Hybrid Coronary Revascularization

and Routine Intraoperative Completion Angiography

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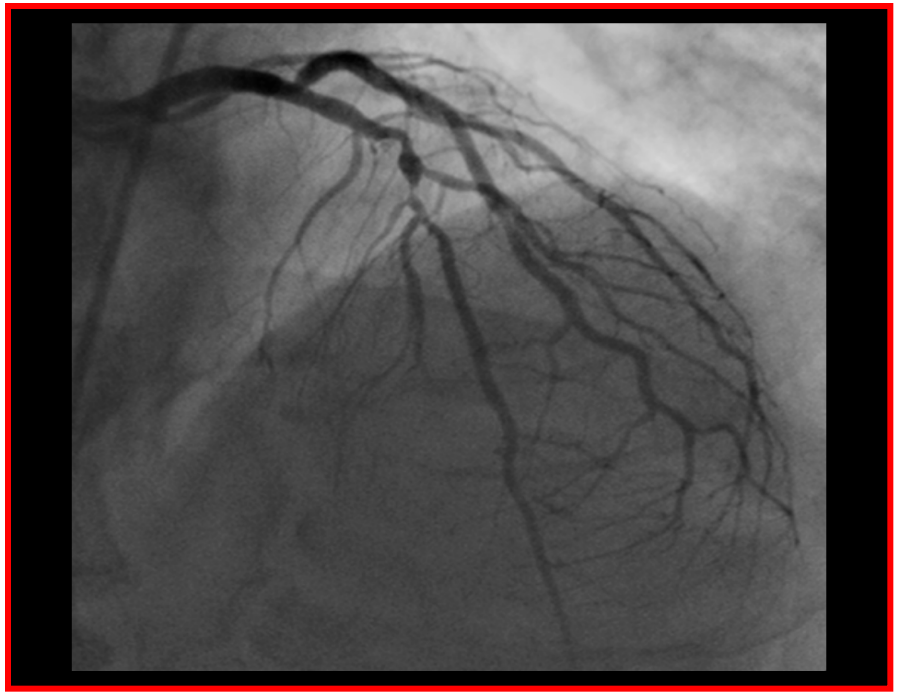
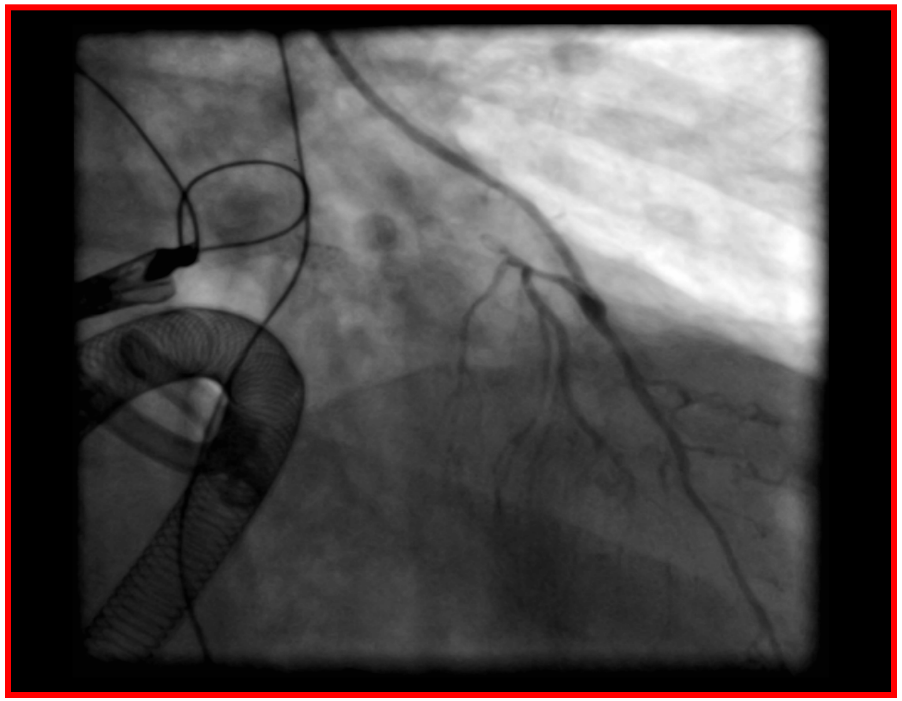
Hybrid Cardiovascular Operating Room

April 2005

First Case in Hybrid Intra-operative Imaging



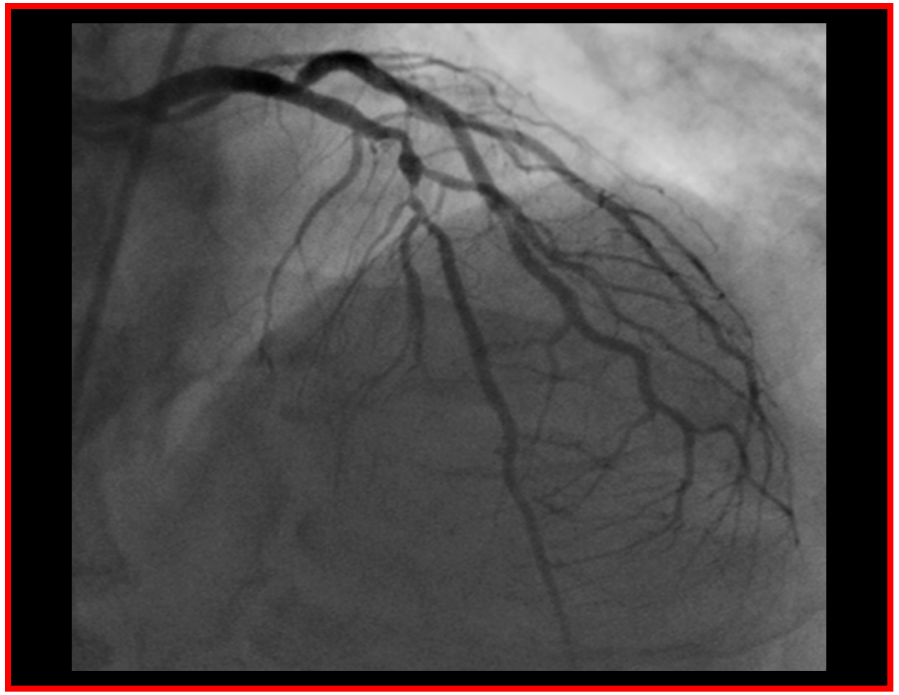
Preoperatively



Intra-operatively

Completion Angiogram: LIMA-LAD

First Case in Hybrid Intra-operative Imaging



Preoperatively

Intra-operatively

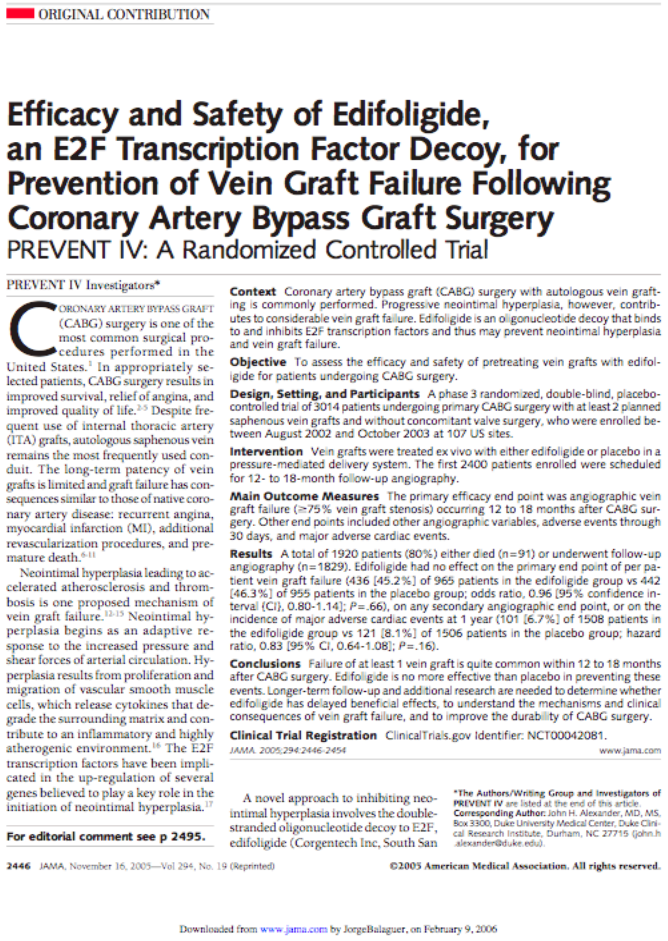
Hybrid Cardiovascular Operating Room

- **Creates a platform to combines the tools of the OR and cath lab**
- **Intra-operative imaging**
- **The embodiment of the hybrid paradigm**

A collaborative working environment

The Heart Team

Current Data: PREVENT IV



ORIGINAL CONTRIBUTION

Efficacy and Safety of Edifoligide, an E2F Transcription Factor Decoy, for Prevention of Vein Graft Failure Following Coronary Artery Bypass Graft Surgery

PREVENT IV: A Randomized Controlled Trial

PREVENT IV Investigators*

Context Coronary artery bypass graft (CABG) surgery with autologous vein grafting is commonly performed. Progressive neointimal hyperplasia, however, contributes to considerable vein graft failure. Edifoligide is an oligonucleotide decoy that binds to and inhibits E2F transcription factors and thus may prevent neointimal hyperplasia and vein graft failure.

Objective To assess the efficacy and safety of pretreating vein grafts with edifoligide for patients undergoing CABG surgery.

Design, Setting, and Participants A phase 3 randomized, double-blind, placebo-controlled trial of 3014 patients undergoing primary CABG surgery with at least 2 planned saphenous vein grafts and without concomitant valve surgery, who were enrolled between August 2002 and October 2003 at 107 US sites.

Intervention Vein grafts were treated ex vivo with either edifoligide or placebo in a pressure-mediated delivery system. The first 2400 patients enrolled were scheduled for 12- to 18-month follow-up angiography.

Main Outcome Measures The primary efficacy end point was angiographic vein graft failure (≥75% vein graft stenosis) occurring 12 to 18 months after CABG surgery. Other end points included other angiographic variables, adverse events through 30 days, and major adverse cardiac events.

Results A total of 1920 patients (80%) either died (n=91) or underwent follow-up angiography (n=1829). Edifoligide had no effect on the primary end point of per patient vein graft failure (436 [45.2%] of 965 patients in the edifoligide group vs 442 [46.3%] of 955 patients in the placebo group; odds ratio, 0.96 [95% confidence interval (CI), 0.80-1.14]; $P=.66$), on any secondary angiographic end point, or on the incidence of major adverse cardiac events at 1 year (101 [6.7%] of 1508 patients in the edifoligide group vs 121 [8.1%] of 1506 patients in the placebo group; hazard ratio, 0.83 [95% CI, 0.64-1.08]; $P=.16$).

Conclusions Failure of at least 1 vein graft is quite common within 12 to 18 months after CABG surgery. Edifoligide is no more effective than placebo in preventing these events. Longer-term follow-up and additional research are needed to determine whether edifoligide has delayed beneficial effects, to understand the mechanisms and clinical consequences of vein graft failure, and to improve the durability of CABG surgery.

Clinical Trial Registration ClinicalTrials.gov Identifier: NCT00042081.

JAMA. 2005;294:2446-2454 www.jama.com

CORONARY ARTERY BYPASS GRAFT (CABG) surgery is one of the most common surgical procedures performed in the United States.[1] In appropriately selected patients, CABG surgery results in improved survival, relief of angina, and improved quality of life.[2-5] Despite frequent use of internal thoracic artery (ITA) grafts, autologous saphenous vein remains the most frequently used conduit. The long-term patency of vein grafts is limited and graft failure has consequences similar to those of native coronary artery disease: recurrent angina, myocardial infarction (MI), additional revascularization procedures, and premature death.[6-11]

Neointimal hyperplasia leading to accelerated atherosclerosis and thrombosis is one proposed mechanism of vein graft failure.[12-15] Neointimal hyperplasia begins as an adaptive response to the increased pressure and shear forces of arterial circulation. Hyperplasia results from proliferation and migration of vascular smooth muscle cells, which release cytokines that degrade the surrounding matrix and contribute to an inflammatory and highly atherogenic environment.[16] The E2F transcription factors have been implicated in the up-regulation of several genes believed to play a key role in the initiation of neointimal hyperplasia.[17]

A novel approach to inhibiting neointimal hyperplasia involves the double-stranded oligonucleotide decoy to E2F, edifoligide (Corgentech Inc, South San

For editorial comment see p 2495.

