

# Angiographic Predictor of Cardiac Events After CTO-PCI



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# Angiographic Predictor of Cardiac Events After CTO-PCI

- Limited data, limited large-scaled study
- **PCI procedural success** is the best predictor for favorable prognosis – historical and meta-analysis data

Meta-analyses or multi-national studies: success versus failed CTO PCI

Publication	Studies	Patients	F/U period	Mortality	MI or MACE	Need of CABG
Hoebers, IJC 2015	27	15,432	-	OR=0.5 (0.4 - 0.6), p<0.001	-	-
Christakopoulos, AJC 2015	25	28,486	-	OR=0.52 (0.43 - 0.63), p<0.001	OR=0.73 (0.52 - 1.03), P=NS	OR=0.18 (0.144 - 0.22), p<0.01
George, JACC 2014	UK	13,443	2.7 year	HR=0.70 (0.56 - 0.87), p=0.002	-	-
Khan, CCI 2013	23	12,970	3.7 year	RR=0.54 (0.45 - 0.65), p<0.001	RR=0.70 (0.60 - 0.83), p<0.001	RR=0.25 (0.21 - 0.30), p<0.001
Panchly, AJC 2013	13	3,932	-	OR=0.39 (0.31 - 0.49), p<0.001	-	-
Mehran, JACC Int 2011	3 centers	1,791	2.9 year	HR=0.40 (0.21 - 0.75), p<0.01	-	HR= 0.21 (0.13 - 0.40), p<0.01
Joyal, AHJ 2010	13	7,288	-	OR=0.56 (0.43 - 0.72), p<0.001	OR=0.74 (0.44-1.25), p=NS	OR=0.22 (0.17 - 0.27), p<0.001

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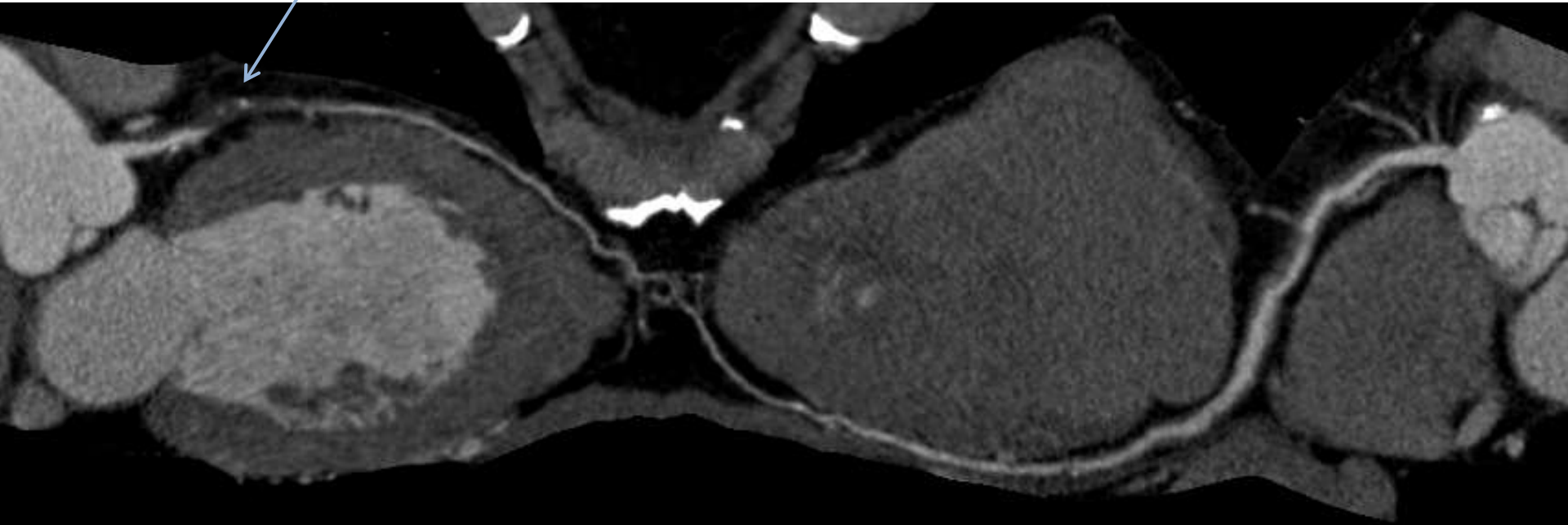
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**Increasing perfusion to ischemic (and viable) myocardium**

**would be the key to the favorable prognosis**

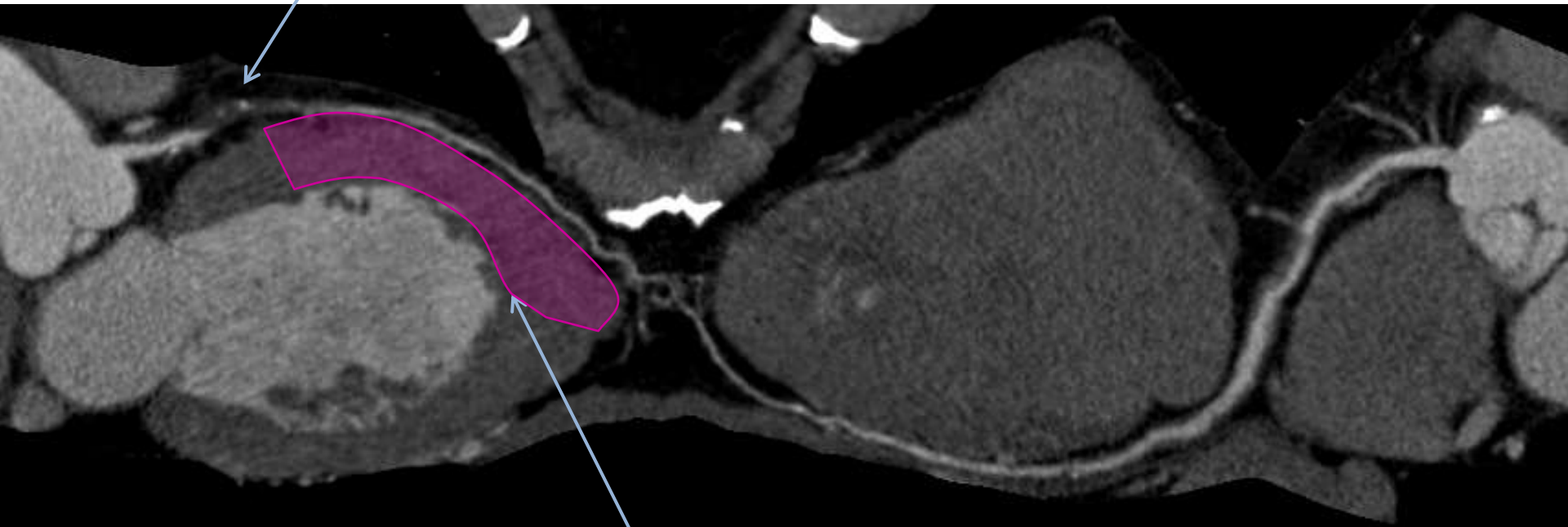
# Schematic image of CTO vessel and donor vessel supplying collateral flow

CTO lesion



# Schematic image of CTO vessel and donor vessel supplying collateral flow

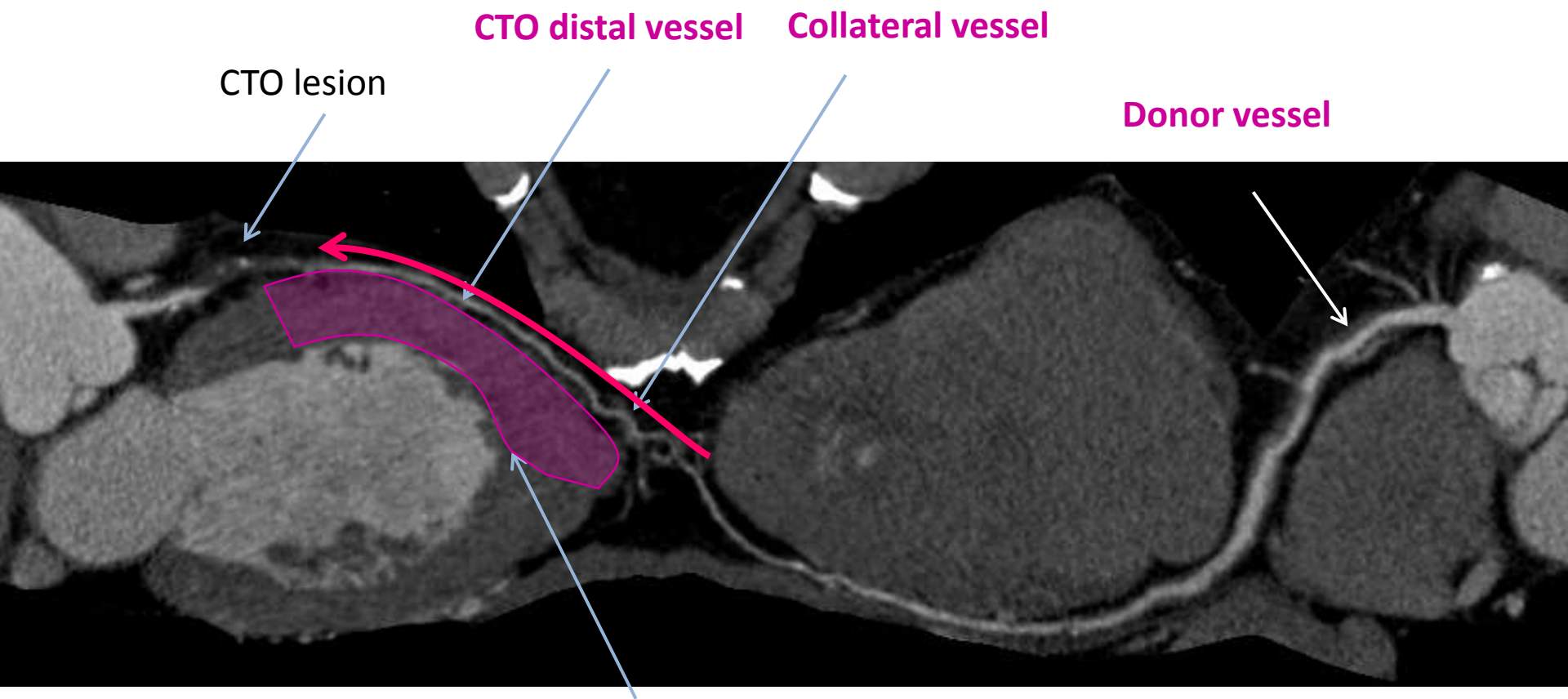
CTO lesion



Myocardium subtended by CTO vessel  
(red area: ischemic myocardium)



