JOURNAL OF THE AMERICAN COLLEGE OF CARDIOLOGY
© 2015 BY THE AMERICAN COLLEGE OF CARDIOLOGY FOUNDATION
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

REVIEW TOPIC OF THE WEEK

Hybrid Coronary Revascularization

Promising, But Yet to Take Off

Vasileios F. Panoulas, MD, PhD,*†‡ Antonio Colombo, MD,*† Alberto Margonato, MD,* Francesco Maisano, MD§

ABSTRACT

Hybrid coronary revascularization (HCR) combines arterial coronary artery bypass surgery (most commonly minimally invasive) and percutaneous coronary intervention in the treatment of a particular subset of multivessel coronary artery disease. It was first introduced in the mid-1990s, and aspired to bring together the "best of both worlds": the excellent patency rates and survival benefits associated with the durable left internal mammary artery graft to the left anterior descending artery alongside the good patency rates of drug-eluting stents, which outlive saphenous vein grafts to non–left anterior descending vessels. Although in theory this is a very attractive revascularization strategy, several years later, only one small randomized controlled trial comparing HCR with coronary artery bypass grafting has recently emerged in the medical literature, raising concerns regarding HCR's role and generalizability. In the current review, we discuss HCR's rationale, the current evidence behind it, its limitations and procedural challenges. (J Am Coll Cardiol 2015;65:85–97) © 2015 by the American College of Cardiology Foundation.

Hybrid coronary revascularization (HCR) was first introduced in the mid-1990s (1) as a pioneering treatment approach to multivessel coronary artery disease (CAD), hoping to bring together the "best of both worlds" (2). HCR aims to reduce surgical trauma while preserving long-term survival and minimizing adverse cardiovascular events.

The hybrid approach includes left internal mammary artery (LIMA) anastomosis to the left anterior descending coronary artery (LAD), typically via a minimally invasive approach, and percutaneous coronary intervention (PCI) for the remaining (non-LAD) lesions. Variations to this schema were discussed in a recent nomenclature paper (3), including the grafting of multiple coronary vessels (e.g., LIMA to LAD and saphenous graft to diagonal).

THE RATIONALE FOR HCR

The rationale for HCR lies in the well-established survival benefit conferred by LIMA-to-LAD grafts (4–6) and the use of new stent platforms (7) featuring lower stent restenosis and thrombosis rates compared with venous graft stenosis and occlusion rates, respectively (8).

THE SURVIVAL BENEFIT OF A SURGICAL LIMA-TO-LAD GRAFT. A unique conduit, the LIMA powerfully resists thrombosis and atherosclerosis (9). Consequently, the LIMA-LAD graft is associated with long-term patency rates reaching 98% at 10 years (10,11). Furthermore, a LIMA graft protects the native coronary tree from the deleterious effects of disease progression (9).

From the *Interventional Cardiology Unit, San Raffaele Scientific Institute, Milan, Italy; †Interventional Cardiology Unit, EMO-GVM Centro Cuore Columbus, Milan, Italy; ‡National Heart and Lung Institute, Imperial College London, London, United Kingdom; and the §Cardiac Surgery Department, Zurich University Hospital, Zurich, Switzerland. Dr. Maisano has served as a consultant for Medtronic, St. Jude, Abbott Vascular, and Valtech Cardio Ltd; has received royalties from Edwards Lifesciences; and is the cofounder of 4TechAll. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose. Drs. Panoulas and Colombo contributed equally to this work.

Listen to this manuscript's audio summary by *JACC* Editor-in-Chief Dr. Valentin Fuster.

You can also listen to this issue's audio summary by *JACC* Editor-in-Chief Dr. Valentin Fuster.

Manuscript received February 8, 2014; revised manuscript received April 7, 2014, accepted April 8, 2014.

ABBREVIATIONS AND ACRONYMS

CABG = coronary artery bypass graft surgery

DES = drug-eluting stent(s)

HCR = hybrid coronary revascularization

LAD = left anterior descending artery

LIMA = left internal mammary artery

MIDCAB = minimally invasive direct coronary artery bypass grafting

PCI = percutaneous coronary intervention

SVG = saphenous vein graft

VEIN GRAFT PATENCY VERSUS STENT RESTENOSIS AND THROMBOSIS: THE RATIONALE FOR COMPLETING THE REVASCULARIZATION WITH PCI. Unlike arterial conduits, veins were not designed to bear the load of systemic pressure; hence, venous grafts are more prone to atherosclerotic degeneration and progressive narrowing with high early and long-term failure rates. In the ex vivo PREVENT IV (Vein graft Engineering via Transfection IV) study (12), angiographic midterm (1 to 1.5 years) saphenous vein graft (SVG) failure, defined as stenosis ≥75%, stood as high as 46%, whereas reported graft occlusion rates in the literature range from 6.2% to 32% at 1 year (averaging ~20%) (13–17), 29% at 10 years, and 68% at 15 years (10) post-coronary artery bypass graft surgery (CABG).

