uomo 44 anni. DA Dicembre 2016 episodi di angor da stress. ECG: scarsa crescita R in V1-V5, T negativo-difasiche: Eco: ipocinesia anteriore medio-distale, FE lievemente depressa; Coronarografia: occlusione cronica IVA media



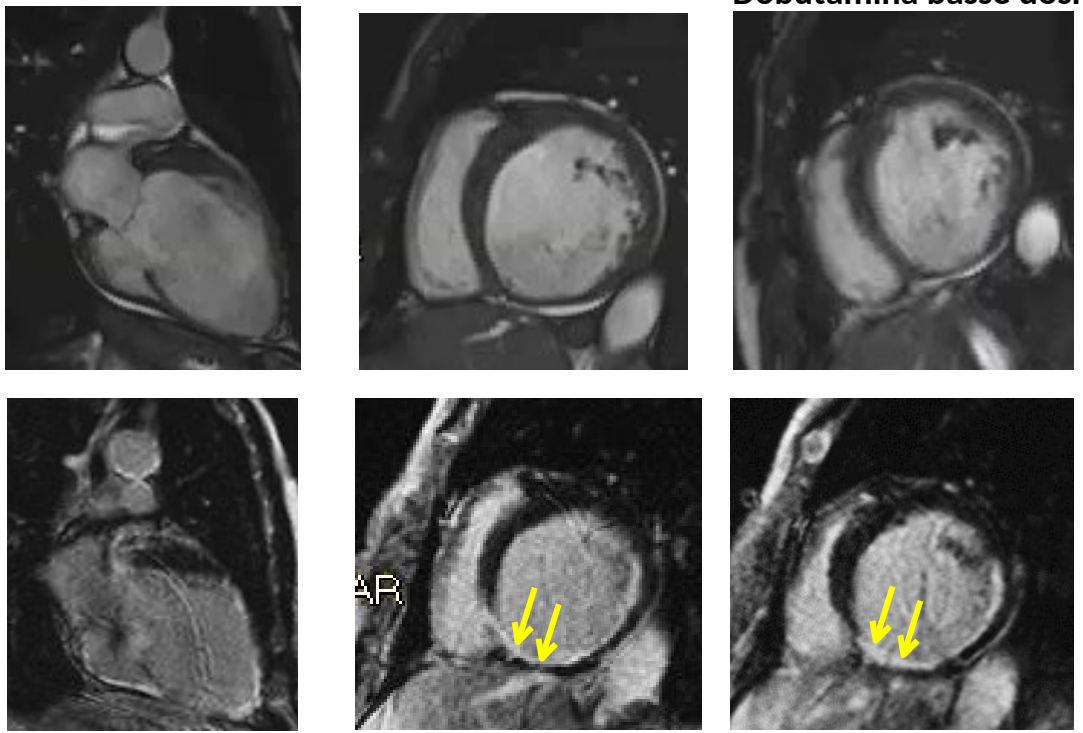
CTO-PCI indicata

Pica S CARISMA Study Design IJC 2018

The role of CMR to select the patients

CARISMA STUDY

#CASE 3: Uomo 55 anni; 2016 IMA anterolaterale ☾ PCI IVA, MO. Occlusione cronica coronaria destra



Acinesia ed assottigliamento parete inferiore, acinesia inferolaterale e SIV inferiore. Assente recupero contrattile

VITALITA' ASSENTE CDX

Cicatrice >75% SIV e parete inferiore

Pica S CARISMA Study Design IJC 2018

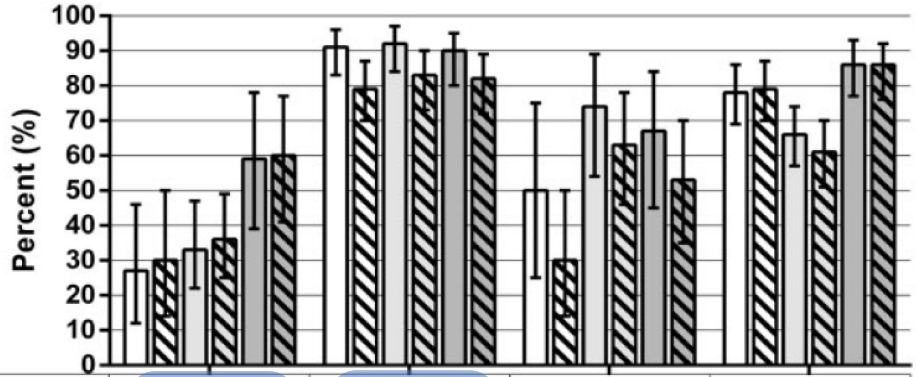
The role of CMR to select the patients

The concern of limited sensitivity of stress imaging test in presence of known obs CAD

ESC European Society of Cardiology
European Heart Journal - Cardiovascular Imaging (2018) 0, 1–9
doi:10.1093/ehjci/jex342

Diagnosing coronary artery disease after a positive coronary computed tomography angiography: the Dan-NICAD open label, parallel, head to head, randomized controlled diagnostic accuracy trial of cardiovascular magnetic resonance and myocardial perfusion scintigraphy

L. Nissen[1]*, S. Winther[2], J. Westra[2], J. A. Ejlersen[3], C. Isaksen[4], A. Rossi[5], N. R. Holm[2], G. Urbonaviciene[6], L. C. Gormsen[7], L. H. Madsen[1], E. H. Christiansen[2], M. Maeng[2], L. L. Knudsen[1], L. Frost[6], L. Brix[4], H. E. Bøtker[2], S. E. Petersen[5], and M. Bøttcher[1]



	Sensitivity	Specificity	PPV	NPV
MPS - FFR 0.80	27% (12-46)	91% (83-96)	50% (25-75)	78% (69-86)
CMR - FFR 0.80	30% (14-50)	79% (70-87)	30% (14-50)	79% (70-87)
MPS - QCA 50% stenosis	33% (22-47)	92% (84-97)	74% (54-89)	66% (57-74)
CMR – QCA 50% stenosis	36% (25-49)	83% (73-90)	63% (46-78)	61% (51-70)
MPS – Visual 90 % stenosis	59% (39-78)	90% (80-95)	67% (45-84)	86% (77-93)
CMR – Visual 90 % stenosis	60% (41-77)	82% (72-89)	53% (35-70)	86% (76-92)

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The role of CCT to improve the CTO-PCI success_J-CTO score

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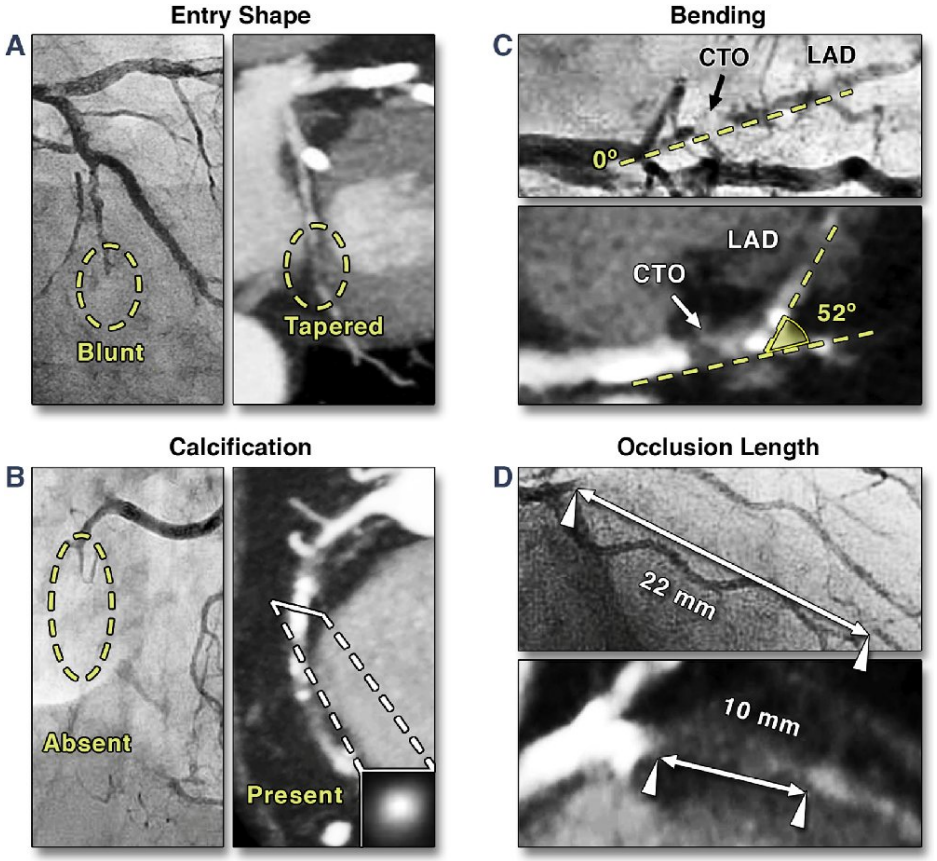
VOL. 11, NO. 2, 2018

Accuracy of J-CTO Score Derived From Computed Tomography Versus Angiography to Predict Successful Percutaneous Coronary Intervention

