# *Hybrid Coronary Revascularization: An Evolving Paradigm*

## *From Meta-analysis to the NIH Multicenter Observational and Randomized Studies*


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# Disclosure

Royalty Payments from surgical instruments invented by the author and manufactured/marketed by Scanlan, Inc (Minneapolis MN).

Most important “conflict” of interest: I am a cardiac surgeon with a special interest in ischemic heart disease. I am also a relentless, evidence-based patient advocate.

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# Anatomic and Clinical Eligibility for HCR

1. Proximal (complex) or ostial LAD lesion with distal LAD amenable to LIMA-LAD bypass grafting, esp by minimally invasive techniques
2. Non-LAD lesion(s) amenable to PCI; esp Type A focal lesions
3. No contraindications to dual antiplatelet therapy
4. Complex distal LM lesions if the ostial LCx artery is amenable to PCI

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# Standardizing definitions for hybrid coronary revascularization

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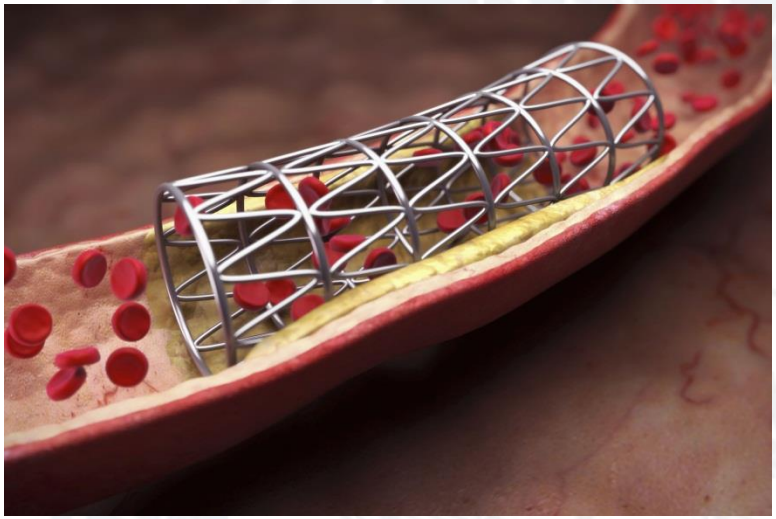
The Journal of Thoracic and Cardiovascular Surgery • February 2014

**TABLE 1. Currently used definitions for hybrid coronary revascularization**

| Guideline/registry | Definition |
|---|---|
| 2011 ACCF/AHA/SCAI Guidelines for PCI; 2011 ACCF/AHA Guidelines for CABG[11,12] | The planned combination of LITA-LAD artery grafting and PCI of ≥1 non-LAD coronary arteries. Hybrid coronary revascularization may be performed in a hybrid suite in a single operative setting or as a staged procedure (PCI and CABG performed in 2 different operative suites, separated by hours to 2 d, but typically during the same hospital stay). |
| 2010 ESC/EACTS Guidelines on Myocardial Revascularization[10] | Planned, intentional combination of CABG, with a catheter-based intervention to other coronary arteries during the same hospital stay. Procedures can be performed consecutively in a hybrid operating room or sequentially on separate occasions in the conventional surgical and PCI environments. |
| STS Adult Cardiac Registry National Database (version 2.73)[9] | A *hybrid procedure* is defined as a procedure that combines surgical and transcatheter interventional approaches: (1) planned, concurrent is performed in same setting; (2) planned, staged is performed in the same hospital admission; (3) unplanned is performed after incomplete revascularization or graft closure during the same hospital admission. |
| NCDR CathPCI Registry (version 4.4)[13] | Hybrid therapy occurs when both surgical and percutaneous coronary revascularization are planned, with different lesions treated with the different techniques. |
| Clinicaltrials.gov (definitions by registered studies) | Minimal invasive LITA-to-LAD and PCI of non-LAD lesions. Procedures can be performed either in the same operating suite or during the same hospitalization |

# Hybrid Coronary Revascularization:

*Planned combination of surgical and percutaneous techniques in two different coronary territories, both scheduled and performed within a predefined time period in a patient with multi-vessel coronary artery disease*

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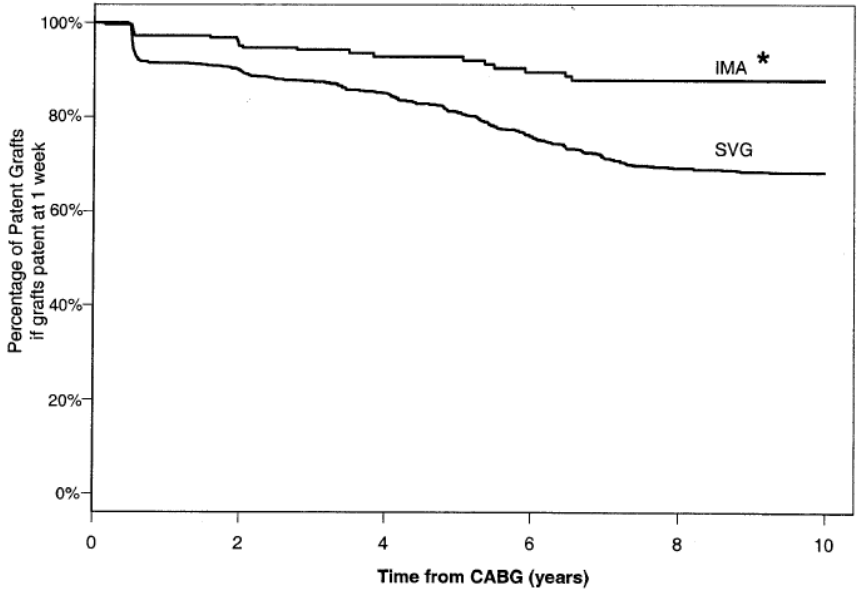
Journal of the American College of Cardiology
© 2004 by the American College of Cardiology Foundation
Published by Elsevier Inc.

Vol. 44, No. 11, 2004
ISSN 0735-1097/04/$30.00
doi:10.1016/j.jacc.2004.08.064

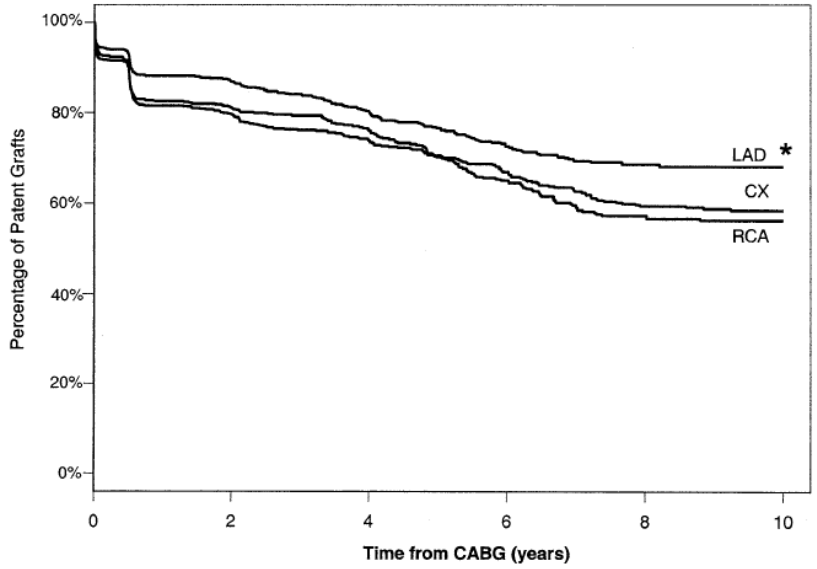
# Long-Term Patency of Saphenous Vein and Left Internal Mammary Artery Grafts After Coronary Artery Bypass Surgery

## Results From a Department of Veterans Affairs Cooperative Study




| 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).



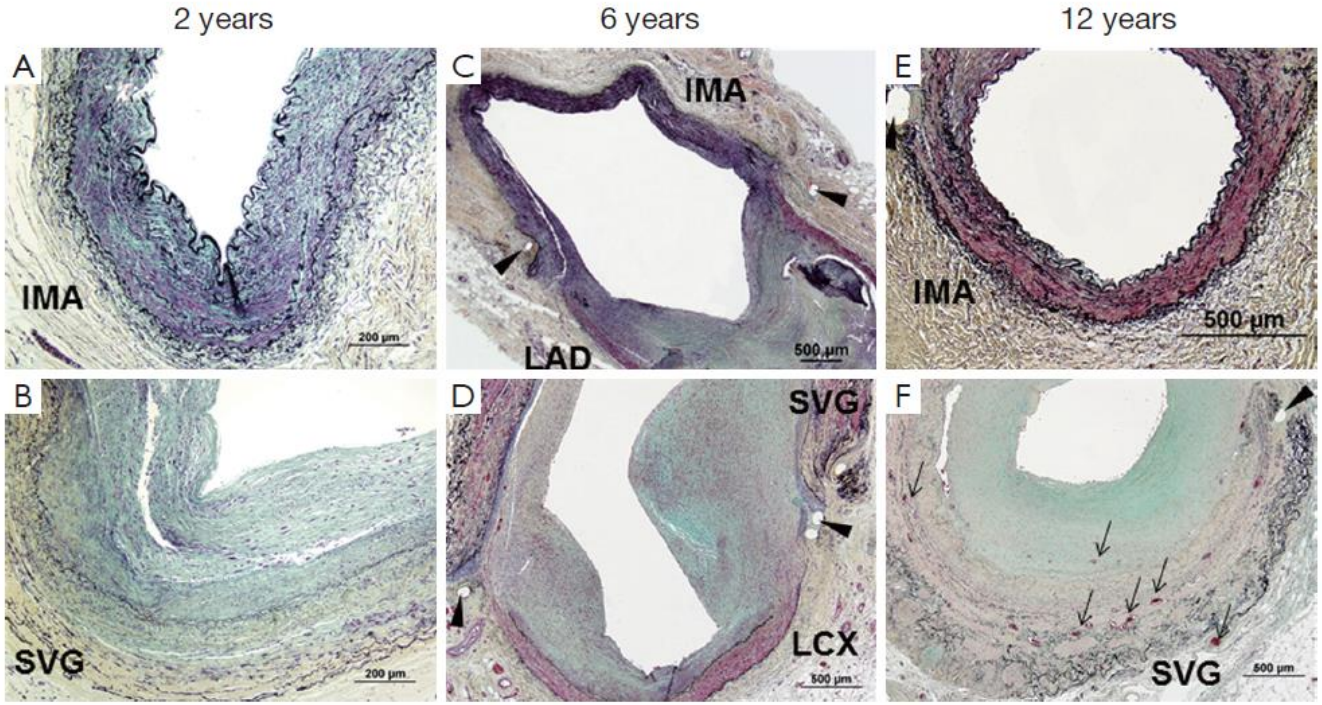

| Time | 1 Week | 1 Year | 3 Years | 6 Years | 10 Years |
|---|---|---|---|---|---|
| # Patients | 915 | 652 | 426 | 259 | 75 |

**Figure 3.** Plot of time-related graft patency (or freedom from graft occlusion) for saphenous vein grafts (SVG) to the left anterior descending (LAD), circumflex (CX), and right coronary (RCA) arteries. The number of patients at each time point is listed in the figure. *$p < 0.001$ (LAD vs. CX and/or RCA). CABG = coronary artery bypass grafting.