# Schematic image of CTO vessel and donor vessel supplying collateral flow



CTO lesion

CTO distal vessel

Collateral vessel

Donor vessel

Myocardium subtended by CTO vessel  
(red area: ischemic myocardium)

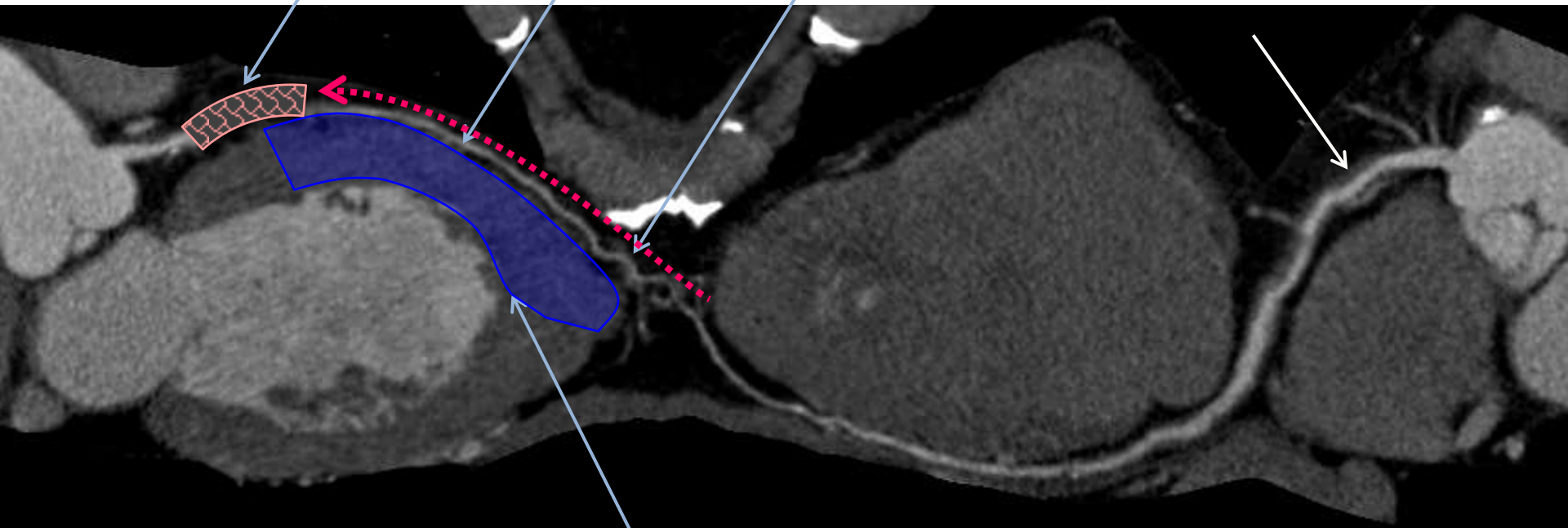
CTO PCI supplying **viable myocardium** → a large benefit

**Less endothelial dysfunction  
in distal vessel**

**Well-developed  
collateral flow**

Donor vessel

Stent



**Amount of saved ischemic myocardium by CTO PCI**

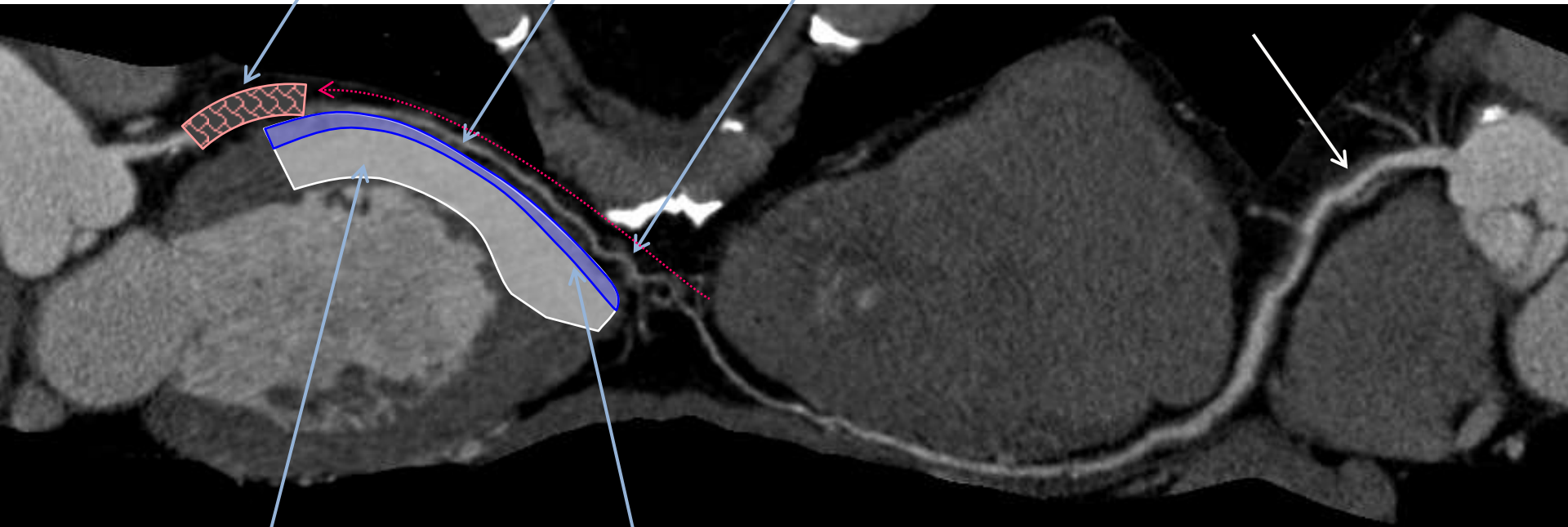
CTO PCI supplying **minimally viable myocardium** → a limited benefit

