Hybrid Coronary Revascularization:

The Future of Coronary Artery Bypass Surgery or an Unfulfilled Promise?

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Advancement in technique and technology over the last two decades has helped improve clinical outcomes in both surgical and interventional percutaneous coronary revascularization. Hybrid coronary revascularization (HCR) procedures introduced in 2011 by AHA/ACCF updated guidelines for coronary artery bypass grafting (CABG) surgery \(^1\) combine the superiority of the left internal mammary artery (LIMA) to the left anterior descending artery (LAD) revascularization\(^2,3\) with percutaneous coronary intervention by means of drug-eluting stents for non-LAD vessels\(^4\). Various minimally invasive surgical approaches are used to perform the LIMA to LAD graft. These approaches and techniques include off pump coronary revascularization, robotically assisted procedures, small left thoracotomy or partial sternotomy.

In the current issue of *Circulation*, Harskamp and colleagues\(^5\) describe contemporary practice patterns and clinical outcomes after hybrid coronary artery revascularization in the United States. Isolated CABG in patients that underwent HCR in Society of Thoracic Surgeons Adult Data Base between July 2011 and March 2013 were the subject of the study. The authors found only 0.48% (n=950) out of 198,622 CABG patients had HCR with 809/950 (85%) patients having a staged procedure while a small number of patients 141/950 (15%) had HCR done concurrently.

Only 1/3\(^{rd}\) of centers performing CABG procedures participated in the HCR cohort. Patients with HCR had higher cardiovascular risk profiles compared to CABG patients, while CABG patients had more complex coronary anatomy. HCR patients had more off pump procedures performed and more non-sternotomy approaches. HCR patients also had higher incidence of robotic assistance. Overall, outcomes were similar between the groups for the composite in hospital mortality and major morbidity.

The concept of HCR was introduced by Angelini and colleagues\(^6\) in 1996 by performing
a minimally invasive thoracotomy LIMA-LAD anastomosis and balloon angioplasty of the non-LAD vessels. Since then implementation of this procedure has been limited due to the complexity and learning curve of the surgical techniques and suboptimal results of bare metal stenting compared to surgical revascularization. With the introduction of drug eluting stents and the decreased rate of stent re-stenosis, HCR has reemerged as an alternative to conventional surgical revascularization in high-risk patients. In recent years several institutional series have confirmed that HCR can be accomplished safely with low operative mortality (<2%) and low morbidity.

Thus, is HCR the future in coronary revascularization? The results from the practice patterns in the USA by Harskamp warrants caution. The learning curve, the financial and time commitment as well as the need for a hybrid OR create stringent requirements that many programs will not be able to support. Also the clinical benefit of HCR over CABG has still not been evaluated by a randomized trial.

When to perform HCR

The most common indications for HCR are ungraftable non-LAD vessels, lack of conduit, reoperations, severe aortic atherosclerosis, severe calcification of the mitral annulus or prior chest radiation. Other indications include high-risk patients (recent myocardial infarction, prior stroke, frailty, end-stage renal disease on dialysis) in whom a less invasive approach may reduce the operative time and ischemic time. In a retrospective study, comparing the outcomes of HCR versus CABG surgery according to preoperative clinical risk stratification (Euroscore ≤ 5 or >5), there were no differences in 30-day composite index outcome in CABG surgery vs. HCR, however, in patients with complex coronary anatomy (Syntax score ≤ 32 vs. >33) and with higher preoperative clinical risk (Euroscore >5), results were worse for HCR than with
conventional CABG. While use of DES have shown lower rates of repeat revascularization and thrombosis in several trials, in reality they are often used in more complex patients such as those with bifurcating lesions, type C lesions, multiple stents or occluded vessels than those included in the trials.

**How and where to perform HCR**

Several minimally invasive techniques have been used to perform HCR despite the common theme being the steep learning curve for the surgeon and the need for specialized training in these techniques. Thus, the use of HCR depends significantly on the availability of surgeons trained in minimally invasive procedures.

The question of where to perform HCR and the best sequence, concurrent vs. staged, remains unresolved. The most compelling approach is the concurrent approach (one stage) in which during the same session PCI and CABG are performed in the same area. However, this approach is limited by hybrid operating room availability, the need for cross training of personnel, the potential risk of bleeding following administration of anti-platelets agents and the risk of contrast induced nephrotoxicity. The most common approach (staged) reported by Harskamp et al. (85% of all HCR procedures) poses several challenges including the need for two procedures and two hand-offs among teams. In the staged approach, the optimal sequence (PCI first and then CABG vs. CABG first and then PCI) depends on the coronary anatomy of the patient and their clinical presentation. On one end of the spectrum there is the risk of performing multi-vessel stenting in an unprotected LAD territory, vs. the need for re-intervention in the presence of anastomotic problems.

**The true value of HCR**

Some studies report reduced length of stay and shorter hospital stay in HCR vs. CABG.
depending on the timing of PCI and CABG and the modality. A recent report by Bachinsky and colleagues\textsuperscript{10} compared same setting robotic-assisted hybrid CABG to OPCAB. Patients after HCR had improved quality of life measures and a shorter time to return to work compared to off-pump coronary artery revascularization. Due to higher procedural costs, however, HCR was more expensive than off-pump coronary revascularization.

Another financial analysis of hospital costs and reimbursement showed that HCR results in not only higher procedural costs, but also higher reimbursement rate with improved resource utilization due to less blood transfusion, shorter ventilation time and shorter length of stay than off-pump coronary revascularization\textsuperscript{11}. Thus, compared to OPCAB, HCR results in greater contribution margin for the hospital\textsuperscript{11}.

With new DES and lower re-intervention rates it is possible that patency of saphenous vein grafts are no better than the newer generation of DES. There are no randomized trials comparing HCR versus CABG; thus the clinical significance must be validated by large pooled meta-analysis studies and single large institutional data. The overall assessment of the clinical value of HCR is that HCR has lower in-hospital morbidity than CABG surgery, but has the same in-hospital mortality and 1-year major adverse cardiovascular or cerebrovascular events. However, there is a higher re-intervention rate due to stent re-stenosis\textsuperscript{12}. Thus, the question of the true value of HCR remains undetermined. HCR, albeit with higher initial procedural costs but lower in-hospital costs related to lower morbidity, may have the same or better initial value than regular CABG surgery which is probably offset by future coronary re-intervention due to stent re-stenosis. Therefore, the wide application of HCR is limited by the uncertainty of the long-term effectiveness of DES and the higher cost.

\textbf{Conclusion}
Unless the overall patient experience, outcomes and financial implications of HCR are significantly better than standard CABG alone in the long-term, HCR will continue to play a limited niche in coronary revascularization.

Harskamp and colleagues\(^5\) delineate the current practice of HCR in the United States. HCR remains a valuable alternative to conventional CABG surgery in the hands of expert centers where there is integration between cardiac surgery and cardiologists and cardiac surgeons are trained in minimally invasive procedures. Patients with complex lesions in the LAD (high Syntax score derived from LAD lesions) are most amenable to LIMA to LAD bypass and PCI to non-complex non-LAD lesions. The ideal subset of patients in whom the medical and financial risks of a minimally invasive procedure are acceptable is still to be determined.

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**References:**


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