# Why is the mammary artery so special and what protects it from atherosclerosis?

Fumiyuki Otsuka, Kazuyuki Yahagi, Kenichi Sakakura, Renu Virmani

*Ann Cardiothorac Surg* 2013;2(4):519-526

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# SVG graft patency for non-LAD targets

| | YEAR | n | SVG imaged (SVG occluded) at 12 m | SVG occlusion rate % |
|---|---|---|---|---|
| Puskas et al | 2004 | 153 | 306 (10) | 3.2 |
| Alexander et al | 2005 | 1920 | 4537 (500) | 11 |
| Sabik et al | 2005 | 4333 | 8733 (1621) | 18 |
| Cho et al | 2007 | 833 | 218 (40) | 13 |
| Desai et al | 2007 | 440 | 440 (60) | 13.6 |
| Kim et al | 2008 | 240 | 121 (11) | 9.9 |
| | | | 14355 (2242) | 11.45 |

# DES stents patency for non-LAD target

| | YEAR | n | Restenosis > 50% 6-12 m | Stent thrombosis |
|---|---|---|---|---|
| Silber et al TAXUS II | 2009 | 536 | 2.4 | 0.1 |
| Meredith et al ENDEAVOR I | 2009 | 100 | 5.4 | 1 |
| Fajadet et al ENDEAVOR II | 2010 | 1197 | 9.4 | 0.5 |
| Kandzari et al ENDEAVOR III | 2011 | 436 | 9.2 | 0 |
| Serruys et al SPIRIT I | 2005 | 60 | 0 | 0 |
| Serruys et al SPIRIT II | 2006 | 300 | 2.1 | 0.9 |
| Stone et al SPIRIT III | 2008 | 1002 | 2.3 | 0.8 |
| Average | | | 4.39 | 0.47 |

| ONE STAGE (SIMULTANEOUS) | TWO-STAGE HCR | |
|---|---|---|
| **MID-CAB followed by PCI within minutes** | **MID-CAB 1st, then PCI** | **PCI 1st, then MID-CAB** |
| Advantages<br>• LIMA-LAD graft can be studied by the interventional cardiologist before PCI stent implantation<br>• PCI to high-risk non-LAD lesions can be performed with a protected LAD area<br>• In cases of unsuccessful stent implantation, conventional CABG remains an option<br>• Cost effective, as it reduces hospital length of stay (single-step complete revascularization)<br>• Patient satisfaction: condenses revascularization therapy in one patient encounter | Advantages<br>• Allows angiographic validation of the LIMA-LAD graft<br>• Full antiplatelet inhibition following CABG with no perioperative bleeding risk<br>• Protected anterior wall, lowering procedural risks during PCI of non-LAD vessels<br>• On some occasions, after minimally invasive LIMA to LAD, patients become asymptomatic in the immediate post-operative period | Advantages<br>• Allows angiographic evaluation of the size of LIMA<br>• Lower risk of ischemia during the MID-CAB in a partially revascularized heart<br>• Useful in the setting of acute myocardial infarction when culprit is a non-LAD lesion<br>• In cases of unsuccessful stent implantation, suboptimal CABG can be performed |
| Disadvantages<br>• Only feasible in hybrid suites, featuring state-of-the-art surgical and interventional equipment<br>• Inflammatory response to surgery offers a risk for stent thrombosis<br>• Dual antiplatelet therapy increases the risk of bleeding<br>• Chronic kidney disease patients are exposed to the dual nephrotoxic insult of surgery and contrast media utilization | Disadvantages<br>• Risk of ischemia of non-LAD territories during the LIMA-LAD grafting (although this is very unlikely in stable patients)<br>• Risk of a high-risk surgical reintervention in case of an unsuccessful PCI | Disadvantages<br>• No angiographic control of LIMA-LAD graft<br>• Higher risk of stent thrombosis during surgery (due to inflammatory response to surgery/discontinuation of dual antiplatelet therapy/platelet transfusion)<br>• Increased perioperative bleeding risk due to dual antiplatelet therapy during surgery<br>• Risk of adverse events in the LAD territory during the between-stages interval |

Panoulas, V.F. et al. J Am Coll Cardiol. 2015; 65(1):85–97.

# Case Presentation:
## 2-Vessel CAD Including Proximal LAD Stenosis

- 58 yo male Jehovah's Witness
  (refusing any blood transfusion)

- PMH:
  - testicular cancer s/p resection and chemoRx
  - HTN, HLD

- Presenting with unstable angina for 2 weeks

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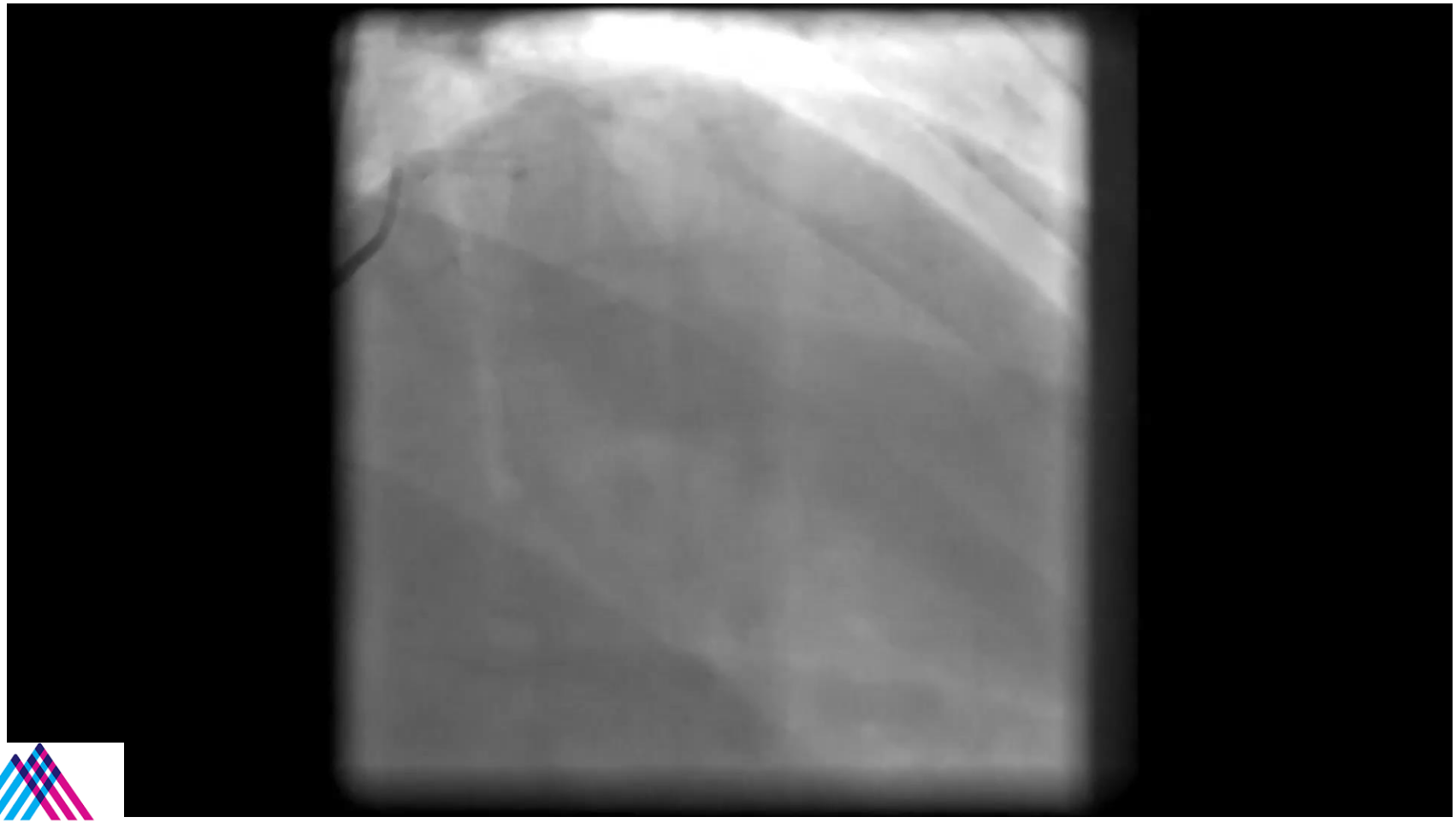
# Preop Coronary Angiography:

## 2VD Including Proximal LAD Stenosis



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# HCR OR Set Up


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# HCR: Robot Set Up

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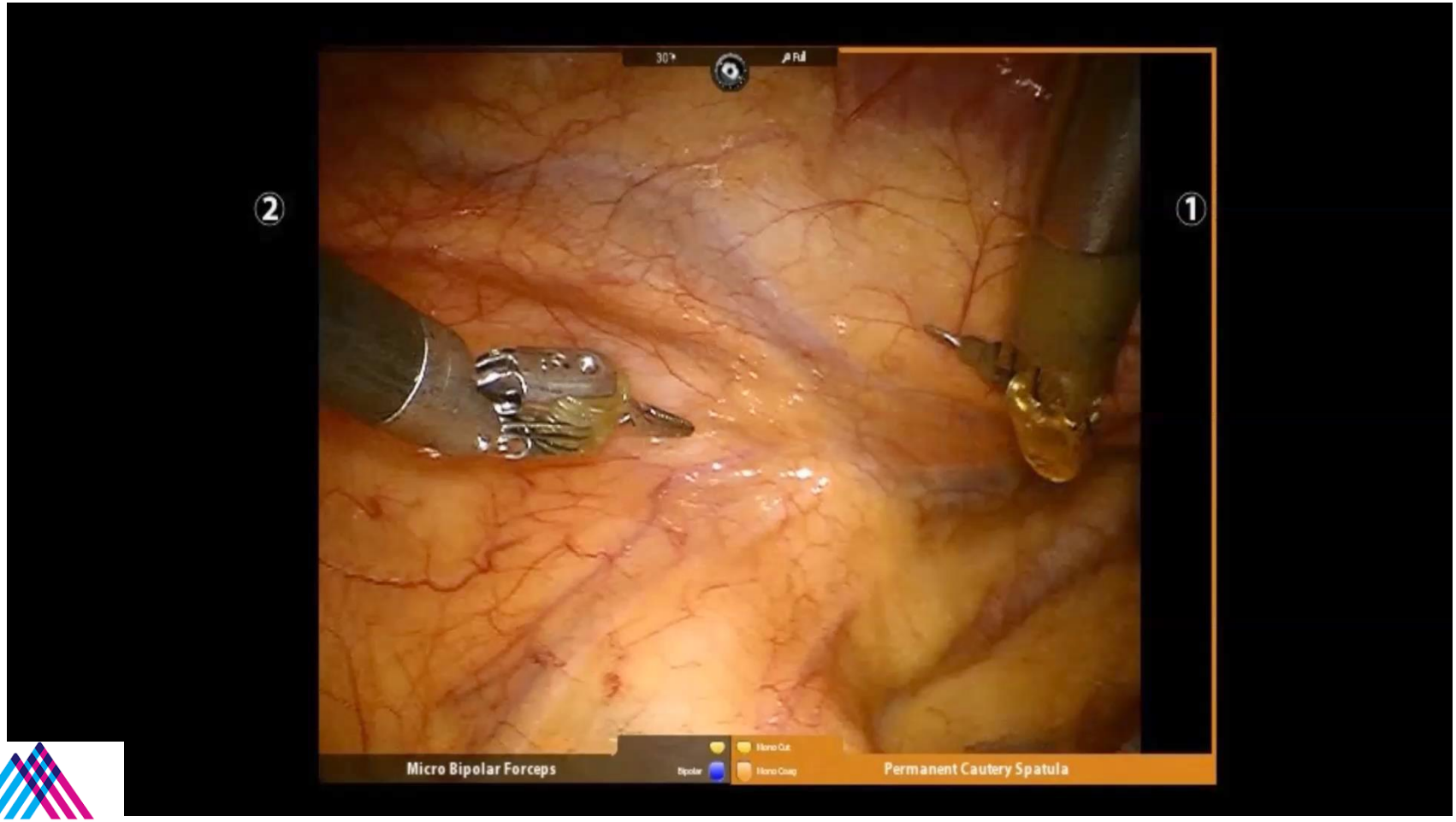
# HCR: Robotic LIMA Harvest

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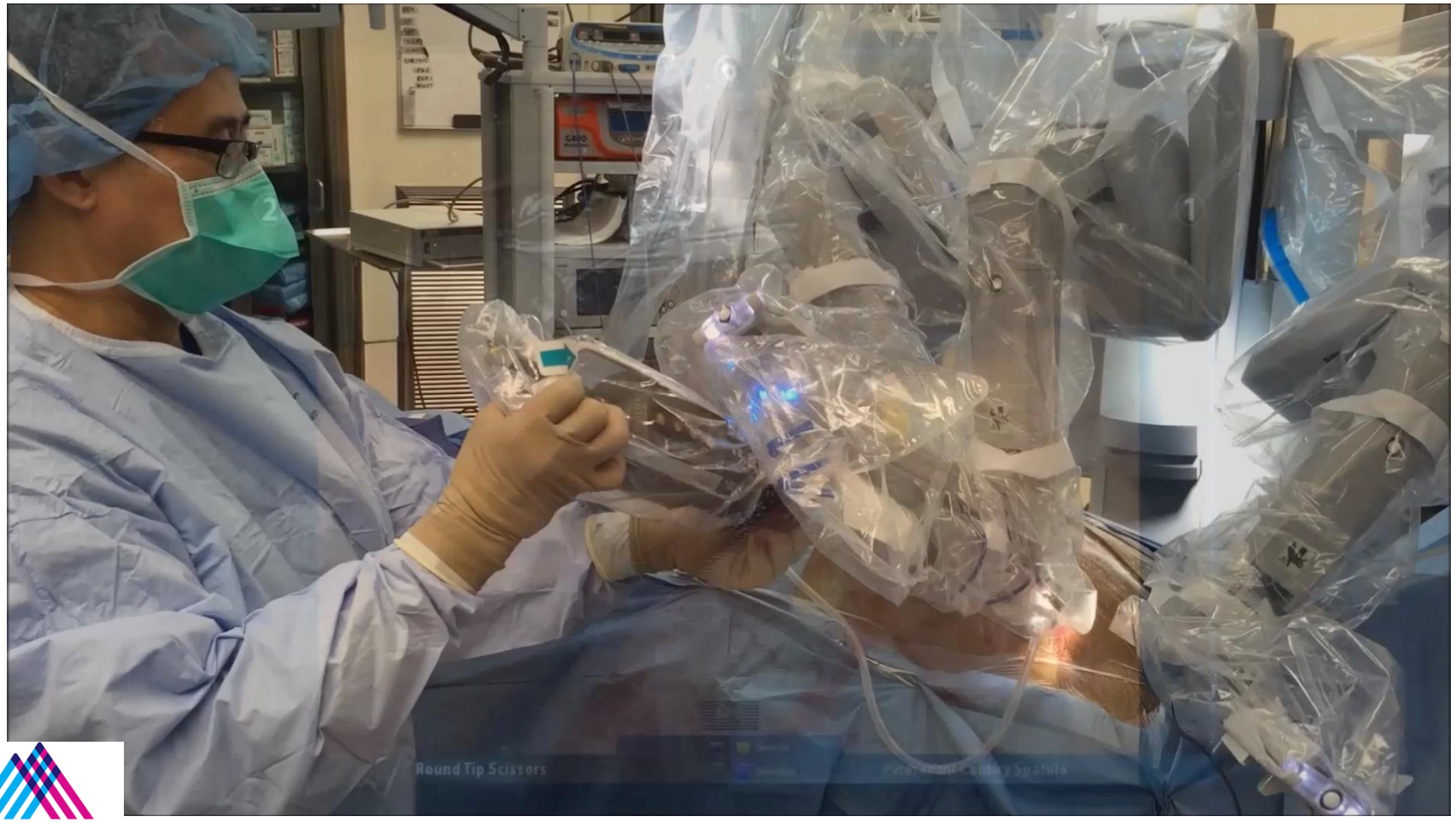
# HCR (1st Stage): LIMA to LAD Anastomosis