*The Authors/Writing Group and Investigators of PREVENT IV are listed at the end of this article.
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- Primary CABG (at least 2 vein grafts)
- Placebo-Controlled
- Prospective/Randomized
- Double Blind
- 3,014 patients
- Multicenter (107 US sites)
- Edifoligide (E2F: Transcription Factor decoy)
- Prevent intimal hyperplasia of vein grafts

Prevent IV Investigators. JAMA 2005

Angiographic Results (12-18 months) 1,900 Patients/4,700 grafts

- **25% incidence of vein graft failure**
- **8% incidence of LIMA failure**
- **No difference between Edifoligide and placebo**

Graft failure was defined as = > 75% loss of lumen

Prevent IV Investigators. JAMA 2005

Two Fundamental Questions from PREVENT IV

- **Can intraoperative imaging improve the quality of bypass grafts?**

- **Are DES better than vein grafts on the non LAD coronary systems?**

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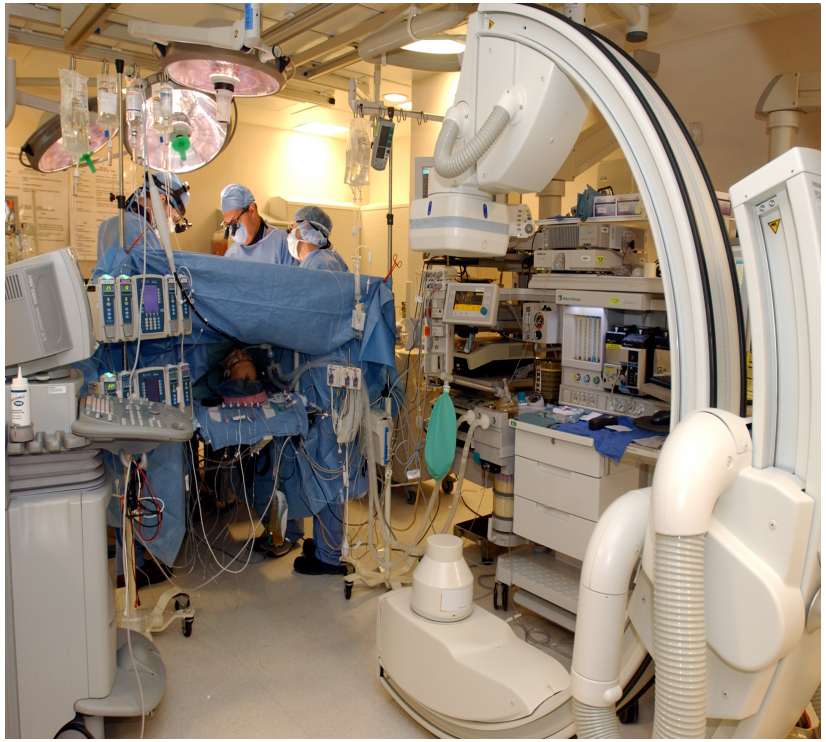
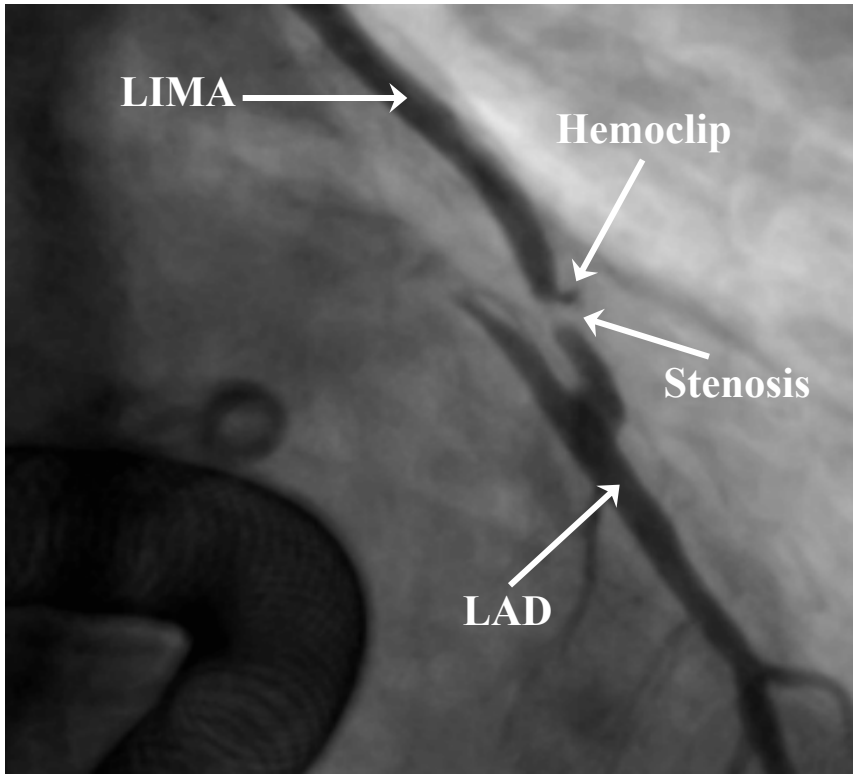
Completion Angiogram after CABG

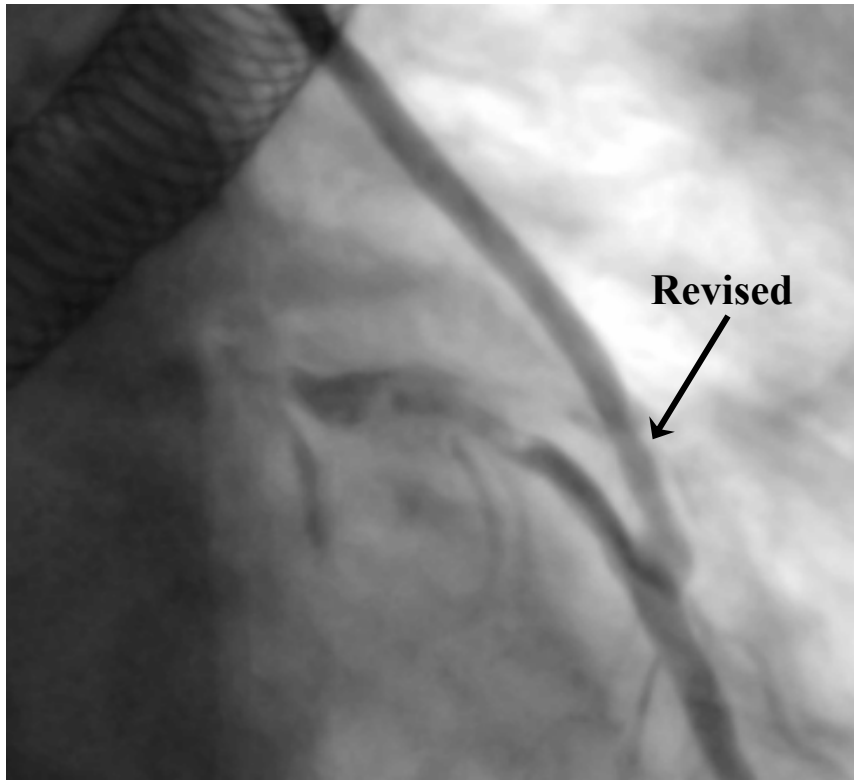


LIMA to LAD graft

Surgical hemoclip across the graft



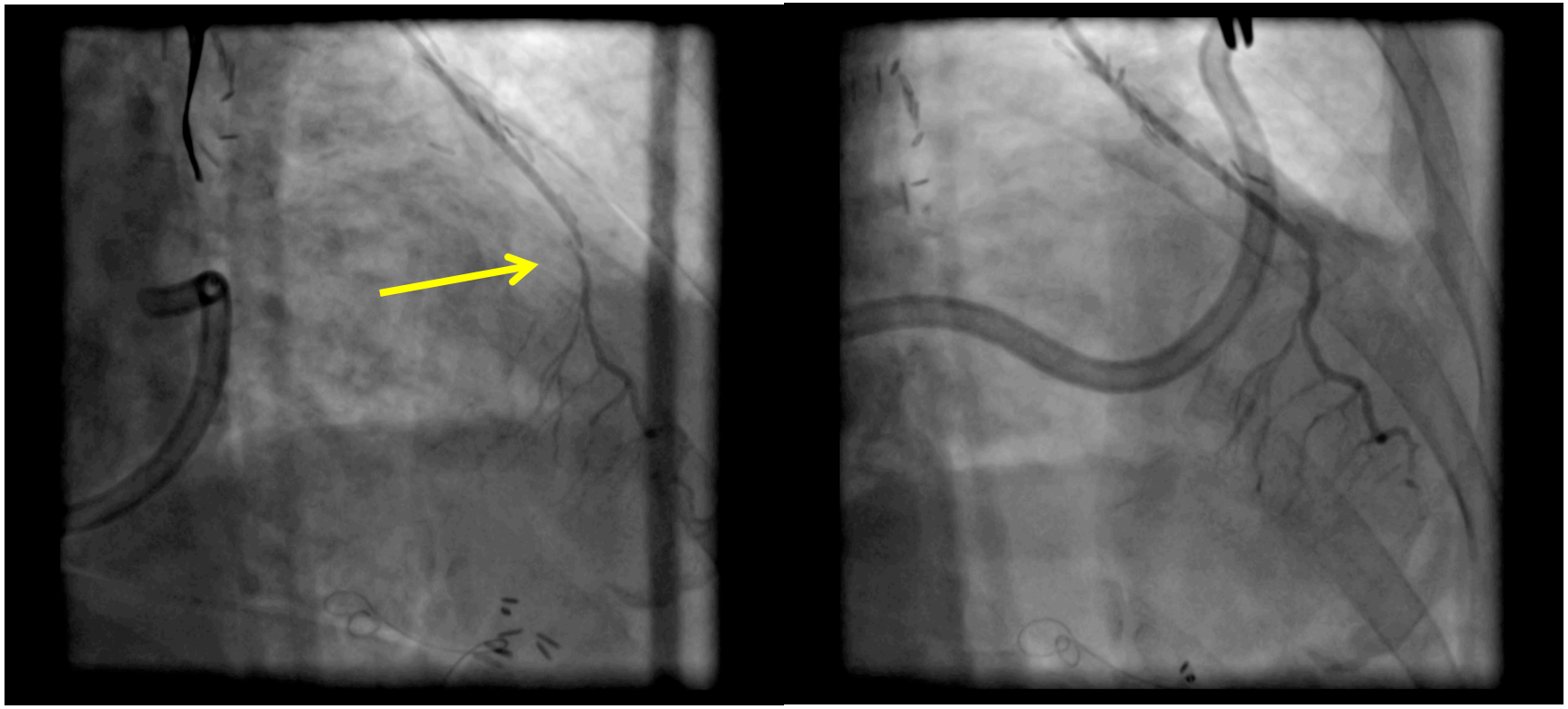
Before revision



After revision

LIMA to LAD

Loss of the lumen on the distal part of the LIMA immediately before the anastomosis

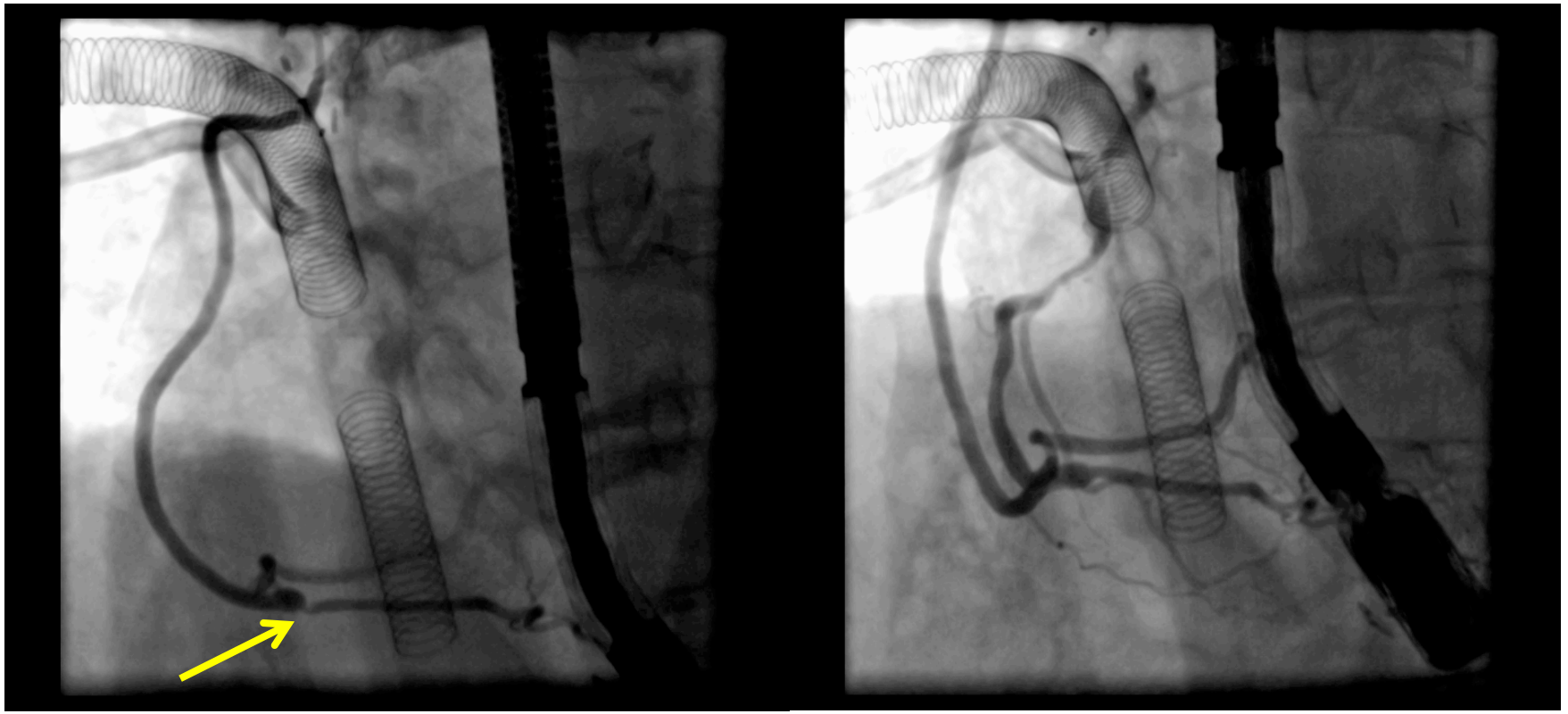


Before revision

After revision

Vein Graft to PDA (RCA)