TABLE 2 Comparison of CTA-Derived and Angiography-Derived J-CTO Score

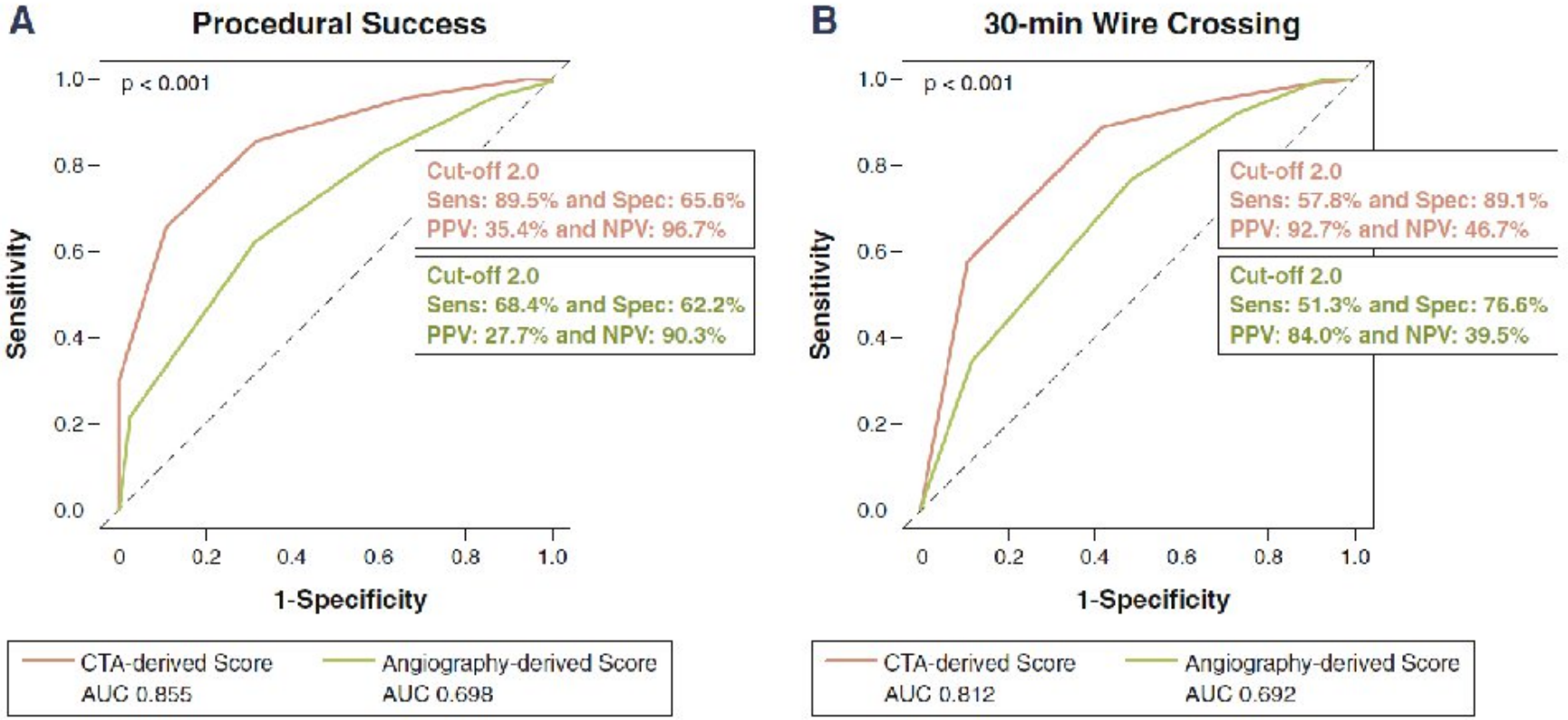
	CTA-Derived	Angiography-Derived	p Value
J-CTO score	1 (1–2)	1 (1–2)	0.698
Entry shape (blunt)	130 (59.6)	150 (68.8)	0.006
Calcification	58 (26.6)	27 (12.4)	<0.001
Bending >45°	59 (27.1)	62 (28.4)	0.647
Occlusion length >20 mm	65 (29.8)	69 (31.7)	0.493
Occlusion length, mm	11.7 (6.4–21.9)	15.0 (10.2–21.7)	<0.001

Categorical variables are n (%) and continuous variables are median (25th–75th percentile).
CTA = computed tomography angiography; J-CTO = Multicenter CTO Registry of Japan.



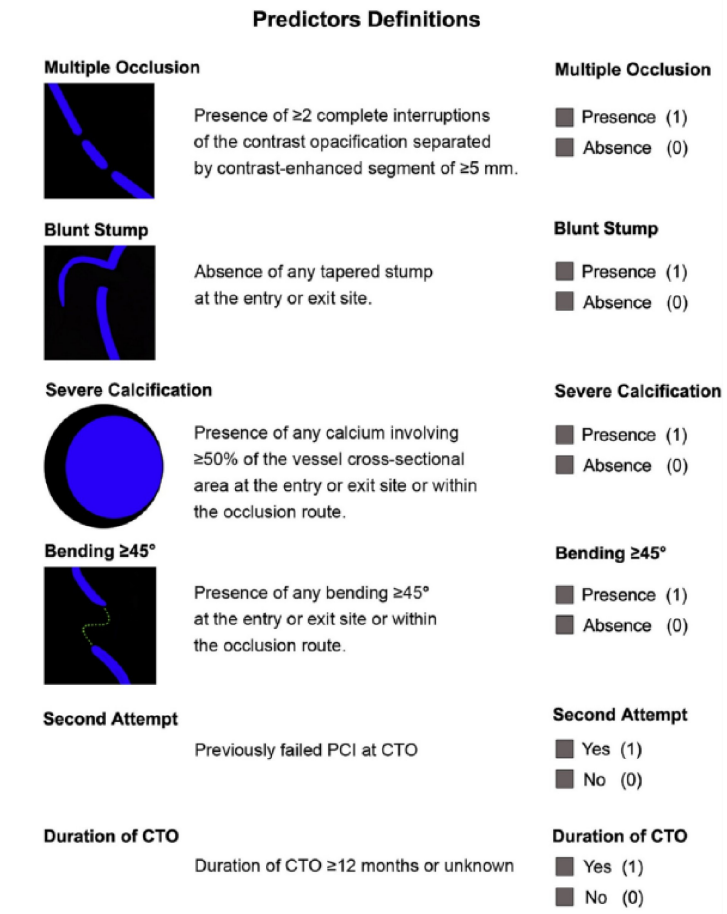
Fujino A JACC CI 2018

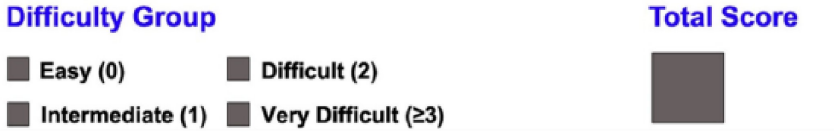
The role of CCT to improve the CTO-PCI success_J-CTO score



Fujino A JACC CI 2018

The role of CCT to improve the CTO-PCI success_CT RECTOR score

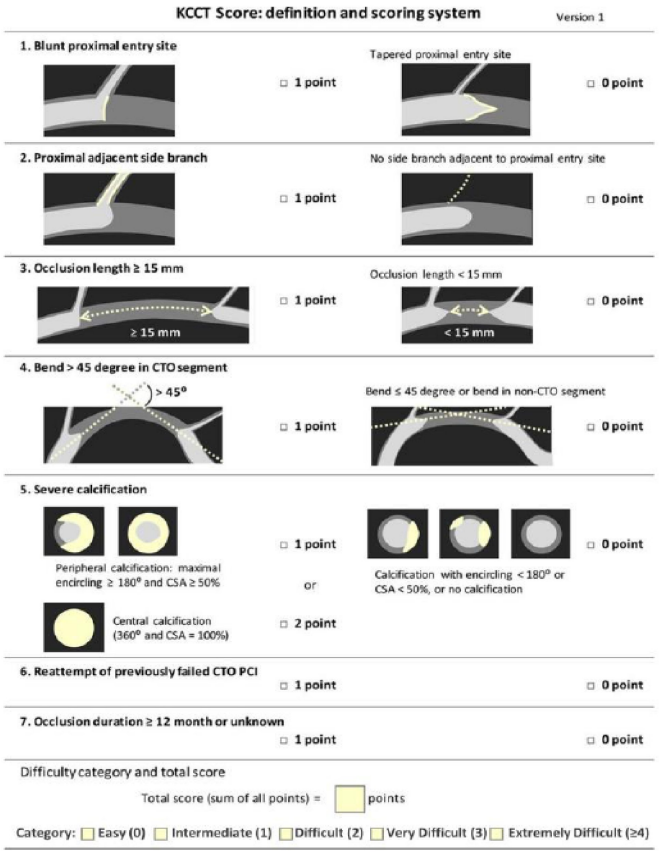




CATEGORY	Crossing<30 min	Success
Easy	95%	95%
Intermediate	88%	91%
Difficult	57%	66%
Very difficult	22%	40%

