# Clinical Considerations for CTO Revascularization

*Whom to treat, Who derives benefit and What can we achieve?*

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# Patient Selection and Clinical Benefit in CTO Revascularization

*Relevant Disclosure*

Employment: Chief Medical Officer,
Cordis Cardiology/ Johnson & Johnson

# CTOs in Perspective

*Despite novel technologies/DES, frequency of attempted CTOs has not changed over the past decade*

- Technical/procedural challenges
- Misperceptions regarding viability, collateral flow
- Uncertainty regarding which patients may benefit balanced by
- Concern for complications in patients who may not derive clinical benefit

Srinivas et al. *Circulation* 2002
Christofferson et al. *Am J Cardiol* 2005

# Impact of Incomplete Coronary Revascularization

## New York State Database for PCI

- 68.9% of MVD patients undergoing PCI had incomplete revascularization
- 30.1% had CTOs and/or ≥2 diseased major vessels with incomplete revascularization
  - Mortality highest in this subgroup (HR 1.36, 1.12-1.66)

Hannan et al. Circulation 2006

# Theoretical Rationale for CTO Revascularization

## ‘Open Artery Hypothesis’

- Increase long-term survival
- Improve left ventricular function
- Electrical stability of myocardium and reduced predisposition to arrhythmic events
- Increased tolerance of future coronary occlusion events

# Why the Occluded Artery Trial (OAT) Does Not Apply to CTO Revascularization

- OAT: Subacute (3-28 days) total occlusions following MI
- OAT: Relatively asymptomatic population excluding severe ischemia by functional study, rest angina and multivessel disease
- Absence of improvement in LV function in OAT substudy
  - *Baseline LVEF 48% (difficult to improve upon relatively normal)*
  - *Spontaneous recanalization (TIMI 2/3) observed at 1 year in 25% of medical therapy cohort*
  - *Reocclusion in ~9% of PCI cohort; no DES*
  - *Greatest predictor of improved LVEF was having a patent target vessel at 1 year follow up*

Hochman et al. *NEJM* 2006
Dzavik et al. *Circulation* 2006

# Long-term Survival with Successful CTO Revascularization

## Support for the Late Open Artery Hypothesis

| Trial | Success (N) | Failure (N) | Follow-up Duration (years) | Mortality (%) | | |
|---|---|---|---|---|---|---|
| | | | | Success | Failure | *P* value |
| British Columbia Cardiac Registry[1] | 1118 | 340 | 6 | 10.0 | 19.0 | <0.001 |
| Suero et al.[2] | 1491 | 514 | 10 | 26.0 | 35.0 | 0.001 |
| TOAST-GISE[3] | 286 | 83 | 1 | 1.1 | 3.6 | 0.13 |
| Aziz et al.[4] | 377 | 166 | 2.4 | 2.5 | 7.3 | 0.049 |
| Hoye et al.[5] | 568 | 306 | 5 | 6.5 | 12.0 | 0.02 |

[1]Ramanathan. TCT2003; [2]Suero. JACC 2001; [3]Olivari. JACC 2003; [4]Aziz. TCT2005; [5]Hoye Eur Heart J 2005

# Long-term Outcome after Intended Recanalization of Non-acute Coronary Occlusions

B.C. Cardiac Registries

## *Multivariate Mortality Model*

| | Hazard Ratio | 95% Confidence | *P* value |
|---|---|---|---|
| *Failure* | 2.27 | 1.56 – 3.30 | <0.0001 |
| *Age (per decade)* | 1.33 | 1.12 – 1.58 | 0.001 |
| *EF <50* | 2.33 | 1.58 – 3.43 | <0.0001 |
| *Multivessel CAD* | 1.62 | 1.09 – 2.40 | 0.02 |
| *Prior CHF* | 1.73 | 1.10 – 2.76 | 0.02 |
| *ESRD* | 2.77 | 1.36 – 5.66 | 0.005 |
| *CVD* | 1.92 | 1.04 – 3.55 | 0.04 |
| *COPD* | 1.64 | 1.01 – 2.67 | 0.05 |
| *Diabetes* | 1.50 | 0.99 – 2.27 | 0.055 |

Ramanathan and Buller *TCT2003*

# Influence of CTO Revascularization on Long-term Outcomes

## In-Hospital Outcomes

| | CTO Success n=1491 | CTO Failure n=514 | *P* value | *Non-CTO n=2007* |
|---|---|---|---|---|
| *Death (%)* | 1.0 | 2.3 | 0.02 | 0.8 |
| *Q MI (%)* | 0.4 | 0.8 | NS | 0.8 |
| *non-Q MI (%)* | 1.5 | 3.1 | 0.02 | 2.4 |
| *urg re-PCI (%)* | 1.9 | 0.2 | 0.01 | 2.0 |
| *MACE (%)* | 3.2 | 5.4 | 0.02 | 3.7 |

Suero et al. *JACC* 2001

# Clinical Considerations

- Is this patient symptomatic, and how? Angina? Heart failure? Arrhythmia?
- Will successful recanalization improve this patient's symptoms?
- Will successful recanalization improve this patient's prognosis?
- What are the risks of attempted recanalization in this patient?

# Predictors of Successful CTO Revascularization

| Procedural Success | Procedural Failure |
|---|---|
| Functional occlusion | Total occlusion |
| Occlusion age < 12 weeks | Occlusion age > 12 weeks |
| Length < 15 mm | Length > 15 mm |
| Tapered stump | Abrupt cut-off |
| No sidebranch at occlusion | Sidebranch present |
| No bridging collaterals | Extensive bridging collaterals |

# ACROSS Pilot

*Predictors of Procedural Outcome, n=103*

| Characteristic | Failed | Successful | *P* value |
|---|---|---|---|
| Multiple wires* | | | |
| >1 wire | 36% vs. 5% | | <0.001 |
| >2 wires | 53% vs. 12% | | <0.001 |
| Fluoro time, min | 28 vs. 21 | | 0.04 |
| TIMI 0 | 24% vs. 7% | | 0.054 |
| Support catheter | 29% vs. 14% | | 0.07 |
| Collaterals | 23% vs. 10% | | 0.12 |
| Female | 29% vs. 16% | | 0.17 |
| Length >15mm | 19% vs. 10% | | 0.24 |
| Ref <3mm | 29% vs. 17% | | 0.23 |
| Multivessel dz | 23% vs. 15% | | 0.30 |