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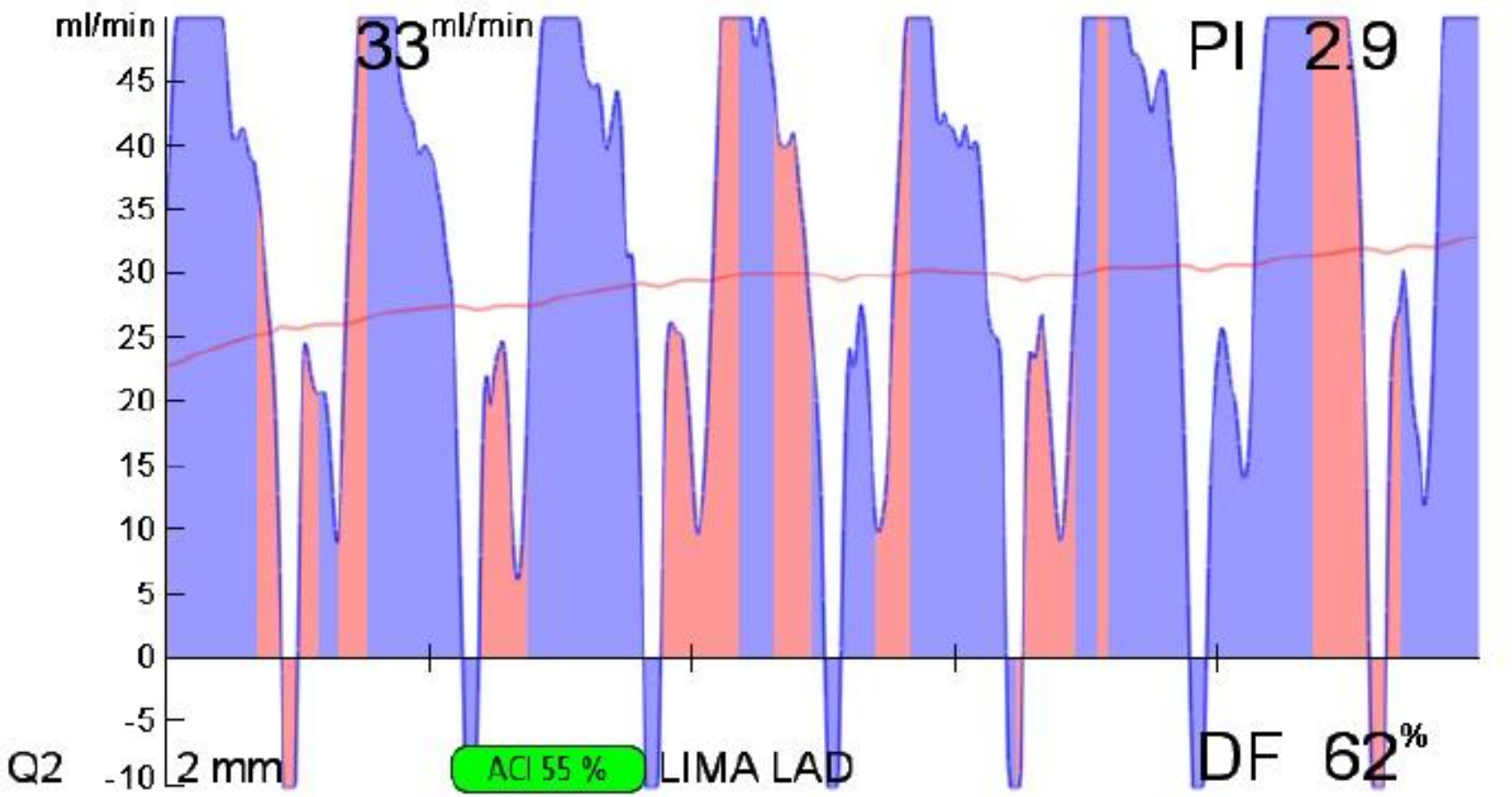
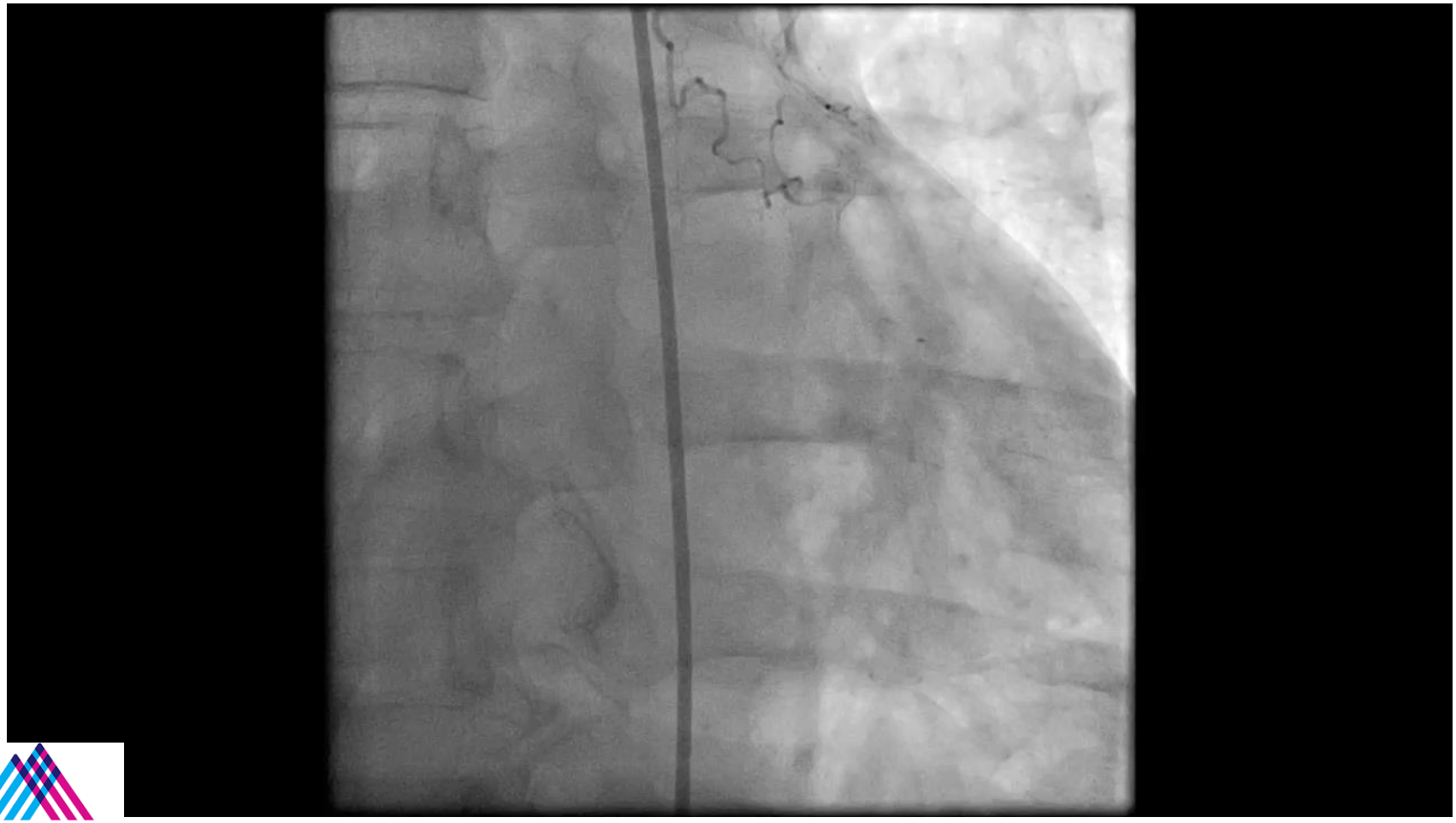
# HCR: LIMA to LAD Flow Measurement

## (Transit Time Doppler)



# HCR (2nd Stage): LIMA Angiography and RCA stent



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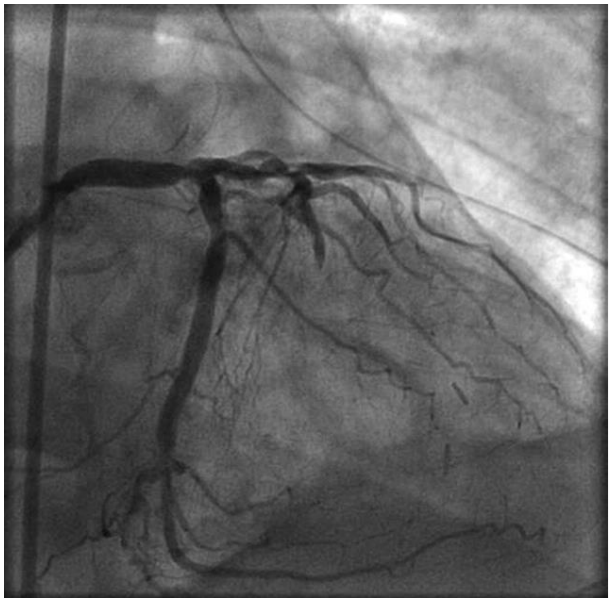
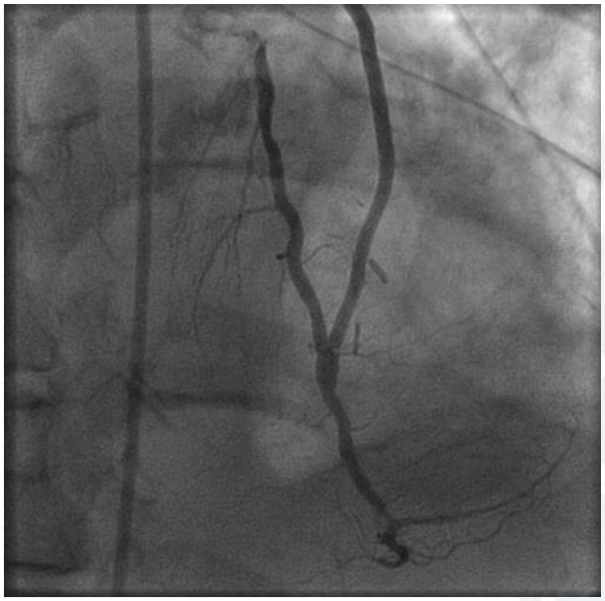
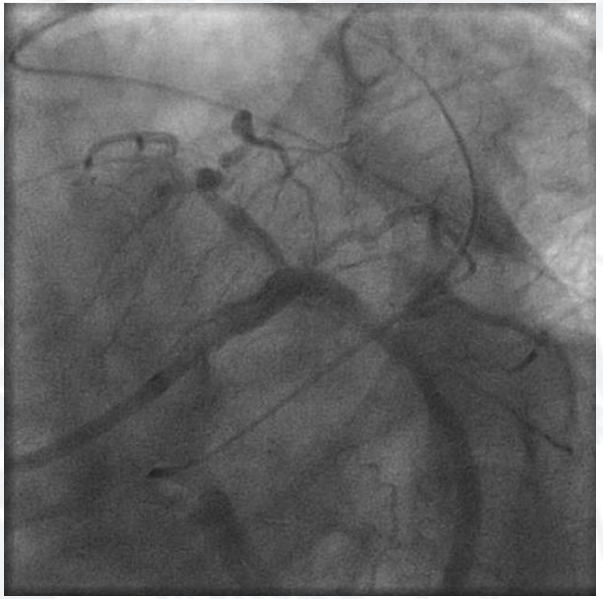
# Hybrid Coronary Revascularization Versus Off-Pump Coronary Artery Bypass for the Treatment of Left Main Coronary Stenosis

Michael E. Halkos, MD, S. Tanveer Rab, MD, Thomas A. Vassiliades, MD, MBA, Douglas C. Morris, MD, John S. Douglas, MD, Patrick D. Kilgo, MS, Henry A. Liberman, MD, Robert A. Guyton, MD, Vinod H. Thourani, MD, and John D. Puskas, MD

(Ann Thorac Surg 2011;92:2155–60)







# Hybrid Coronary Revascularization Versus Off-Pump Coronary Artery Bypass for the Treatment of Left Main Coronary Stenosis

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| In-Hospital Outcomes | OPCAB (n = 81) | HCR (n = 27) | *p* Value |
|---|---|---|---|
| No. with blood transfusion (%) | 50 (61.7) | 9 (33.3) | 0.01 |
| Renal failure (%) | 2 (2.5) | 1 (3.7) | 0.74 |
| Hospital LOS (days, mean ± SD) | 6.6 ± 5.6 | 5.6 ± 2.0 | 0.19 |
| Postoperative atrial fibrillation (%) | 19 (23.5) | 5 (19.2) | 0.65 |
| Ventilator hours (mean ± SD) | 32.8 ± 96.3 | 6.9 ± 7.9 | 0.022 |
| ICU LOS (days, mean ± SD) | 64.3 ± 120.3 | 36.4 ± 29.8 | 0.058 |

HCR = hybrid coronary revascularization; ICU = intensive care unit; LOS = length of stay; OPCAB = off-pump coronary artery bypass grafting; SD = standard deviation.

| 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.