Opolski MP, JACC Interventions 2015

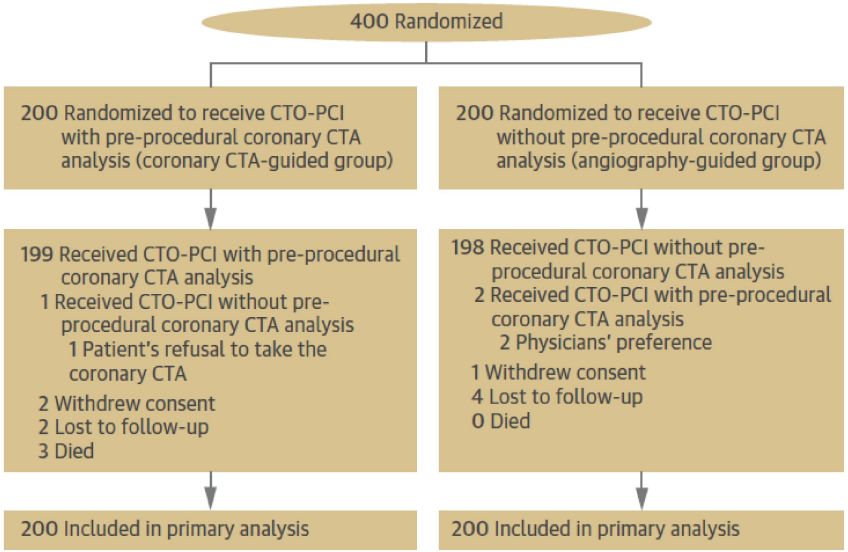
The role of CCT to improve the CTO-PCI success_CT RECTOR score

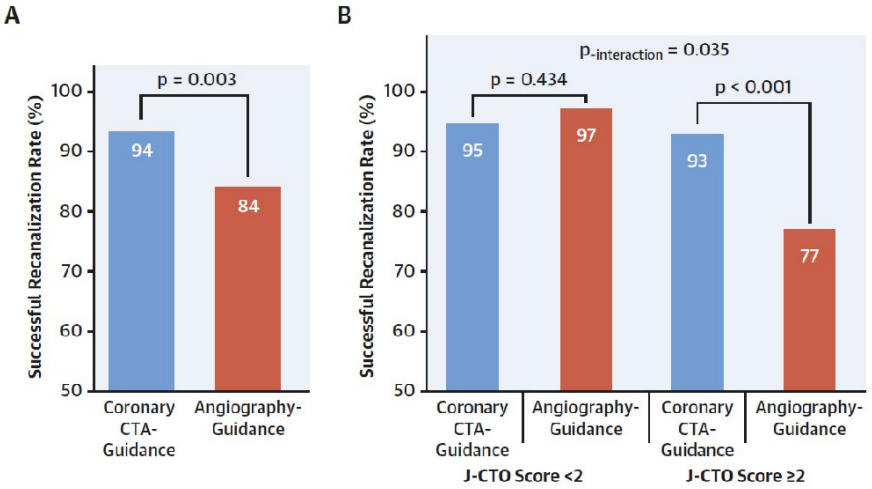


CATEGORY	Crossing<30 min	Success
Score 0	100%	100%
Score 1-2	84%	94%
Score 3	51%	84%
Score 4	30%	62%

Yu C-W Cardiovascular Imaging. 2017;10:e005800

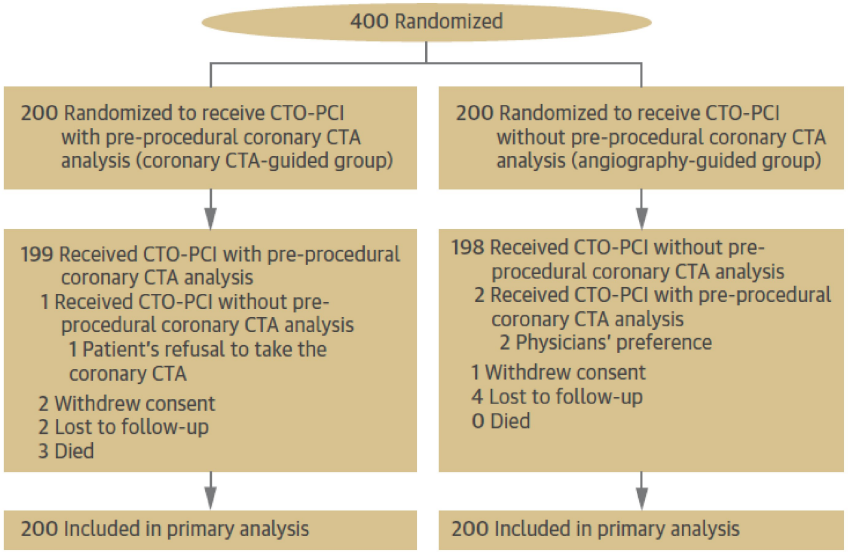
The role of CCT to improve the CTO-PCI success_Clinical Impact

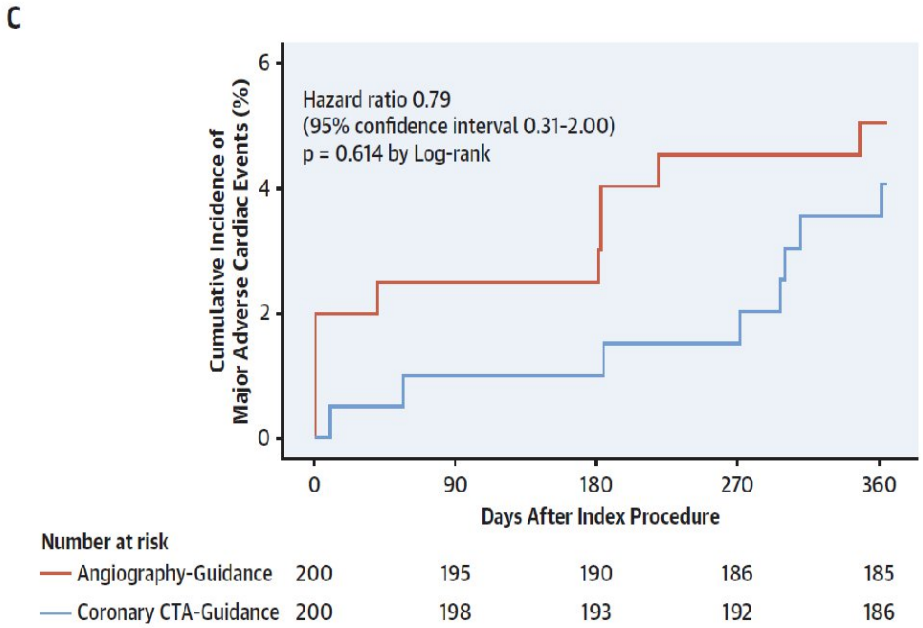




Hong S JACC CVI 2021

The role of CCT to improve the CTO-PCI success_Clinical Impact





Hong S JACC CVI 2021

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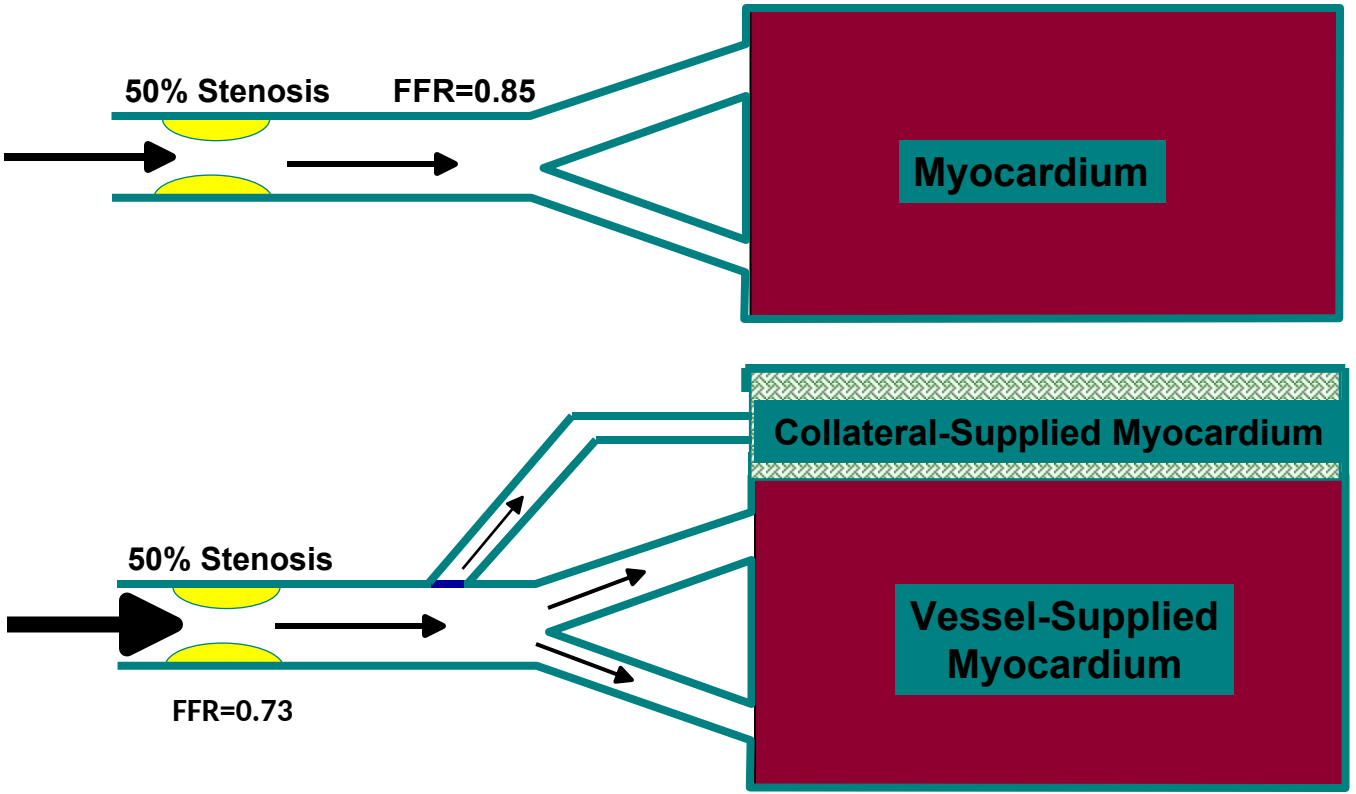
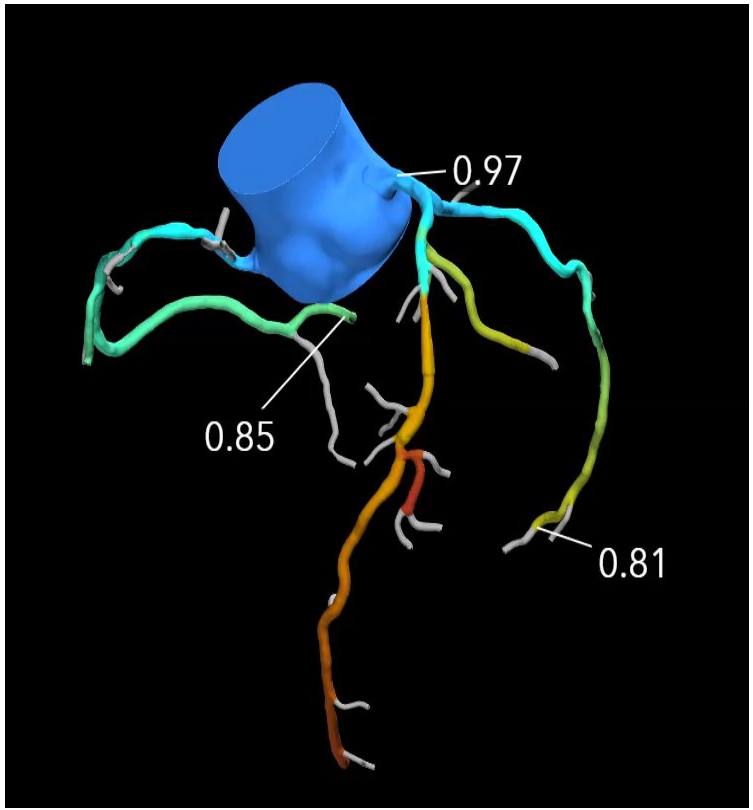
BACKGROUND: invasive FFR