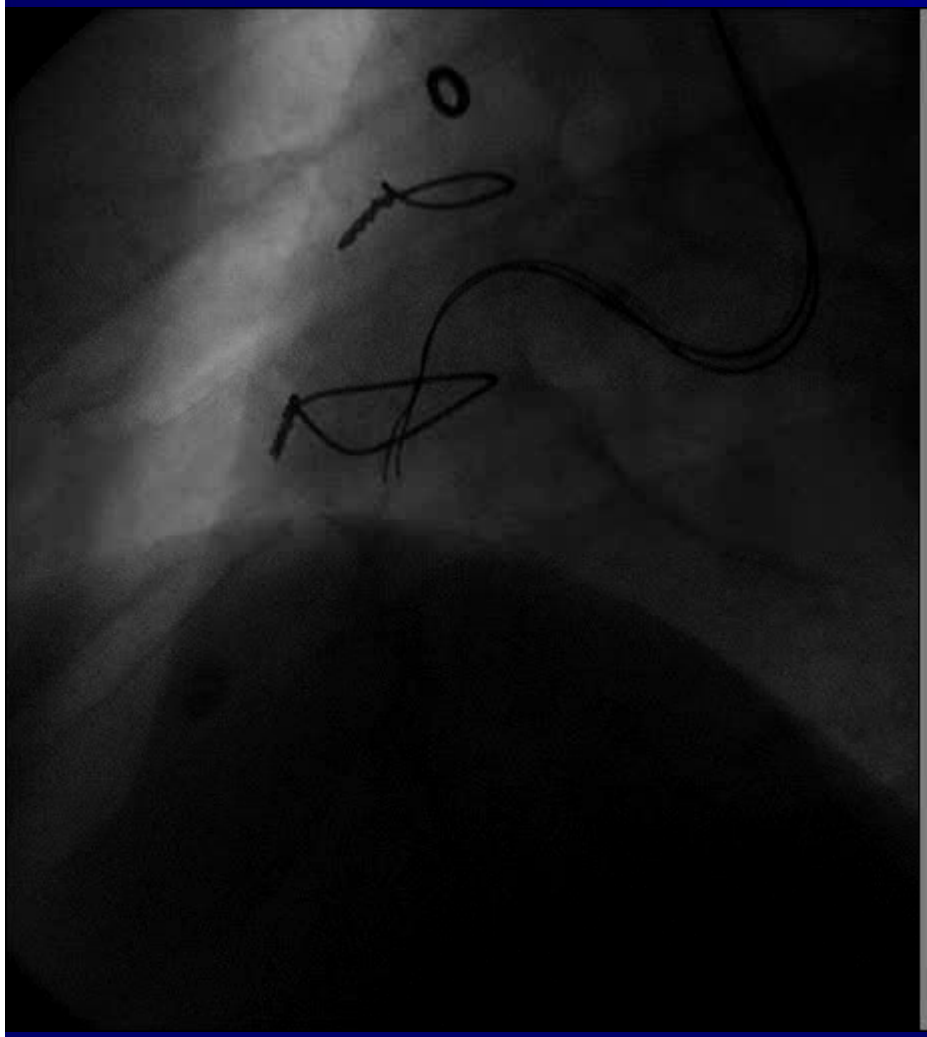
Technical

Clinical/ Angiographic

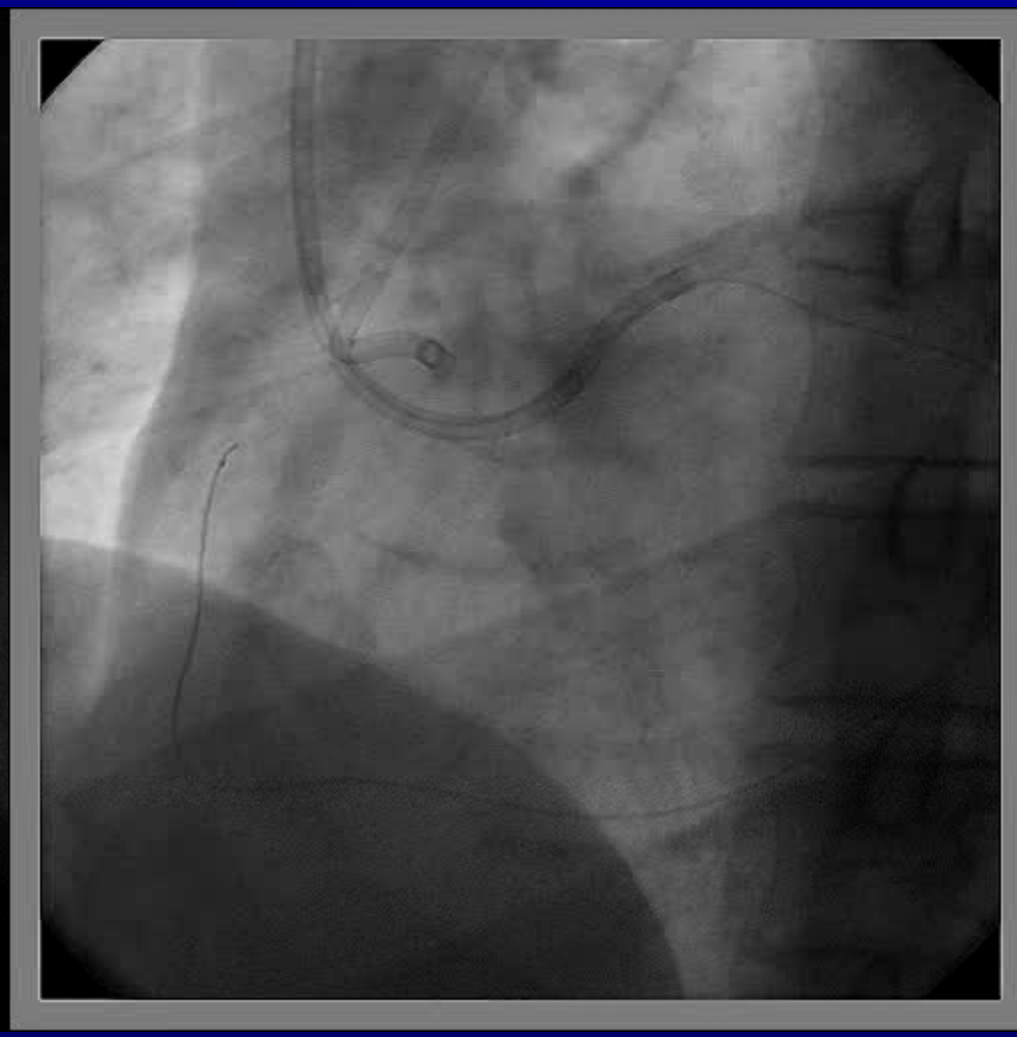
*p<0.05 in multivariable analysis

Kandzari, Menown et al. TCT2003

# Advances in Procedural Technique



Parallel Wires



Retrograde Wire

Courtesy, Dr. Tsuchikane, Toyohashi Heart Center

# CTO Strategies

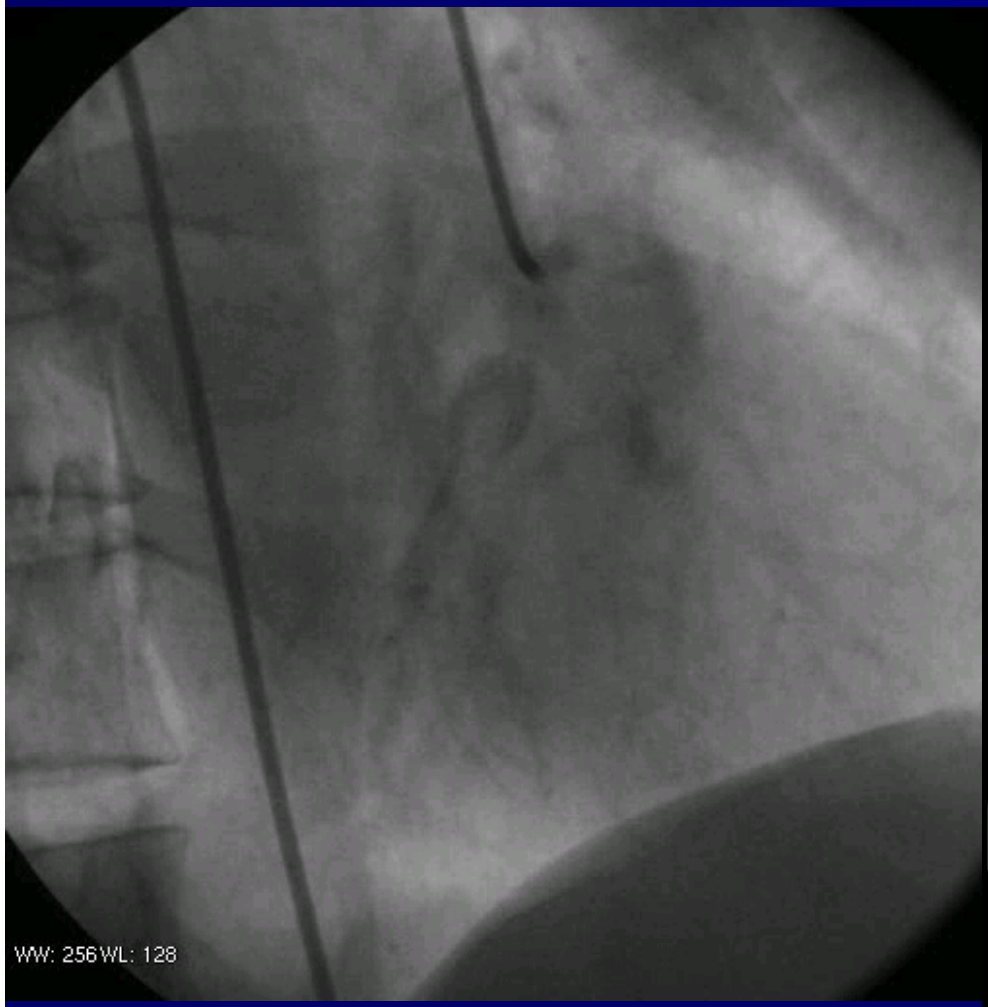
## *Principles of Technique*

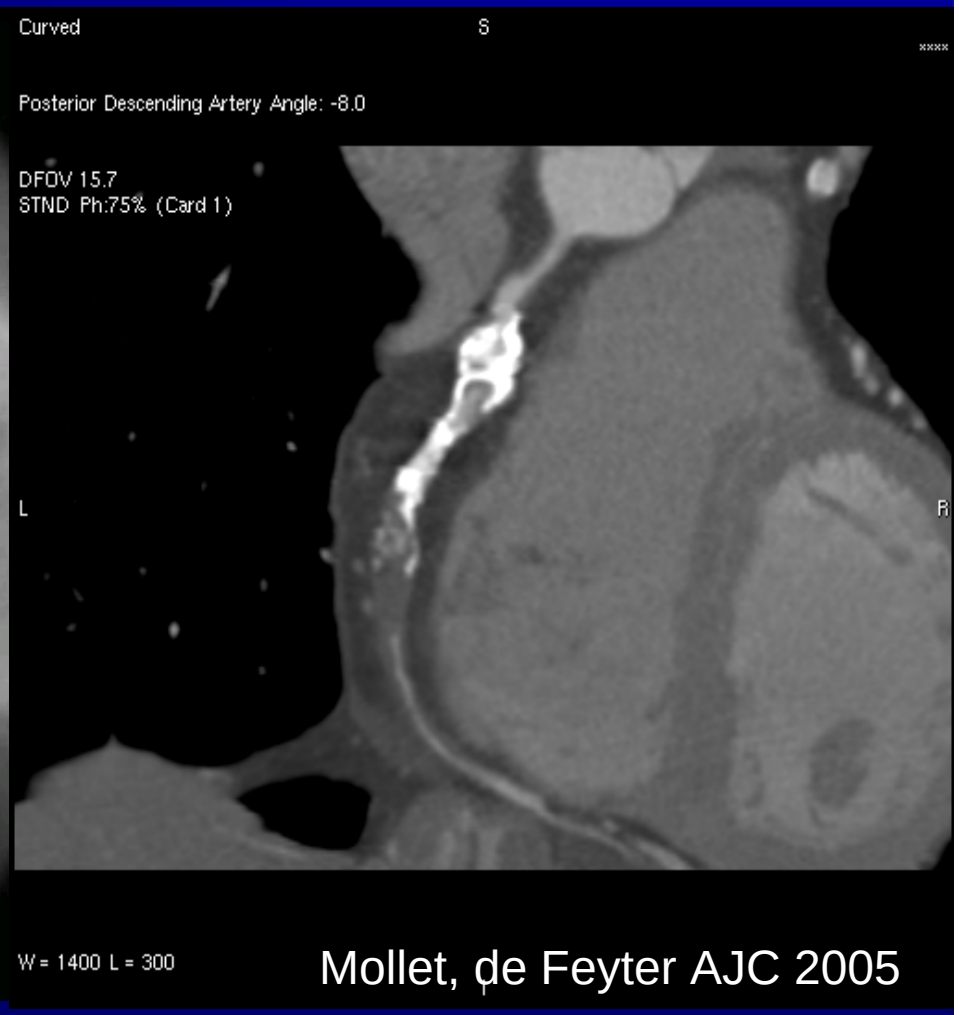
- ✓ Contralateral angiography
- ✓ Multiple views