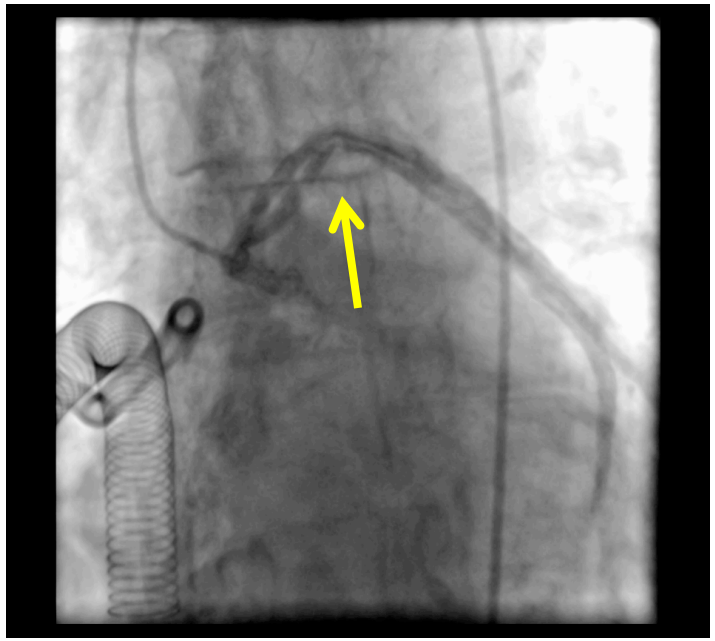
Loss of lumen at the toe of distal anastomosis



Before revision **After revision**

Vein Grafts to LAD and OM1

Kinking of both grafts



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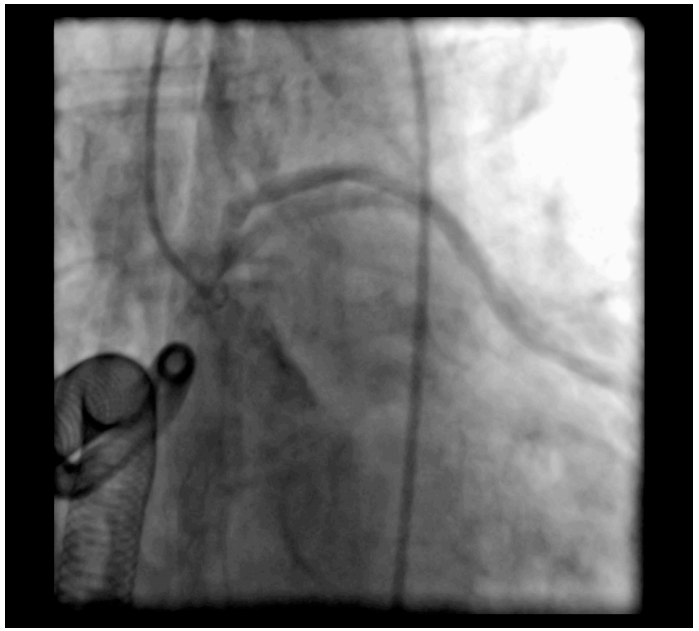
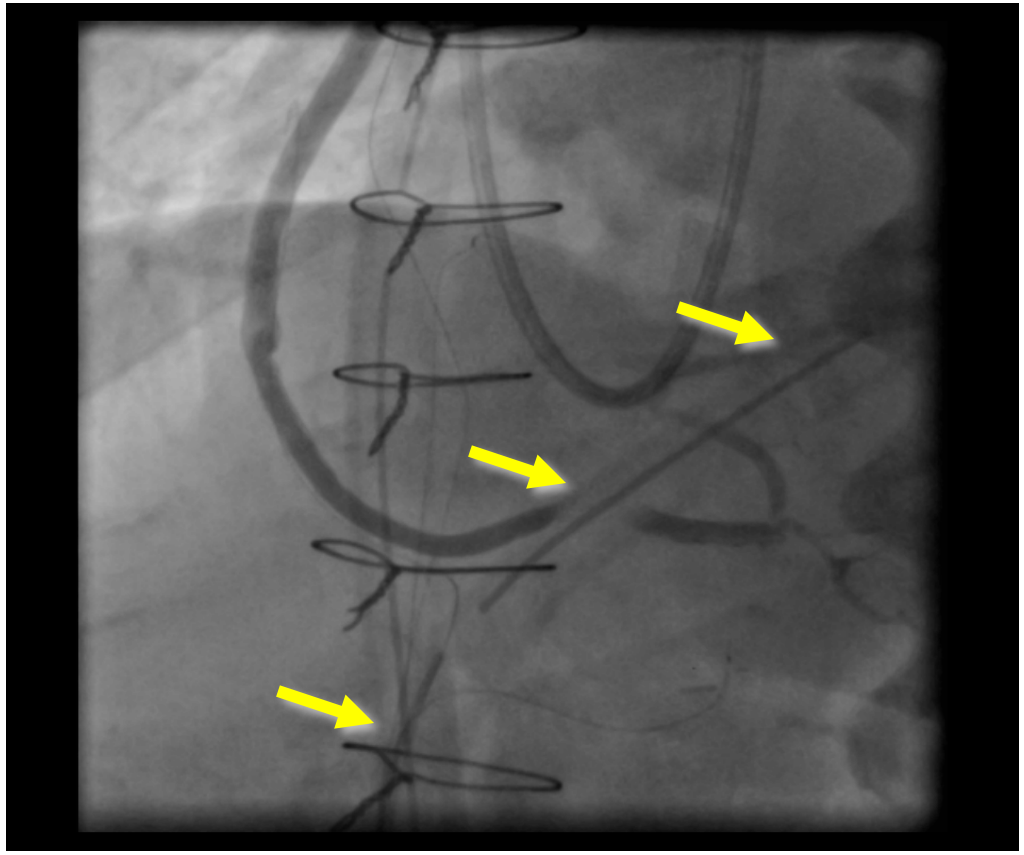