Courtesy of Pijls N (JACC 2012)

Technical Principles of FFR_{CT}



Scientific Principle #1: Resting coronary blood flow proportional to myocardial mass

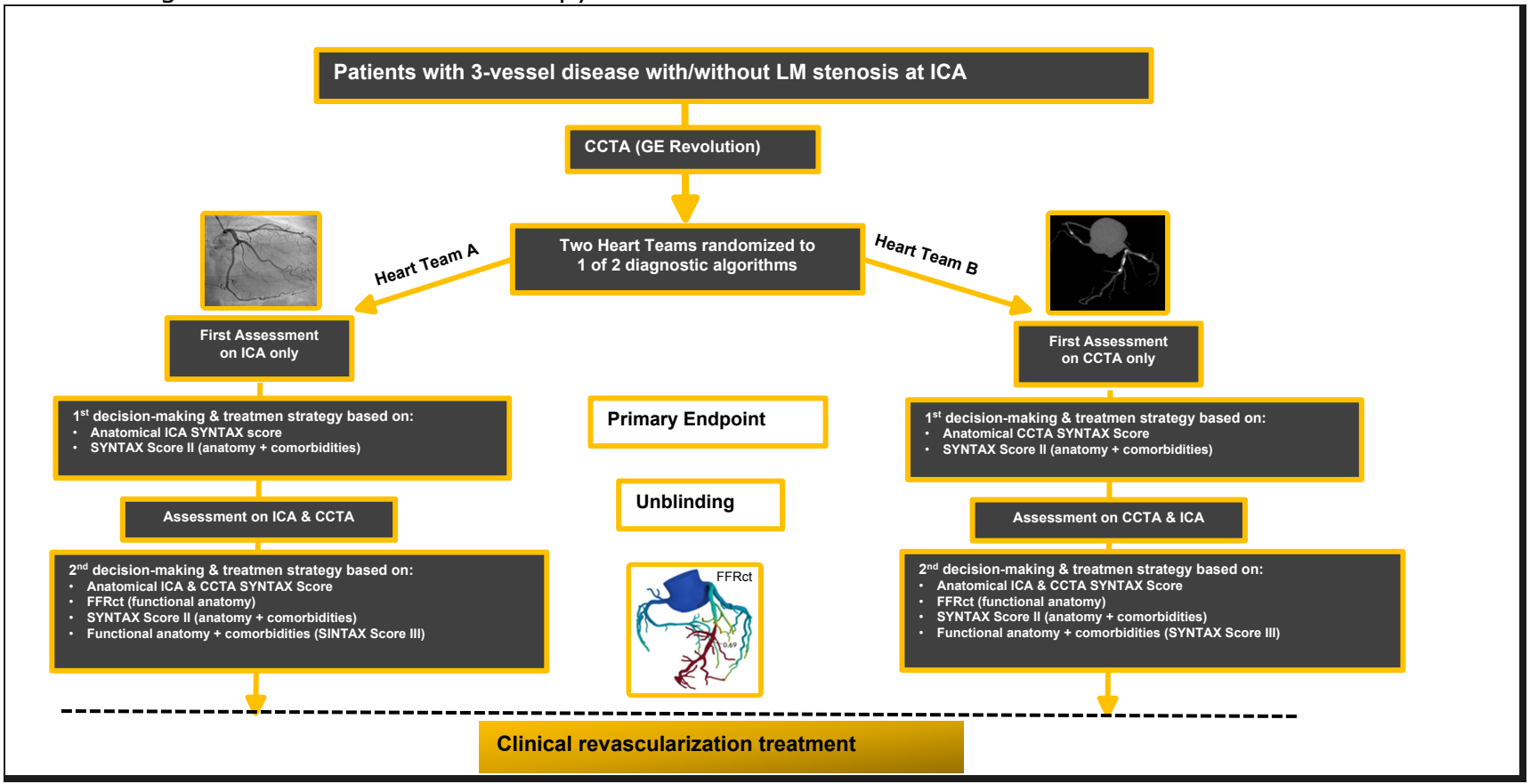
Scientific Principle #2: Resistance of microcirculatory vascular bed at rest is inversely proportional to size of feeding vessel

Scientific Principle #3: Microcirculation has a predictable response to adenosine

Courtesy of Campbell Rogers

Which alternative to traditional stress imaging: FFRct

CCTA + FFRct to guide revascularization therapy



Syntax III study EHJ 2018

Which alternative to traditional stress imaging: FFRct

CCTA + FFRct to guide revascularization therapy

	Heart Team treatment recommendation based on CCTA		
Heart Team treatment recommendation based on ICA	***CABG***	***PCI/Equipoise CABG and PCI***	
CABG	**23.4% (52/222)**	2.7% (6/222)	26.1% (58/222)
PCI/Equipoise CABG and PCI	4.5% (10/222)	**69.4%(154/222)**	73.9% (164/222)
	27.9% (62/222)	72.1 (160/222)	**92.8%(206/222)**

Agreement in 93% of the Heart Team's treatment recommendation

Cohen's kappa coefficient of 0.82 (95% CI 0.73 to 0.90)