**TABLE 1** HCR Registries Published Since 2008

| First Author, Year (Ref. #) | Registry Recruitment | HCR/Total Assessed (N = 998)* | Age, yrs | Male, % | Diabetes, % | LVEF, % | ACS, % | Timing | SYNTAX Score | Risk Score | Surgical Technique | Conversion to Open | Angiographic Type/Location of PCI Lesions | DES/BMS | Type of DES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Adams et al., 2013 (37) | 2004–2012 | 94-96 | 64 ± 12 | 72.9 | N/A | N/A | 38 (UA) | 1-stop | N/A | N/A | MIDCAB Da Vinci-OP | 2 | N/A | 95/10 stents | 91 PES 3 SES 1 ZES |
| Halkos et al., 2013 (33) | 2003–2012 | 269-300 | 64.12 ± 12.1 | 68.3 | 36.7 | 54.7 ± 69.2 | 34 (MI) | 21 1-stop 192 CABG 1st 56 PCI 1st | | 1.6 ± 2.1 (S) | <2,009 Endo-ACAB >2,009 MIDCAB Da Vinci-OP | 6 | N/A | 232/28 patients 28 DES + BMS 4 POBA 3 Unknown | N/A |
| Repossini et al., 2013 (43) | 2004–2011 | 166 | 65.8 ± 10.3 | 90.4 | 24.1 | 9.6 (EF <30%) | 58.4 | 60 CABG 1st 106 PCI 1st | 29.3 ± 7.37 | 3.49 ± 4.77 (EII) 4.69 ± 3.77 (S) | MIDCAB-OP | 4 | N/A | 57/109 patients | N/A |
| Bonatti et al., 2012 (35) | N/A | 140-162 | 61 (31–85) | 79.3 | 28.6 | 60 (20–79) | 43.6 (MI) | 28 1-stop 74 CABG 1st 38 PCI 1st | N/A | 2 (0–13) (Add E) 0.5 (0.2–9.9) (S) | Robotic TECAB On & off pump | 22 | N/A | 98/34 patients 5 patients POBA 3 patients aspiration | N/A |
| Rab et al., 2012 (57) | N/A | 22 | 61.0 ± 13.7 | 59.1 | 27.3 | 54.8 ± 8.8 | N/A | 22 CABG 1st | 22.3 ± 10.0 | 1.6 ± 1.9 (S) | MIDCAB Da Vinci-OP | NA | N/A | 21/1 patients | N/A |
| Bonaros et al., 2011 (61) | 2001–2009 | 130 | 58 (41–75) | 77 | N/A | N/A | N/A | 21 1-stop 97 CABG 1st 12 PCI 1st | N/A | NA | OP MIDCAB (3) AH-TECAB (96) BH-TECAB (31) | 13 | N/A | N/A | N/A |
| Holzhey et al., 2008 (44) | 1996–2007 | 117 | 64.6 ± 12.3 | 83.8 | 24.8 | 59.2 ± 13.1 | 4.3 (UA) | 5 1-stop 59 CABG 1st 53 PCI 1st | N/A | 4.3 (Log E) | MIDCAB (107) OP TECAB (8) TECAB (2) | N/A | N/A | N/A | N/A |
| Kiaii et al., 2008 (38) | 2004–2007 | 58-60 | 59.9 ± 11.7 | 78 | 23 | N/A | 17 (MI) | 58 1-stop | N/A | N/A | Endo-ACAB OP | 2 | A/B1: 31 B2/C: 28 | 53/6 stents | 49 PES 3 SES 6 BMS |

Since 1996 multiple single centers' experience for a total of >3000 patients treated with HCR. CABG was performed before PCI in one half of HCR procedures, PCI was performed first in 26% and one stop/combined procedure was the least popular choice (22.8%).

Panoulas, V.F. et al. J Am Coll Cardiol. 2015; 65(1):85–97.

JOURNAL OF THE AMERICAN COLLEGE OF CARDIOLOGY
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VOL. 65, NO. 1, 2015
ISSN 0735-1097/$36.00
http://dx.doi.org/10.1016/j.jacc.2014.04.093

**TABLE 3** Angiographic and Clinical Follow-up Data in Patients in HCR Registries Published Since 2008

| | | | Angiographic Follow-Up | | | | | In-Hospital Outcomes | | | | Clinical Follow-Up | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| First Author, Year (Ref. #) | Registry Recruitment | N | Follow- Up | Patients in Follow-Up, n | % LIMA Patency Fitzgibbon A or B | ISR >50%, % | IST (Occlusion), % | Perioperative Mortality, % | Blood Transfusion, % | ICU LOS | Hospital LOS, Days | Survival, % (Follow-Up Time) | Event-free Survival, % (Follow-Up Time) | % Revascularization (Follow-Up Time) |
| Adams et al., 2013 (37) | 2004–2012 | 94 | 6.8 months | 89 | 94 | 9 | 2.2 (2/89) | 0 | 7.5 | N/A | 4 (3–7) | 100 (1 yr)<br>91 (5 yrs) | 88.8 (6.8 months) | 13 (5 yrs) |
| Halkos et al., 2013 (33) | 2003–2012 | 269 | On day of MIDCAB | 248 | 97.6 | N/A | N/A | N/A | 31.7 | 1 day (0–11 days) | 5 (2–76) | – | – | – |
| Repossini et al., 2013 (43) | 2004–2011 | 166 | On day of MIDCAB | 60 | 100 | N/A | N/A | 1.25 | 27.5 | 22.3 ± 15.8 h | 6.5 ± 1.8 | 95.8 (1 yr)<br>93 (5 yrs) | 93.1 (1 yr)<br>83 (5 yrs) | 7.2 (4.5 yrs) |
| Bonatti et al., 2012 (35) | N/A | 140 | N/A | N/A | N/A | N/A | N/A | 1.3 | N/A | 22 h (13–250 h) | 6 (3–49) | 95.2 (1 yr)<br>92.9 (5 yrs) | 83.9 (1 yr)<br>75.2 (5 yrs) | 16.9 (5 yrs) |
| Rab et al., 2012 (57) | N/A | 22 | 3.8 days | 22 | 100 | N/A | N/A | N/A | 9 | 1.1 ± 0.4 day | 6.1 ± 2.4 | 95.5 (3.2 yrs) | 95.5 (3.2 yrs) | 0 (3.2 yrs) |
| Bonaros et al., 2011 (61) | 2001–2009 | 130 | N/A | N/A | N/A | N/A | N/A | 0.7 | N/A | 20 h (12-1,048 h) | 6 (3–50) | 99 (2 yrs) | 75 (2 yrs) | 8 (2 yrs) |
| Holzhey et al., 2008 (44) | 1996–2007 | 117 | N/A | N/A | N/A | N/A | N/A | 1.9 | N/A | 7.9 h ICU<br>26.5 h intermediate care | N/A | 92.5 (1 yr)<br>84.8 (5 yrs) | 85.5 (1 yr)<br>75.5 (5 yrs) | 4.3 (1.8 yrs) |
| Kiaii et al., 2008 (38) | 2004–2007 | 60 | 20.2 months | 54 | 91 | 13 | 3.7 | 0 | 15 | 1.1 ± 0.43 day | 4.3 ± 1.42 | 100 (20.2 months) | 88.9 (20.2 months) | 7.4 (20.2 months) |

Values are mean ± SD, median (interquartile range), n, or % as indicated.
ICU = intensive care unit; ISR = in-stent restenosis; IST = in-stent thrombosis; LOS = length of stay; other abbreviations as in Tables 1 and 2.

Outcomes with HCR have been excellent, with ICU LOS < 1d and Hospital LOS 4-6d; survival typically >95% at 1-5yrs; event free survival 75-95% at 1-5yrs; 0-17% repeat revascularization at 2-5 yrs.

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PUBLISHED BY ELSEVIER INC.

VOL. 65, NO. 1, 2015
ISSN 0735-1097/$36.00
http://dx.doi.org/10.1016/j.jacc.2014.04.093

Zhu et al. Journal of Cardiothoracic Surgery (2015) 10:63
DOI 10.1186/s13019-015-0262-5

JOURNAL OF CARDIOTHORACIC SURGERY

RESEARCH ARTICLE Open Access

# Hybrid coronary revascularization versus coronary artery bypass grafting for multivessel coronary artery disease: systematic review and meta-analysis

Peng Zhu[1,2,3], Pengyu Zhou[1,2], Yong Sun[1,2,3], Yilong Guo[2], Mingjie Mai[2] and Shaoyi Zheng[2*]

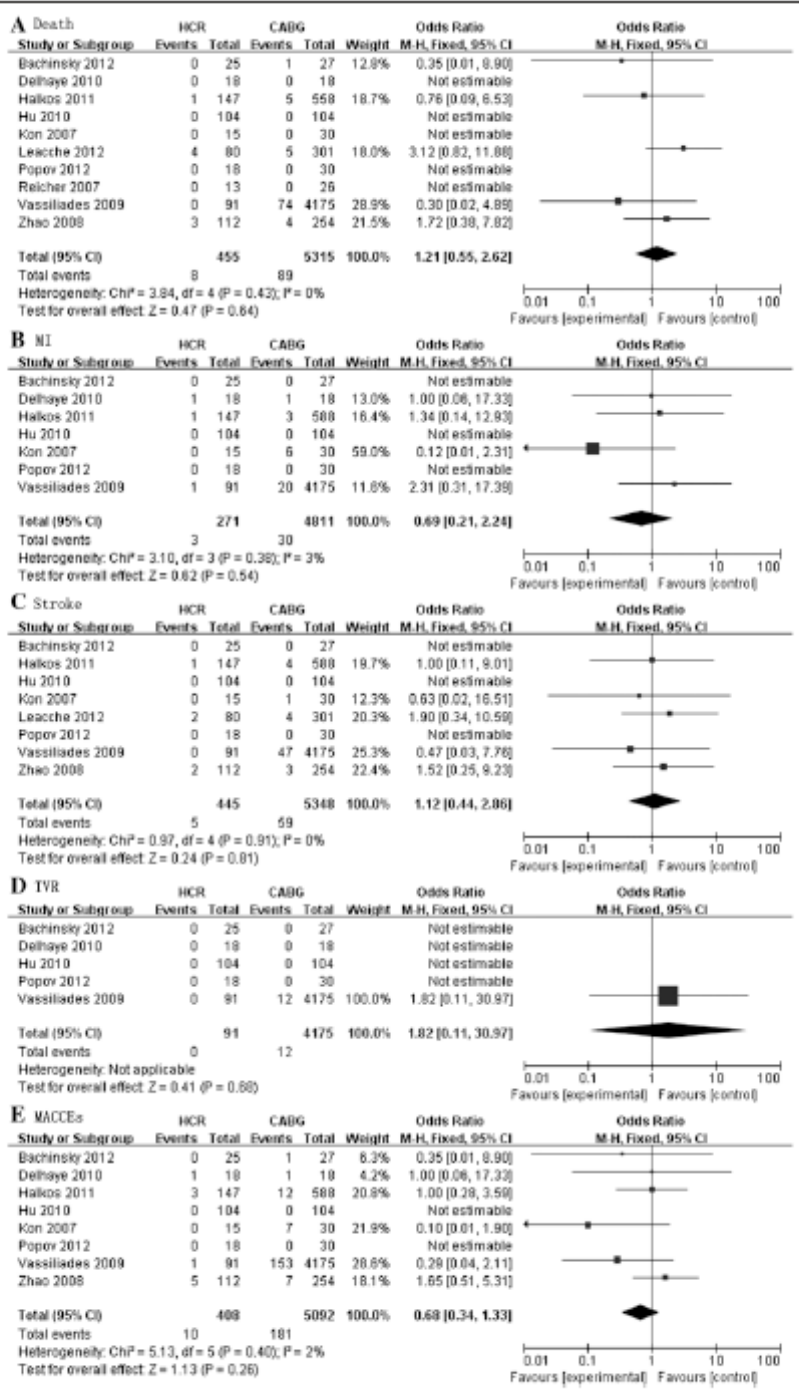


**Figure 2** Forest plot showing a meta-analysis for HCR versus CABG during hospitalization. **A**. Death **B**. MI(Myocardial Infarction) **C**. Stroke **D**. MACCEs (Major Adverse Cardiac or Cerebrovascular Events).