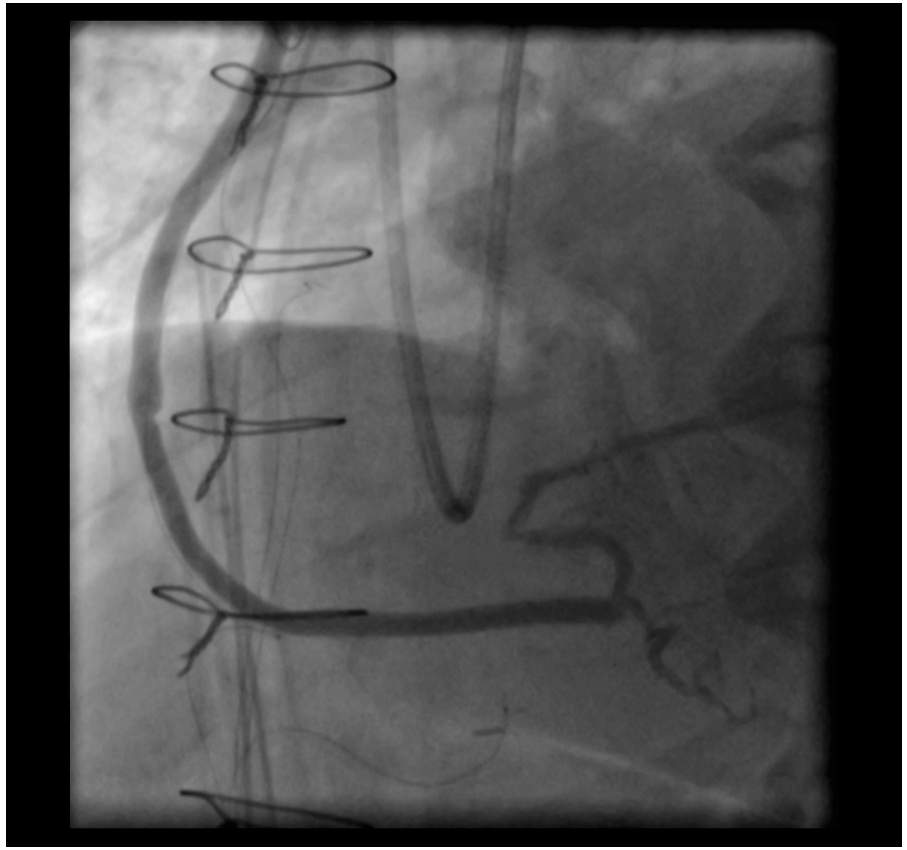
After revision

Vein graft to PDA

Chest tube compressing the graft



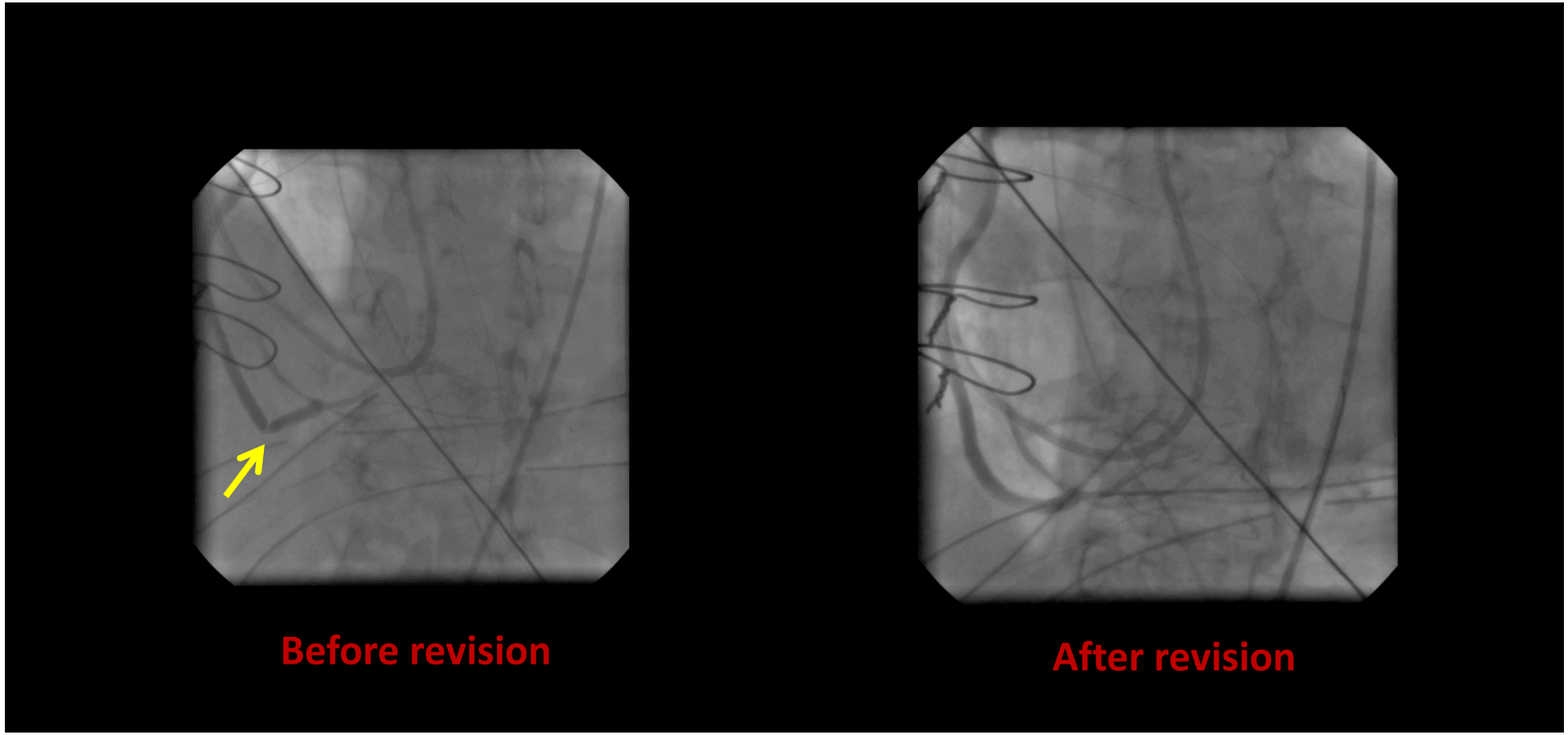
Before revision



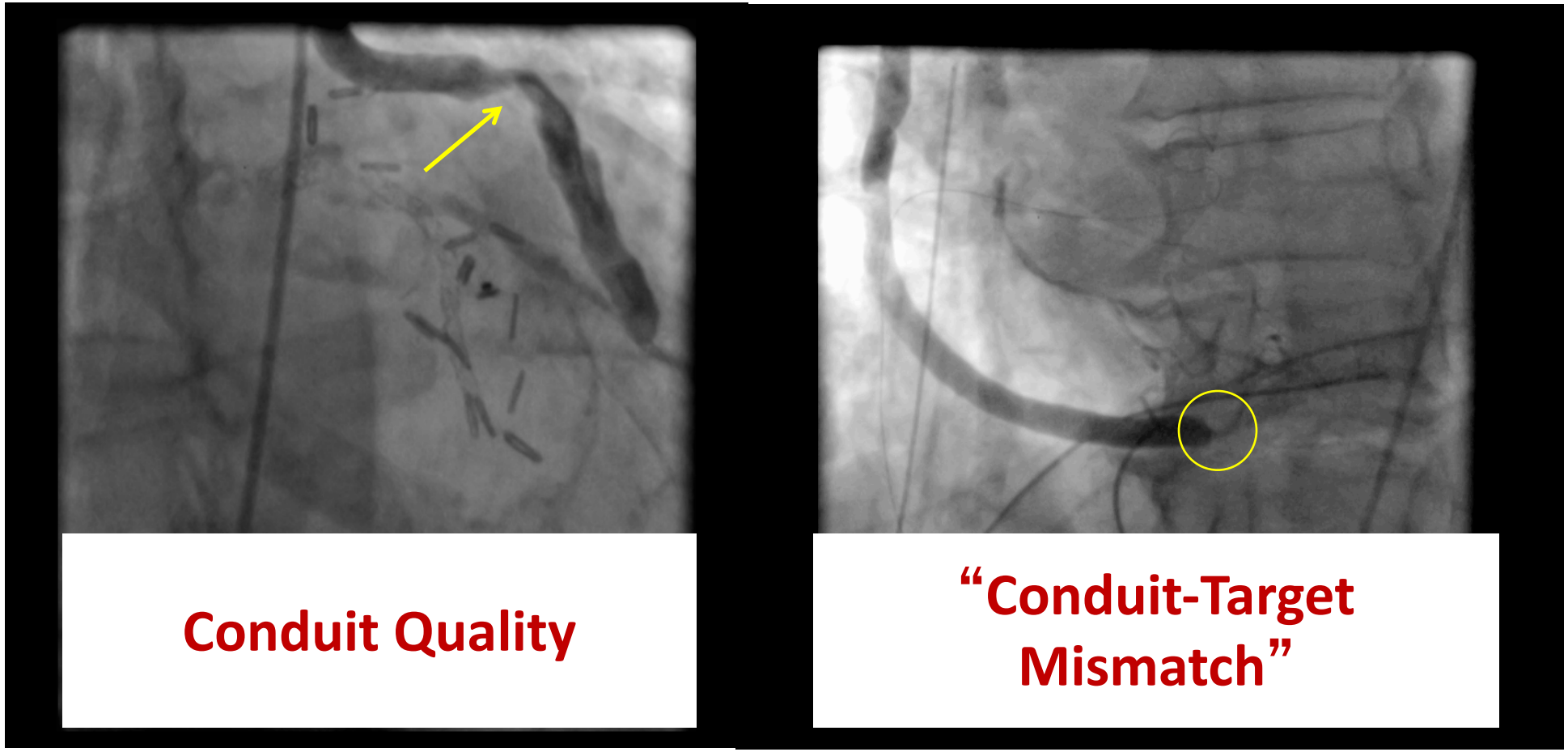
After revision

Vein graft to PDA (RCA)

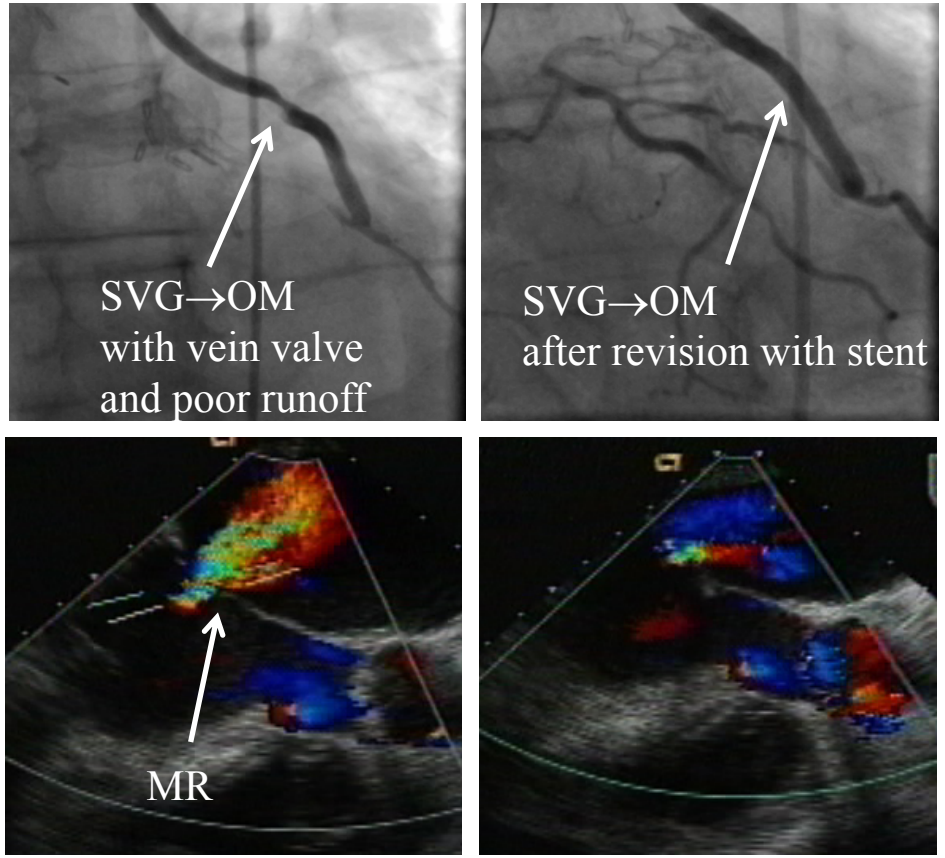
Kink on the graft before distal anastomosis



Hybrid Strategy in Complex Cases



Angiographic bypass defect associated with new onset mitral regurgitation



Greelish et al. JTCVS 2006

Angiographic graft findings (defects)

97 of 796 grafts (12%)

Table 4 Location of Angiographic Graft Finding Versus Type of Graft Intervention*

Type of Graft Intervention	Location of Angiographic Findings in Grafts: Conduit (n = 54 of 796, 6.8% of All Grafts)	Distal Anastomosis (n = 30 of 796, 3.7% of All Grafts)	Target Vessel (n = 13 of 796, 1.6% of All Grafts)
Traditional open surgical revision, n = 27 of 796, 3.4% of all grafts	12 grafts Clip damaging LIMA (n = 3) Suture damaging LIMA (n = 1) Graft kink not correctable with minor adjustment (n = 6) SVG valve impeding flow (n = 2)	12 grafts: LIMA-LAD (n = 11) SVG (n = 1)	3 grafts: Correct vessel, wrong location (n = 1) Wrong vessel (n = 2)
Open-chest PCI, n = 48 of 796, 6% of all grafts (n = 43 unplanned hybrid procedure patients†)	23 grafts: SVG valve impeding flow (n = 9) LIMA dissection (n = 6) Graft kink (n = 7) SVG–coronary size mismatch (n = 1)	15 grafts: SVG (n = 11) LIMA-LAD (n = 4)	10 grafts: Correct vessel, wrong location (n = 7) Wrong vessel (n = 1) Poor runoff, diffuse disease (n = 1) Dissection in the native coronary (n = 1)
Minor adjustment of graft not requiring traditional surgical revision or open-chest PCI, n = 22 of 796, 2.8% of all grafts	19 grafts: Adjustment of conduit lie (n = 7) Clip removal (n = 1) Stitch removal (n = 1) Chest tube removal (n = 2) Intravenous nitroglycerin for LIMA spasm (n = 4) Unroofing of fascia over the SVG conduit that had caused kinking (n = 4)	3 grafts: Unroofing of fascia over the anastomosis (n = 3)	N/A

Surgical: 3.4%

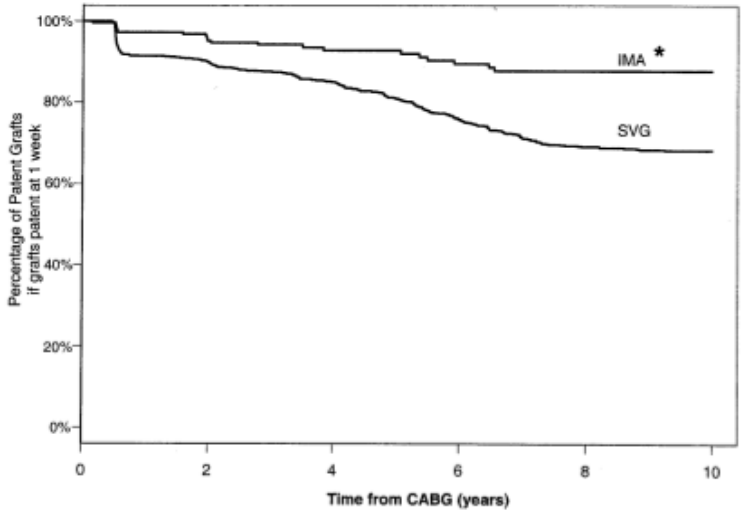
PCI: 6%

Minor adjustment: 2.8%

Conduit	Distal Anastomosis	Target Vessel
6.8%	3.7%	1.6%

Zhao et al. JACC 2009

SVG: Freedom from graft occlusion if the grafts were patent at 1 week post op



Time	1 Week	1 Year	3 Years	6 Years	10 Years
# Patients	906	660	417	255	85

Figure 2. Plot of time-related graft patency (or freedom from graft occlusion) for saphenous vein grafts (SVG) and internal mammary artery (IMA) grafts if the graft was patent at one week after coronary bypass (CABG). The number of patients at each time point is listed in the figure. *$p < 0.001$ (IMA vs. SVG).

VA Cooperative Study
1,254 Patients

Angio F/U	7 years	10 years
SVG Patency	**76%**	**68%**

Goldman et al. JACC 2004

Clinical Impact of Vein Graft Failure

"The benefits of coronary bypass surgery last only as long as the grafts continue to function"

Table 5. Clinical Event in Patients by Vein Graft Failure Status

Type of Event	No./Total (%) of Patients	
	Vein Graft Failure (n = 878)	No Vein Graft Failure (n = 1042)
Perioperative MI in CABG surgery	118 (13.4)	71 (6.8)
Death or MI*	122 (13.9)	9 (0.9)
Death, MI,* or revascularization	228 (26.0)	19 (1.8)

Abbreviations: CABG, coronary artery bypass graft; MI, myocardial infarction.
*Not including perioperative MI in CABG surgery.

PREVENT IV Investigators, JAMA 2005;294:2446-2454

Benefits of Completion Angiogram

- **Opportunity for the early diagnosis of graft problems and immediate correction**
  - ***Surgical***
  - ***Catheter based***
  - ***Minor revisions***
- **Confirm complete revascularization and patent grafts by the time patients leave the OR**
- **Hypothesis: The correction of these defects at the time of surgery may help to reduce the rate of graft failure**

Two Fundamental Questions from PREVENT IV

- **Can intraoperative imaging improve the quality of bypass grafts?**

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1-Stop Hybrid Revascularization

CLINICAL RESEARCH Interventional Cardiology

Routine Intraoperative Completion Angiography After Coronary Artery Bypass Grafting and 1-Stop Hybrid Revascularization

Results From a Fully Integrated Hybrid Catheterization Laboratory/Operating Room

David X. Zhao, MD, FACC, Marzia Leacche, MD, Jorge M. Balaguer, MD, Konstantinos D. Boudoulas, MD, Julie A. Damp, MD, James P. Greelish, MD, John G. Byrne, MD, FACC, the Writing Group on behalf of the Cardiac Surgery, Cardiac Anesthesiology, and Interventional Cardiology Groups at the Vanderbilt Heart and Vascular Institute