Collet C Syntax III study EHJ 2018

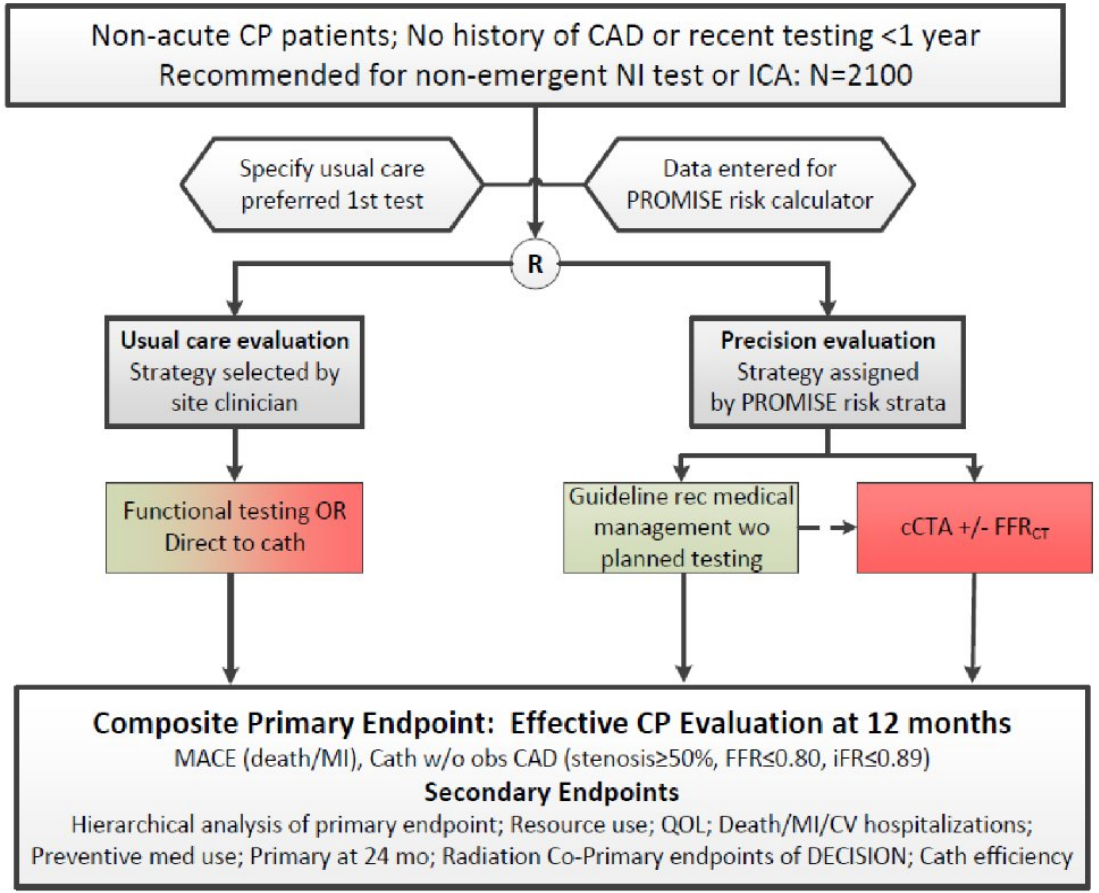
Which alternative to traditional stress imaging: FFRct

The **PRECISE** Protocol

Prospective Randomized Trial of the Optimal Evaluation of Cardiac Symptoms and Revascularization

Study Principal Investigator

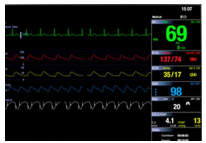
Pamela S. Douglas, MD
Duke University
Durham, NC 27701
USA



Stress CTP protocol

Patient Preparation

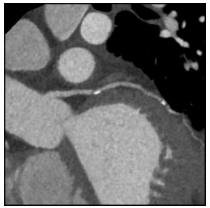
Blood pressure
ECG monitoring
B-blockade i.v. administration
Nitrates s.l administration



10 min

Rest CTA

One beat whole heart coverage
Tube voltage: 100 – 120 kVp
Tube current: 500 mA



5 min

PAUSE

15 min

Adenosine i.v. Injection

(0.14 mg/kg/min over 4 minutes)

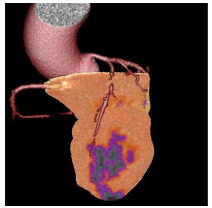
4 min

Static Stress CTP

1 pass whole heart coverage
Tube voltage: 100 – 120 kVp
Tube current: 500 mA

Dynamic Stress CTP

15 passes sampling rate
30' free-breathing acq.
Tube voltage: 100-120kVp
Tube current: 300mA



5 min

Pontone G et al JCCT 2016

Centro Cardiologico Monzino

DYNAMIC CTP_Next steps_Whole heart dynamic CTP

Journal of Cardiovascular Computed Tomography xxx (2016) 1–5

Contents lists available at ScienceDirect

Journal of Cardiovascular Computed Tomography

journal homepage: www.JournalofCardiovascularCT.com

Research paper

Rationale and design of the PERFECTION (comparison between stress cardiac computed tomography PERfusion versus Fractional flow rEserve measured by Computed Tomography angiography In the evaluation of suspected cOroNary artery disease) prospective study

Gianluca Pontone [a,*], Daniele Andreini [a,b], Andrea I. Guaricci [c,d], Marco Guglielmo [a], Saima Mushtaq [a], Andrea Baggiano [a], Virginia Beltrama [a], Daniela Trabattoni [a], Cristina Ferrari [a], Giuseppe Calligaris [a], Giovanni Teruzzi [a], Franco Fabbiocchi [a], Alessandro Lualdi [a], Piero Montorsi [a,b], Antonio L. Bartorelli [a,b], Mauro Pepi [a]

[a] Centro Cardiologico Monzino, IRCCS, Milan, Italy
[b] Department of Cardiovascular Sciences and Community Health, University of Milan, Italy
[c] Institute of Cardiovascular Disease, Department of Emergency and Organ Transplantation, University Hospital "Policlinico Consorziale" of Bari, Bari, Italy
[d] Department of Medical and Surgical Sciences, University of Foggia, Foggia, Italy

Groupe 1			Groupe 2			Groupe 3		
Anatomy	Start	Base of heart	Anatomy	Start	Identical to group1	Anatomy	Start	Identical to group1
	Full FOV Start			Full FOV Start	Identical to group1		Full FOV Start	Identical to group1
	Full FOV End			Full FOV End	Identical to group1		Full FOV End	Identical to group1
	End	Apex of heart		End	Identical to group1		End	Identical to group1
	Range			Range			Range	
	SFOV	Cardiac Small		SFOV	Cardiac Small		SFOV	Cardiac Small
	DFOV	25cm		DFOV	25cm		DFOV	25cm
	Centre A/P	A29.4mm		Centre A/P	A29.4mm		Centre A/P	A29.4mm
	Centre D/G	I24.1mm		Centre D/G	I24.1mm		Centre D/G	I24.1mm
	Auto Scan	On		Auto Scan	On		Auto Scan	On
ECG et synchronisation	Auto Gating	Off	ECG et synchronisation	Auto Gating	Off	ECG et synchronisation	Auto Gating	Off
	Acquisition Window			Acquisition Window			Acquisition Window	
	Part1	70%,150mA		Part1	70%,150mA		Part1	70%,150mA
	Part2	"–"		Part2	"–"		Part2	"–"
	Part 3	"–"		Part 3	"–"		Part 3	"–"
	HR Variation Allowance	4BPM		HR Variation Allowance	4BPM		HR Variation Allowance	4BPM
	Repeat Acquisition	Off		Repeat Acquisition	Off		Repeat Acquisition	Off
	Adaptive Gating	Off		Adaptive Gating	Off		Adaptive Gating	Off
kV et mA	kV Mode	Manuel	kV et mA	kV Mode	Manuel	kV et mA	kV Mode	Manuel
	kV	100		kV	100		kV	100
	mA Mode	Fixed mA = 150		mA Mode	Fixed mA = 150		mA Mode	Fixed mA = 150
	Noise Index	N/A		Noise Index	N/A		Noise Index	N/A
Timing	Prep/Group Delay	5	Timing	Prep/Group Delay	0,8	Timing	Prep/Group Delay	1,8
	Voice	Off,Off		Voice	Off,Off		Voice	Off,Off
Scan type	Scan Type	Cardiac	Scan type	Scan Type	Cardiac	Scan type	Scan Type	Cardiac
	HR	Off		HR	Off		HR	Off
	Temps rotation	0,28s		Temps rotation	0,28s		Temps rotation	0,28s
Coverage Speed	Table Position	One	Coverage Speed	Table Position	One	Coverage Speed	Table Position	One
	Detector Coverage	140mm		Detector Coverage	140mm		Detector Coverage	140mm
	Number of Passes	9		Number of Passes	10		Number of Passes	6
	Minimum Time Betwee	1,8s		Minimum Time Betwee	0,8		Minimum Time Betwee	2,8s
	Scan Intervall	0,000mm		Scan Intervall	0,000mm		Scan Intervall	0,000mm
	Rotation Time	0,28s		Rotation Time	0,28s		Rotation Time	0,28s
	Overlap Amount	Minimum		Overlap Amount	Minimum		Overlap Amount	Minimum
Recon.	Thickness	1,25	Recon.	Thickness	1,25	Recon.	Thickness	1,25
	Recon Type	Standard		Recon Type	Standard		Recon Type	Standard
	Asir V	100%		Asir V	100%		Asir V	100%
	Window Width	1200		Window Width	1200		Window Width	1200
	Window Level	240		Window Level	240		Window Level	240

Pontone G et al JCCT 2016

DYNAMIC CTP_Whole heart low dose dynamic CTP

JACC: CARDIOVASCULAR IMAGING
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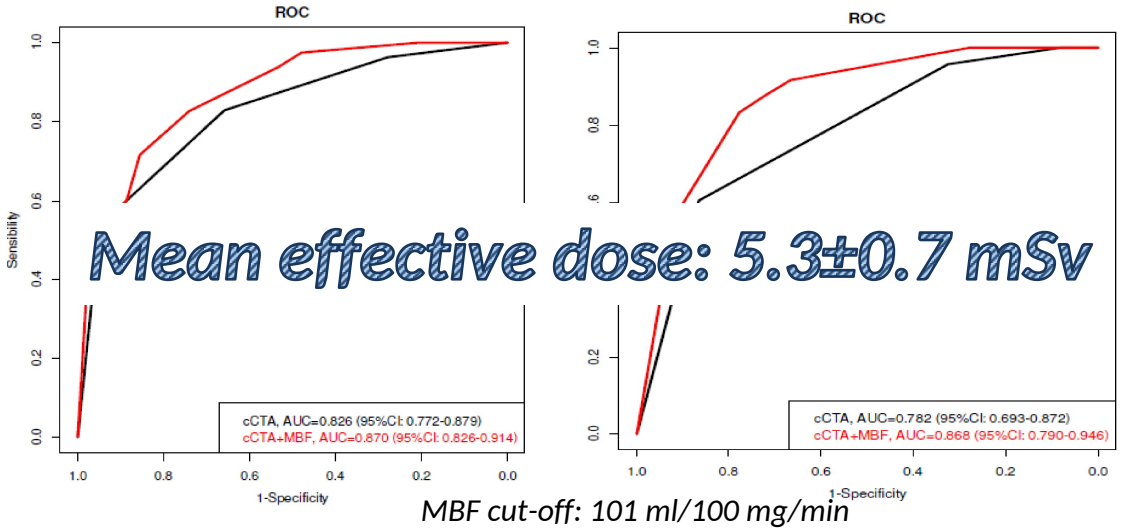
VOL. ■, NO. ■, 2019