**Severe endothelial dysfunction in distal vessel**

**Poor collateral flow**

Donor vessel

Stent



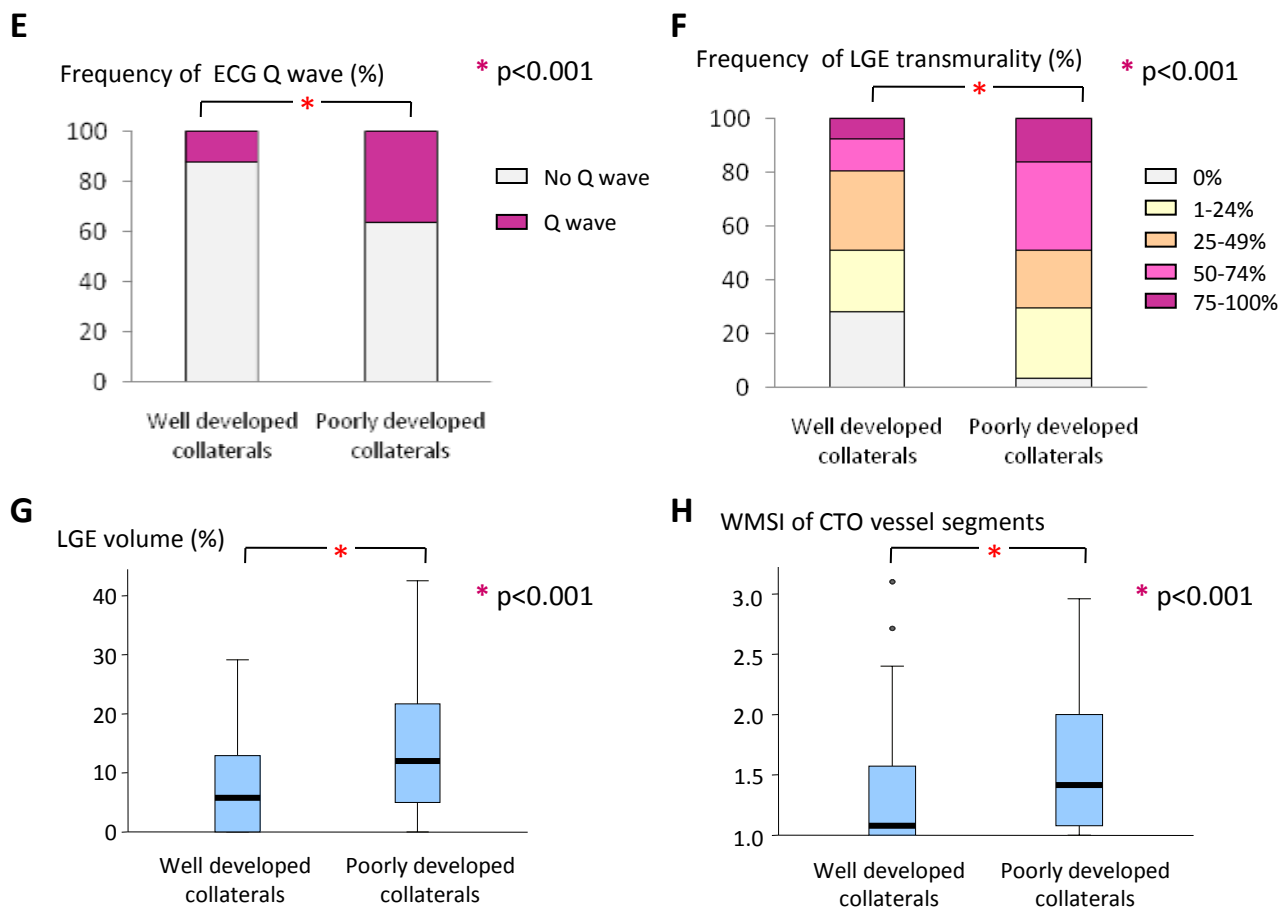
Infarct scar

**Amount of saved ischemic myocardium by CTO PCI**

# Cardiac MRI study

## Well-developed collateral

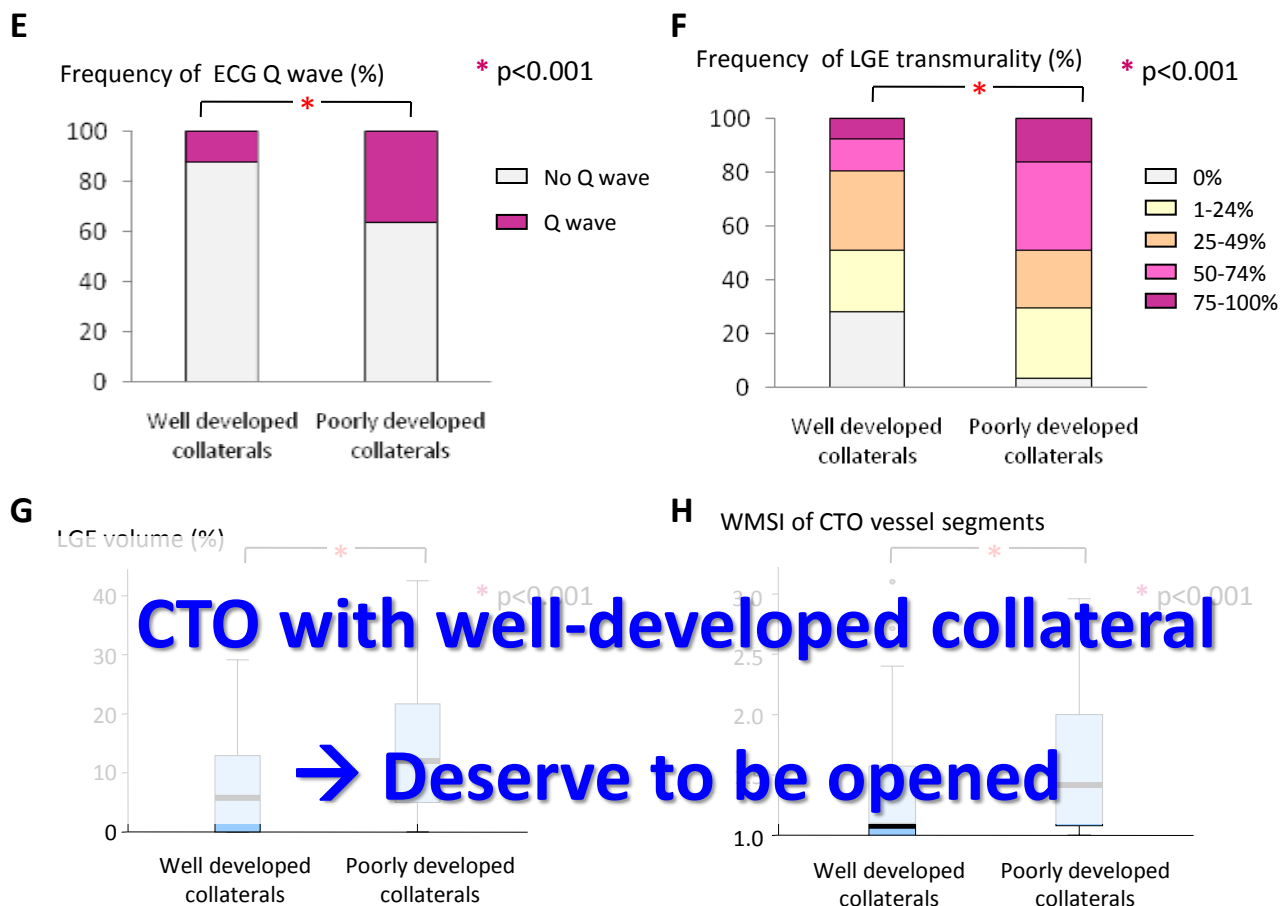
→ more viable myocardium, less infarct transmuralty, better wall motion



# Cardiac MRI study

## Well-developed collateral

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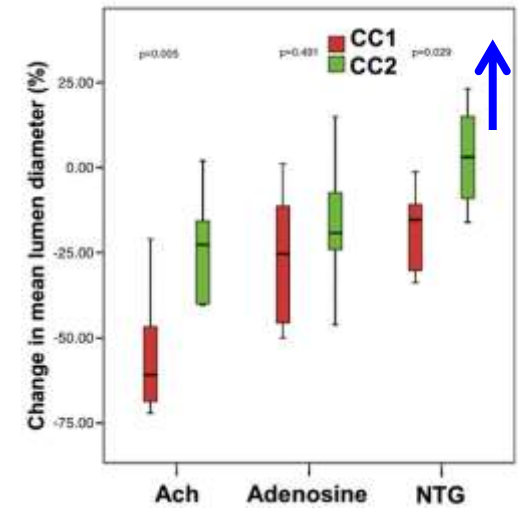
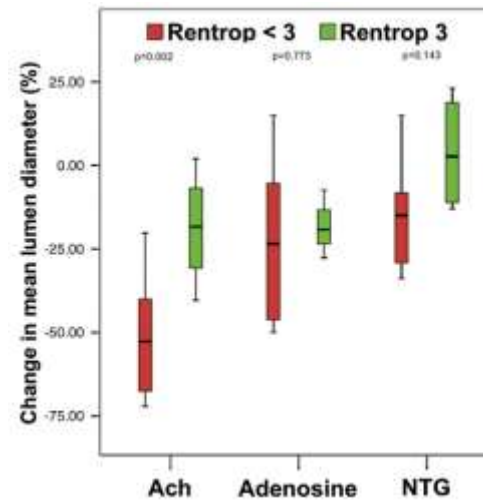


# Doppler wire study: Less distal vessel endothelial dysfunction in case of Well-developed collaterals

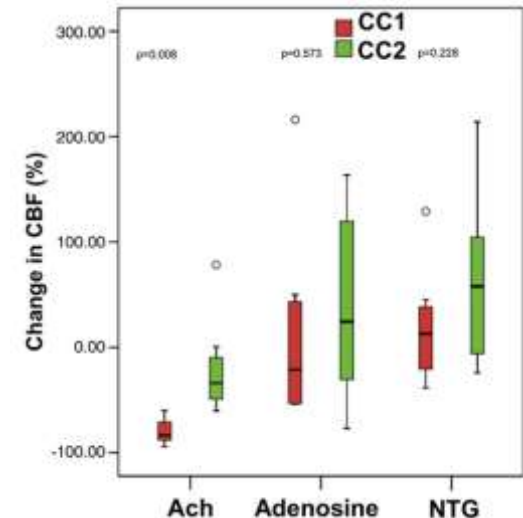
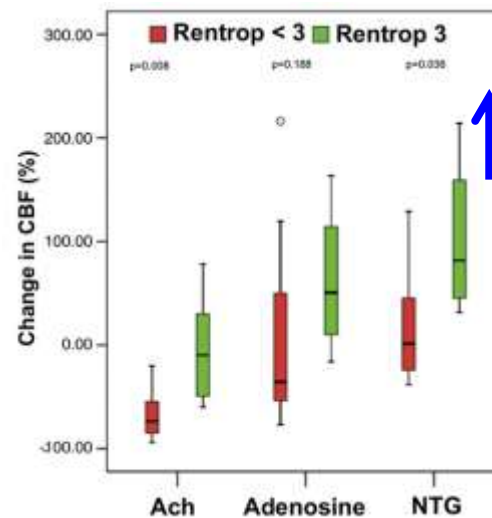
Doppler wire study after CTO PCI, 19 patients

- Vasoconstriction with Ach
- No response to adenosine
- Vasodilatation with NG

## Vessel diameter

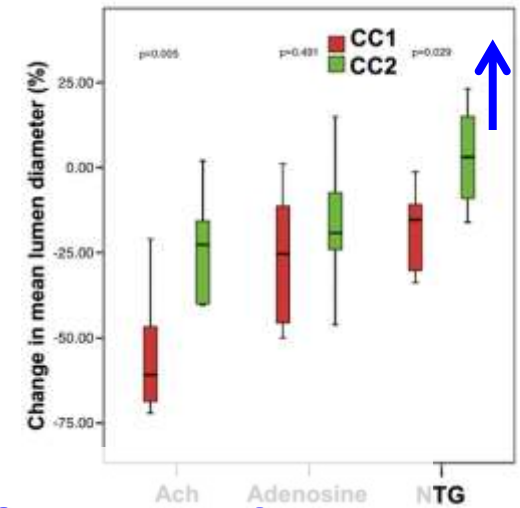
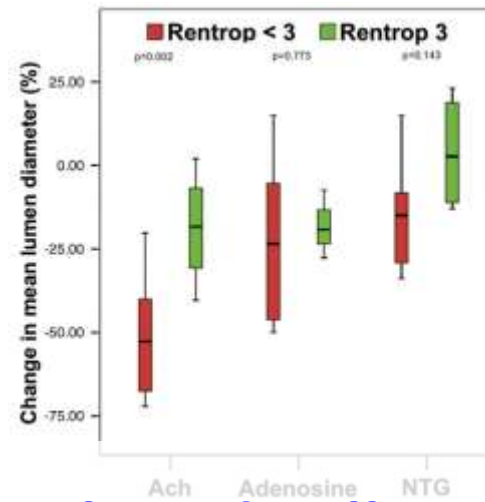