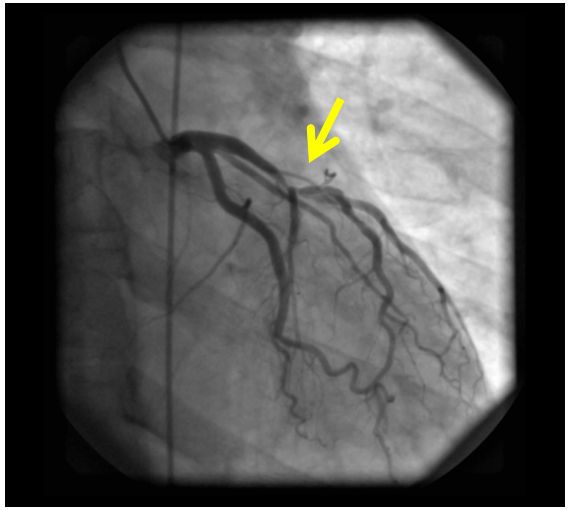
Nashville, Tennessee

JACC 2009

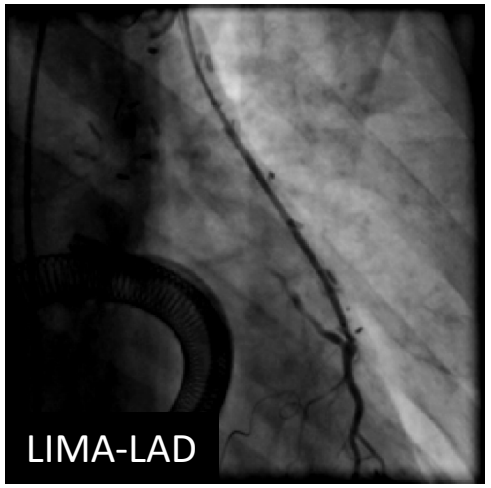
Hybrid Strategy in Complex Cases

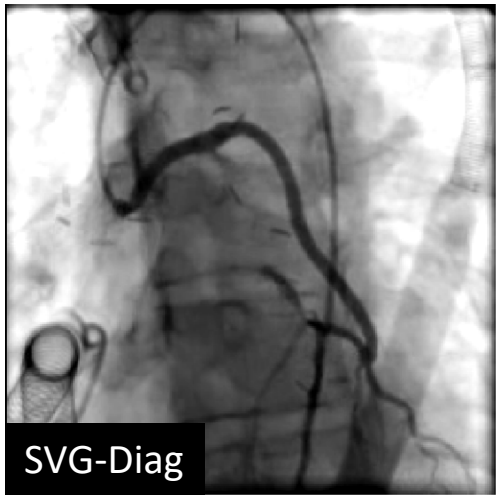
Indication: Complex trifurcation lesion. Septal branch: Favorable PCI lesion with no target vessel

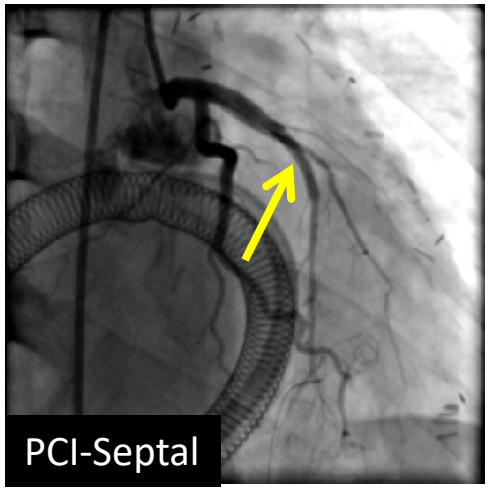
Hybrid Strategy in Complex Cases



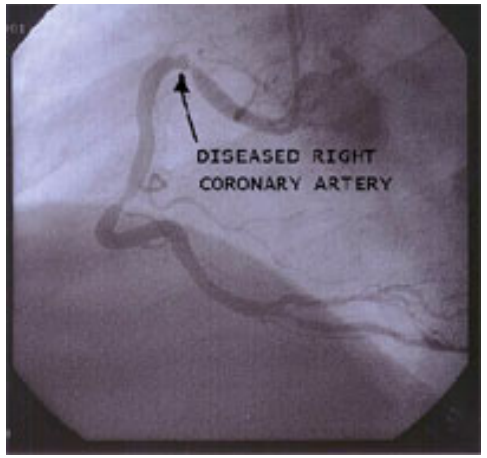
Indication: Complex trifurcation lesion

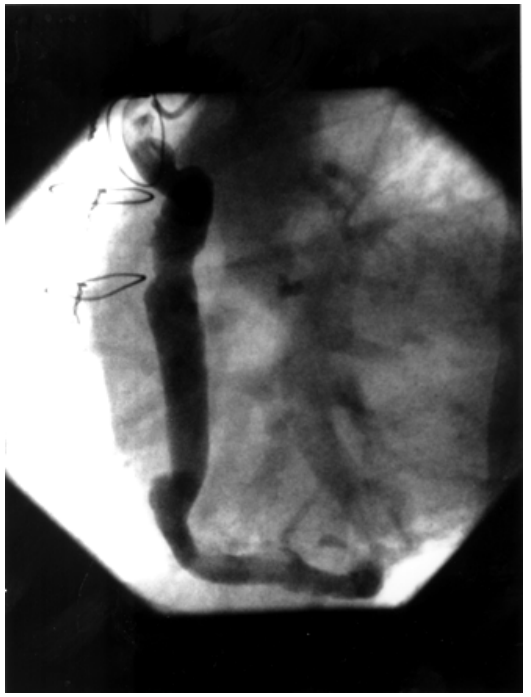






Hybrid Strategy in Complex Cases





Indication: Lack of adequate conduit. Favorable lesion for PCI

Hybrid Revascularization (n=112)

Demographics and baseline characteristics

Table 1 Pre-Operative Characteristics

Variables	Entire Group (n = 366)	Standard (n = 254)	Hybrid (n = 112)	p Value*
Median age (yrs)	63 (32–89)	63 (32–89)	63 (32–85)	0.29
Female	95 (26%)	62 (24%)	33 (29%)	0.18
Median body mass index (kg/m^2)	29 (15–48)	29 (15–48)	29 (15–48)	0.52
Hypertension	303 (83%)	211 (83%)	92 (82%)	0.46
Diabetes	143 (39%)	99 (39%)	44 (39%)	0.52
History of smoking	236 (64%)	160 (63%)	76 (68%)	0.23
Dyslipidemia	277 (75%)	198 (78%)	79 (70%)	0.08
Chronic obstructive pulmonary disease	83 (23%)	55 (22%)	28 (25%)	0.27
Median Canadian Cardiovascular Class	2 (1–4)	2 (1–4)	2 (1–4)	0.75
Unstable angina	202 (56%)	140 (55%)	62 (57%)	0.45
Left main coronary artery stenosis	87 (24%)	67 (27%)	20 (18%)	0.04
Three-vessel disease	245 (67%)	160 (63%)	85 (76%)	0.01
Left ventricular ejection fraction (%)	50 (10–72)	54 (10–72)	50 (15–70)	0.26
Acute myocardial infarction	49 (13%)	30 (12%)	19 (17%)	0.11
Nonelective surgery	224 (61%)	157 (62%)	67 (60%)	0.42
Prior stroke	30 (8%)	21 (8%)	9 (8%)	0.56
Pre-operative intra-aortic balloon pump	11 (3%)	8 (3%)	3 (3%)	0.57
Low cardiac output syndrome	7 (2%)	5 (1.9%)	2 (1.8%)	0.63
Renal failure on hemodialysis	7 (2%)	5 (1.9%)	2 (1.8%)	0.56
Prior percutaneous coronary intervention	106 (29%)	77 (30%)	29 (26%)	0.23
Previous cardiac operation	12 (3%)	10 (4%)	2 (1.8%)	0.23
Median baseline creatinine (mg/dl)	0.9 (0.2–12)	0.9 (0.2–12)	0.9 (0.5–5.9)	0.68
Median baseline platelets (K/μl)	220 (60–626)	220 (98–626)	220 (60–504)	0.66
Median baseline hematocrit (%)	40 (29–55)	40 (29–55)	40 (29–50)	0.23

Indications for the Hybrid Procedure

Hybrid Revascularization procedures	(n=112)	
Attempt to decrease risk	32	Planned Hybrid
Poor conduit	4	
Left subclavian stenosis	3	
Non graftable vessel/favorable PCI lesion	31	
Graft defect (Completion angiogram)	43	Unplanned Hybrid

PCI component of the Hybrid Procedure

DES	84%
BMS	8%
DES + BMS	7%
Mean # stents	1.8 +/- 1.1
Contrast	200 cc (20-500)

30-day Results
No "Achilles Heels" for Hybrid Approach

Table 5 Post-Operative Characteristics

Variables	Entire Group (n = 366)	Standard (n = 254)	Hybrid (n = 112)	p Value*
Median chest tube drainage (ml)	1,420 (110–12,700)	1,382 (170–7,240)	1,550 (110–12,700)	0.18
Reoperation for bleeding	10 (3%)	7 (3%)	3 (3%)	0.63
Median PRBC transfusions (units/patient) at 48 h	1 (0–20)	1 (0–20)	1 (0–10)	0.13
Median creatinine at 24 h (mg/dl)	0.9 (0.3–12.1)	0.9 (0.3–12.1)	0.9 (0.4–5)	0.90
Median creatinine at 48 h (mg/dl)	1 (0.3–12.3)	1 (0.4–12.3)	1 (0.3–5.9)	0.78
Median creatinine at 72 h (mg/dl)	1 (0.3–13.2)	1 (0.3–13.2)	1 (0.4–4)	0.58
Median CPK at 48 h (U/l)	906 (189–7,788)	452 (189–7,788)	1,492 (736–6,430)	0.01
Median CK-MB at 48 h (ng/ml)	16 (2–164)	10 (2–140)	28 (11–164)	0.01
Median CK-MB ratio at 48 h (%)	1.6 (0.5–8.4)	1.4 (0.5–8.4)	1.9 (0.6–2.7)	0.33
Median troponin I at 48 h (ng/ml)	0.4 (0.01–4.6)	0.3 (0.03–1.8)	1.2 (0.01–4.6)	0.42
New acute renal failure	13 (4%)	10 (3.9%)	3 (2.6%)	0.39
25% increase in creatinine at 72 h	126 (34%)	89 (35%)	37 (33%)	0.40
New stroke	5 (1.4%)	3 (1.1%)	2 (1.7%)	0.48
New renal failure requiring hemodialysis	3 (1%)	3 (1%)	0 (0%)	0.33
New atrial fibrillation	83 (23%)	61 (24%)	22 (19%)	0.21
New intra-aortic balloon pump	13 (4%)	7 (3%)	6 (5%)	0.17
* Intrastent thrombosis	1 (0.3%)	N/A	1 (1%)	N/A
New low cardiac output syndrome	10 (3%)	5 (1.9%)	5 (4.5%)	0.15
Deep sternal wound infection	5 (1%)	3 (1%)	2 (1.8%)	0.48
Median length of stay (days)	5 (1–97)	5 (1–33)	6 (1–97)	0.08
Operative mortality	7 (2%)	4 (1.5%)	3 (2.6%)	0.33

Zhao; Leacche, Balaguer et al. JACC 2009

Conclusions

- **One-stop hybrid revascularization was**
  - **Reasonable**
  - **Safe**
  - **Feasible**
- **Enhances options for the treatment of patients with complex CAD**
  - **By combining tools (cardiologist and cardiac surgeons)**
  - **Providing imaging**

Zhao; Leacche, Balaguer et al. JACC 2009

In patients with multi-vessel CAD

Hybrid revascularization
LIMA to LAD + Stents

In order for the Hybrid Approach to be of value, the surgical component has to be performed minimally Invasive

- Minimally Invasive LIMA-LAD
- Complete revascularization with DES to non-LAD vessels

→

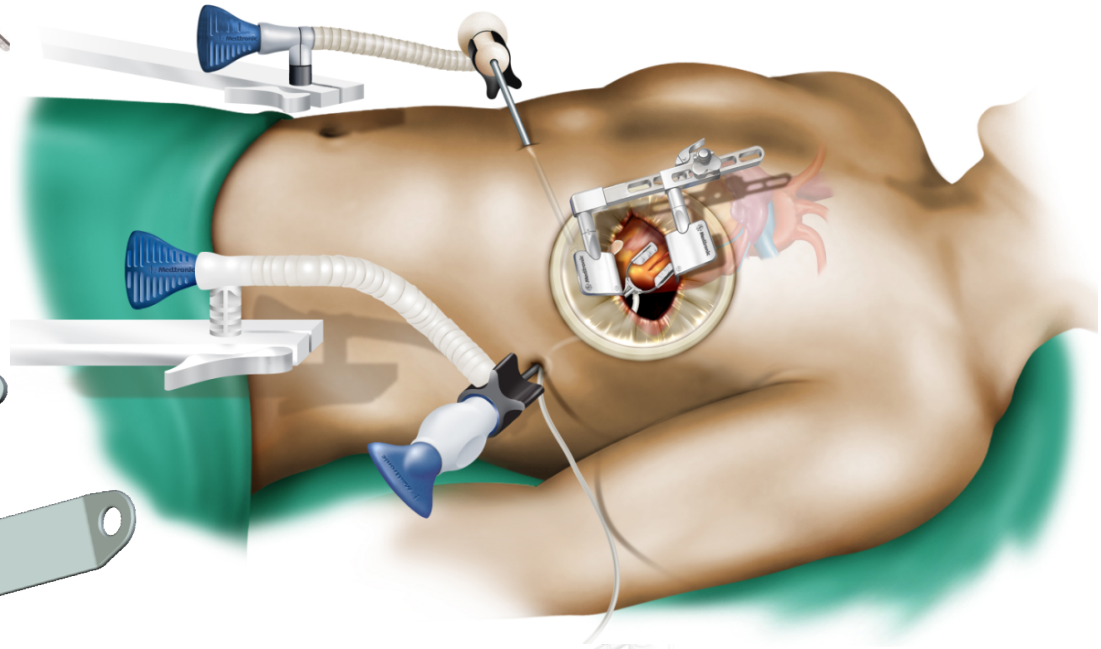
- Survival benefits (LIMA-LAD)
- Enhanced recovery of the minimally Invasive approach
- Complete revascularization