- ✓ Guiding catheter selection
- ✓ Wire/device selection
- ✓ Incremental stiffness ('drilling') vs. 'penetration'
- ✓ Parallel/Seesaw wiring, STAR
- ✓ IVUS
- ✓ Retrograde via collaterals

↑ Success vs.
↑ Complications

# MDCT CTA for Complex Lesion Morphologies

*'CT Facilitated PCI'*

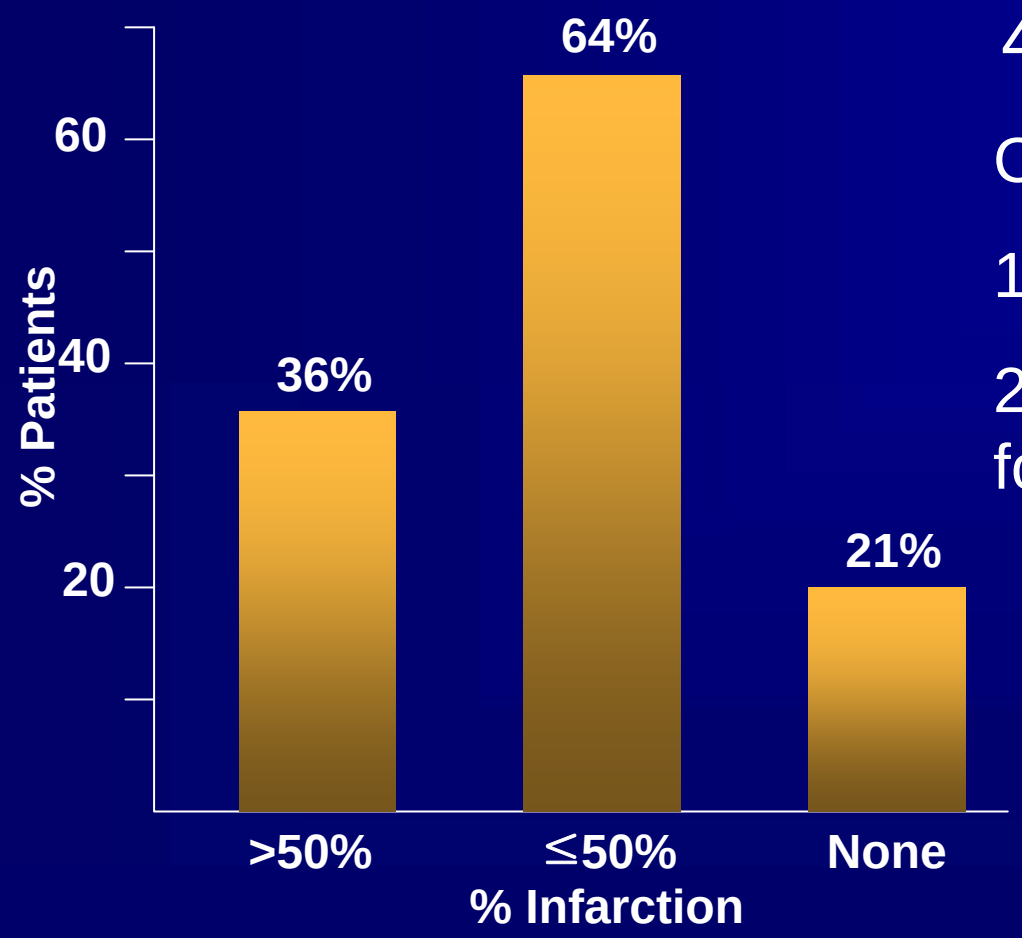



Mollet, de Feyter AJC 2005

# Myocardial Viability, Collateral Flow, and Regional Wall Motion

*Cardiac MR Imaging*




44 pts, 58 CTO segments

Collateral flow *did not* predict:

1. Myocardial viability

2. Regional improvement following revascularization

Kim, Shah, Kandzari et al AHA 2003

# Cardiac MR Imaging in CTO Revascularization

*Influence of Revascularization on Wall Motion and LVEF*

| | Baseline | Follow-up | %Δ | *P* value |
|---|---|---|---|---|
| LVEF, % | 43.2 ± 8.1 | 47.6 ± 7.1 | 4.4 ± 6.1 | 0.009 |
| WMS | 1.10 ± 0.79 | 0.52 ± 0.76 | -0.59 ± 0.63 | 0.001 |

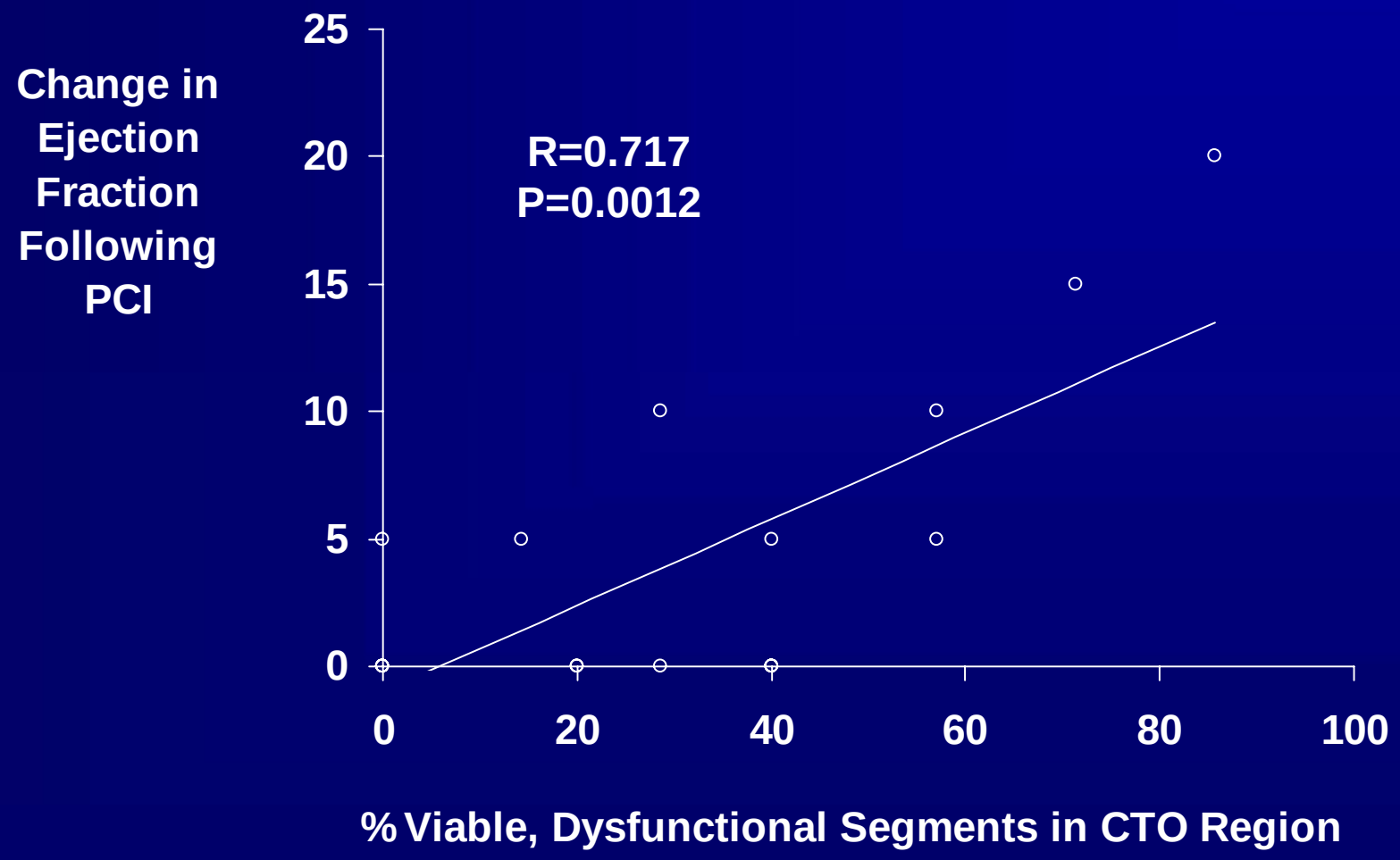
Values expressed as mean ± SD

Median follow up 139 days; N=20

Patel, Kandzari *TCT2005*

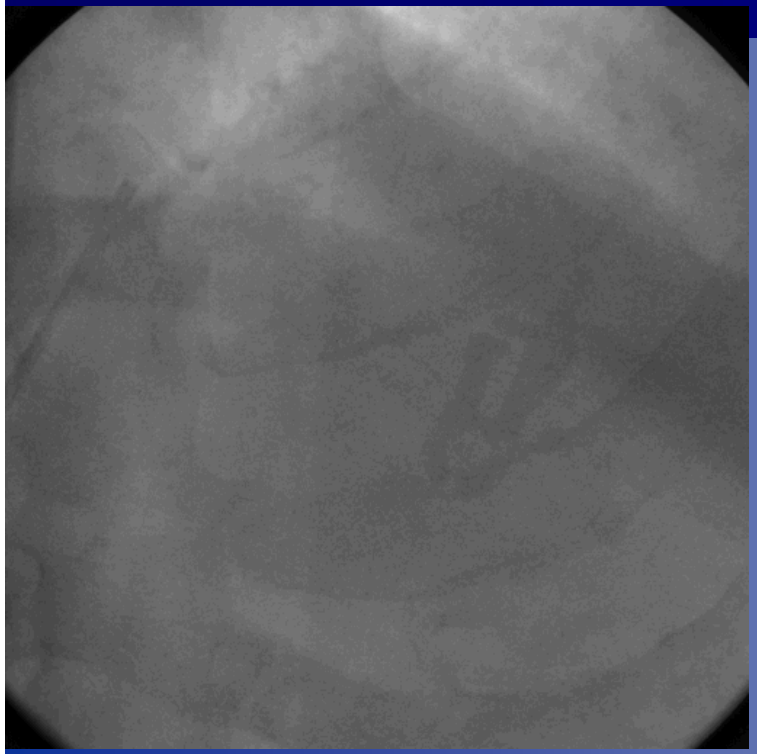
# Cardiac MR Imaging in CTO Revascularization