## Coronary blood flow



# Doppler wire study: Less distal vessel endothelial dysfunction in case of Well-developed collaterals

## Vessel diameter

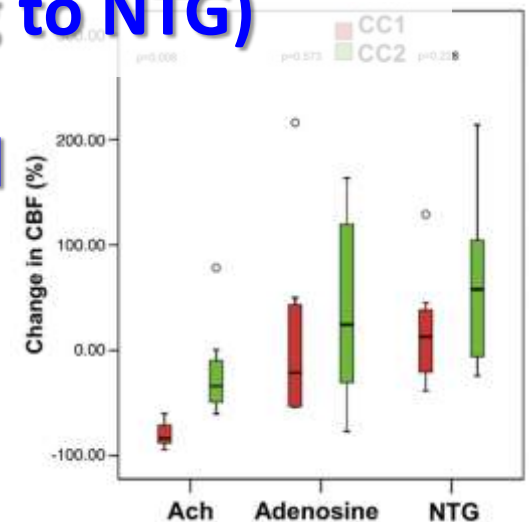
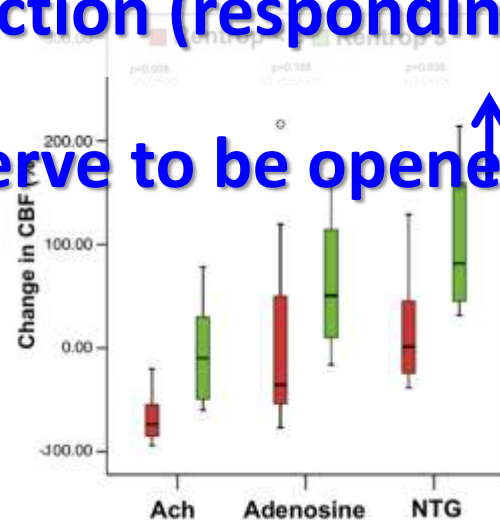


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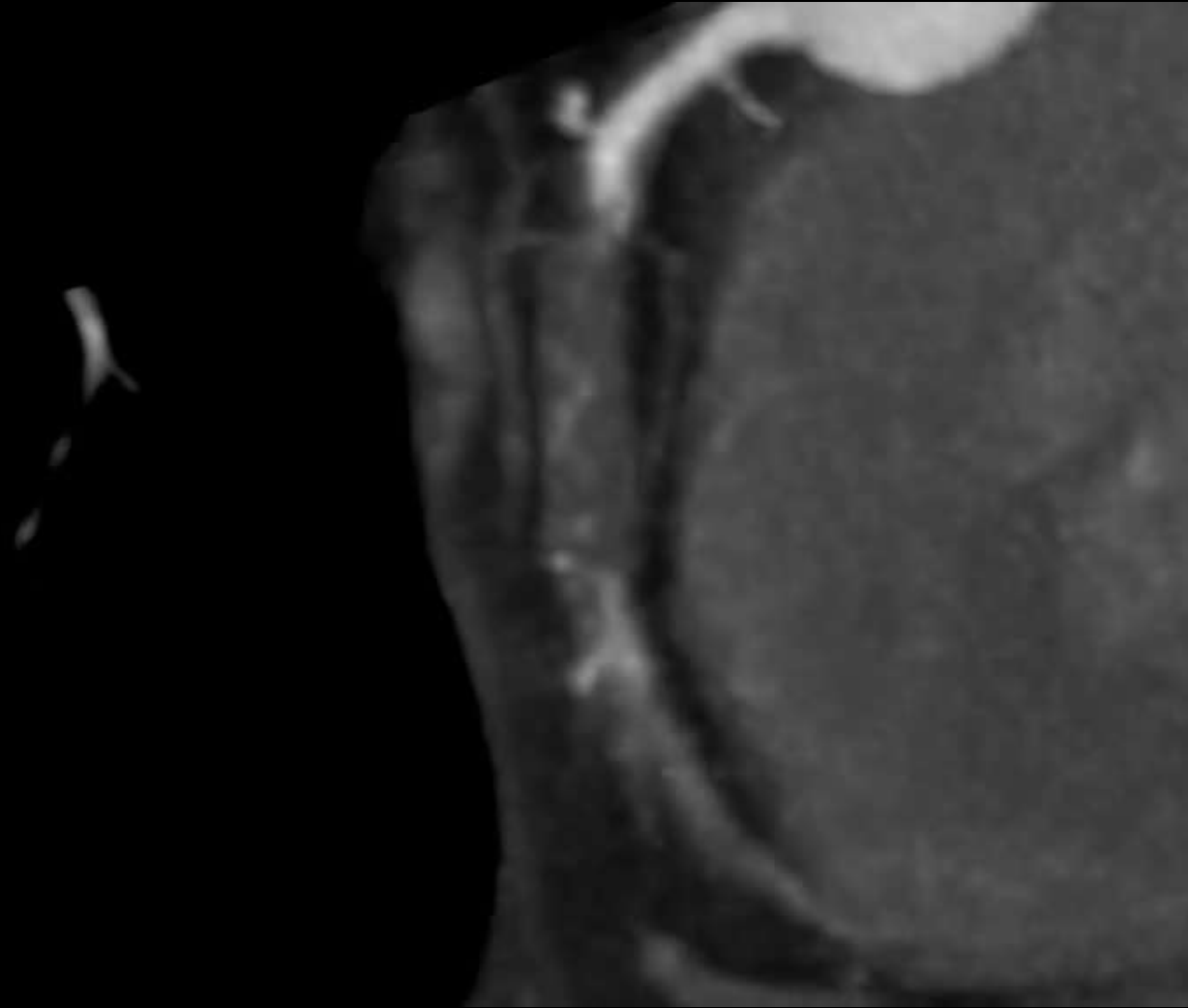
- Vasoconstriction with Ach
- No response to adenosine
- Vasodilatation with NTG

**CTO with well-developed collateral or good endothelial function (responding to NTG)**

→ **Deserve to be opened**

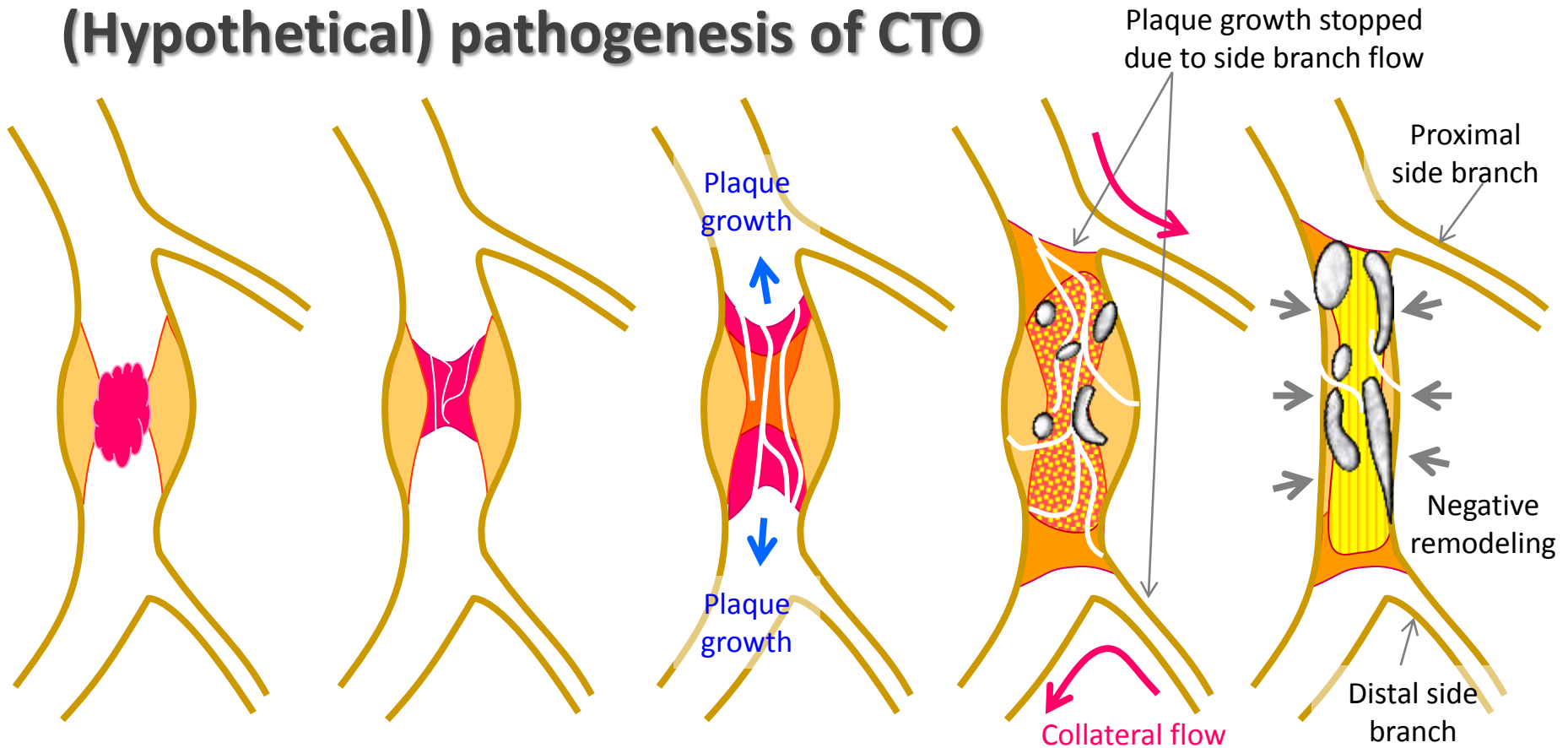


CTO is “**Inter-Bifurcation**” disease





# (Hypothetical) pathogenesis of CTO



1. Subclinical thrombotic occlusion and progression of occlusive lesion (until branches)
2. Organized thrombi and proteoglycan/fibrin → Type I collagen and calcification
3. Negative remodeling of CTO body
4. Microchannel formation – intraplaque, or connected to vasa vasorum