Attractive alternative for patients with multi-vessel CAD

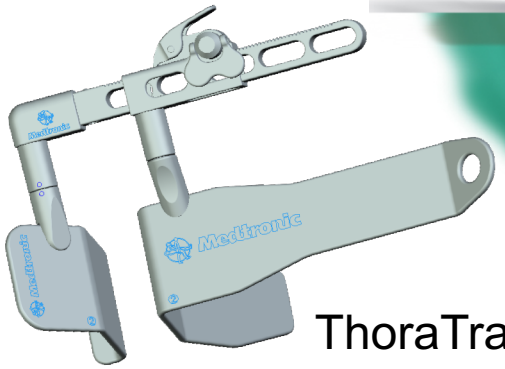
MICS CABG

Putting the future of MICS in your hands today

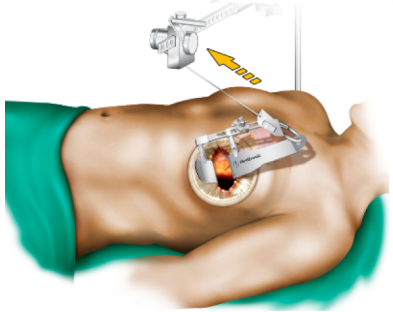
Octopus ® Nuvo



Starfish ® NS



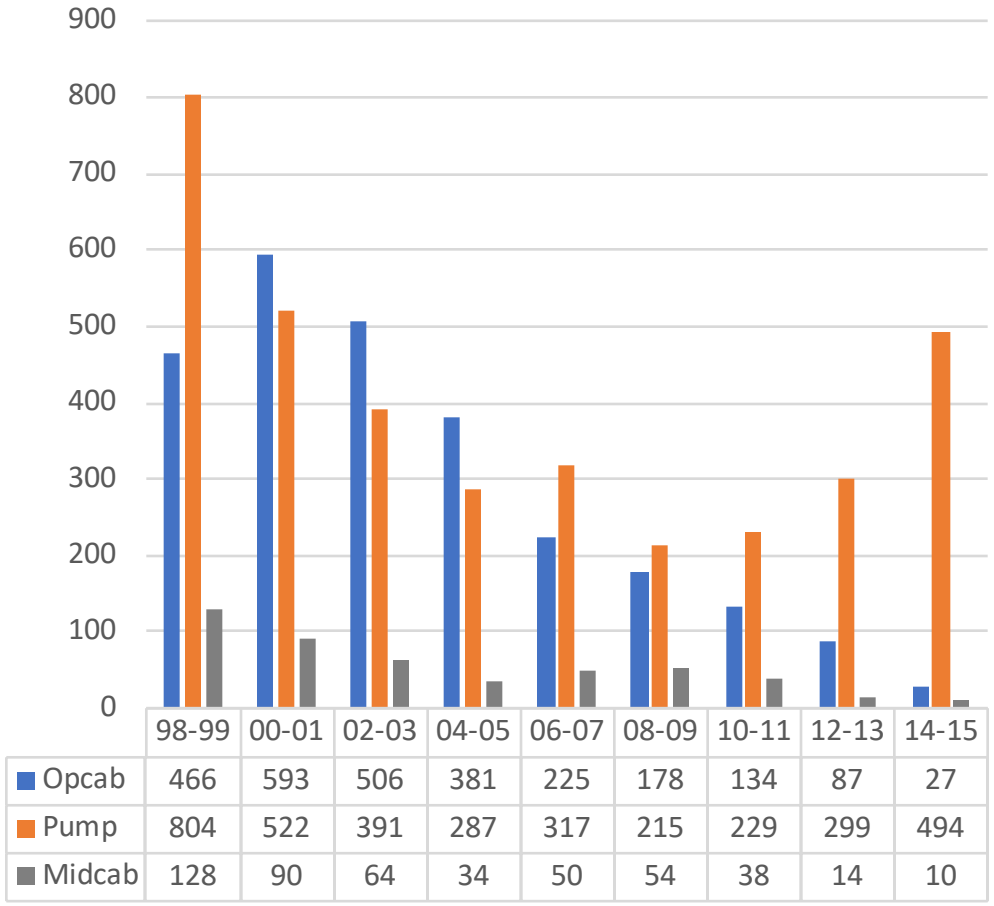
ThoraTrak ®
MICS Retractor System



U-CLIP ®
Anastomotic Device

Primary CABG & Midcab: Case Volume

SUMC: 1998 thru 2015



	98-99	00-01	02-03	04-05	06-07	08-09	10-11	12-13	14-15
Opcab	466	593	506	381	225	178	134	87	27
Pump	804	522	391	287	317	215	229	299	494
Midcab	128	90	64	34	50	54	38	14	10

Surg#	Opcab	Pump	Mcab
1	1839	78	468
2	592	323	0
3	17	725	0
4	1	958	0
5	116	232	0
6	18	413	11
7	6	267	2
8	4	292	1
9	4	270	0

†: 94 % of the Opcab's done by 2 surgeons; 97 % of the Midcabs done by one surgeon

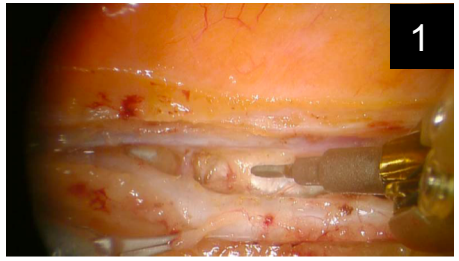
Mortality: 1.2%
O/E Ratio: 0.7

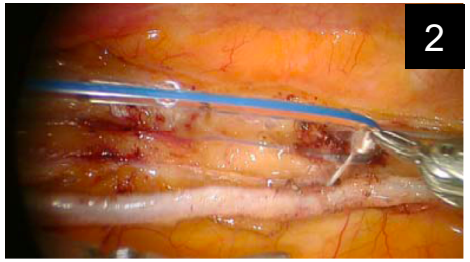
Stony Brook data provided by Dr. Siefer

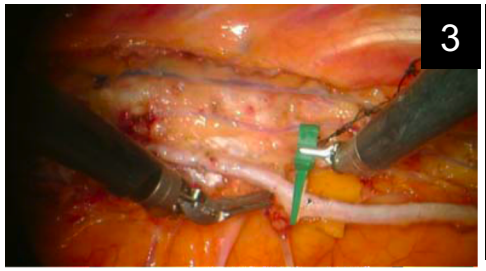
Robotic Cardiac Surgery

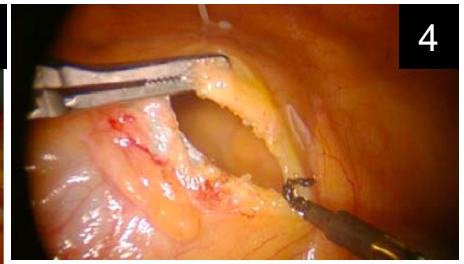
TE CAB

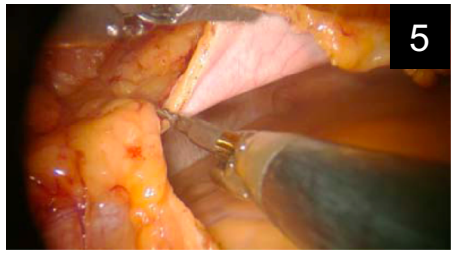
Totally Endoscopic Coronary Artery Bypass

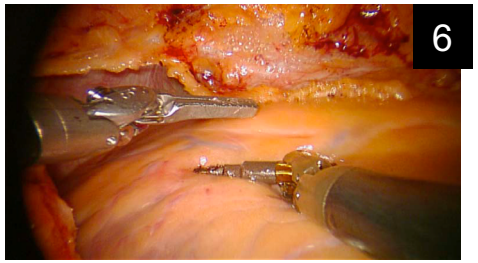


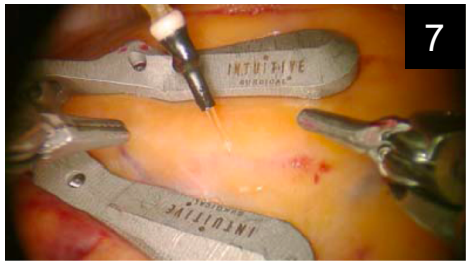


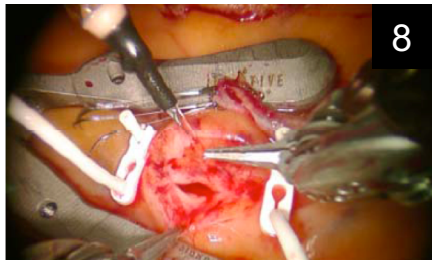


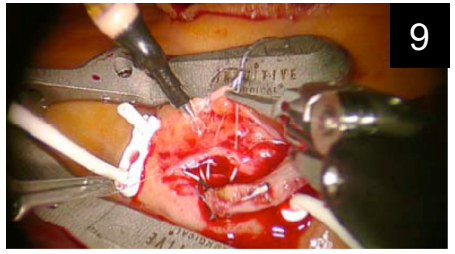


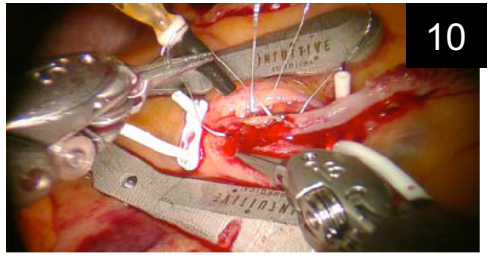


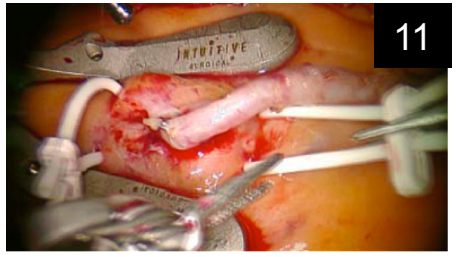












Minimally Invasive Approaches for Coronary Surgery

Small Anterolateral Thoracotomy

Lower Mini-Sternotomy

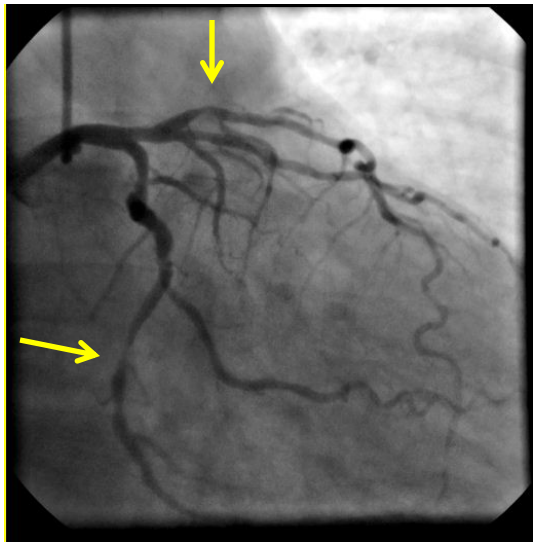
Only Ports. TE CAB

Most series
Mortality: < 1%
Conversions < 5%
LOS: 3 to 4 days

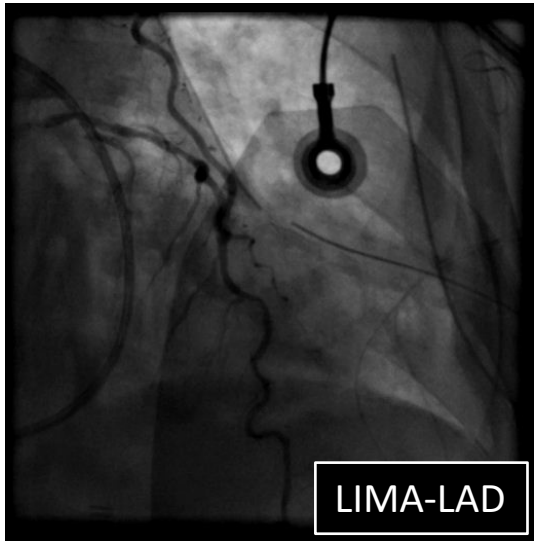
Patients driving in 2 weeks
Go back to normal activity: 4-6 weeks

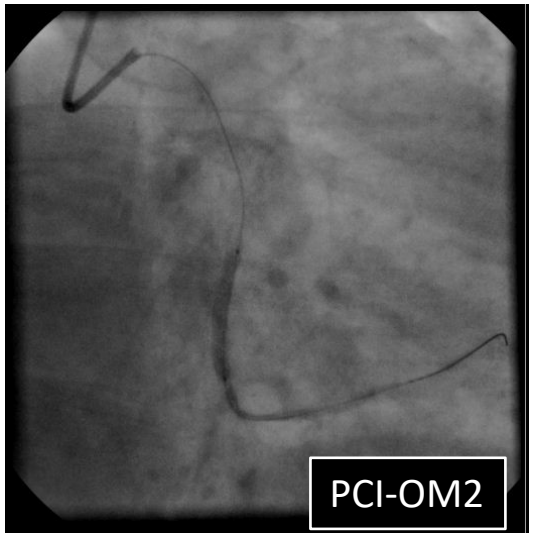
If TE CAB, recovery is even faster: LOS 1 or 2 days