International Journal of Cardiology 179 (2015) 484–488

Contents lists available at ScienceDirect

International Journal of Cardiology

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Letter to the Editor

# Hybrid coronary revascularization versus coronary artery bypass surgery: Systematic review and meta-analysis☆

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[c] Gosford Hospital, Gosford, Australia



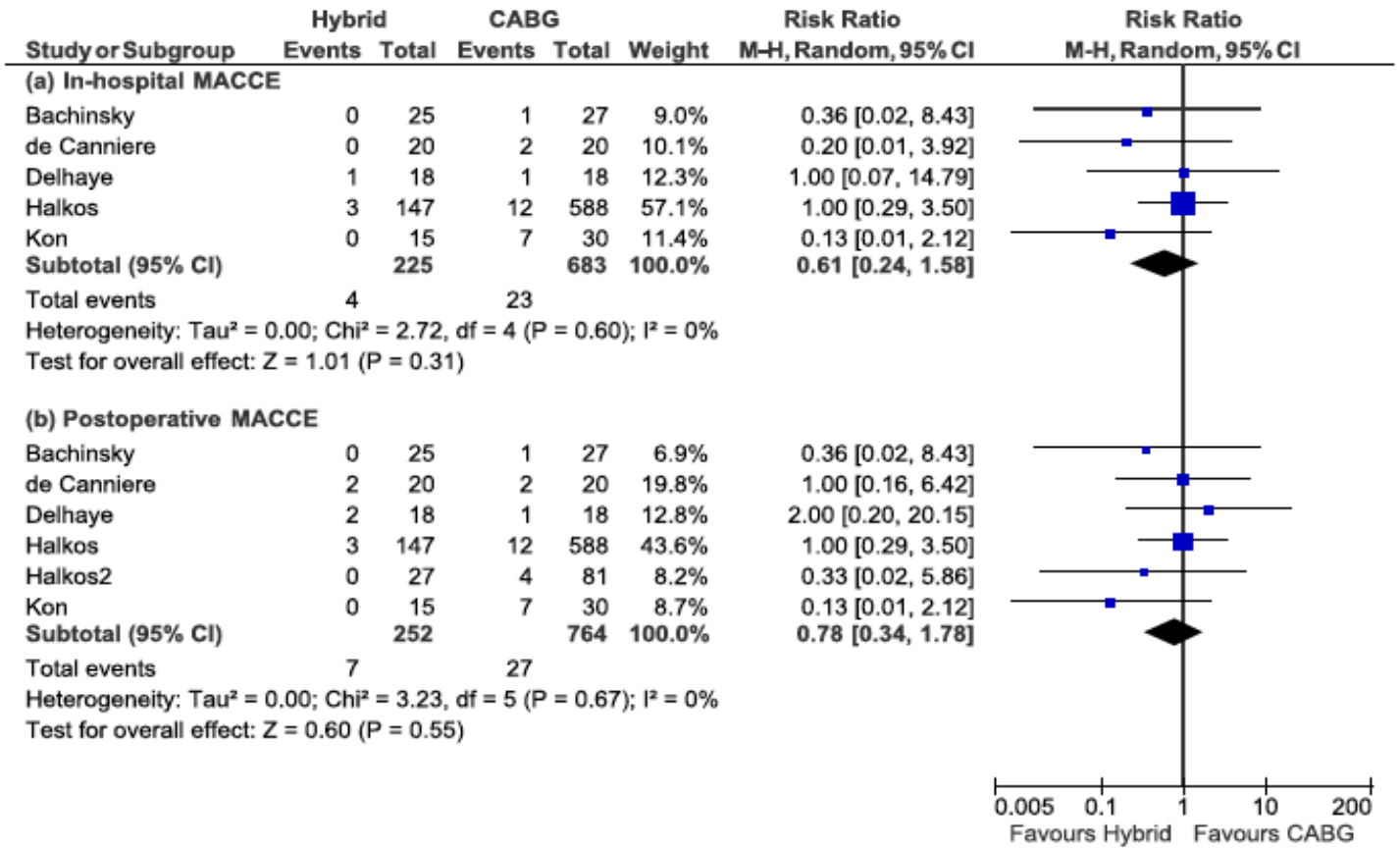
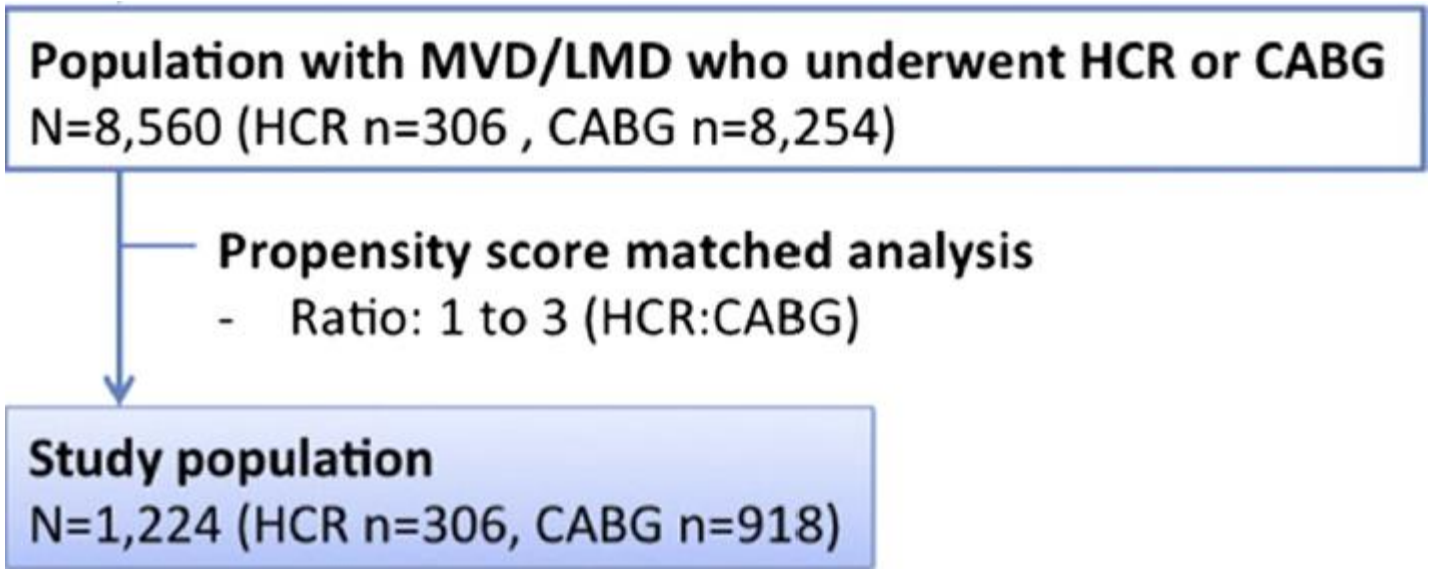



**Fig. 1.** Forest plot of (a) in-hospital MACCE, (b) postoperative MACCE, from eligible studies comparing hybrid coronary revascularization with coronary artery bypass grafting in a random-effects model.

# Comparative Effectiveness of Hybrid Coronary Revascularization vs Coronary Artery Bypass Grafting

Ralf E Harskamp, MD, Thomas A Vassiliades, MD, FACS, Rajendra H Mehta, MD, MS, Robbert J de Winter, MD, PhD, Renato D Lopes, MD, PhD, Ying Xian, MD, PhD, Eric D Peterson, MD, MPH, John D Puskas, MD, MS, FACS, Michael E Halkos, MD, MS, FACS

(J Am Coll Surg 2015;221:326–334. © 2015 by the American College of Surgeons)



# Comparative Effectiveness of Hybrid Coronary Revascularization vs Coronary Artery Bypass Grafting

Ralf E Harskamp, MD, Thomas A Vassiliades, MD, FACS, Rajendra H Mehta, MD, MS, Robbert J de Winter, MD, PhD, Renato D Lopes, MD, PhD, Ying Xian, MD, PhD, Eric D Peterson, MD, MPH, John D Puskas, MD, MS, FACS, Michael E Halkos, MD, MS, FACS

**Table 3.** Thirty-Day Major Adverse Cerebrovascular and Cardiovascular Events and In-Hospital Outcomes

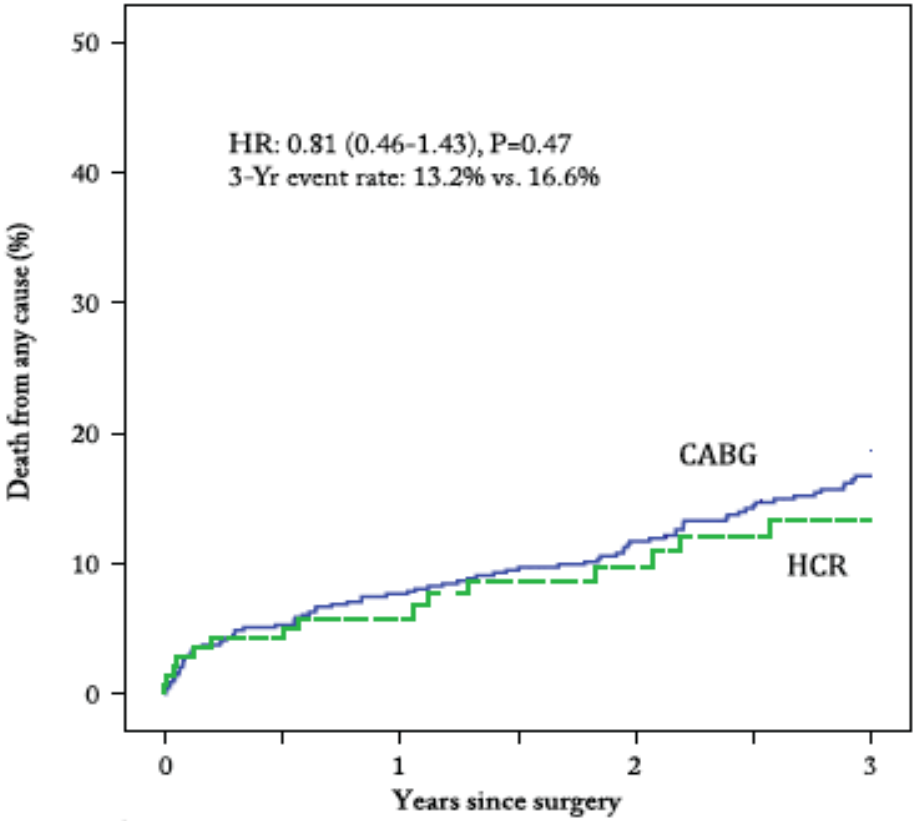
| Characteristics | HCR (n = 306) | CABG (n = 918) | OR (95% CI) | p Value |
|---|---|---|---|---|
| Composite of 30-d death, MI, stroke, n (%) | 10 (3.3) | 28 (3.1) | 1.07 (0.52–2.21) | 0.85 |
| Death | 5 (1.6) | 10 (1.1) | 1.50 (0.51–4.39) | 0.46 |
| MI | 2 (0.7) | 8 (0.9) | 0.75 (0.16–3.53) | 0.72 |
| Stroke | 3 (1.0) | 16 (1.7) | 0.56 (0.16–1.93) | 0.36 |
| In-hospital major morbidity, n (%) | 26 (8.5) | 142 (15.5) | 0.55 (0.36–0.83) | 0.005 |
| Reoperation | 13 (4.2) | 53 (5.8) | 0.74 (0.40–1.35) | 0.32 |
| Renal failure | 5 (1.7) | 21 (2.3) | 0.71 (0.27–1.89) | 0.50 |
| Prolonged ventilation, >24 h | 16 (5.3) | 102 (11.1) | 0.48 (0.28–0.81) | 0.006 |
| Access site infection | 0 (0.0) | 11 (1.2) | — | — |
| Bleeding outcomes | | | | |
| CABG-related bleeding, n (%) | 22 (7.2) | 85 (9.3) | 0.78 (0.49–1.24) | 0.29 |
| Need for blood transfusion, n (%) | 66 (21.6) | 428 (46.6) | 0.46 (0.36–0.60) | <0.001 |
| Chest tube drainage, mL/24 h | 690 (485–1,050) | 920 (710–1,230) | $\beta = -1.58$, $t = -5.57$* | <0.001 |
| Recovery parameters, n (%) | | | | |
| Short PLOS, <5 d | 161 (52.6) | 350 (38.1) | 1.38 (1.15–1.66) | 0.001 |
| Long PLOS, >14 d | 7 (2.3) | 46 (5.0) | 0.46 (0.21–1.01) | 0.053 |

*Linear regression models were used.
HCR, hybrid coronary revascularization; OR, odds ratio; PLOS, postoperative length of stay.