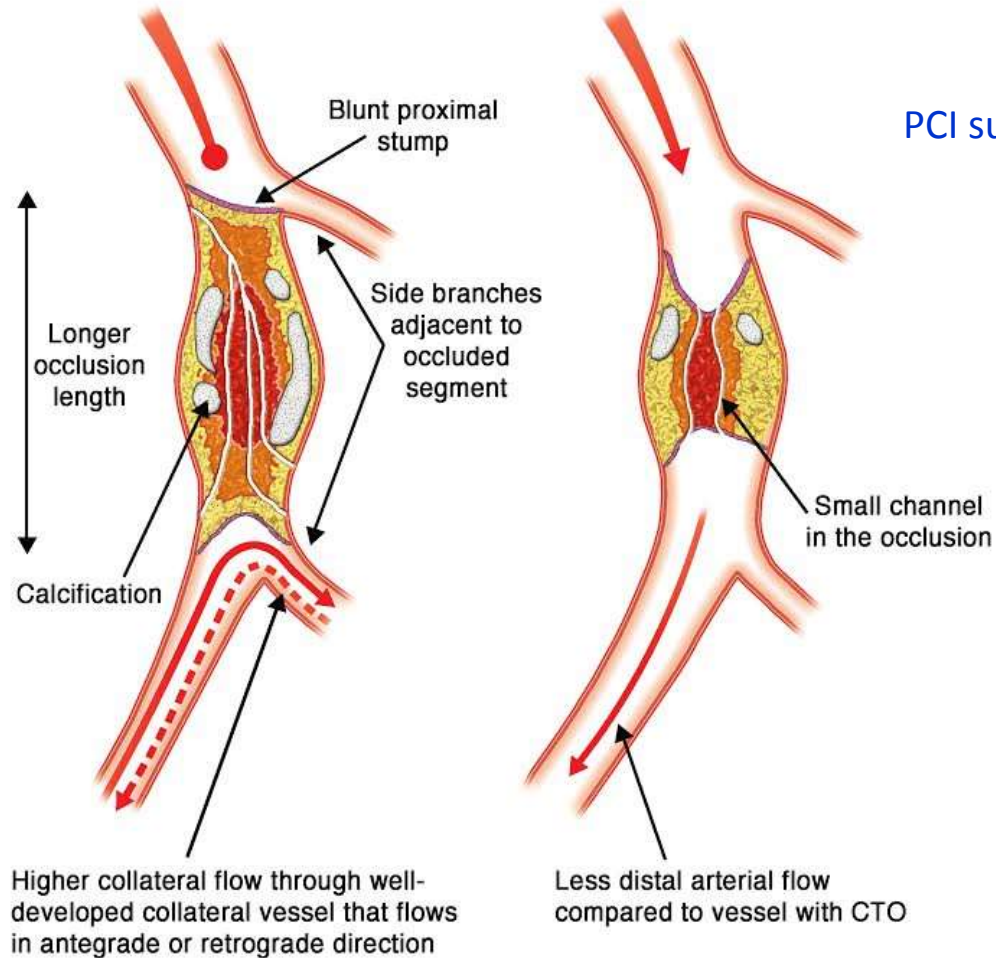
# True CTO is inter-bifurcation disease

## Chronic total occlusion

## Subtotal occlusion

PCI success  $\approx$  75%

PCI success > 95%



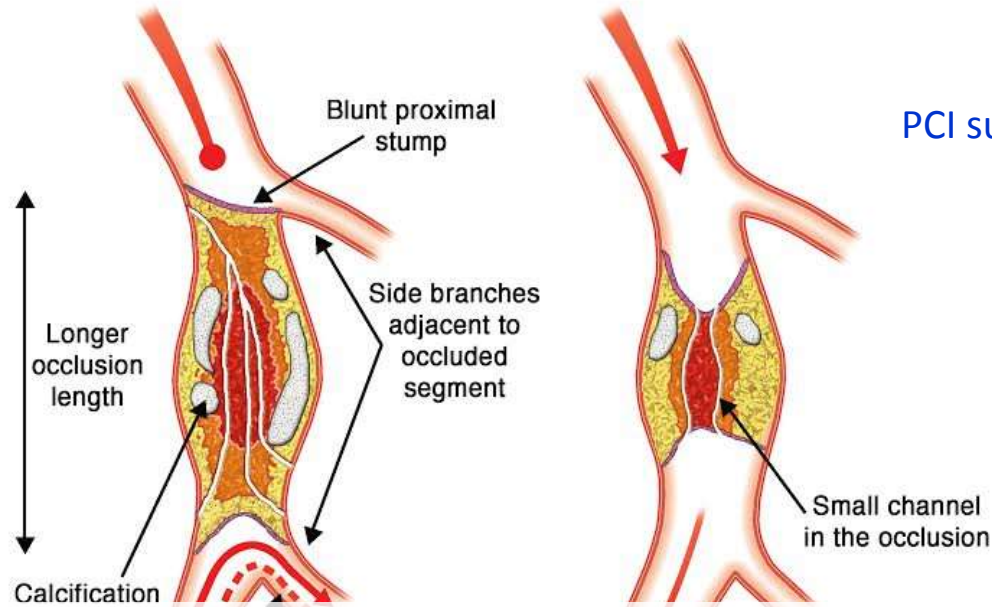
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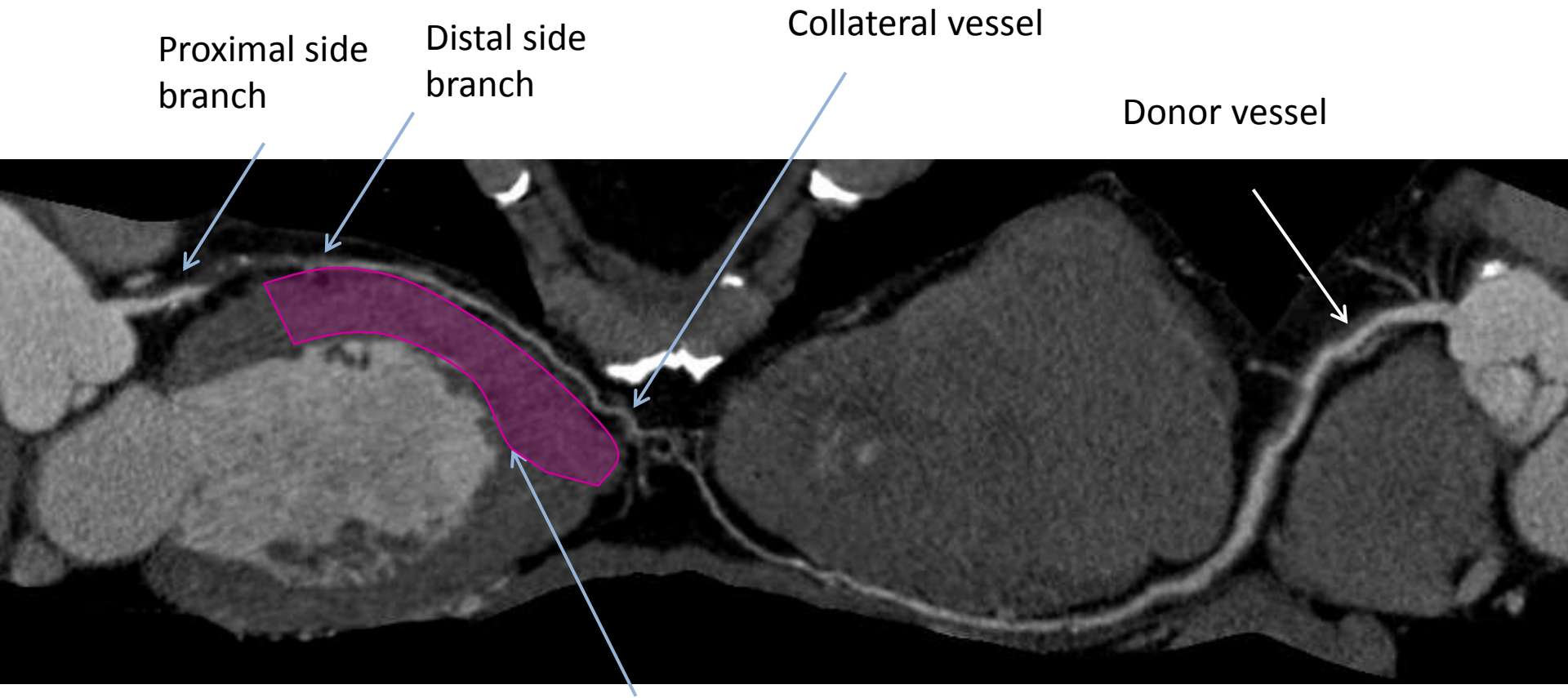


**Side branches of CTO should be opened to achieve maximal increase of perfusion**

Higher collateral flow through well-developed collateral vessel that flows in antegrade or retrograde direction

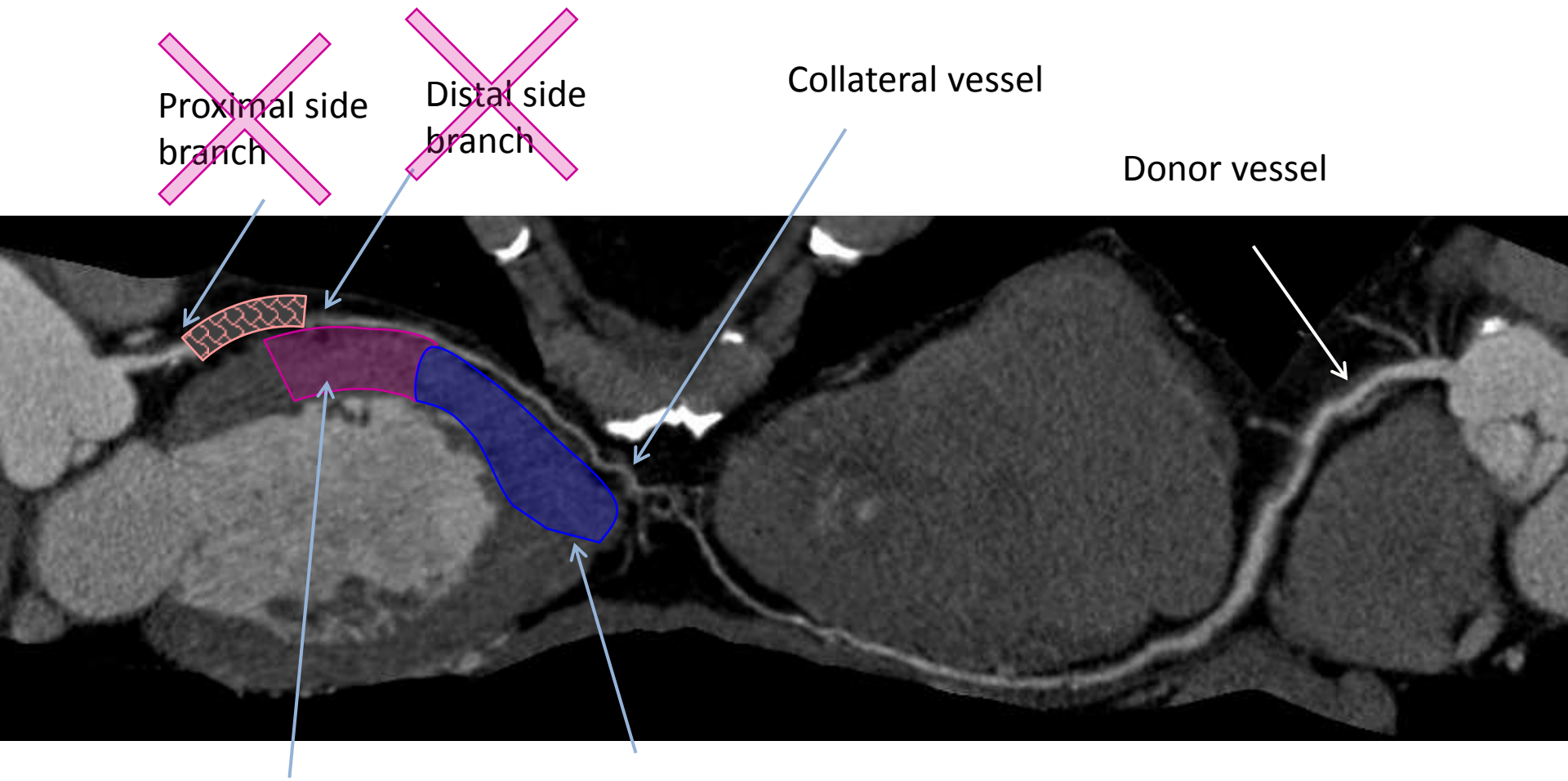
Less distal arterial flow compared to vessel with CTO