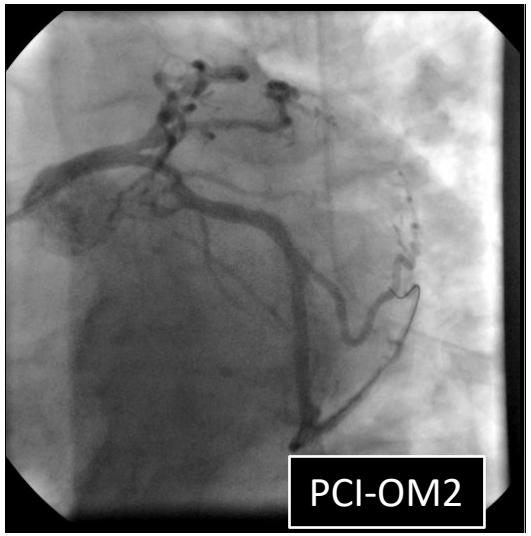
Hybrid Strategy



Minimally Invasive LIMA-LAD
PCI to Cx System







Hybrid Coronary Revascularization (MIDCAB/PCI) vs. OP CAB for multi-vessel CAD

LIMA-LAD minimally Invasive + PCI to non LAD vessels

- **Comparable 30 days outcomes (Mortality, Stroke, MI, ICU and Hospital Stay)**
- **Fewer blood Tx for the HCR group. Higher repeat revascularization in the Hybrid**

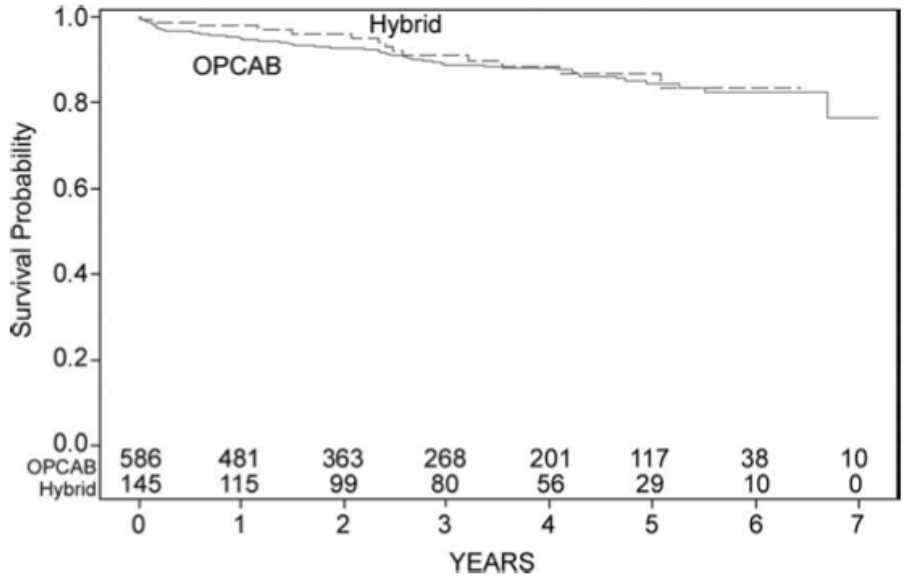


Table 5. Details of Repeated Revascularization Events

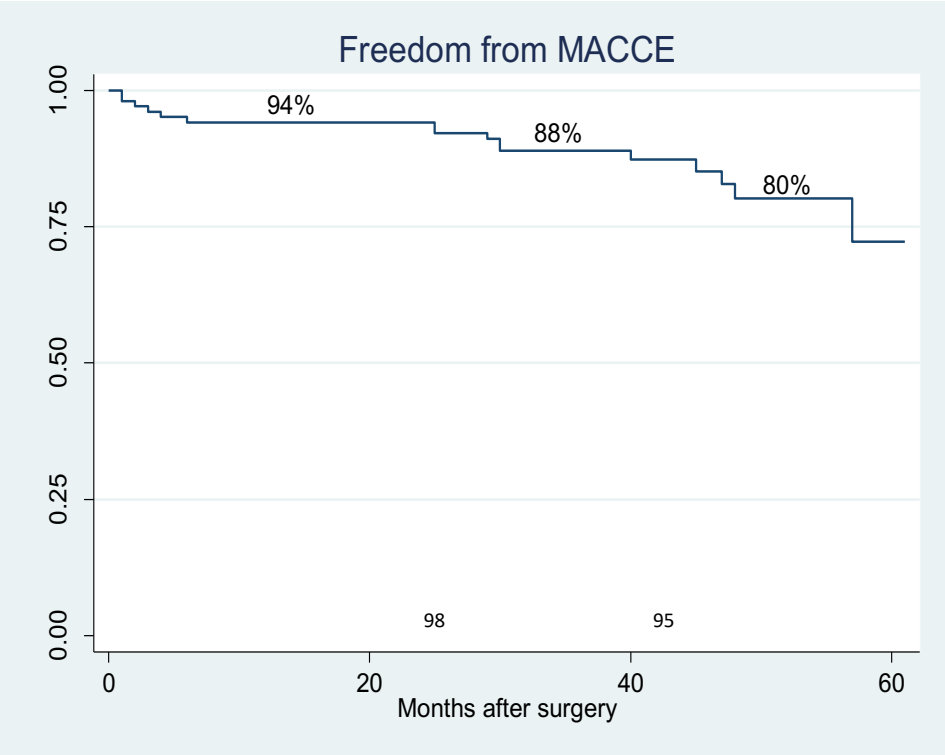
Repeated Revascularization Events	OPCAB (N = 588)	HCR (N = 147)	*p* Value	
All repeat revascularization events (%)	22 (3.7)	18 (12.2)	<0.001	
PCI (%)	21 (3.6)	16 (10.9)	<0.001	
CABG (%)	1 (0.2)	2 (1.4)	0.043	
Target vessel revascularization (%)	18 (3.1)	13 (8.8)	0.002	
Progression of native disease (%)	5 (0.9)[a]	7 (4.8)	<0.001	
Lesion in IMA or IMA-LAD (%)	6 (1.0%)	7 (4.8%)	<0.001	*
Occlusion or stenosis of SVG (%)	14 (2.4)	0 (0.0)	0.06	
In-stent restenosis (%)	0 (0.0)	5 (3.4)	<0.001	

* *High rate of LIMA-LAD re-interventions reflects early phase without the performance of completion angiograms*

Halkos et al. Ann Thorac Surg 2011

Hybrid Group. Long-Term Outcomes

Mean follow-up: 3 years (95% complete)



- **Survival** **94%**
- **Repeat Revascularization** **6.5%**
  - *For Stent restenosis* *5.5%*
  - *For SVG failure* *1 %*
- **No re-intervention needed for LIMA-LAD grafts**

3 year follow-up

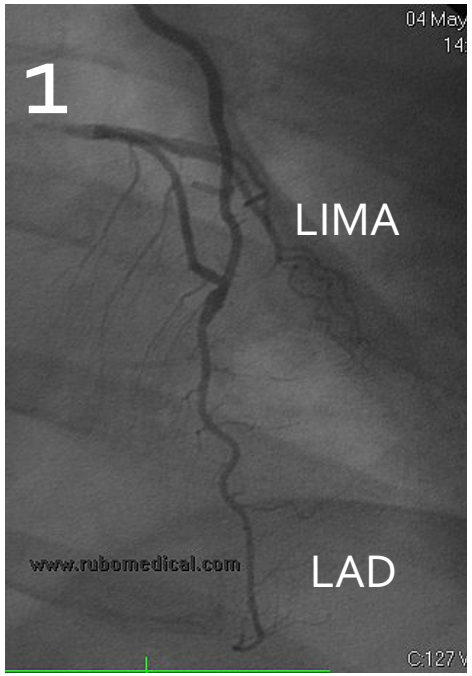
Syntax Trial	
CABG	PCI
92%	90%
11%	20%

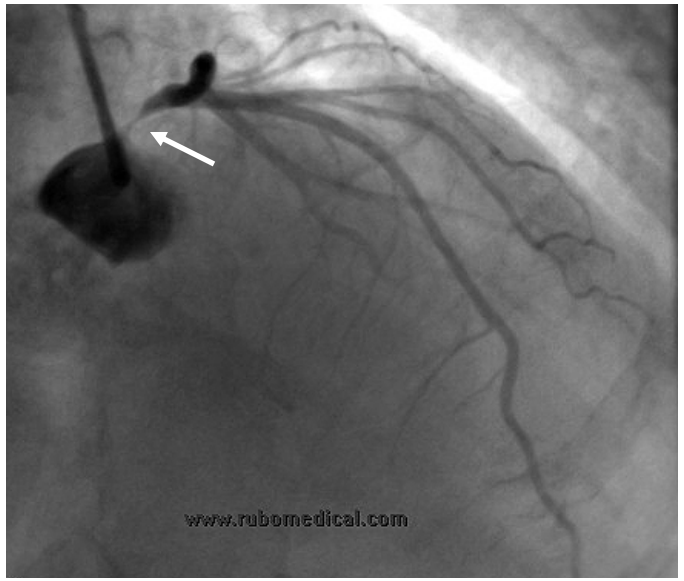
Mean Syntax Score

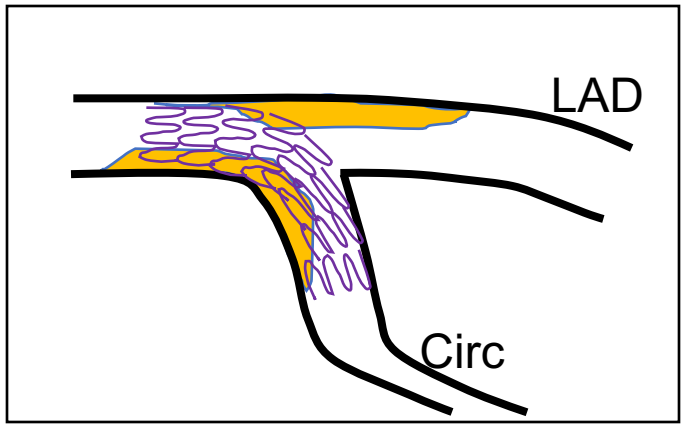
29	28

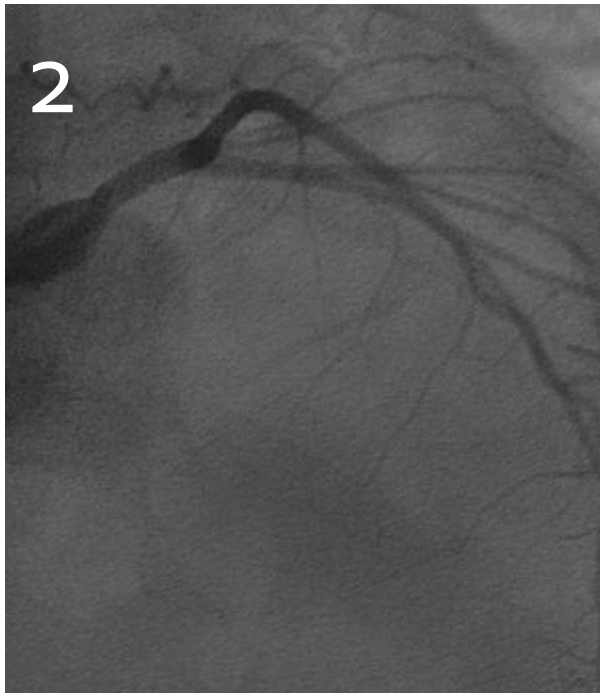
Leacche et al.Vanderbilt University

Hybrid Revascularization (MIDCAB/PCI) for Left Main for high risk CABG









Halkos et al. Ann Thorac Surg 2011

Hybrid Coronary Revascularization (MIDCAB/PCI) vs. Op CAB for Left Main CAD

LIMA-LAD minimally Invasive + PCI to Left Main

- **Comparable 30 days outcomes (Mortality, Stroke, MI, ICU and Hospital Stay)**
- **Fewer blood Tx for the HCR group**

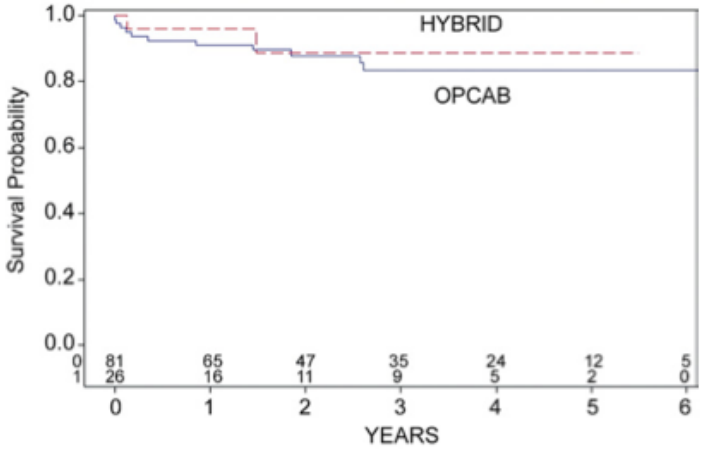


Fig 5. Estimated 5-year survival was similar after off-pump coronary artery bypass grafting (OPCAB; 83.4%) versus hybrid coronary revascularization (HYBRID; 88.6%; p = 0.55).