# Comparison of Hybrid Coronary Revascularization Versus Coronary Artery Bypass Grafting in Patients ≥65 Years With Multivessel Coronary Artery Disease

(Am J Cardiol 2014;114:224–229)

Ralf E. Harskamp, MD[a,b,*], John D. Puskas, MD, MS[c], Jan G. Tijssen, PhD[b], Patrick F. Walker, BS[c], Henry A. Liberman, MD[c], Renato D. Lopes, MD, PhD[a], Thomas A. Vassiliades, MD, MBA[c], Eric D. Peterson, MD, MPH[a], and Michael E. Halkos, MD, MS[c]




| No. at Risk | | | | |
|---|---|---|---|---|
| HCR | 143 | 106 | 80 | 60 |
| CABG | 572 | 463 | 401 | 327 |

Figure 1. Kaplan-Meier curve for death from any cause up to 3 years after HCR and conventional bypass surgery. Shown are rates of death from any cause truncated at 3 years after surgery. The hazard ratio (HR) was calculated using Cox modeling stratified on matched pairs.

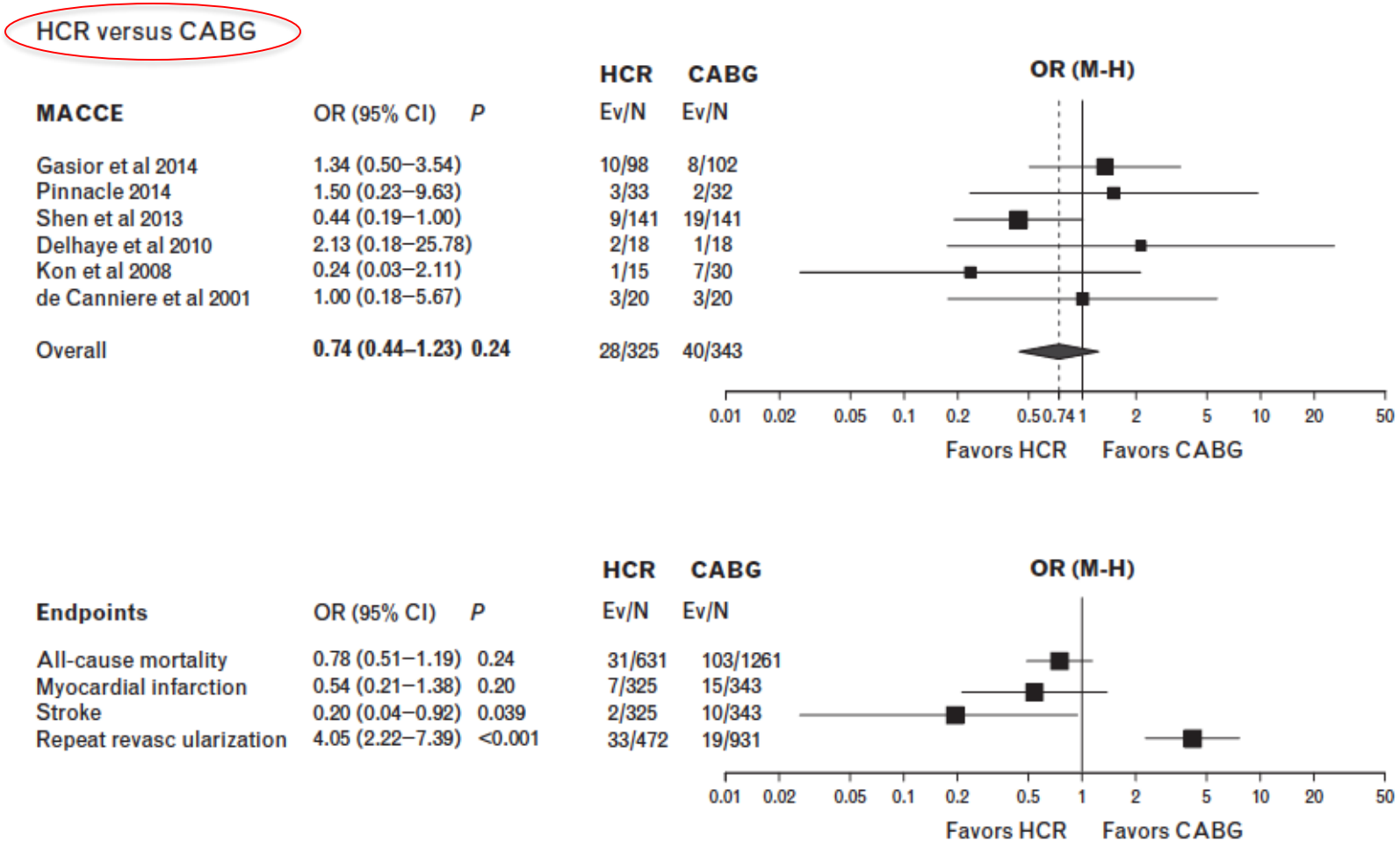
CURRENT OPINION

# Current state and future direction of hybrid coronary revascularization

Curr Opin Cardiol 2015, 30:643–649
DOI:10.1097/HCO.0000000000000223

Ralf E. Harskamp

**FIGURE 2.** Meta-analysis of available studies on long-term clinical outcomes (1–5 years) of HCR versus CABG (upper panel) or HCR versus PCI (lower panel). OpenMetaAnalyst software was used to perform this meta-analysis, in which a fixed effect model was used applying the Mantel–Haenszel test method. In-criteria and exclusion criteria were similar to those used in a previous meta-analysis of our group on this topic [17], and the literature search was updated until 3 May 2015. A total of



CURRENT OPINION

# Current state and future direction of hybrid coronary revascularization

Curr Opin Cardiol 2015, 30:643–649
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*Ralf E. Harskamp*

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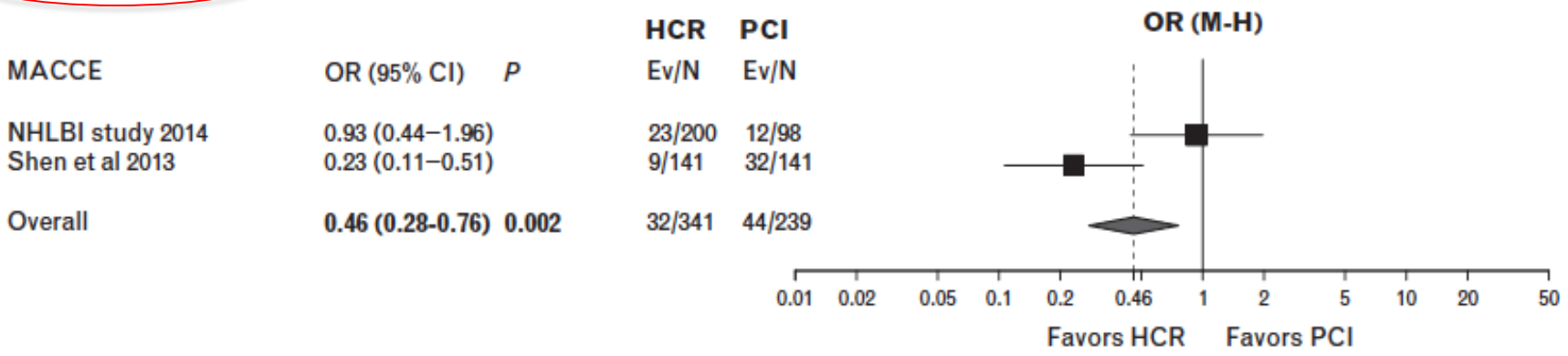
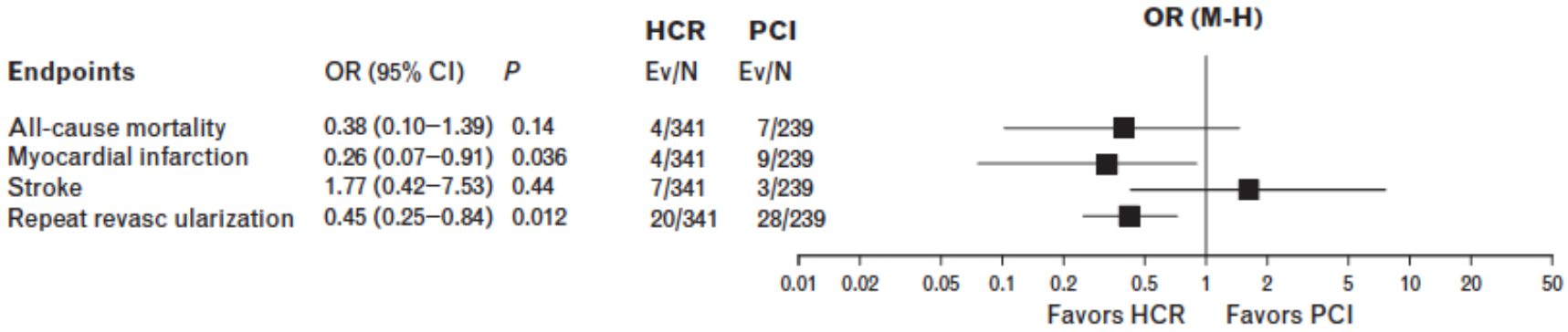
HCR versus PCI



Journal of the American College of Cardiology
© 2013 by the American College of Cardiology Foundation
Published by Elsevier Inc.

Vol. 61, No. 25, 2013
ISSN 0735-1097/$36.00
http://dx.doi.org/10.1016/j.jacc.2013.04.007

# One-Stop Hybrid Coronary Revascularization Versus Coronary Artery Bypass Grafting and Percutaneous Coronary Intervention for the Treatment of Multivessel Coronary Artery Disease

## 3-Year Follow-Up Results From a Single Institution

Liuzhong Shen, MD,*† Shengshou Hu, MD,*† Haoran Wang, MD,*† Hui Xiong, MD,*†
Zhe Zheng, MD,*† Lihuan Li, MD,‡ Bo Xu, MD,§ Hongbing Yan, MD,§ Runlin Gao, MD§

*Beijing, China*

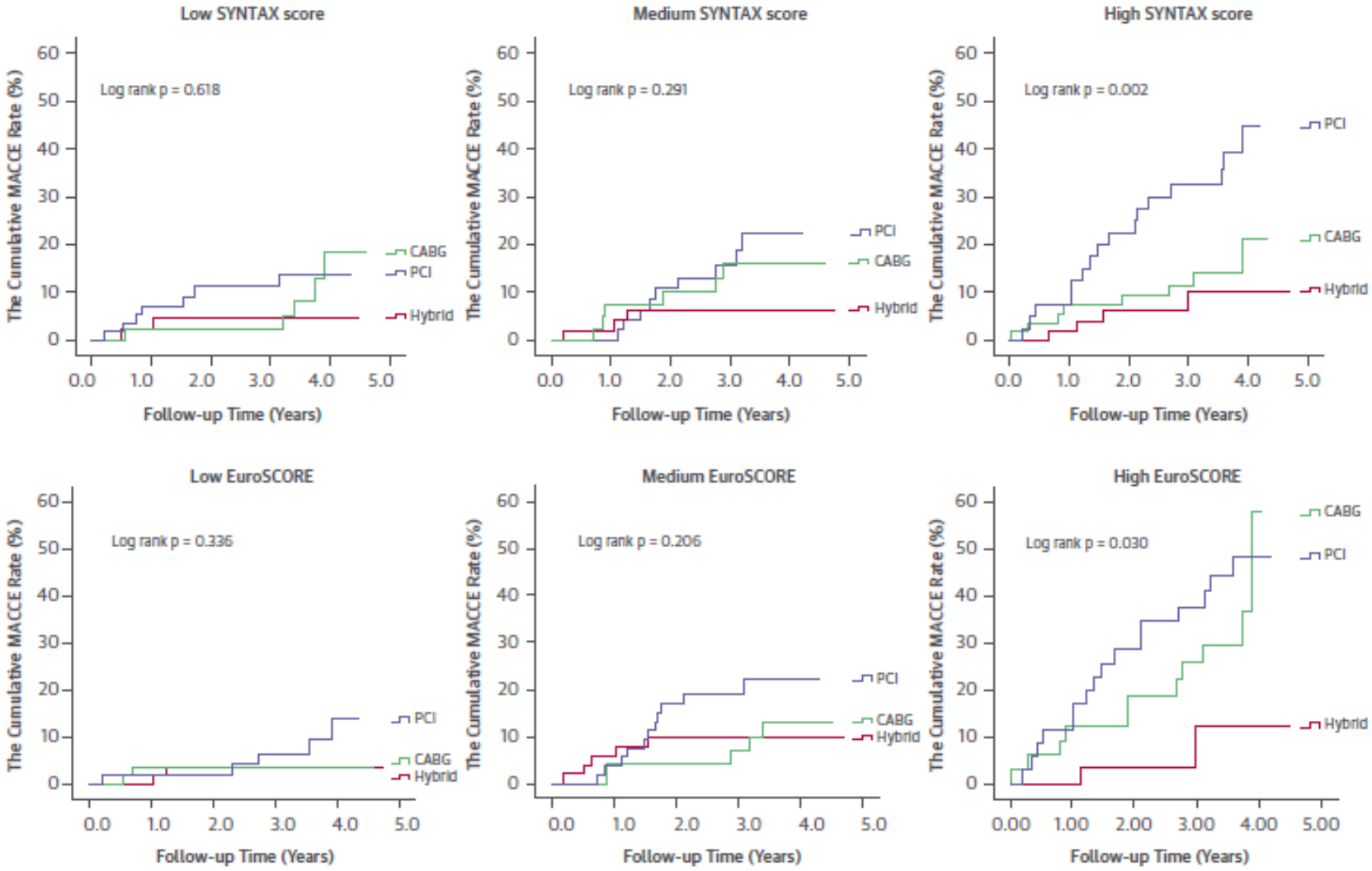
## Methods

From June 2007 to December 2010, 141 consecutive patients underwent 1-stop HCR at Fuwai Hospital. Using propensity score methodology, these patients were matched with 2 separate groups of 141 patients who underwent isolated CABG or PCI during the same period. All patients were stratified by the EuroSCORE (European System for