## Proximal and distal side branch of CTO vessel



Myocardium subtended by CTO vessel

# Proximal and distal side branch of CTO vessel needs to be saved



Proximal side branch

Distal side branch

Collateral vessel

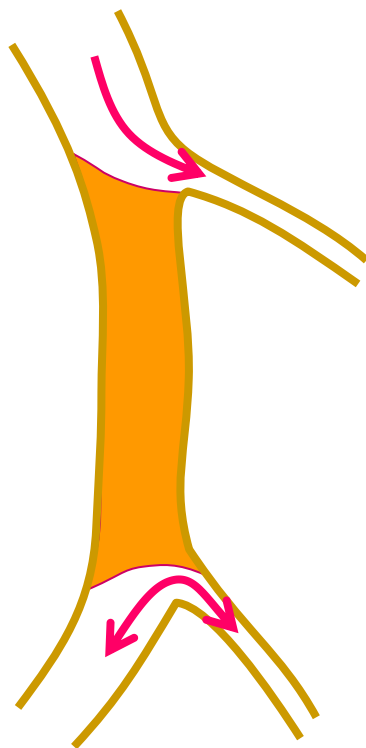
Donor vessel

Persistently ischemic myocardium

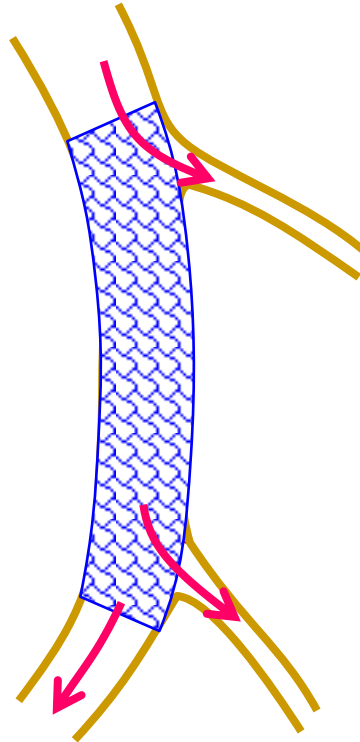
Amount of saved ischemic myocardium by CTO PCI

# Potential disadvantage of subintimal tracking and reentry technique

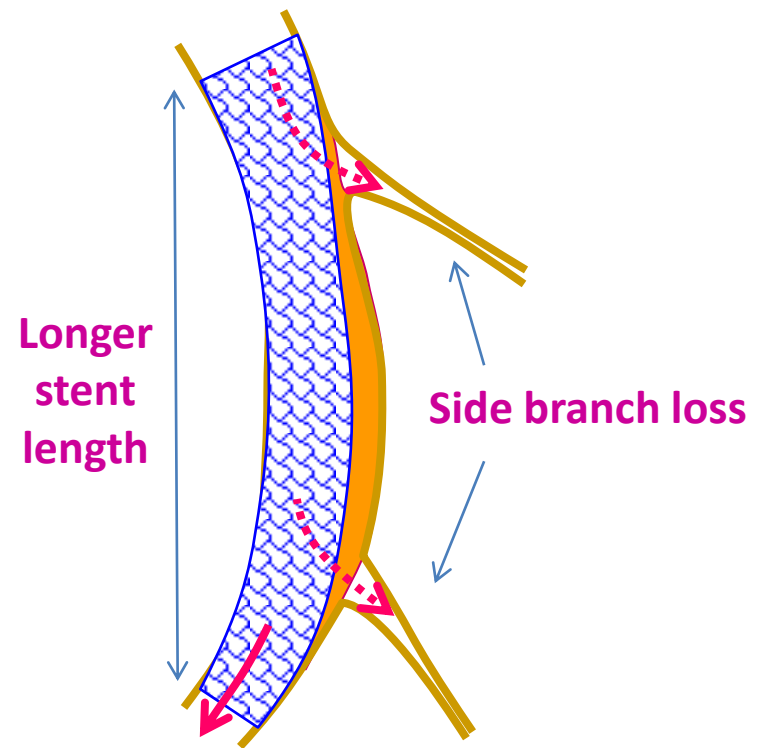
- A bail-out maneuver with lower procedural success rate
- May lose distal side branches
- May lead to higher restenosis rate



**CTO**



**Stent implanted in true lumen**



**Stent with subintimal tracking or jailed side branch**

# Outcome of STAR or subintimal tracking technique

Publication	Tech	N	Restenosis	MACE
Galassi, Can J Cardiol 2014	Mini-STAR as bail-out	100	<b>25%</b>	11%
Godini, CCI, 2012	STAR	281	<b>54%</b>	-
	conventional	74	30%	-
Rinfret, AJC 2014	STAR	82	-	Log-rank P=0.17
	conventional	105	-	
Muramatsu, Euroint 2014	Subintimal tracking (ante or retro approach)	31	<b>13%</b>	
	No subintimal tracking (ante or retro approach)	125	10%	

# Higher MACE and restenosis STAR technique, a single center study

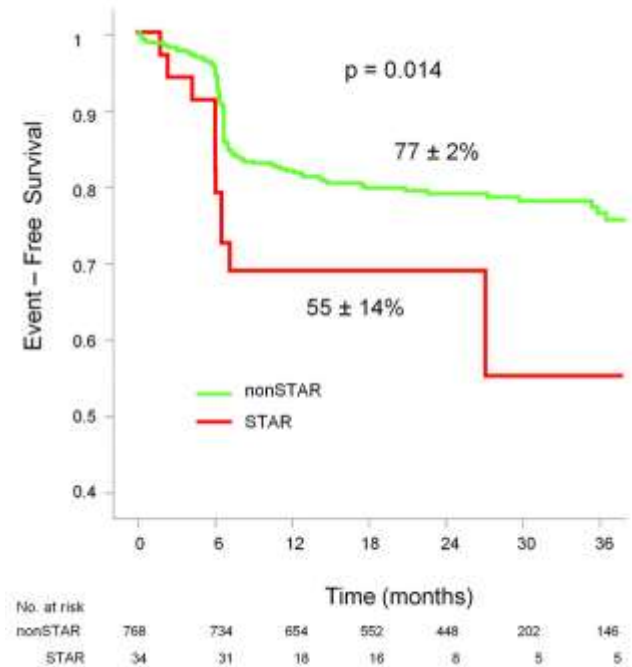
Single center study

CTO PCI success rate = 77% (N=802), CAG F/U rate 82%

Reocclusion rate of non-STAR: **3%** (30/588)

Reocclusion rate of STAR: **57%** (16/28)

Significantly higher MACE in STAR group.