ORIGINAL RESEARCH

Dynamic Stress Computed Tomography Perfusion With a Whole-Heart Coverage Scanner in Addition to Coronary Computed Tomography Angiography and Fractional Flow Reserve Computed Tomography Derived

Gianluca Pontone, MD, PhD,[a] Andrea Baggiano, MD,[a] Daniele Andreini, MD, PhD,[a,b] Andrea L. Guaricci, MD,[c] Marco Guglielmo, MD,[a] Giuseppe Muscogiuri, MD,[a] Laura Fusini, MD,[a] Margherita Soldi, MD,[b] Alberico Del Torto, MD,[b] Saima Mushtaq, MD,[a] Edoardo Conte, MD,[a] Giuseppe Calligaris, MD,[a] Stefano De Martini, MD,[a] Cristina Ferrari, MD,[a] Stefano Galli, MD,[a] Luca Grancini, MD,[a] Paolo Olivares, MD,[a] Paolo Ravagnani, MD,[a] Giovanni Teruzzi, MD,[a] Daniela Trabattoni, MD,[a] Franco Fabbiocchi, MD,[a] Piero Montorsi, MD,[a,b] Mark G. Rabbat, MD,[c,e] Antonio L. Bartorelli, MD,[e,f] Mauro Pepi, MD[a]

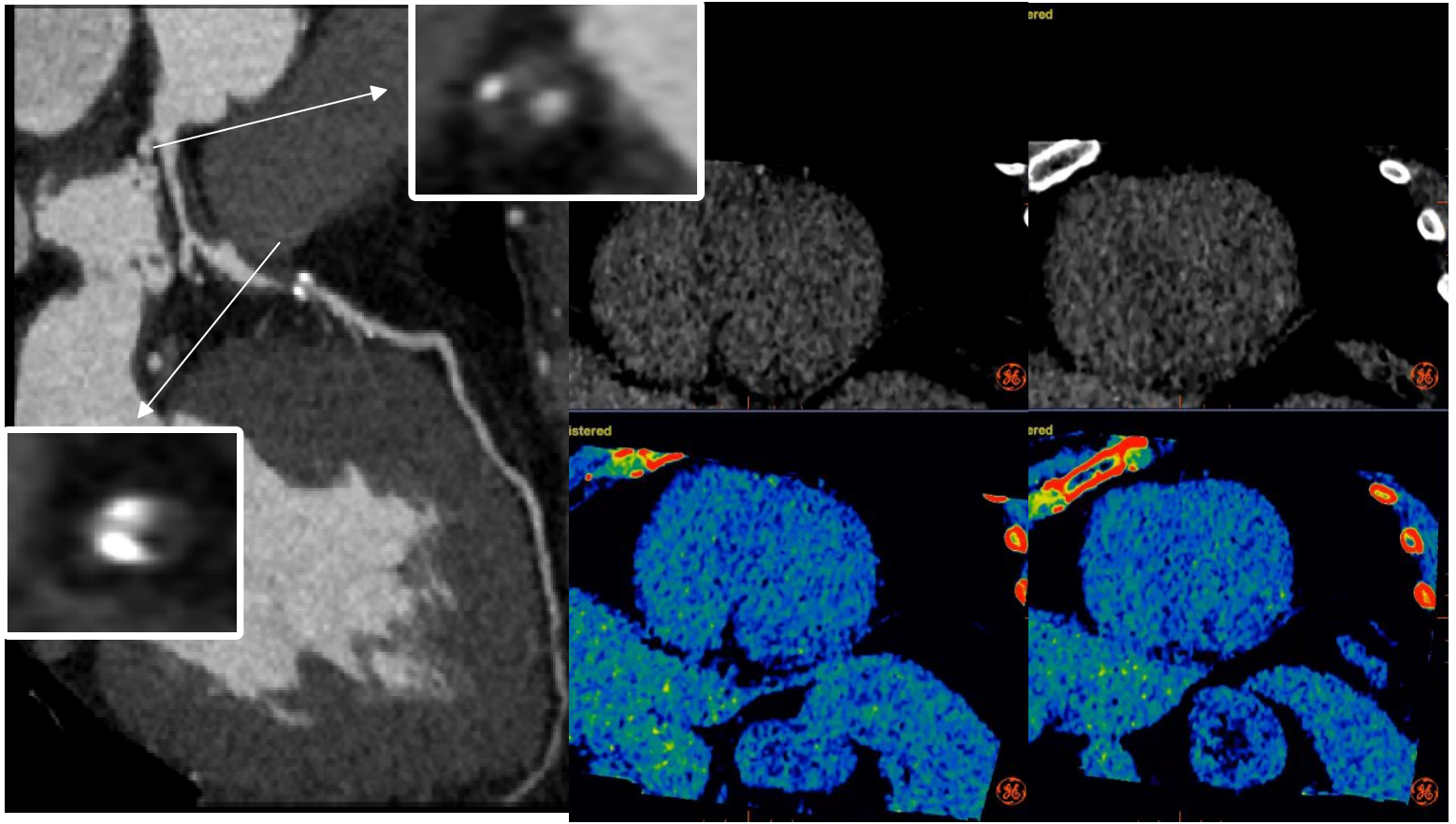


Receiver Operating-Characteristic Curve. Analysis of diagnostic accuracy per vessel (left) and patient-based model (right) for cCTA alone or integrated evaluation of cCTA+CTP to detect functionally significant CAD as reference standard. *AUC: area under the curve; CAD: coronary artery disease; CI: confidence interval; cCTA: coronary computed tomography angiography; CTP: computed tomography perfusion; MBF: myocardial blood flow; ROC: Receiver Operating Characteristics*.

Pontone G et al JACC CI 2019

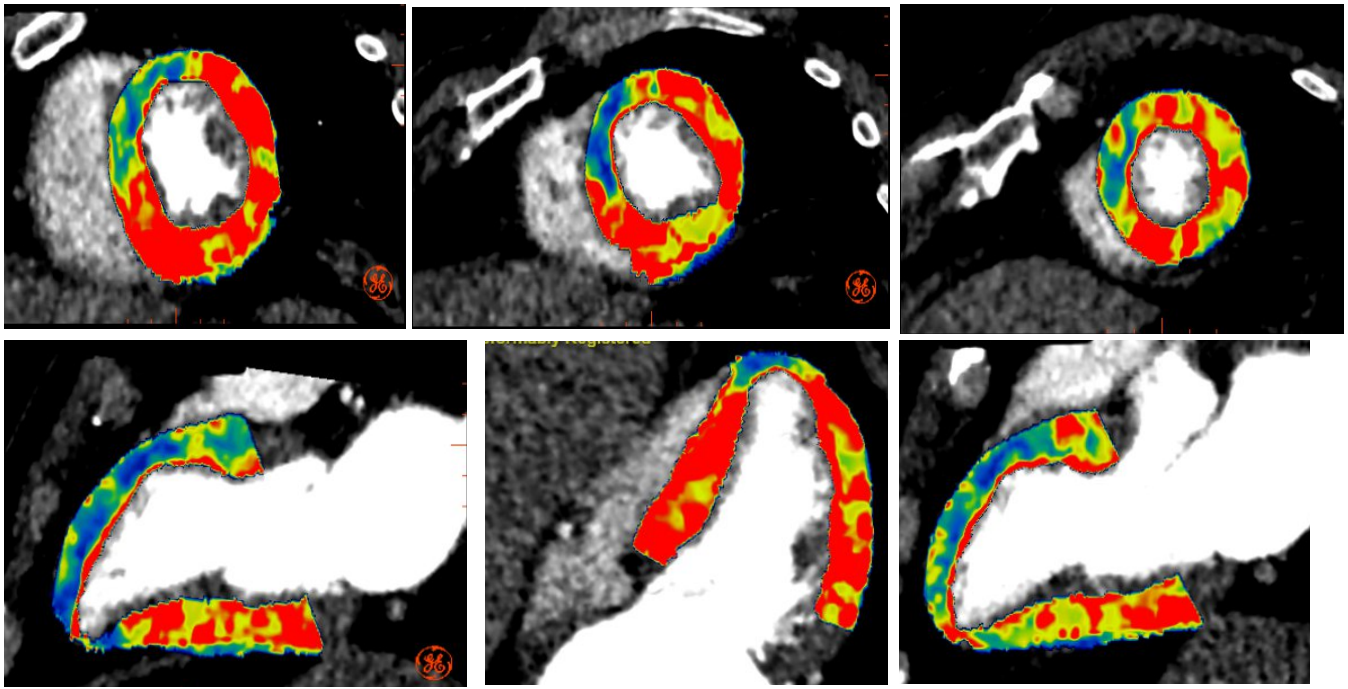
DYNAMIC CTP_Next steps_Whole heart dynamic CTP