Table 6. Repeat Revascularization

Repeat Revascularization	OPCAB (n = 81)	HCR (n = 27)	*p* Value
All repeat revascularization events (%)	1 (1.2)	2 (7.4)	0.09
Target vessel revascularization (%)	1 (1.2)	1 (3.7)	0.41
Progression of native disease (%)	0 (0.0)	1 (3.7)	0.08
Occlusion or stenosis of SVG (%)	1 (1.2)	0 (0.0)	0.56
In-stent restenosis (%)	0 (0.0)	1 (3.7)	0.08

HCR = hybrid coronary revascularization; OPCAB = off-pump coronary artery bypass; SVG = saphenous vein graft.

Halkos et al. Ann Thorac Surg 2011

TABLE 3 Procedure and Procedure Staging

	HCR (n = 200)	PCI With DES (n = 98)
Surgical approach to LITA-LAD grafting		
Robotic MIDCAB (robotic ITA harvest with direct anastomosis)	108 (54)	
Robotic TECAB (robot used for ITA harvest and anastomosis)	42 (21)	
MIDCAB (small left thoracotomy with direct ITA harvest and anastomosis)	38 (19)	
Sternotomy (planned)	12 (6)	
Cardiopulmonary bypass used	32 (16)	
Hybrid procedures: staging of surgery and initial PCI		
Surgery followed by PCI	110 (55.0)	2 (2.0)
PCI followed by surgery	43 (21.5)	0 (0.0)
Simultaneous surgery and PCI	24 (12.0)	0 (0.0)
Surgery only	16 (8.0)	0 (0.0)
Surgery and PCI completed on same day (order unknown)	7 (3.5)	0 (0.0)
PCI-only procedure staging		
Single PCI procedure	0 (0.0)	63 (64.3)
2 PCI procedures	0 (0.0)	30 (30.6)
3 PCI procedures	0 (0.0)	3 (3.1)

Values are n (%).

ITA = internal thoracic artery; LITA = left internal thoracic artery; MIDCAB = minimally invasive direct coronary artery bypass; TECAB = totally endoscopic coronary artery bypass; other abbreviations as in Table 1.

Hybrid Revascularization
HCR vs PCI

Relatively Low-risk population

- Good EF
- 3 VD (38%)
- Syntax Score 18
- No BMI > 40
- No Recent ACS

LIMA Harvesting + Operation

- Robotic LIMA + Open anastomosis 54%
- Robotic LIMA + endo-anastomosis TECAB) 21%
- Traditional MID CAB 19%

Sequence

- Surgery first, then PCI 55%
- PCI, then Surgery 21%
- Simultaneous 12%
- Unknown 12%

Staged Hybrid: ¾ of all cases

Puskas et al. JACC 2016

HCR vs. Multi vessel PCI

TABLE 4 Incidence of MACCE at 30 Days, 12 Months, and Through End of Study

	HCR (n = 200)		PCI With DES (n = 98)		
	n	Incidence Rate Per Person-Year	n	Incidence Rate Per Person-Year	HR (95% CI)
MACCE incidence at 30 days					
Any MACCE	6	0.393	2	0.264	2.658 (0.839-8.421)
Death	1	0.064	0	0.000	
Myocardial infarction	3	0.195	1	0.131	
Stroke	0	0.000	0	0.000	
Revascularization	4	0.260	1	0.131	
MACCE incidence at 12 months					
Any MACCE	23	0.143	10	0.119	1.063 (0.666-1.697)
Death	3	0.017	1	0.011	
Myocardial infarction	4	0.024	3	0.034	
Stroke	5	0.030	0	0.000	
Revascularization	14	0.085	8	0.094	
MACCE incidence through end of study					
Any MACCE	23	0.103	12	0.103	0.868 (0.556-1.355)
Death	3	0.012	2	0.016	
Myocardial infarction	4	0.017	3	0.024	
Stroke	5	0.021	0	0.000	
Revascularization	14	0.061	10	0.084	

CI = confidence interval; HR = hazard ratio; MACCE = major adverse cardiac and cerebrovascular events; other abbreviations as in Table 1.

- NIH funded
- Retrospective
- Propensity Matched
- Multicenter
- Syntax score : 18
- 1 Year follow-up
- **Comparable results**

Towards the end of the study, PCI adverse Outcomes started to increase

Puskas et al. JACC 2016

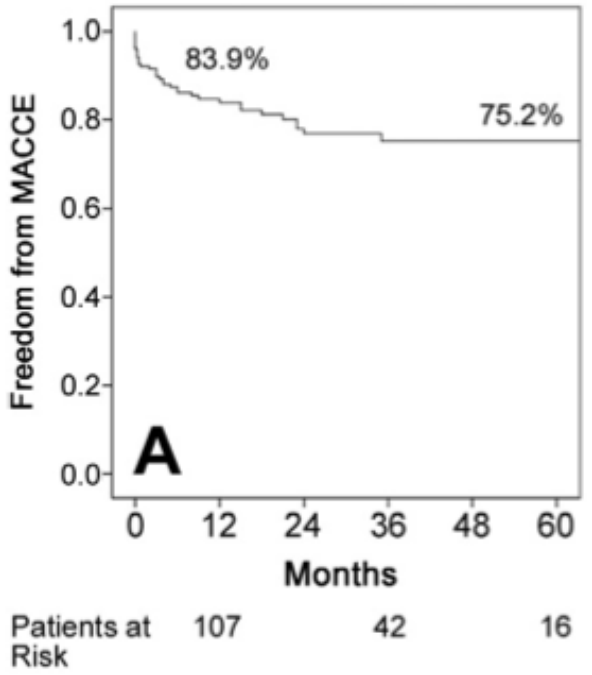
TE CAB and Hybrid Revascularization

Robotic Totally Endoscopic LIMA-LAD + PCI to non LAD vessels

- **Most CABG performed on pump on arrested heart**
- **Most hybrid procedures performed staged**

Table 3. Postoperative Results

Variable	Total (n = 226)	Hybrid (n = 140)	Converted (n = 22)	Wait and See (n = 64)	*p* Value
Revision bleeding	8 (3.5%)	5 (3.6%)	2 (9.5%)	1 (1.5%)	0.227
IABP	2 (0.9%)	0 (0.0%)	0 (0.0%)	2 (3.1%)	0.078
AFib	39 (17.3%)	24 (17.1%)	5 (22.7%)	10 (15.6%)	0.748
Ventilation time (h)	9 (0–349)	9 (0–85)	14 (4–288)	9 (0–349)	0.003
Pneumonia	8 (3.5%)	3 (2.1%)	2 (9.1%)	3 (4.7%)	0.220
Stroke	2 (0.9%)	1 (0.7%)	0 (0.0%)	1 (1.6%)	0.749
CVVH	3 (1.3%)	0 (0.0%)	1 (4.5%)	2 (3.1%)	0.074
Mortality	3 (1.3%)	0 (0.0%)	1 (4.8%)	2 (3.1%)	0.071
ICU stay (h)	22 (13–1048)	22 (13–250)	42 (16–384)	21 (16–1048)	0.064
Hospital stay (days)	6 (3–54)	6 (3–49)	8 (6–22)	6 (3–54)	0.002
Time to walking outside (days)	7 (1–90)	7 (1–90)	14 (2–60)	7 (1–90)	0.258
Time to household work (days)	15 (2–180)	14 (3–180)	21 (10–120)	14 (2–168)	0.082
Time to all activities (days)	42 (0–720)	42 (0–720)	75 (21–359)	42 (7–360)	0.180



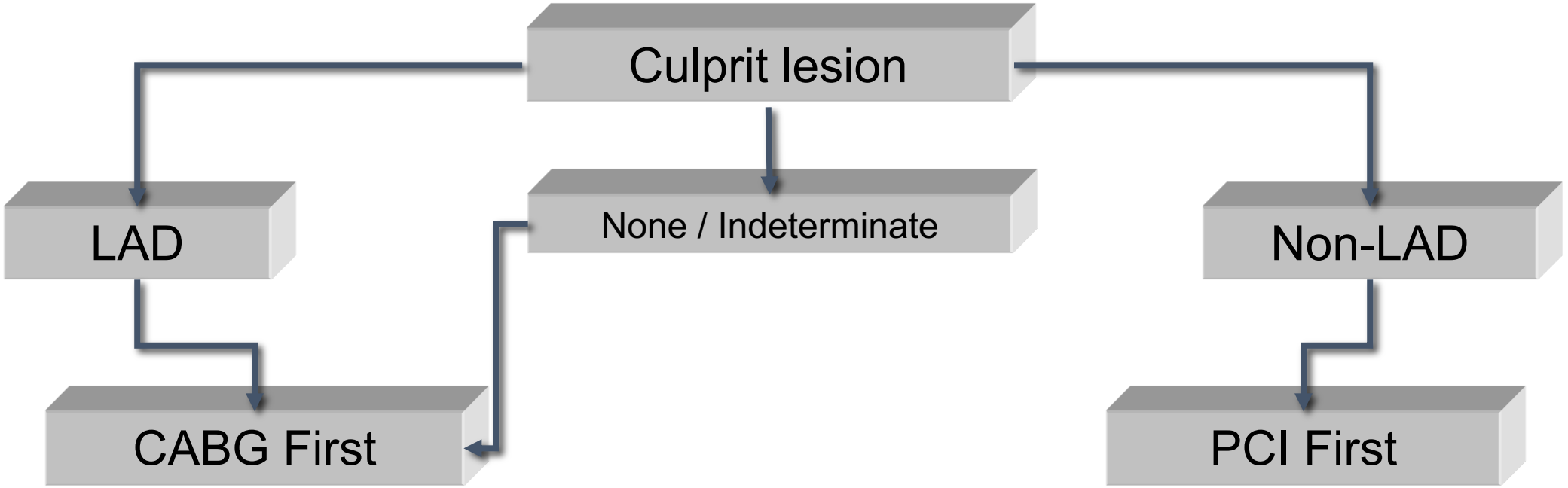
Bonatti et al. Ann Thorac Surg 2012

Sequence of Hybrid Revascularization

- **Simultaneous**
  - Vanderbilt approach in the Hybrid OR
- **Staged** (separated by a few days to months).
  - It is easier to schedule.
  - It might have a financial benefit.

  - **CABG first**
    - **Surgery performed without Plavix, Effient or Brillinta**
    - **At the time of PCI, LIMA to LAD arteriogram**

  - **PCI first**
    - **Antiplatelet bridging needed (Cangrelor) at the time of CABG**
    - **Only recommended if non-LAD lesions are critical or culprit ACS**



Performed during the same hospitalization approximately 48 hrs apart

Anti-coagulation/anti-platelet strategy for Staged Hybrid Procedure, surgery first**

- Aspirin (81mg) prior to procedure
- Routine heparin during MICS CABG procedure
- Full reversal with protamine
- Daily aspirin (81mg) and clopidogrel (75mg)
- 24 hour recovery
- Load with clopidogrel (600mg)
- Routine heparin or bivalirudin
- Perform PCI
- Daily aspirin (81mg) and clopidogrel (75mg)

* *Procedural guidelines developed by clinicians at Emory University, Atlanta, GA. Applicable to patients of average height and weight.

Anti-coagulation/anti-platelet strategy for Simultaneous Hybrid Procedure***

- Aspirin (81mg) and clopidogrel load (300-600mg) prior to procedure
- Routine heparin during MICS CABG procedure
- Do not reverse heparin
- Perform PCI
- Give half-dose protamine (if bleeding concerns)
- Give clopidogrel 75 mg daily dose starting at 12hrs postop.

*** Procedural guidelines developed by clinicians at Vanderbilt Heart Institute, Nashville, TN. Applicable to patients of average height and weight.

3.11. Hybrid Coronary Revascularization: Recommendations

CLASS IIa

1. Hybrid coronary revascularization (defined as the planned combination of LIMA-to-LAD artery grafting and PCI of ≥1 non-LAD coronary arteries) is reasonable in patients with 1 or more of the following (508–516) *(Level of Evidence: B)*:
   a. Limitations to traditional CABG, such as heavily calcified proximal aorta or poor target vessels for CABG (but amenable to PCI);
   b. Lack of suitable graft conduits;
   c. Unfavorable LAD artery for PCI (i.e., excessive vessel tortuosity or chronic total occlusion).

CLASS IIb

1. Hybrid coronary revascularization (defined as the planned combination of LIMA-to-LAD artery grafting and PCI of ≥1 non-LAD coronary arteries) may be reasonable as an alternative to multivessel PCI or CABG in an attempt to improve the overall risk–benefit ratio of the procedures. *(Level of Evidence: C)*

AHA/ACC and European Guidelines For Hybrid Coronary Revascularization

IIa. Should be considered

IIb. May be considered

2018 ESC/EACTS Guidelines on myocardial revascularization

Where expertise exists, minimally invasive CABG through limited thoracic access should be considered in patients with isolated LAD lesions or in the context of hybrid revascularization.[143,534,535,561]	IIa	B
Hybrid procedures, defined as consecutive or combined surgical and percutaneous revascularization, may be considered in specific patient subsets at experienced centres.[536,561–563]	IIb	B

Conclusions

- **Hybrid Revascularization Procedures are safe and effective**
- **Represent a reasonable alternative for patients with multivessel CAD, with particular benefits for those with complex disease**
- **If the surgical component (LIMA-LAD) can be performed minimally invasive adds a great value to the Hybrid approach**
- **A completion angiogram is recommended in these cases**

Teamwork and Collaboration

Thank You

Stony Brook Heart Institute