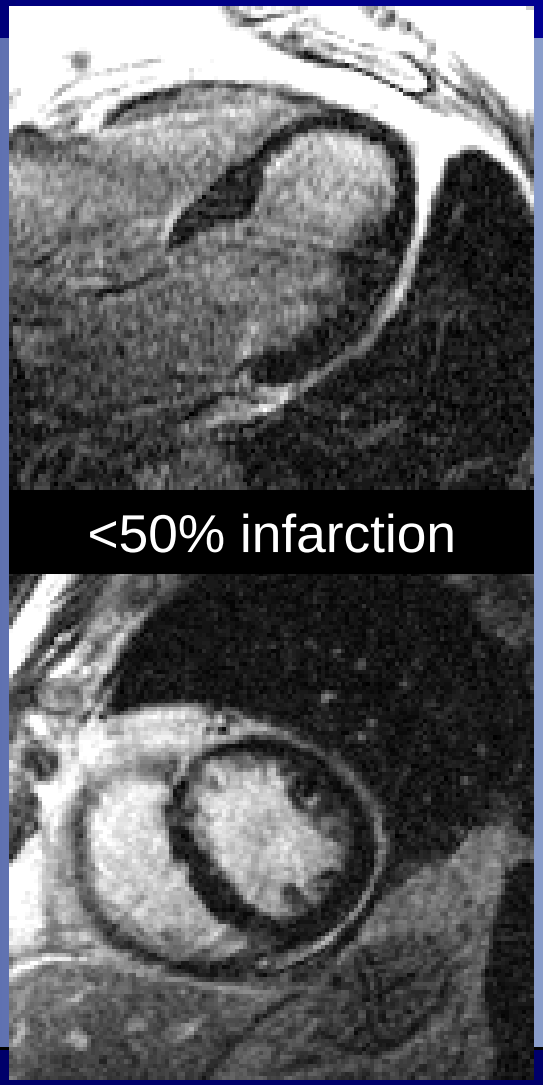
*Influence of Revascularization on Wall Motion and LVEF*

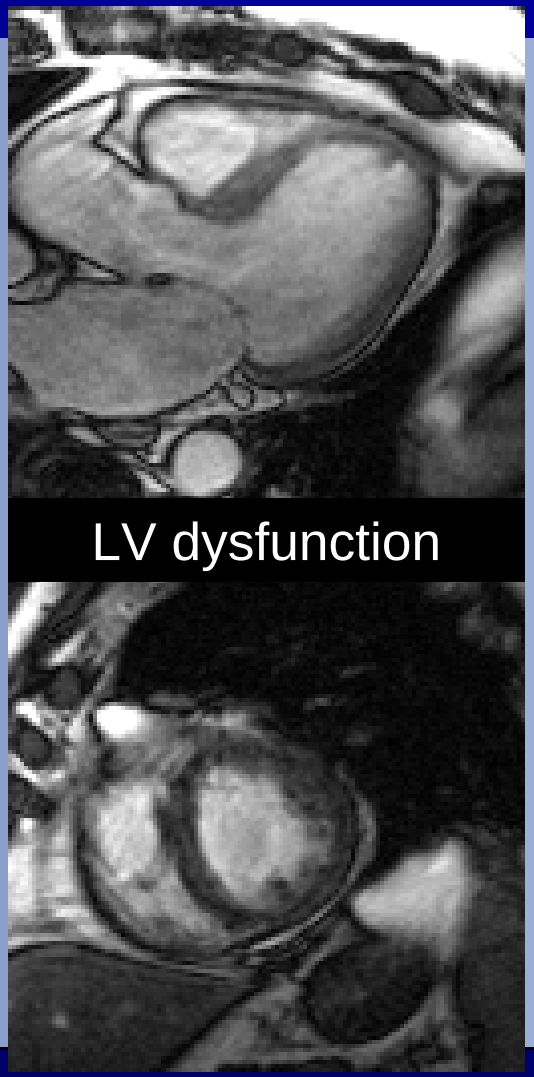



Kandzari.*AngioplastySummit*

# MR Imaging of Myocardial Viability and Performance in CTO Revascularization

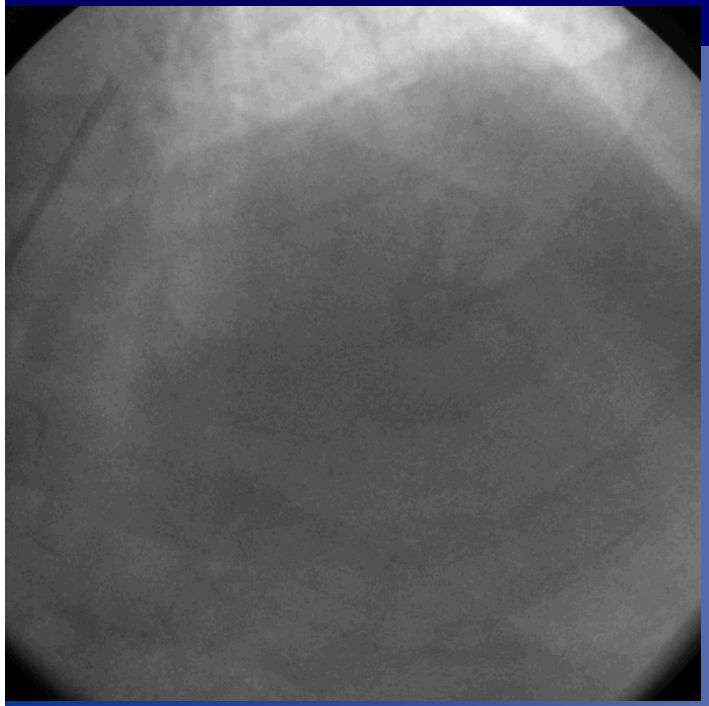




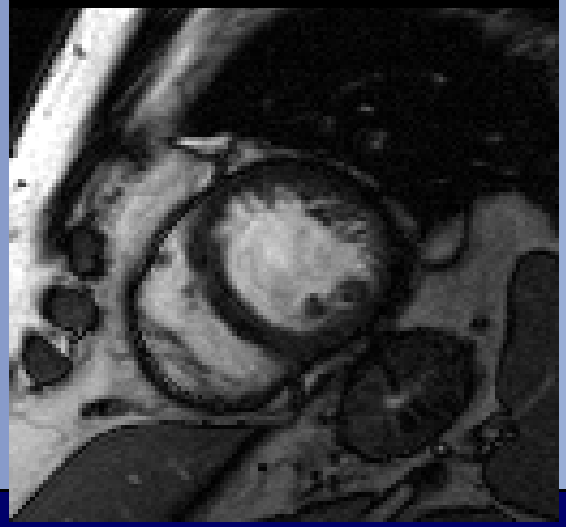
# CTO Revascularization: Myocardial Performance