Clinical Case: 72 y/o patient, risk factors: former smoker, hypertension, diabetes, dyslipidemia. No angina. Dispnea. SPECT positive in inferolateral wall



DYNAMIC CTP_Next steps_Whole heart dynamic CTP

Clinical Case: 72 y/o patient, risk factors: former smoker, hypertension, diabetes, dyslipidemia. No angina. Dispnea. SPECT positive in inferolateral wall



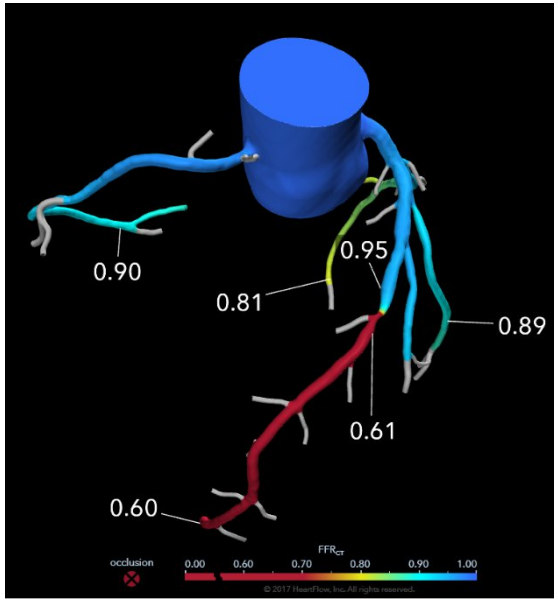
MBF: 45 ml/100 ml/min in LAD segments
ED: 5.1 mSv

Pontone G et al unpublished data

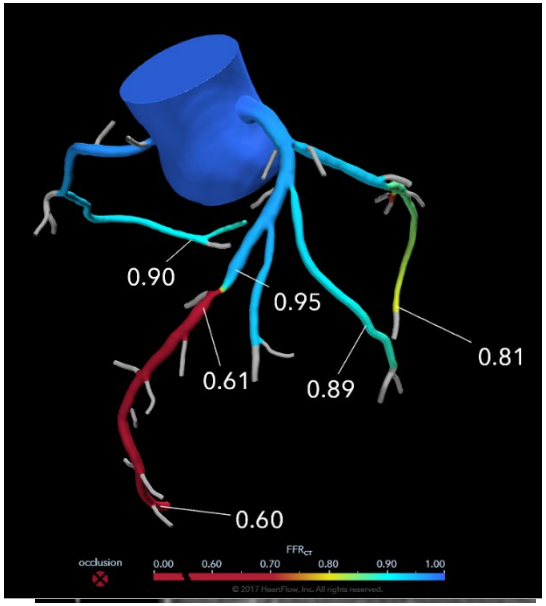
DYNAMIC CTP_Next steps_Whole heart dynamic CTP

Clinical Case: 66 y/o man with several CV risk factors, known PAD and recent Ex-ECG inconclusive.

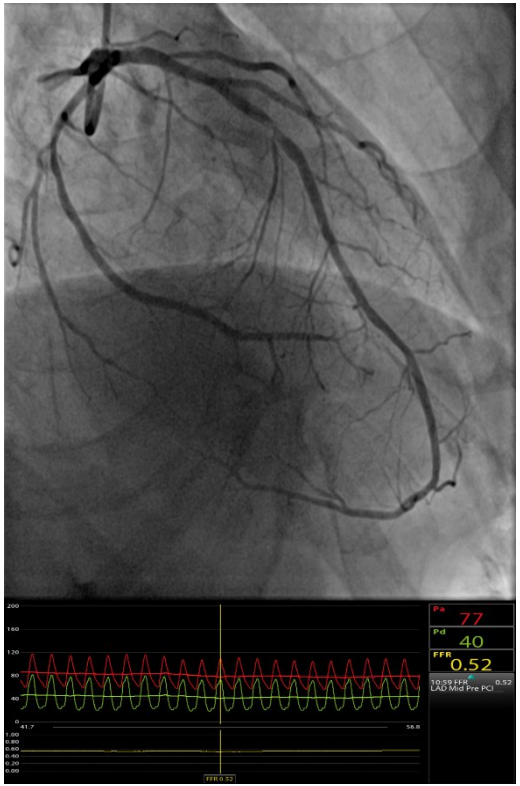
LAD



LCx



RCA



DYNAMIC CTP_Next steps_Whole heart dynamic CTP

ARTICLE IN PRESS

Journal of Cardiovascular Computed Tomography xxx (xxxx) xxx

Contents lists available at ScienceDirect

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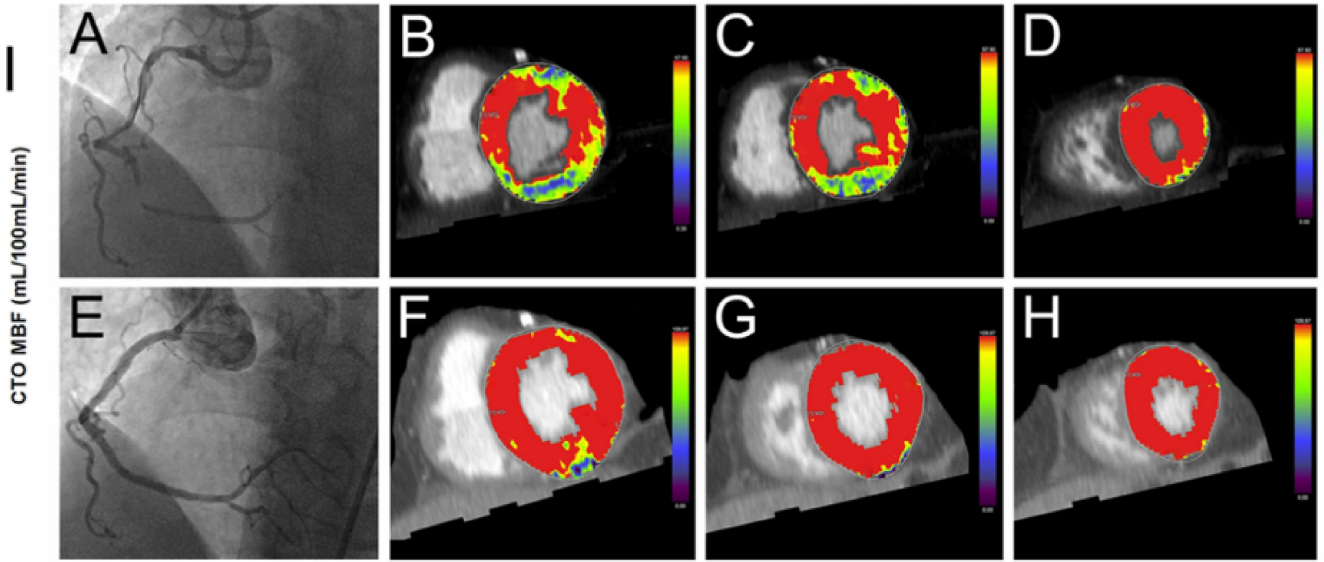
journal homepage: www.JournalofCardiovascularCT.com

Feasibility of computed tomography perfusion in patients with chronic total occlusion undergoing percutaneous coronary intervention

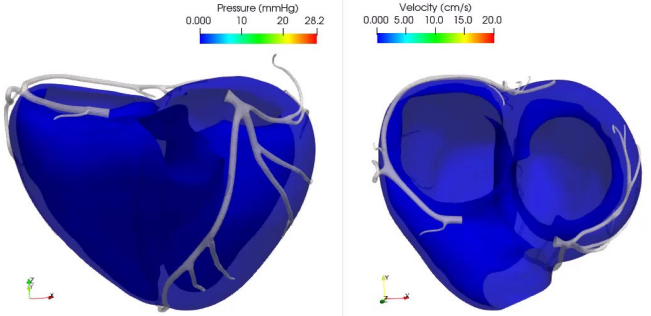


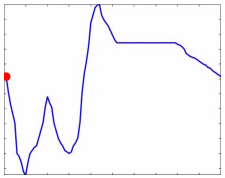
European Journal of Nuclear Medicine and Molecular Imaging
https://doi.org/10.1007/s00259-021-05667-8