# CTO PCI reduce the burden of donor vessel

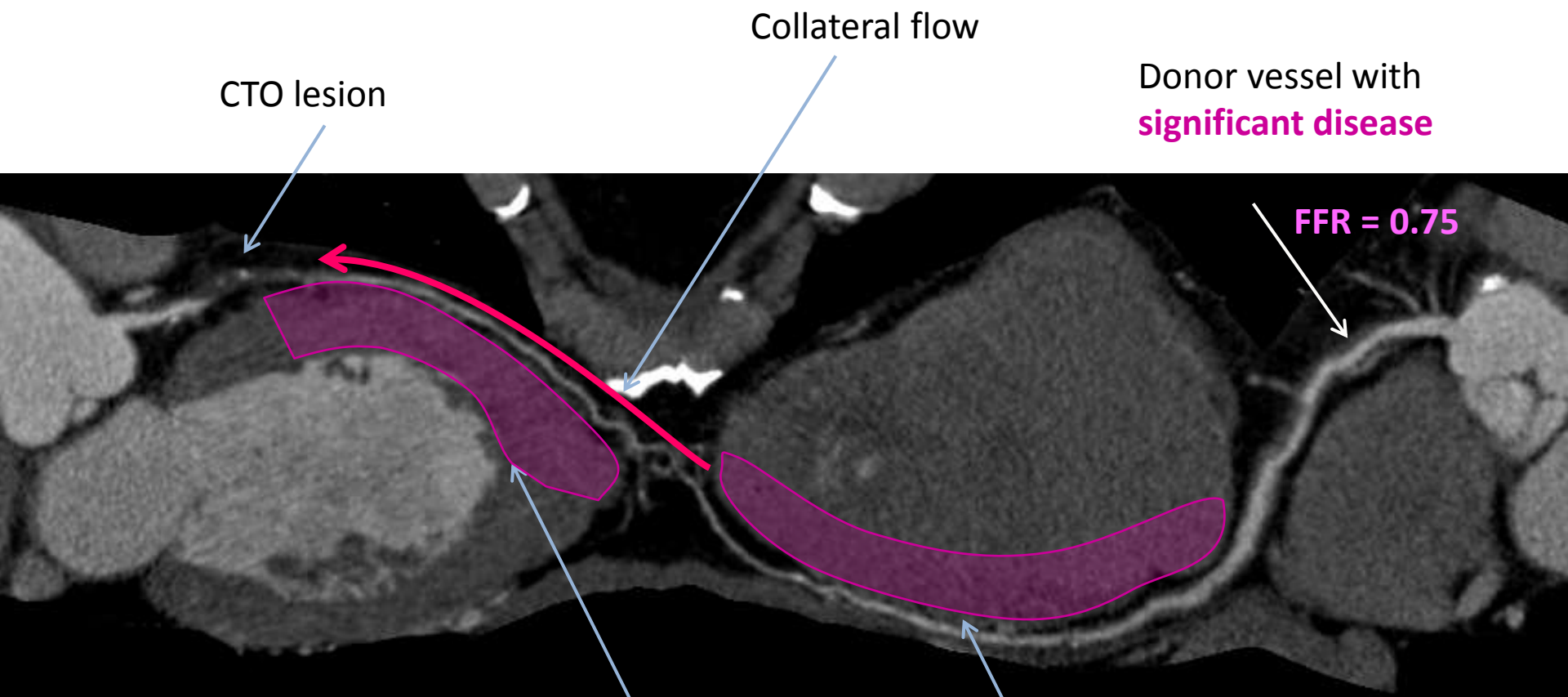
**Donor vessel only**



**If CTO is opened, both vessels can supply myocardium**



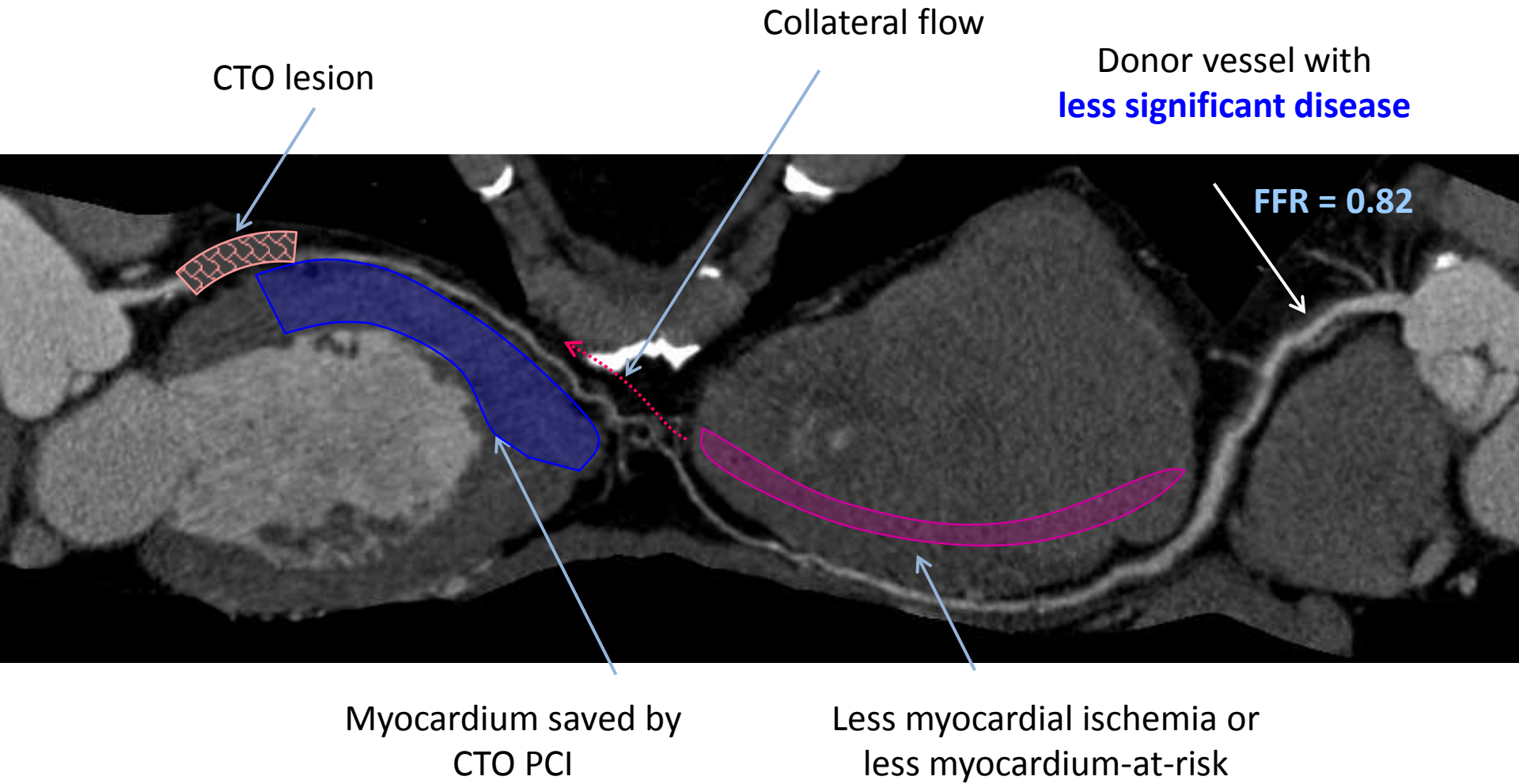
# Both CTO vessel and donor vessel are functionally significant



Myocardium subtended by CTO vessel

Myocardium-at-risk or ischemic and subtended by donor vessel

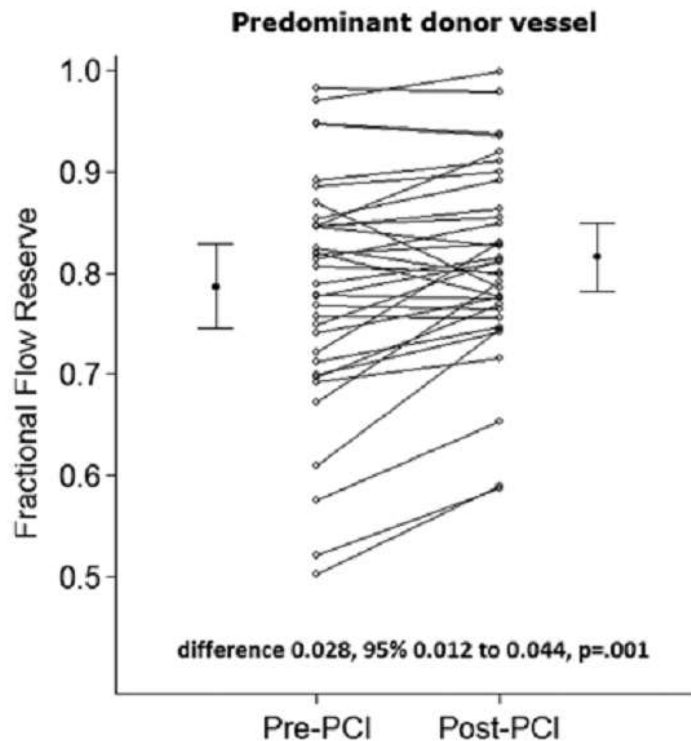
# CTO PCI relieves the burden of donor vessel



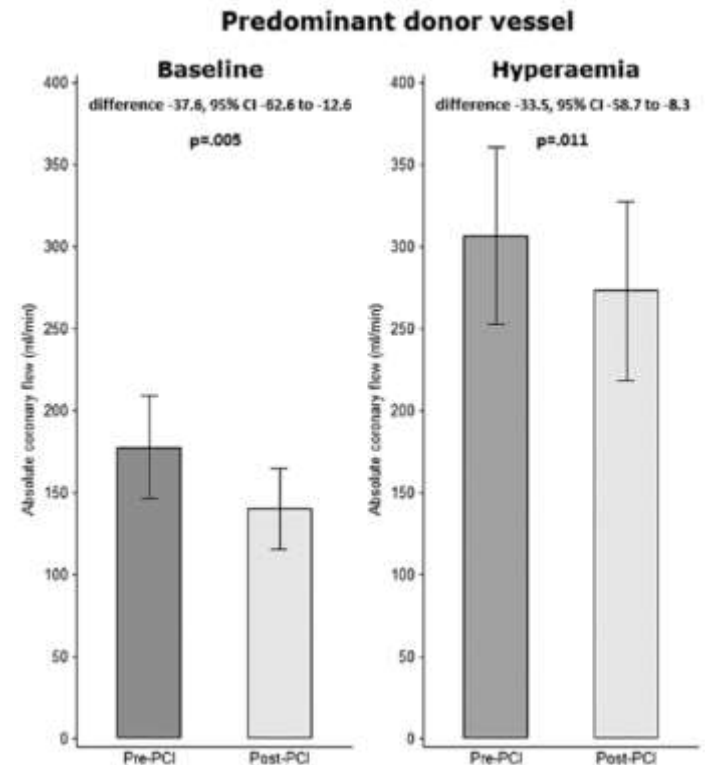
# Modest improvement of major donor vessel hemodynamics after CTO PCI

