

# Hybrid Coronary Revascularization: Present and Future

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**C**oronary revascularization provides symptomatic relief and improves long-term outcomes in patients with multi-vessel coronary artery disease (CAD).<sup>1</sup> The ideal revascularization strategy remains controversial and depends on the anatomic complexity of the lesions that require revascularization, the comorbidities, and the ability to use dual antiplatelet therapy.<sup>1</sup> Though coronary artery bypass grafting (CABG) is considered the gold standard of the revascularization approaches, the development of newer-generation coronary stents and safer medications have challenged this status quo. The major advantage of CABG over percutaneous coronary intervention (PCI) remains the use of the left internal mammary artery (LIMA) to bypass the left anterior descending (LAD), irrespective of its lesion complexity. The superiority of the LIMA-LAD bypass is translated into relief from angina and better long-term survival.<sup>1</sup> On the other hand, the benefit of surgically bypassing other coronary arteries is less clear, mostly because the saphenous vein grafts (the most widely used grafts) have inferior patency rates in the long term. PCI for these lesions has been proven to be equivalent and reliable. From the patient's perspective, PCI involves much less discomfort, a shorter hospital stay, faster recovery, and a lower risk of complications such as stroke and bleeding.<sup>2</sup>

In order to combine the advantages of the LIMA-LAD surgical bypass with the minimal invasiveness of the PCI, a hybrid approach to coronary revascularization was introduced. According to the 2011 ACCF/AHA guidelines for coronary artery bypass surgery, hybrid coronary revascularization (HCR) is defined "as the planned combination of LIMA-to-LAD artery grafting and PCI of one or more non-LAD coronary arteries".

The guidelines recommend that hybrid revascularization is reasonable (level of evidence B) in patients with one or more of the following:

- Limitations to traditional CABG, such as a heavily calcified proximal aorta or poor target vessels for CABG (but amenable to PCI).
- Lack of suitable graft conduits.
- Unfavorable LAD artery for PCI (i.e. excessive vessel tortuosity or chronic total occlusion).

Finally, a level of evidence C is assigned to hybrid coronary revascularization as an alternative to multivessel PCI or CABG in an attempt to improve the overall risk-benefit ratio of the procedures.<sup>3</sup>

## Modes of hybrid coronary revascularization

In clinical practice, there are 3 basic modes of HCR that are used to address CAD. The decision making should involve

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the “Heart Team”, which consists of an interventional cardiologist and a cardiac surgeon.

### **One stage HCR**

The development of hybrid operating rooms has made it feasible to have both CABG and PCI performed during the same session. In this way a LIMA-LAD anastomosis can be performed, followed by PCI of the non-LAD lesions. The main advantages of this approach are the one-stop treatment of CAD, the lower cost, and the reduced length of stay. Other advantages of this strategy are the immediate confirmation of the patency of the LIMA graft prior to chest closure and the ability to correct any issues on the spot. The major drawback is the risk of bleeding due to the immediate use of dual antiplatelet therapy and incomplete heparin reversal for fear of stent thrombosis.<sup>4</sup> Furthermore, not all hospitals have hybrid operating rooms available.

### **Two-stage HCR: PCI followed by CABG**

This approach is mainly reserved for patients who have an acute coronary syndrome with a non-LAD culprit lesion. The major disadvantage of this setting is the increased risk of bleeding due to the use of dual antiplatelet therapy before the CABG, which should be used in the perioperative period in order to avoid stent thrombosis. Moreover, the PCI is performed in an unprotected environment with the LAD territory still not revascularized.

### **Two-stage HCR: CABG followed by PCI**

This is currently the most widely used method of HCR. The major advantage is the use of dual antiplatelet therapy a few days after the CABG is performed, when the risk of bleeding is minimal. In addition, the patency of the LIMA-LAD anastomosis can be confirmed during the PCI. The biggest challenge of this approach is for the surgeon, as the CABG takes care of the LAD distribution, leaving the other areas ischemic until the performance of the PCI.<sup>1</sup>

### **Surgical techniques used for HCR**

Single LIMA-LAD anastomosis can be performed with the following techniques. Each one should be chosen by the surgeon based on expertise, individual patient needs, and the clinical scenario. However,

regardless of the technique used, the surgeon has to make sure to perform ideal LIMA harvesting and anastomosis, in order to offer the patient the advantage of the LIMA-LAD bypass and prolong survival. In general, current trends favor the use of minimal incisions with off-pump techniques.