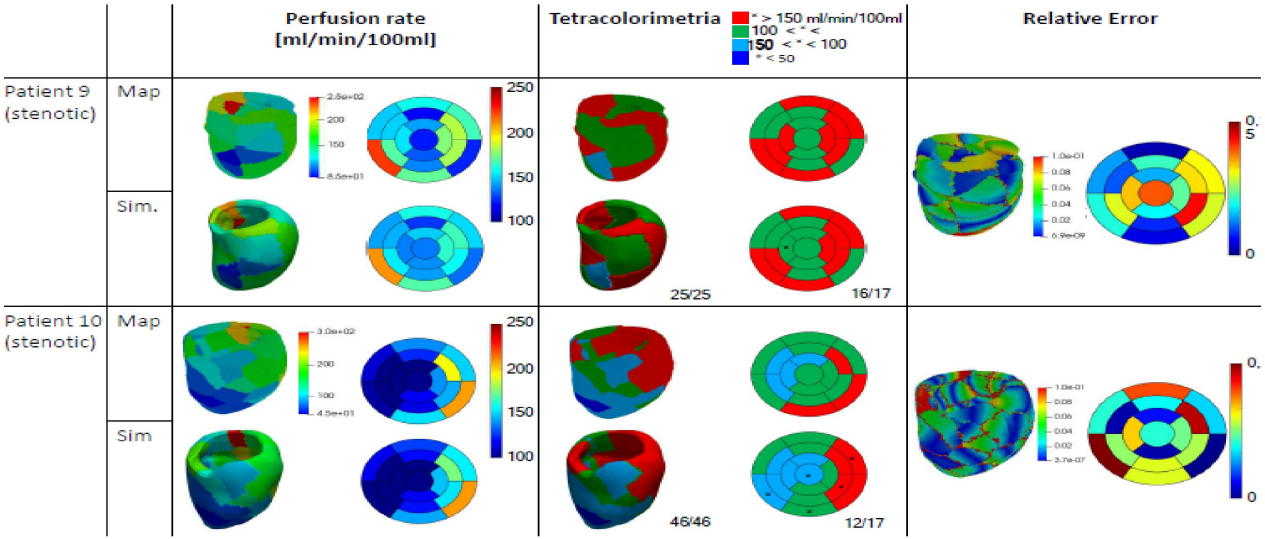
ORIGINAL ARTICLE

Prediction of myocardial blood flow under stress conditions by means of a computational model

Simone Di Gregorio[1] · Christian Vergara[2] · Giovanni Montino Pelagi[1] · Andrea Baggiano[3,4] · Paolo Zunino[1] · Marco Guglielmo[3] · Laura Fusini[3,5] · Giuseppe Muscogiuri[3] · Alexia Rossi[6,7] · Mark G. Rabbat[8,9] · Alfio Quarteroni[1,10] · Gianluca Pontone[3]



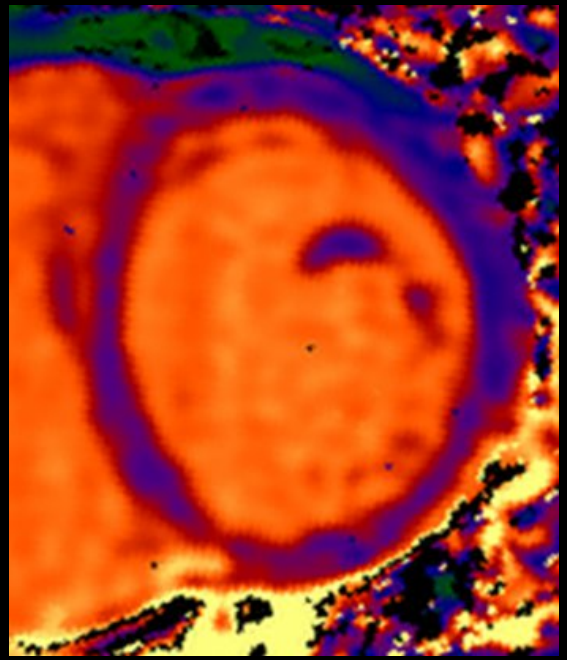




CT mapping vs CMR mapping in the diagnosis of acute myocarditis

TC riprocessata con ACM

TC originale



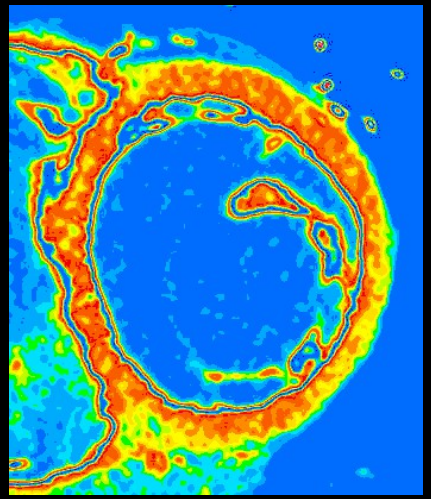
MR T1

Centro Cardiologico Monzino

CT mapping vs CMR mapping in the diagnosis of acute myocarditis

TC riprocessata con ACM

TC originale



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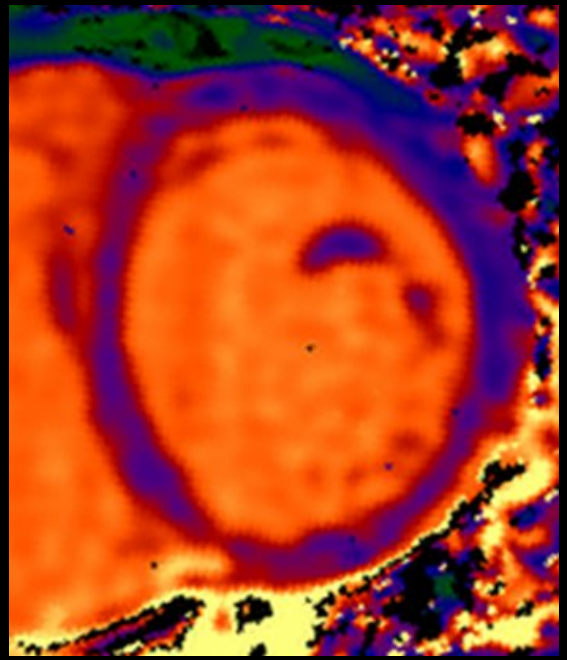

MR T1

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TAKE HOME MESSAGE

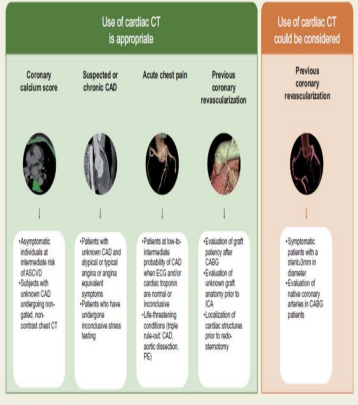
- ❑ CTO is a frequent collateral findings
- ❑ The indication of CTO-PCI is mainly symptoms driven
- ❑ Benefits of CTO-PCI on QOL is showed but the improvement of outcome in terms of MACE is still controversial
- ❑ A CTO-PCI strategy CMR guided (Ischemia + viability) could improve the benefits on outcome
- ❑ A pre-procedural CCT could improve the rate of success of the procedure
- ❑ New emerging technique (FFRct & stress CTP and ECVct) are growing but their values in the specific setting of CTO has still to be established

ESC European Society of Cardiology
European Heart Journal - Cardiovascular Imaging (2022) 23, 299–314
https://doi.org/10.1093/ehjci/jeab293
EACVI DOCUMENT

Clinical applications of cardiac computed tomography: a consensus paper of the European Association of Cardiovascular Imaging—part I

Gianluca Pontone [1,*,†], Alexia Rossi [2,3,†], Marco Guglielmo [1], Marc R. Dweck [4], Oliver Gaemperli [5], Koen Nieman [6], Francesca Pugliese [7,8], Pal Maurovich-Horvat [9], Alessia Gimelli [10], Bernard Cosyns [11], and Stephan Achenbach [12]

Graphical Abstract



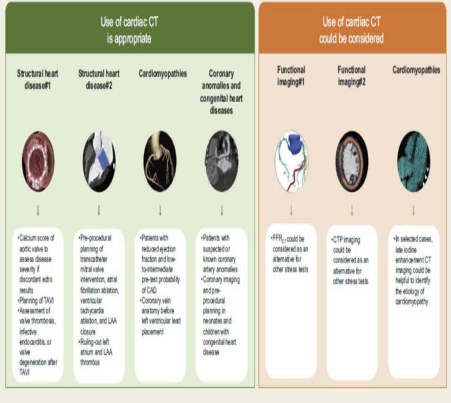
Clinical applications of cardiac CT. For more details, please see Table 1, which summarizes the main applications of cardiac CT. ASCVD, atherosclerotic cardiovascular disease; CABG, coronary artery by-pass graft; CAD, coronary artery disease; CT, computed tomography; ECG, electrocardiogram; ICA, invasive coronary angiography; PE, pulmonary embolism.

ESC European Society of Cardiology
European Heart Journal - Cardiovascular Imaging (2022) 00, 1–26
https://doi.org/10.1093/ehjci/jeab292
EACVI DOCUMENT

Clinical applications of cardiac computed tomography: a consensus paper of the European Association of Cardiovascular Imaging—part II

Gianluca Pontone [1,*,†], Alexia Rossi [2,3,†], Marco Guglielmo [1], Marc R. Dweck [4], Oliver Gaemperli [5], Koen Nieman [6], Francesca Pugliese [7,8], Pal Maurovich-Horvat [9], Alessia Gimelli [10], Bernard Cosyns [11], and Stephan Achenbach [12]

Graphical Abstract



Clinical applications of cardiac CT. For more details, please refer to Table 1 which summarizes the main applications of cardiac CT. CAD, coronary artery disease; CT, computed tomography; CTP, computed tomography perfusion; FFR$_{CT}$, CT-derived fractional flow reserve; LAA, left atrial appendage; TAVI, transcatheter aortic valve implantation.