- 34 CTO PCI, physiological study

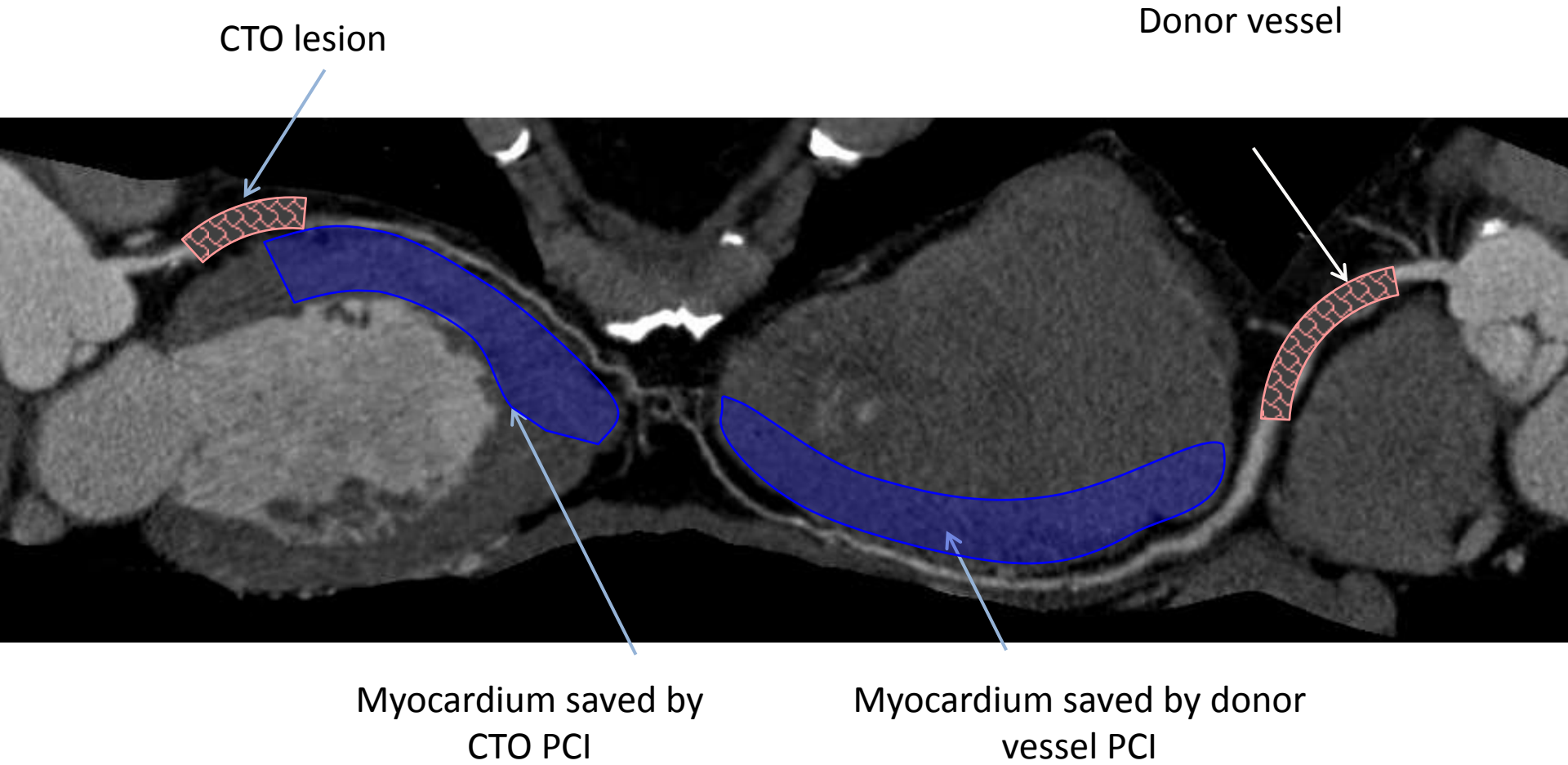
FFR = 0.782 → 0.810 (p<0.001)



Donor flow decreased in both baseline and hyperemia

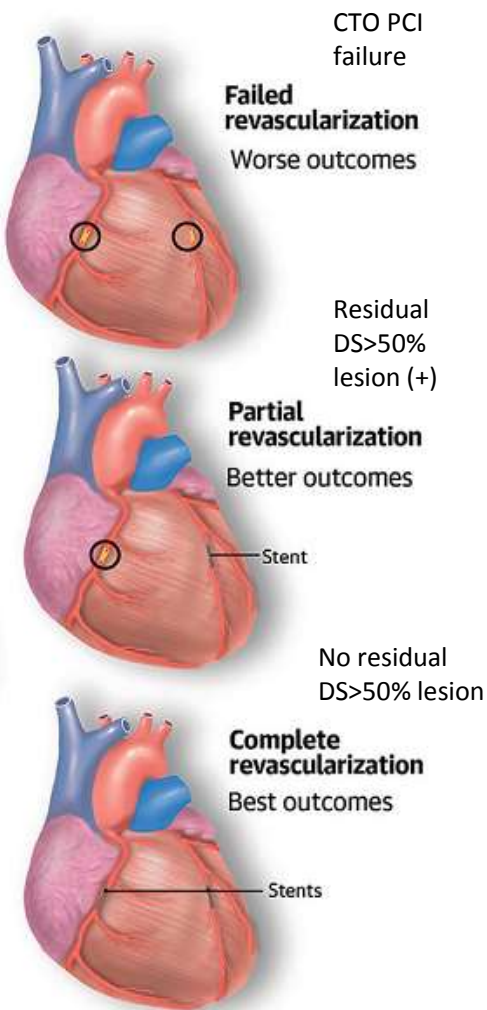
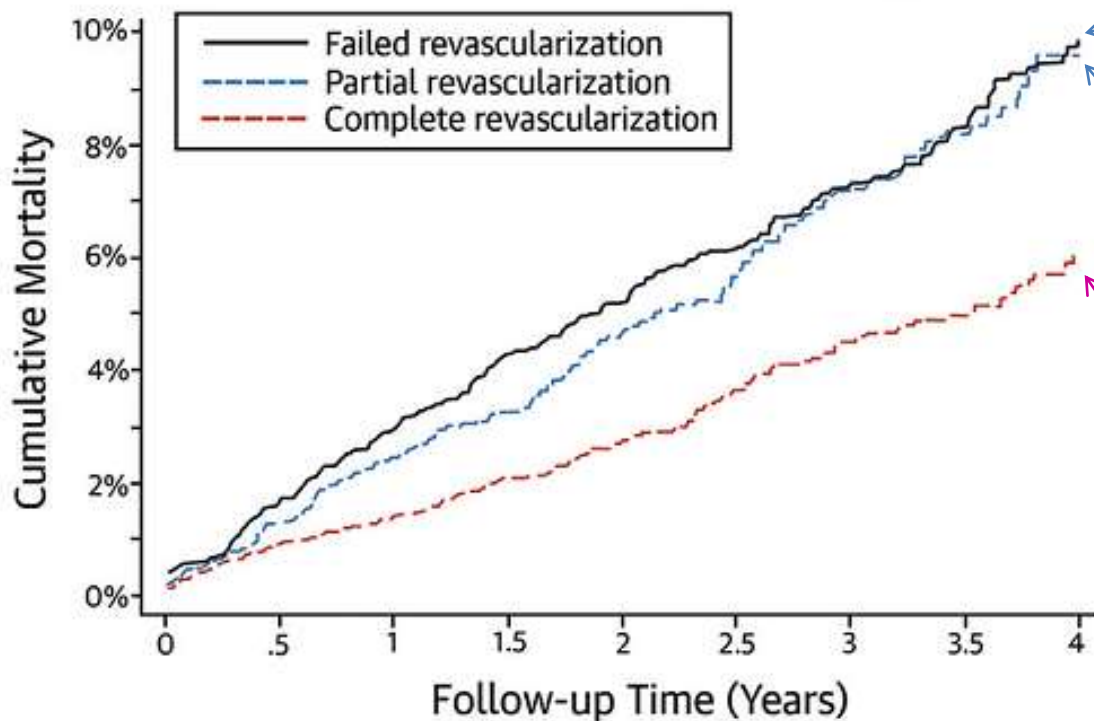


# Complete revascularization of CTO



# Complete CTO PCI was better than partial or failed PCI

UK central database, 13,443 patients, success rate 70%. 2.7 year follow-up

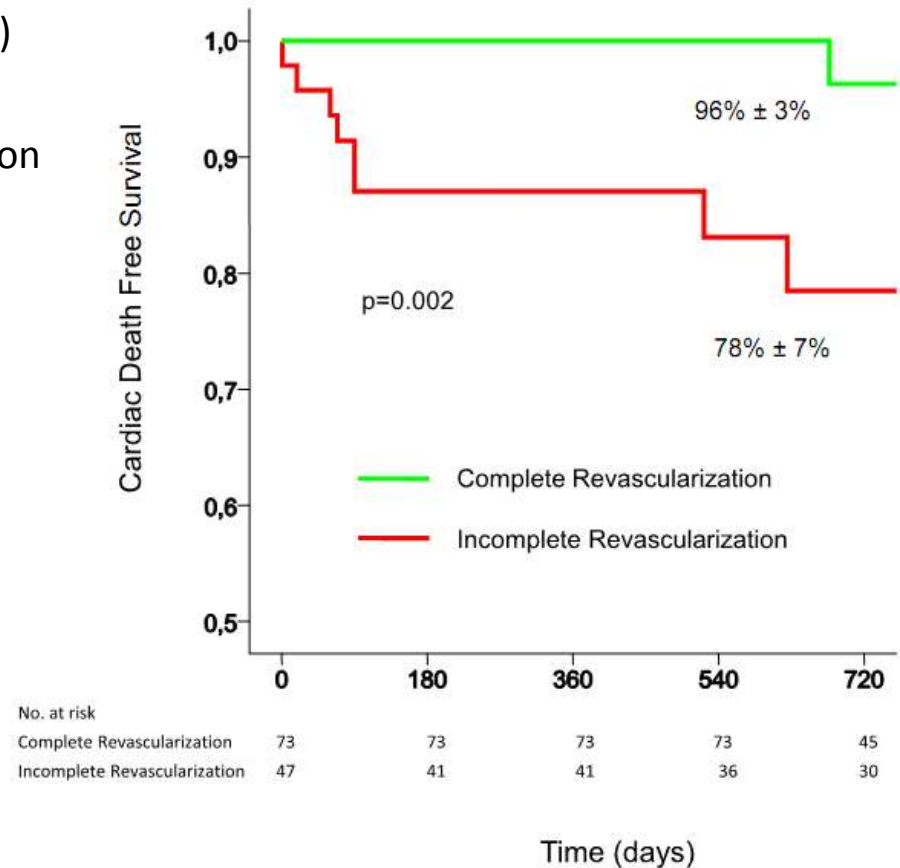


# Complete revascularization for multiple CTO

Florence CTO PCI registry

Multiple CTO, N=120 (mean Syntax score = 41)

Less cardiac death in complete revascularization



# Angiographic predictor of (potentially good) prognosis after CTO PCI

## 1. PCI for CTO increases **perfusion to viable myocardium**

- Well-developed collateral
- Large and functional vessel

## 2. PCI for CTO **maximizes perfusion**

- No side branch loss
- Minimal or absent subintimal tracking (that results in side branch loss)

## 3. PCI for the patient **maximizes perfusion**

- Complete revascularization including donor vessel



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**None of above has been validated in large clinical datasets**



“Prediction is very difficult,  
especially if it’s about the future.”

Niels Bohr, 1922 Nobel prize laureate



“We will find a way,  
we always have.”