1. Traditional median sternotomy: a full or partial sternotomy is performed, the LIMA is harvested from the chest wall, and the LIMA-LAD anastomosis is performed with direct vision of the operating field.
2. Minimally invasive CABG: a mini thoracotomy is performed in the 5th intercostal space, and the LIMA harvesting and LIMA-LAD anastomosis are performed under direct vision.
3. Endoscopic CABG: the whole operation is performed with the use of thoracoscopic ports and camera, with or without one-lung ventilation.
4. Robotic CABG: same as the endoscopic approach, but the surgeon is at a remote site, operating the robotic arms through a console.
5. On-pump or off-pump CABG: current trends favor the use of off-pump surgery, since the morbidity and bleeding risk is minimized. However, traditional cardiopulmonary bypass is used in cases where the patient may become hemodynamically unstable.

### **Antiplatelet therapy in HCR**

The major perioperative concern in patients undergoing HCR is the complication of bleeding or acute stent thrombosis related with the use of antiplatelet agents. Unfortunately, there are no guidelines for the use of such agents, only some published reports and case series.

Most authors believe that the challenge has to do with the timing of each procedure.<sup>1</sup> Thus, in cases of CABG followed by PCI in a one-stage approach, a loading dose of clopidogrel (300 or 600 mg) can be given either before the surgery,<sup>5</sup> after the LIMA-LAD anastomosis,<sup>6</sup> or after the PCI is completed.<sup>5,7</sup> The new P2Y12 inhibitors, such as prasugrel, ticagrelor, and cangrelor, are more potent and have a faster onset of action or reversal than clopidogrel, and may play a future role in HCR.<sup>1</sup> However, so far there is no substantial experience or data to support their routine use.

### **Patient outcomes with HCR**

There have been a number of smaller case reports

**Table 1.** Suggested indications for hybrid revascularization. (Adapted from reference 26. Reproduced with permission).

| Indications                                                                          |
|--------------------------------------------------------------------------------------|
| LAD lesion with suitable caliber for minimally invasive or endoscopic CABG           |
| Unfavorable non-LAD targets or distal lesions in circumflex or right coronary artery |
| Absence of suitable venous conduits                                                  |
| Patients with a predicted high incidence of mortality with conventional CABG         |
| Older disabled or deconditioned patients                                             |
| Limited mobility or marked frailty (difficult rehabilitation)                        |
| Patients unwilling to undergo median sternotomy                                      |

**Table 2.** Suggested contraindications for hybrid revascularization. (Adapted from reference 26. Reproduced with permission).

|                                           | Contraindications                                                                                                                                                                                                                                                                                                             |
|-------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Clinical conditions                       | Hemodynamic instability<br>Malignant ventricular arrhythmias<br>Decompensated congestive heart failure or severely depressed ejection fraction<br>History of chronic lung disease (FEV1 < 50%) predicted or home oxygen dependence precluding intubation<br>Coagulopathy<br>History of pericarditis<br>Prior left thoracotomy |
| Conditions that exclude LIMA-LAD grafting | Unusable or previously used LIMA<br>Previous thoracic surgery involving the left pleural space<br>Poor quality or diffusely diseased LAD<br>Chest wall irradiation<br>Left subclavian artery stenosis                                                                                                                         |
| Limitations for HCR                       | Longer operating time<br>Technically demanding for the surgeon<br>Lower anastomosis patency depending on the learning curve<br>Need for intraoperative imaging requiring hybrid suite<br>Collaboration between surgeons and cardiologists                                                                                     |

or case series comparing the outcomes of HCR with either CABG or PCI with drug-eluting stents. All of these studies are non-randomized.<sup>8-24</sup> The overall conclusion that can be drawn is that in-hospital mortality, stroke, and reoperation for bleeding were comparable among the patients with the various techniques.<sup>1</sup>

### Conclusions and future challenges

Hybrid coronary revascularization has been developed as a promising technique for the treatment of high-risk patients with CAD. However, it lacks validation from a randomized clinical trial that would compare HCR with CABG and PCI. Such a study would be extremely important in order to show that HCR is superior, or at least non-inferior, to CABG or PCI in the areas of mortality, coronary events, bleeding, stroke, and length of stay. The published results

of the first multicenter observational trial comparing outcomes of patients undergoing clinically indicated HCR and percutaneous coronary intervention (PCI) for hybrid-eligible CAD will hopefully shed light on the above questions.<sup>25</sup> Another key point that needs to be studied is the timing and staging of the two procedures (CABG and PCI) and, of course, the ideal antiplatelet agent, its dosage, and the timing of its administration. Finally, in Tables 1 and 2 we have included a short list of suggested indications and contraindications, adapted from Holzhey et al,<sup>26</sup> that could be used as a map for the future development of HCR guidelines.

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