## MR Imaging to Identify Revascularization Candidates



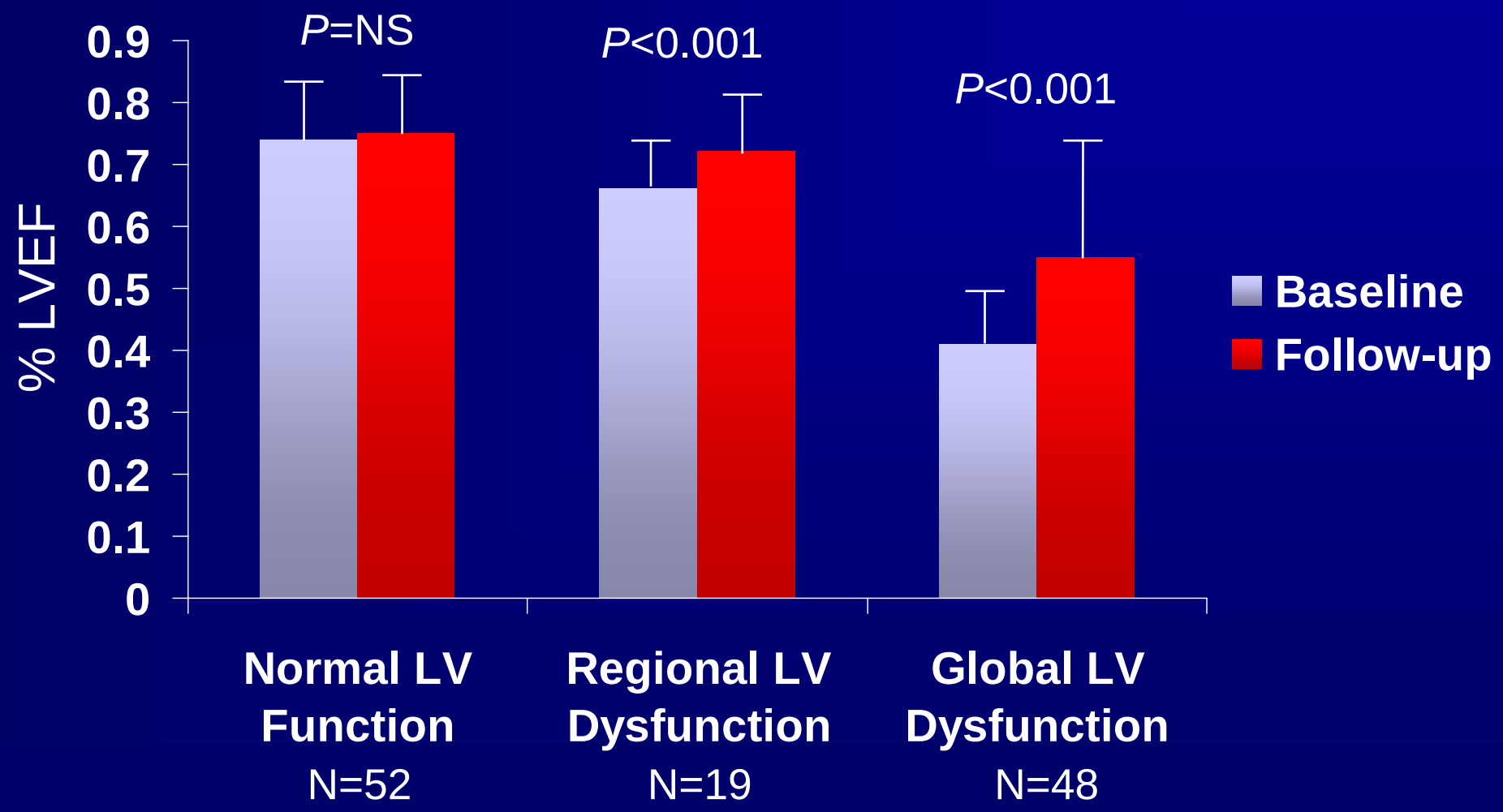
1 year post PCI

Normal wall motion



# Recovery of LV Function After CTO Recanalization

## Most Improvement with Baseline LV Dysfunction




Werner et al. Am Heart J 2005

# Recovery of LV Function After CTO Recanalization
## Predictors of Improvement in LV Function

**Positive**

- **Baseline LV dysfunction**
- **Preserved microvasculature**

**No Effect**

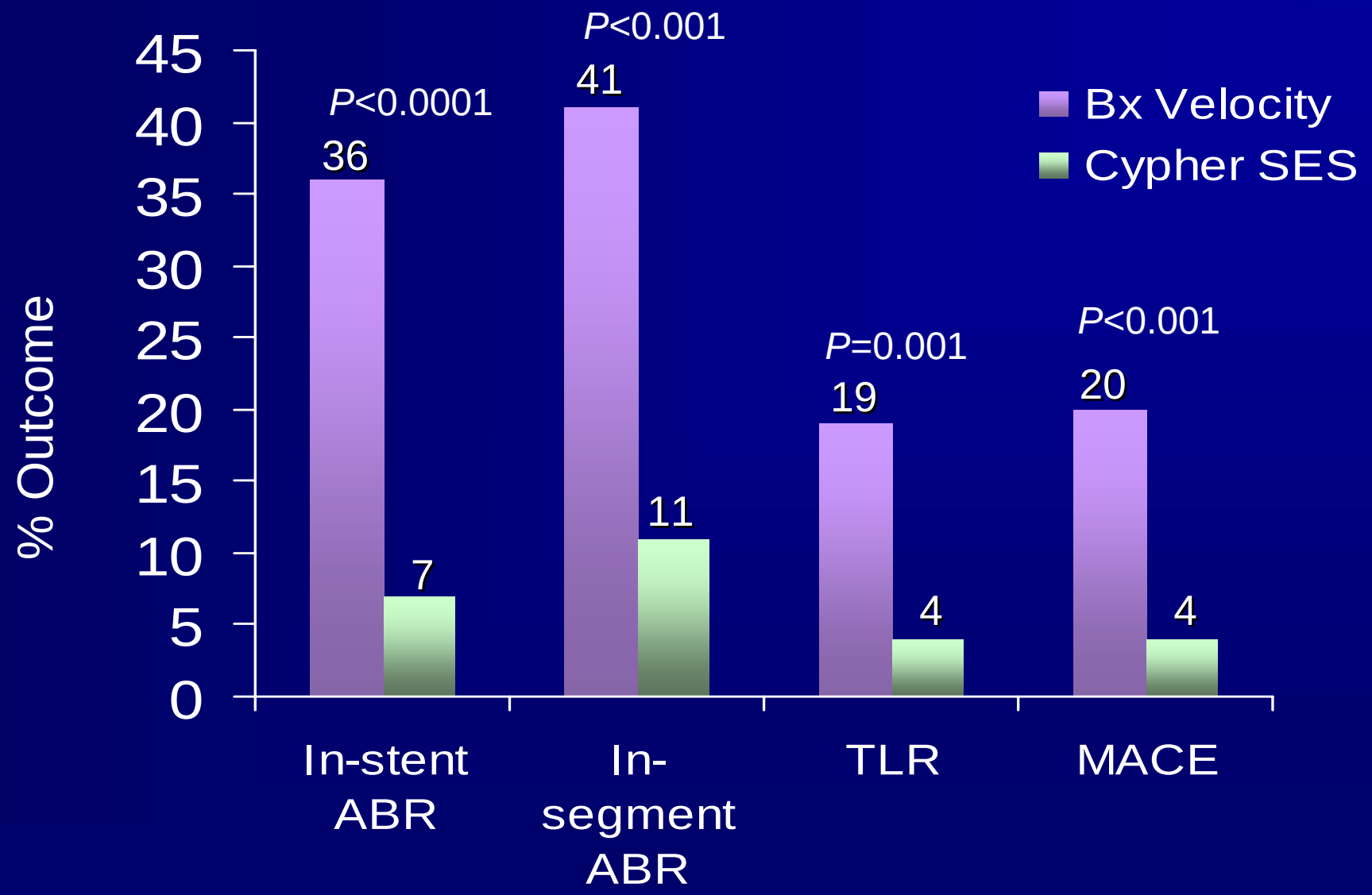
- **Collateral development**
- **Prior MI**
- **Duration of occlusion**
- **Nonocclusive restenosis**