Newer drug-eluting stent (DES) platforms with (e.g., everolimus-eluting stents [EES] or zotarolimus-eluting stents [ZES]) or without (bioresorbable polymer-based or polymer-free stents) durable polymers show favorable outcomes, with 1-year target lesion revascularization (TLR) rates as low as 3% to 3.25% (7) and midterm binary (≥50%) restenosis rates of 2.3% for EES (8 months) (18) and 3.1% for the amphilimus-eluting, polymer-free stent (6 months) (19). Even in high-risk patients and complex lesions, ZES and EES maintain very low 1-year TLR rates of 4.4% and 4%, respectively (20). Thus, PCI and stenting provide strong competition for SVG revascularization because, unlike an LIMA-LAD graft, disease progression in the proximal native coronary segment occurs alongside SVG deterioration.

Moreover, significant angiographic SVG stenosis occurs at least twice as frequently as binary in-stent restenosis using the latest technology platforms. However, ischemia-driven revascularization rates are considerably higher in stented patients with treated multivessel CAD (21). Furthermore, even though SVG occlusion occurs at a higher rate compared with stent thrombosis (10), the clinical consequences of the latter are more dramatic, as it is more frequently associated with major adverse clinical events (MACE) (22).

PATIENT SELECTION FOR HCR

The role of the heart team in guiding appropriate patient selection for HCR is crucial (23). In our view, an important anatomical feature favoring HCR should be plaque burden in the proximal LAD well characterized by the SYNTAX (SYNergy Between PCI With TAXUS and Cardiac Surgery) score (24). The classic indication for HCR is multivessel CAD including: 1) a proximal complex LAD lesion with optimal distal anatomy amenable to LIMA-to-LAD grafting; 2) non-LAD lesions amenable to PCI, in a patient with no contraindications to dual antiplatelet therapy (DAPT); and 3) a high likelihood of achieving "reasonable incomplete revascularization" (25,26) with such an approach.

Complex distal left main lesions are also ideal for HCR if the circumflex artery territory is amenable for PCI. HCR appears particularly appealing for patients with the aforementioned coronary anatomy and others considered too high risk for open cardiopulmonary bypass surgery via midline sternotomy, including those with a high risk of deep sternal wound infection (e.g., diabetics, morbidly obese) (26), severely impaired left ventricular function, chronic kidney disease, significant carotid or neurological disease, severe aortic calcification, prior sternotomy, and lack of venous conduits. The 2011 American College of Cardiology Foundation/American Heart Association guidelines for CABG state that the "primary purpose of performing HCR is to decrease the morbidity rate of traditional CABG in high-risk patients" (27). Even in the more recent European Society of Cardiology/European Association for Cardio-Thoracic Surgery guidelines on myocardial revascularization (28), HCR has a Class IIb recommendation for specific patient subsets and only at experienced centers. The lack of several large randomized controlled trials (RCTs) involving different risk groups, hinders the identification of an HCR target group. Consequently, physicians and surgeons do not embrace HCR in routine clinical practice. In a recent study from the Society of Thoracic Surgeons (STS) Adult Cardiac Surgery Database (29), HCR represented just 0.48% (n = 950 patients) of the total CABG volume (n = 198,622) between July 2011 and March 2013.

TECHNICAL ISSUES

1- VERSUS 2-STAGED APPROACH. HCR can be performed either simultaneously or as a "2-staged" procedure. The former implies concurrent CABG and PCI in a single operative suite, with PCI following CABG within minutes. In the "2-staged" approach, the optimal order—PCI first versus CABG first—is debated because each approach has advantages and disadvantages (**Central Illustration**). Currently, decisions should be guided by patient characteristics, operator skill/expertise, and available facilities.

A simultaneous approach is only feasible in hybrid suites featuring state-of-the-art surgical and