## Results

One-stop HCR incurred MACCE rate lower than that with PCI ($p < 0.001$), but similar to that with CABG ($p = 0.140$). After stratification by EuroSCORE or SYNTAX score, the cumulative MACCE rates were similar among the 3 groups in low and medium tertiles. But in the high EuroSCORE tertile, patients who underwent 1-stop HCR had a lower MACCE rate than did the groups that underwent CABG ($p = 0.030$) and PCI ($p = 0.006$). Meanwhile, patients with a high SYNTAX score who underwent 1-stop HCR had a MACCE rate lower than did those who underwent PCI ($p = 0.002$), but similar to that of those who underwent CABG ($p = 0.362$).

**FIGURE 2** **Improved MACCE in HCR Group**




Improved major adverse cardiac and cerebrovascular events (MACCE) among patients in the HCR group versus conventional CABG and percutaneous coronary intervention (PCI) in the high EuroSCORE tertile. Adapted with permission from Shen et al. (36). SYNTAX = SYNergy Between PCI With TAXUS and Cardiac Surgery; other abbreviations as in Figure 1.

# One-stop hybrid coronary revascularization versus off-pump coronary artery bypass in patients with diabetes mellitus

Zhizhao Song, MD,[a] Liuzhong Shen, MD,[a] Zhe Zheng, MD,[a] Bo Xu, MD,[b] Hui Xiong, MD,[a] Lihuan Li, MD,[c] and Shengshou Hu, MD[a]

The Journal of Thoracic and Cardiovascular Surgery • June 2016

| Variable | HCR (n = 120) | OPCAB (n = 240) | *P* value |
|---|---|---|---|
| Chest tube drainage within 24 hours, mL, median (IQR) | 573 (320-835) | 700 (530-950) | <.001 |
| Total chest tube drainage, mL, median (IQR) | 748 (540-1080) | 990 (730-1250) | <.001 |
| Transfusion of packed RBCs, n (%) | 22 (18.3) | 71 (29.6) | .032 |
| Transfusion of plasma, n (%) | 23 (19.2) | 53 (22.1) | .523 |
| Transfusion of any blood products, n (%) | 35 (29.2) | 95 (39.6) | .076 |
| Reoperation for controlling bleeding, n (%) | 1 (0.8) | 6 (2.5) | .307 |
| Mechanical ventilation time, hour, median (IQR) | 13.7 (10.3-16.9) | 16.8 (13.0-19.6) | <.001 |
| Length of ICU stay, hour, median (IQR) | 21.7 (19.0-44.3) | 46.5 (24.3-72.7) | <.001 |
| Length of hospital stay, day, median (IQR) | 7 (7-9) | 7 (7-9) | .627 |

*HCR*, Hybrid coronary revascularization; *OPCAB*, off-pump coronary artery bypass grafting; *IQR*, interquartile range; *RBC*, red blood cell; *ICU*, intensive care unit.

DM patients who underwent one-stop HCR from June 2007 to September 2014. (n = 120)

Propensity score matching.
(One-stop HCR : OPCAB = 1 : 2)

DM patients who underwent OPCAB. (n = 1658)

# Hybrid Revascularization for Multivessel Coronary Artery Disease

Mariusz Gąsior, MD,* Michael Oscar Zembala, MD, PhD,† Mateusz Tajstra, MD, PhD,* Krzysztof Filipiak, MD, PhD,† Marek Gierlotka, MD,* Tomasz Hrapkowicz, MD, PhD,† Michał Hawranek, MD, PhD,* Lech Poloński, MD,* Marian Zembala, MD,† on behalf of the POL-MIDES (HYBRID) Study Investigators

JACC: CARDIOVASCULAR INTERVENTIONS VOL. 7, NO. 11, 2014

**OBJECTIVES** The aim of this study was to assess the feasibility of hybrid coronary revascularization (HCR) in patients with multivessel coronary artery disease (MVCAD) referred for standard coronary artery bypass grafting (CABG).

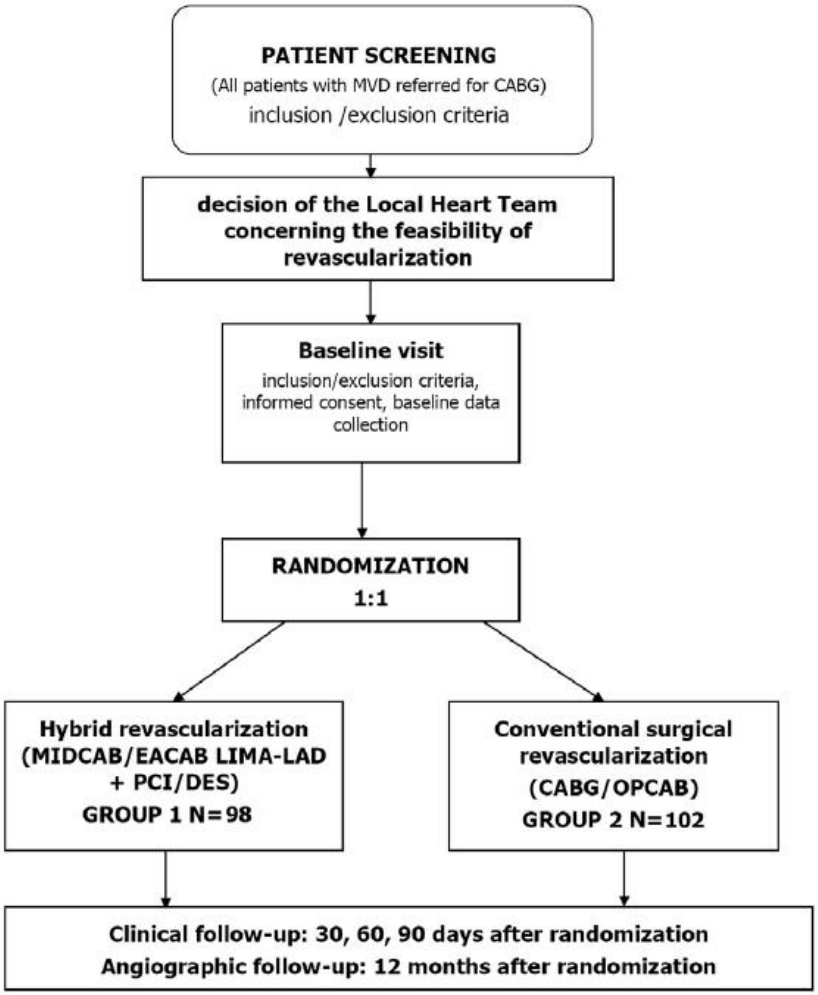
**METHODS** A total of 200 patients with MVCAD involving the left anterior descending artery (LAD) and a critical (>70%) lesion in at least 1 major epicardial vessel (except the LAD) amenable to both PCI and CABG and referred for conventional surgical revascularization were randomly assigned to undergo HCR or CABG (in a 1:1 ratio). The primary endpoint was the evaluation of the safety of HCR. The feasibility was defined by the percent of patients with a complete HCR procedure and the percent of patients with conversions to standard CABG. The occurrence of major adverse cardiac events such as death, myocardial infarction, stroke, repeated revascularization, and major bleeding within the 12-month period after randomization was also assessed.

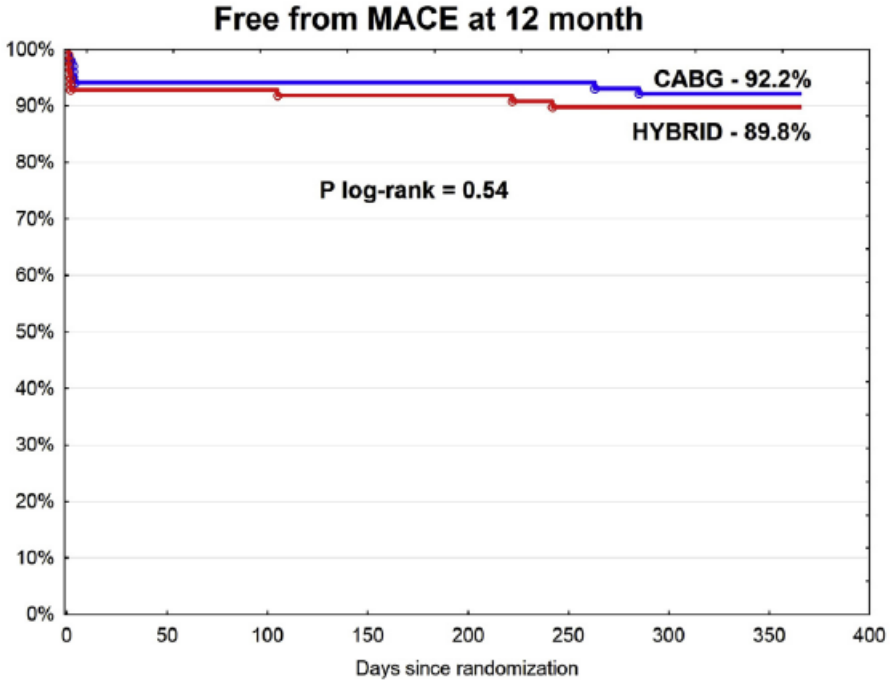
**CONCLUSIONS** HCR is feasible in select patients with MVCAD referred for conventional CABG. (Safety and Efficacy Study of Hybrid Revascularization in Multivessel Coronary Artery Disease [POL-MIDES]; NCT01035567) (J Am Coll Cardiol Intv 2014;7:1277–83) 

# Hybrid Revascularization for Multivessel Coronary Artery Disease

JACC: CARDIOVASCULAR INTERVENTIONS VOL. 7, NO. 11, 2014

POL-MIDES (HYBRID) Study Investigators



JACC: CARDIOVASCULAR INTERVENTIONS
VOL. 7, NO. 11, 2014

ISSN 1936-8798/$36.00
PUBLISHED BY ELSEVIER INC.
http://dx.doi.org/10.1016/j.jcin.2014.06.013

EDITORIAL COMMENT

# Hybrid Coronary Revascularization

## A New Treatment Paradigm for Selected Patients With Multivessel Coronary Artery Disease*

John D. Puskas, MD, MSc, Amit Pawale, MD, Samin K. Sharma, MD

It may be more appropriate and impactful to study the safety and efficacy of HCR in patients with less extensive, hybrid-eligible coronary anatomy referred for either multivessel PCI or surgical coronary revascularization. Any patient with proximal LAD stenosis and significant lesion(s) in 1 or at most 2 other non-LAD vessels could be eligible for randomization to HCR versus multivessel PCI.

(Am Heart J 2015;169:557-563.e6.)

# A nationwide survey on perception, experience, and expectations of hybrid coronary revascularization among top-ranked US hospitals

Ralf E. Harskamp, MD,[a,f] Michael E. Halkos, MD, MS,[b] Ying Xian, MD, PhD,[a] Molly A. Szerlip, MD,[c] Robert S. Poston, MD,[d] Stephanie L. Mick, MD,[e] Renato D. Lopes, MD, PhD,[a] Jan G. Tijssen, PhD,[f] Robbert J. de Winter, MD, PhD,[f] and Eric D. Peterson, MD, MPH[a] *Durham, NC; Atlanta, GA; Plano, TX; Tucson, AZ; Cleveland, OH; and Amsterdam, The Netherlands*

**Background** Hybrid coronary revascularization (HCR) combines a surgical and percutaneous approach for treatment of multivessel coronary artery disease.