**Negative**

- **Reocclusion**

Werner GS, Am Heart J, 2005

# PRISON II

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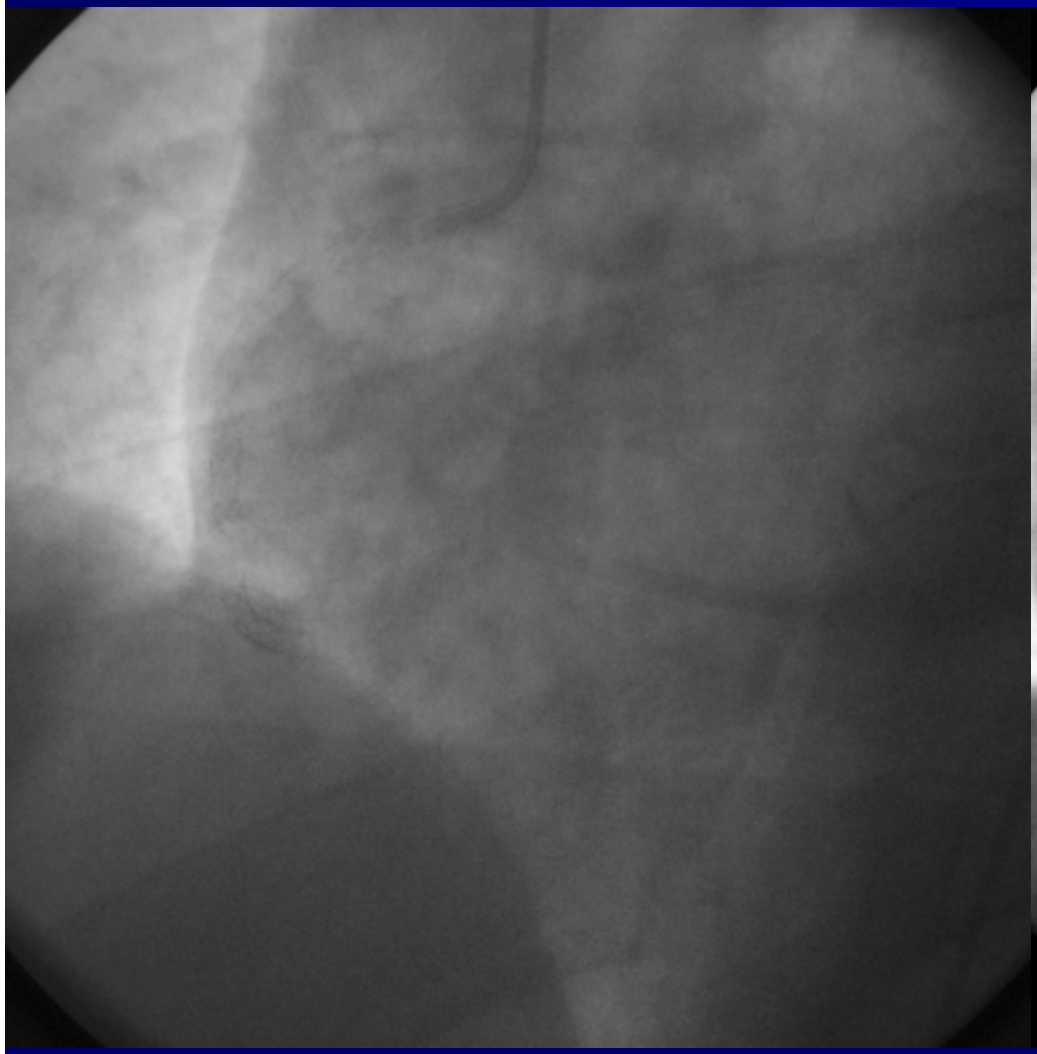
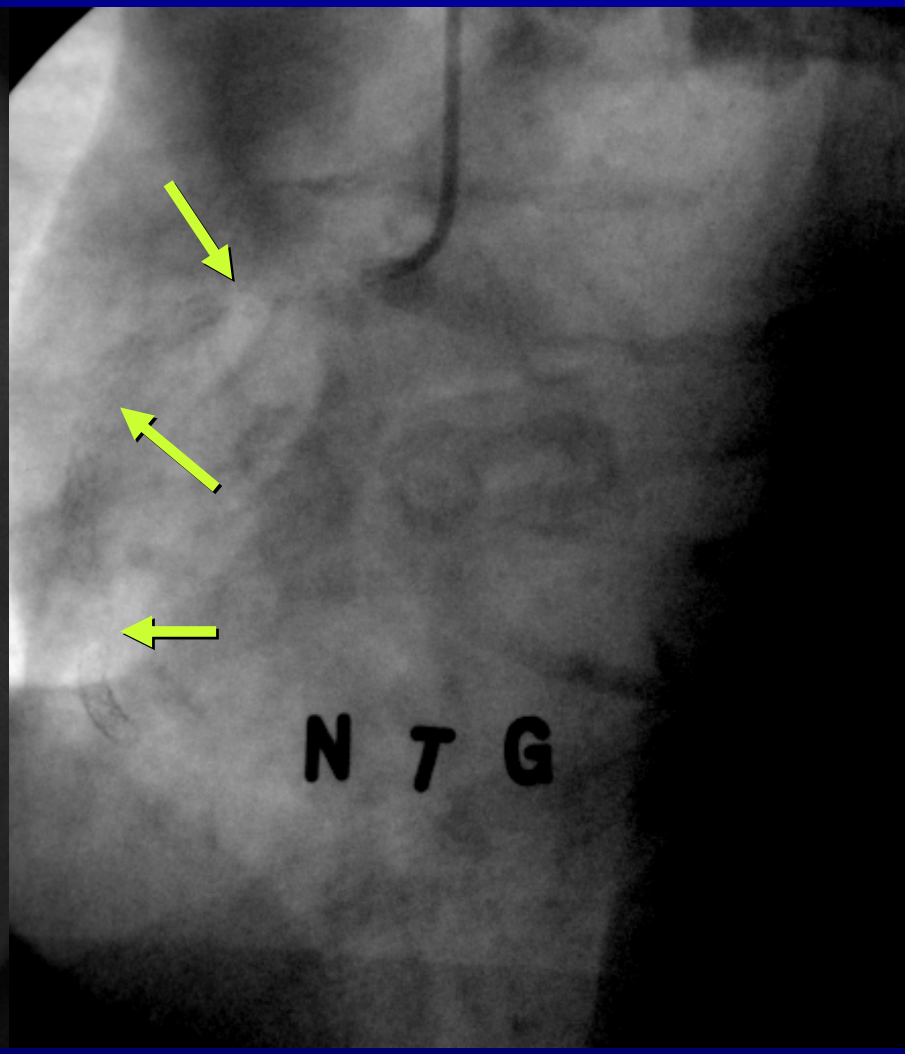
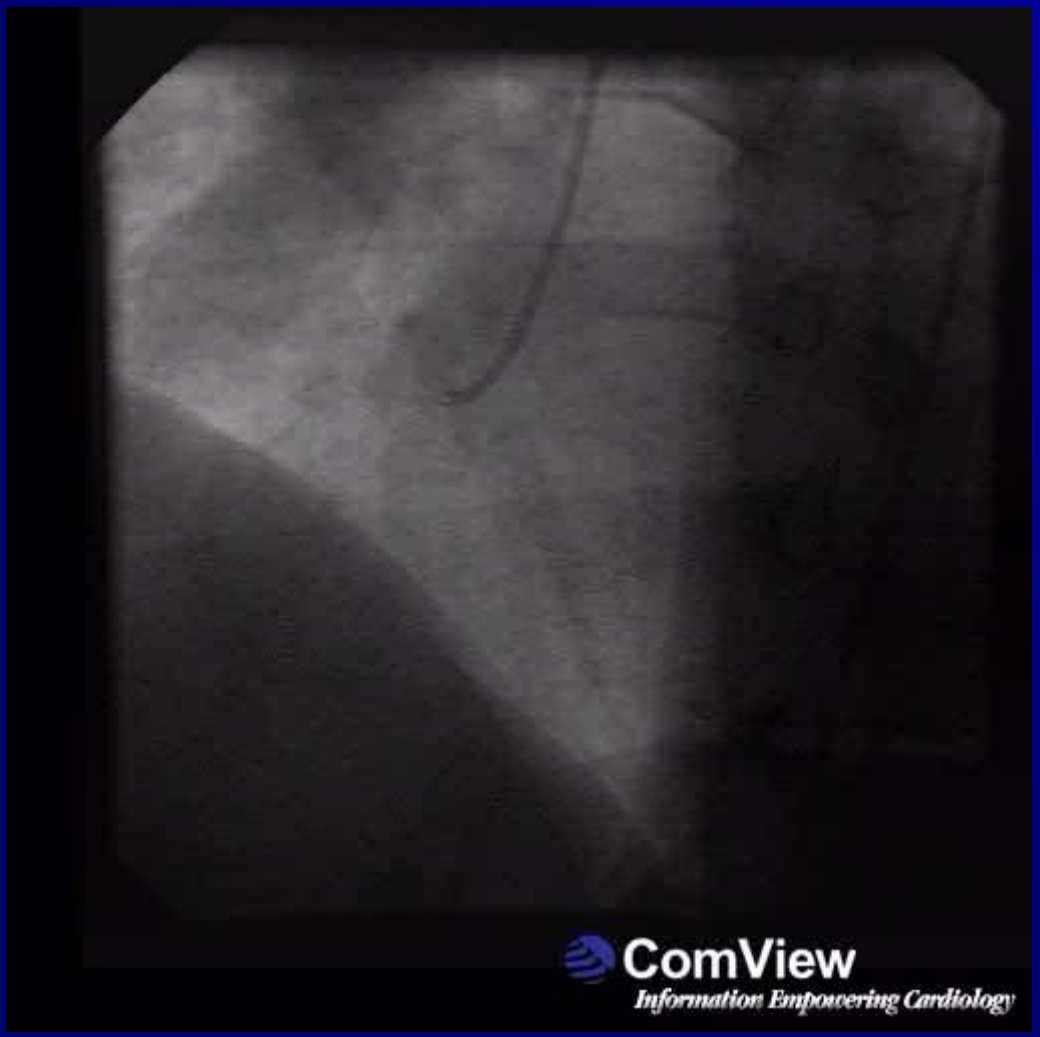
# 7 month angiographic follow-up: 92 mm DES