**Methods** A survey was conducted among 200 cardiologists and cardiac surgeons from 100 top-ranked US hospitals. Questions were asked involving the perception, experience, and future expectations of HCR.

**Conclusion** In this nationwide survey, cardiologists and cardiac surgeons felt that HCR is a reasonable alternative technique for coronary revascularization among suitable patients. Most felt that use of HCR would increase in the next decade. (Am Heart J 2015;169:557-563.e6.)

JOURNAL OF THE AMERICAN COLLEGE OF CARDIOLOGY
VOL. 68, NO. 4, 2016

ISSN 0735-1097/$36.00
PUBLISHED BY ELSEVIER
http://dx.doi.org/10.1016/j.jacc.2016.05.032

# Hybrid Coronary Revascularization for the Treatment of Multivessel Coronary Artery Disease

## A Multicenter Observational Study

John D. Puskas, MD,[a,b] Michael E. Halkos, MD,[c] Joseph J. DeRose, MD,[d] Emilia Bagiella, PhD,[e] Marissa A. Miller, DMV, MPH,[f] Jessica Overbey, MS,[e] Johannes Bonatti, MD,[g] V.S. Srinivas, MD,[d] Mark Vesely, MD,[h] Francis Sutter, MD,[i] Janine Lynch, MPH,[j] Katherine Kirkwood, MS,[e] Timothy A. Shapiro, MD,[i] Konstantinos D. Boudoulas, MD,[j] Juan Crestanello, MD,[j] Thomas Gehrig, MD,[k] Peter Smith, MD,[k] Michael Ragosta, MD,[l] Steven J. Hoff, MD,[m] David Zhao, MD,[n] Annetine C. Gelijns, PhD,[e] Wilson Y. Szeto, MD,[o] Giora Weisz, MD,[p] Michael Argenziano, MD,[p] Thomas Vassiliades, MD,[c,q] Henry Liberman, MD,[c] William Matthai, MD,[o] Deborah D. Ascheim, MD[a,e]

# Hybrid Observational Study

- Prospective cohort observational study
- 11 US clinical sites
- To inform design of an RCT of HCR vs. multivessel PCI (DES)
  - Feasibility of recruitment (# anatomically eligible pts)
  - More precise characterization of population undergoing HCR
  - Variability of treatment approaches
  - Event rates (MACCE)

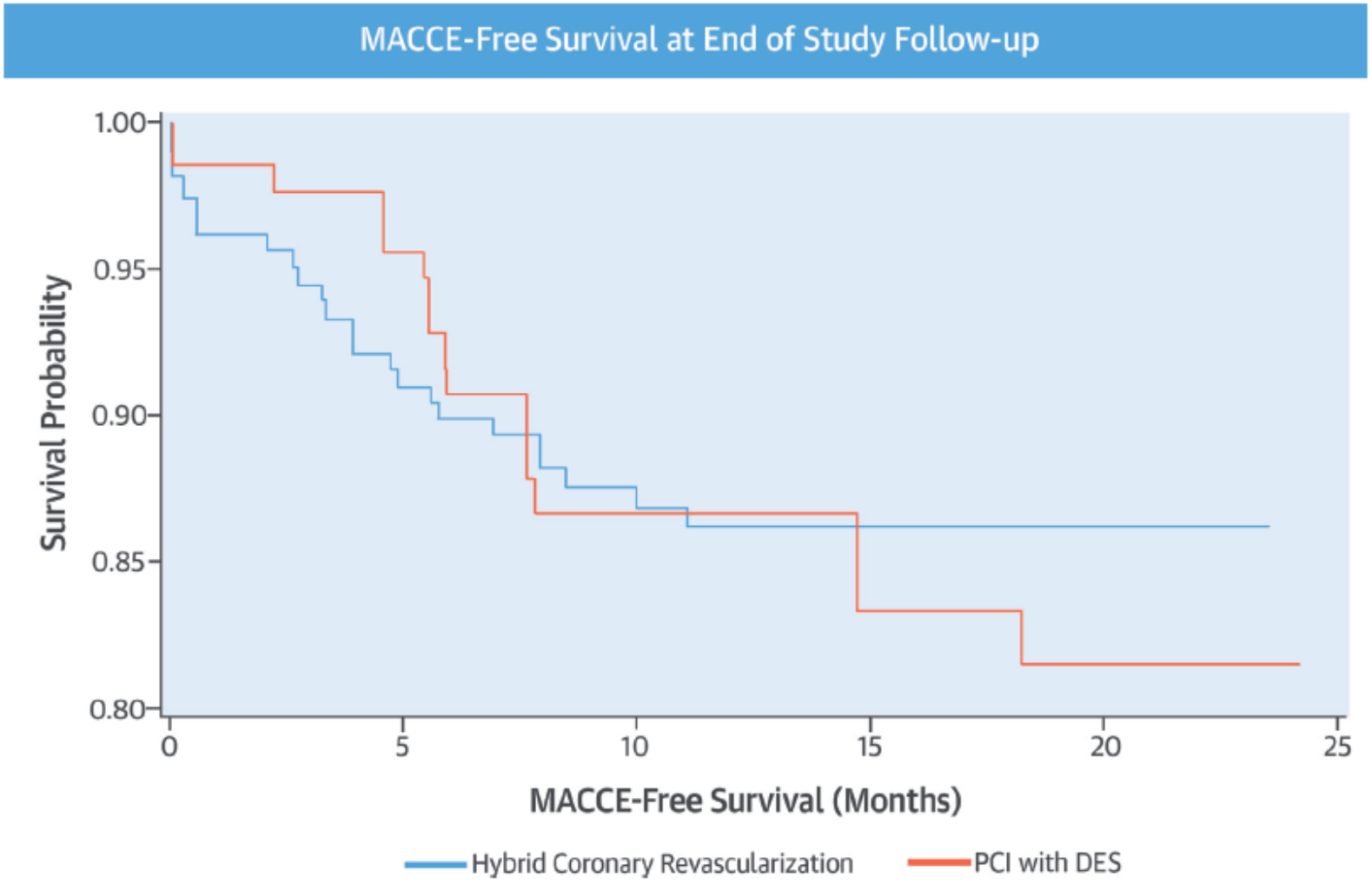
# HCR Study Population

| Clinical Site | HCR | PCI* |
|---|---|---|
| Brigham and Women's Hospital | 0 | 1 |
| Columbia University | 3 | 23 |
| Duke University Medical Center | 3 | 5 |
| Emory University | 79 | 4 |
| Lankenau Hospital | 31 | 7 |
| Montefiore Medical Center | 26 | 14 |
| Ohio State University | 9 | 6 |
| University of Maryland Medical Center | 36 | 6 |
| University of Pennsylvania | 9 | 26 |
| University of Virginia Health System | 2 | 4 |
| Vanderbilt University Medical Center | 2 | 2 |
| **Total** | **200** | **98** |

- Median follow-up post-revasc 17.6 ± 6.5 months
- Analysis included 339.8 person-years at risk

*All anatomically & clinically eligible for HCR

**CENTRAL ILLUSTRATION** **Multicenter HCR Study: MACCE-Free Survival at End of Study Follow-Up**




**Puskas, J.D. et al. J Am Coll Cardiol. 2016;68(4):356-65.**

In this first multicenter observational study of hybrid coronary revascularization (HCR) and multivessel percutaneous coronary intervention (PCI) for patients with hybrid-eligible coronary anatomy, risk-adjusted major adverse cardiovascular and cerebrovascular events (MACCE) rates were similar between groups through 12 months of follow-up. During longer follow-up, at 18 months, MACCE-free survival curves for HCR versus PCI began to diverge, with increasing MACCE in the multivessel PCI group. DES = drug-eluting stent(s).

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# NIH Hybrid Coronary Revascularization Randomized Trial

CCC: John Puskas (Mount Sinai) and Gregg Stone (CRF)
DCC: Emilia Bagiella, Alan Moskowitz (Mount Sinai)

NIH National Institutes of Health
National Heart, Lung, and Blood Institute
National Institute of Neurological Disorders and Stroke

CIHR IRSC
Canadian Institutes of Health Research
Instituts de recherche en santé du Canada

# Objectives

- To evaluate the safety and effectiveness of hybrid coronary revascularization (HCR) compared to multi–vessel percutaneous coronary intervention (PCI) with drug-eluting stents (DES) in patients with multi-vessel coronary artery disease (CAD) involving the Left Anterior Descending (LAD) and/or Left Main (LM) arteries.
- The primary objective of this trial is to determine whether hybrid coronary revascularization is associated with a reduction in Major Adverse Coronary and Cerebrovascular Events (MACCE) compared to PCI with DES.

# Study Design

- Prospective, randomized, multi-center, comparative effectiveness trial
- Patients randomized with equal allocation (1:1).
- Registry-based Trial
  - Society of Thoracic Surgeons (STS) Data Registry
  - National Clinical Data Registry (NCDR) Cath/PCI databases

# Centralized Data Acquisition

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- Baseline and peri-procedural data collection will be extracted directly from the Society of Thoracic Surgeons (STS) Data Registry and the National Clinical Data Registry (NCDR) Cath/PCI databases.
- Limited additional data may be collected to assess coronary anatomy, pharmacology specific to the procedure, device usage, etc.
- All follow-up data collection, with the exception of minimal data collection at a point of care post-intervention clinical visit, will be collected centrally via phone follow-up by the Hybrid Trial Data Coordinating Center (DCC), will focus solely on patient-reported MACCE and QOL, and will be supplemented by limited supporting documentation to verify MACCE events and obtain costing data.
- All MACCE events will be adjudicated by a Clinical Events Committee (CEC).

# Target Population & Interventions

- Patients with multi-vessel CAD involving the proximal or mid LAD distribution with a clinical indication for revascularization *and* eligible for both HCR and multi-vessel PCI with DES
- 2354 patients will be randomized:
  - HCR with Left Internal Mammary Artery (LIMA) to LAD + PCI of non-LAD vessels
  - Multi-vessel PCI with DES, including the LAD

# Primary Endpoint

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The occurrence of MACCE, defined as all-cause mortality, myocardial infarction (MI), stroke, and repeat revascularization over a minimum of 5 year follow-up after randomization

# Secondary Endpoints

## Cardiovascular Events

- MACCE at each data collection time point
- Individual components of MACCE
  - All-cause mortality
  - Repeat revascularization (all-cause)
  - Stroke
  - Myocardial infarction (MI)
- Ischemia-driven repeat revascularization
- Cardiovascular mortality

**Hospitalizations**

- Re-hospitalization (all-cause and cardiovascular)

## Health Status

- Angina Score (Canadian Cardiovascular Society Classification [CCSC])
- Quality of Life (SF-12 and EuroQOL)

**Cost and Cost Effectiveness**

- Resource utilization: length of hospital stay for index procedure (as relevant), readmissions
- Days alive out of hospital
- Cost and cost-effectiveness (cost per quality-adjusted life year)

# Selected Inclusion Criteria

- Clinical indication for coronary revascularization
- Coronary anatomy requiring revascularization as follows:
  - Multi-vessel CAD involving the LAD *and/or*
  - Distal LM *and/or*
  - Ostial or mid-shaft LM *and* disease in at least 1 other epicardial coronary artery *and/or*
  - LAD disease *and* involvement of a major Diagonal artery, both of which require revascularization
- Suitable candidate for both PCI with DES and HCR as determined by joint angiogram review by an interventional cardiologist and a cardiac surgeon at the clinical site
- Ability to tolerate and no plans to interrupt dual anti-platelet therapy for ≥ 12 months

# Sample Size

- 2354 patients across a network of >50 clinical sites
- Assuming an estimated event rate of approximately 25% in the PCI group at 5 years; 0.05 type I error (2-sided) and

  (a) minimum follow-up of 5 years,

  (b) 80% power,

  (c) drop-in and drop-out rates of approximately 0.5% and 2% respectively, annually, and

  (d) 15% loss to follow-up by end of the study,
- 530 events will need to be observed (or 2354 patients) to detect a relative decrease in MACCE of ≥ 20% in the HCR compared to the PCI group.
- Estimates of loss to follow-up, and cross-over rates are conservative and justify fixing the power at 80%.

# Duration and Funding

- Trial launch Q1 2017
- Accrual over 2 years across Network of >50 sites
- **Still recruiting sites: john.puskas@mountsinai.org**
- The study will be terminated when 530 events have occurred or the last accrued participant has completed the 5 year evaluation, whichever comes first

- Funded by Collaborative RO-1 grants (convertible to UO-1)
  - Mount Sinai DCC, Annetine Gelijns, Emilia Bagiella
  - John Puskas, Gregg Stone, CCC

# Hybrid Coronary Revascularization

- Evolving treatment paradigm for patients with proximal LAD disease and low SYNTAX score
- Meta-analyses and NIH HCR Observational Study suggest outcomes with PCI vs HCR are similar at 12 months.
- Just-funded NIH HCR Randomized Trial will explore whether HCR may offer longer-term advantages over multivessel PCI for hybrid-eligible patients.

Mount Sinai Heart

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