# Late Incomplete Apposition and Aneurysm Formation

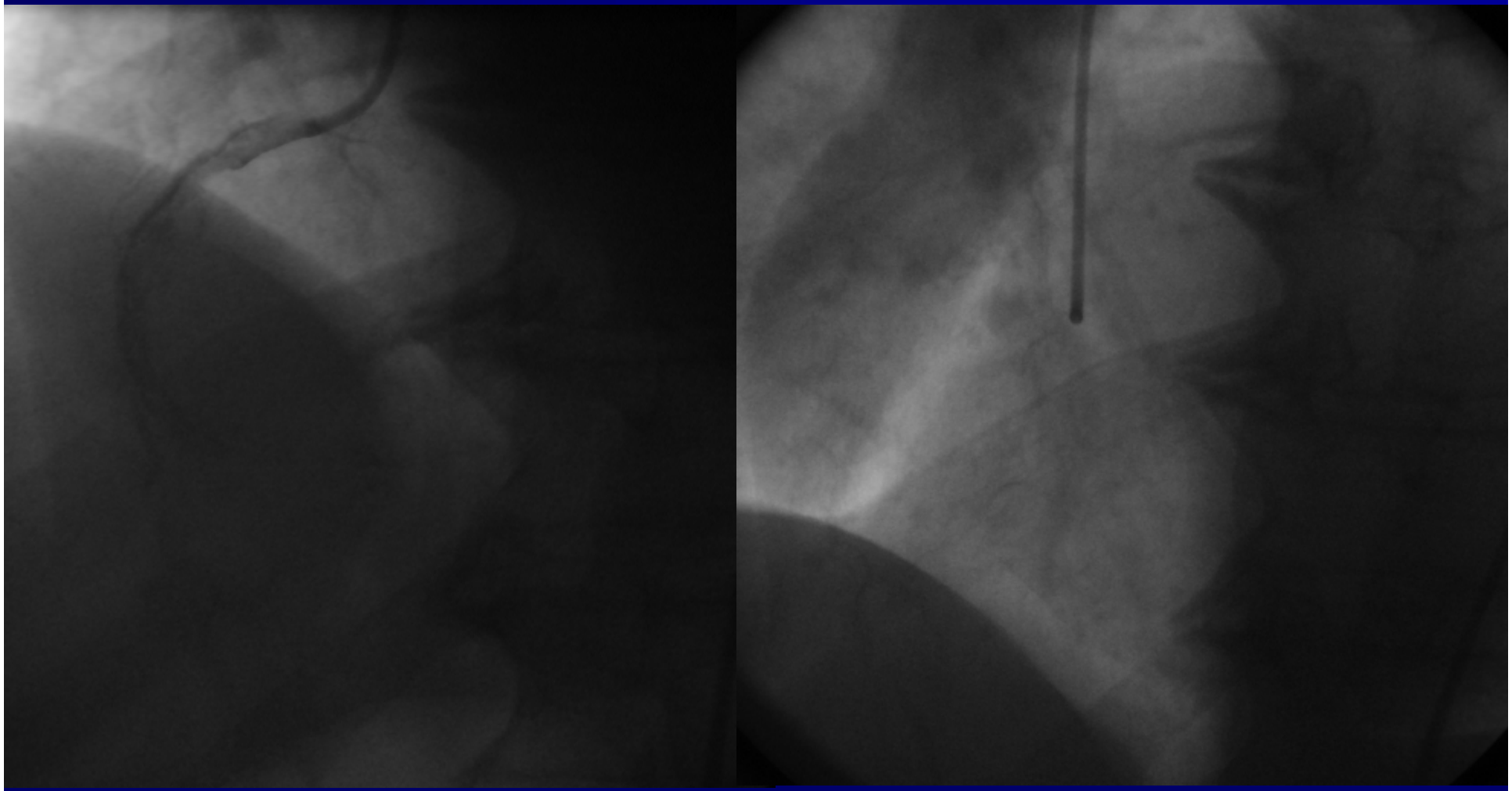



Late Stent Malapposition by IVUS: 25.7% of CTOs

Hong et al. Circulation 2006

# Persistence

*If at first you don't succeed….*



# Practical Considerations

## Developing a CTO Program

- Attend CTO meetings and workshops
- Start with ‘less complex’ coronary CTOs or peripheral (eg, SFA) CTOs
- Perform CTOs with a partner
- Choose a dedicated CTO day
- Be versatile and willing to change strategy
- Be patient and willing to accept failure

# Patient Selection and Clinical Benefit in CTO Revascularization

## Summary

- The 'Last Great Barrier to PCI Success'─ most frequently encountered yet least treated lesion subset
- Major advances in CTO treatment are: technique/strategy, wire technology, noninvasive imaging for patient selection
- Despite advances, there is no systematic evidence that procedural outcomes have changed for the better or worse
  - *New techniques and therapies introduce new complications*
  - *Need CTO-specific clinical trials that better inform procedural and late outcomes*
- Pathophysiologic rationale to support late open artery hypothesis
  - *Consistency in late survival with CTO revascularization*
  - *LV dysfunction and viability are greatest predictors of improvement*