Role and Rationale for Hybrid Coronary Artery Revascularization

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Abstract

The optimal revascularization strategy for patients with multi-vessel coronary artery disease remains controversial. The advent of percutaneous coronary intervention (PCI) has challenged the superiority of coronary artery bypass graft (CABG) surgery for multi-vessel disease. In the late 1990s, an integrated approach, now referred to as "hybrid coronary revascularization" (HCR), was pioneered combining CABG and PCI to offer appropriate patients a less invasive option for revascularization while still capitalizing on the superior patency rates of the left internal mammary artery (LIMA) to the left anterior descending (LAD) artery bypass . The operative techniques continue to evolve as well as the timing strategies for intervention and use of anti-platelet therapy. While more research is needed, current data supports hybrid coronary revascularization as a promising technique to optimize outcomes in patients with multi-vessel coronary artery disease.

Keywords: Hybrid Coronary Revascularization, Coronary Artery Disease, Coronary Artery Bypass Grafting, Percutaneous Coronary Intervention, Robotics

1. Introduction

The optimal revascularization strategy for patients with multi-vessel coronary artery disease remains controversial. The advent of percutaneous coronary intervention (PCI) has challenged the superiority of coronary artery bypass graft (CABG) surgery for multi-vessel disease as PCI offers a less invasive option with faster recovery time and lower risk. Despite a survival benefit in high-risk groups and superior long-term freedom from revascularization, trends continue to move toward increasing percutaneous approaches. In the late 1990s, an integrated approach, now referred to as "hybrid coronary revascularization" (HCR), was pioneered combining CABG and PCI to offer appropriate patients a less invasive option for revascularization while still capitalizing on the superior patency rates of the left internal mammary artery (LIMA) to left anterior descending (LAD) artery bypass. The technology has evolved tremendously since the introduction of HCR with some LIMA-LAD grafts now performed completely robotically. As HCR evolves, questions regarding indications, optimal surgical technique, timing, and outcomes as well as cost-benefit analysis continue to permeate current practice and will define the future of HCR in the algorithm of coronary revascularization.

2. Rationale

CABG has long been the established standard of care to treat left main or three vessel coronary artery disease [1]. The therapeutic benefit of this approach lies in the LIMA-LAD revascularization. Patency rates of this anastomosis lie between 95%–98% at 10 years [2]. Radial arterial conduits have been explored as another option for total arterial revascularization; however, results do not compare with the long-term patency of LIMA utilization [3]. Saphenous vein grafts (SVG) also do not provide the same longevity of the LIMA-LAD revascularization. Failure of SVG is multifactorial including technical failure within 30 days, neo-intimal hyperplasia at 1–24 months, and atherosclerotic degeneration beyond 2 years. Patient risk factors such as hyperlipidemia and ongoing tobacco are also associated with accelerated graft failure. Failure rates are estimated as high as 10%–15% at 1 year after CABG with almost 50% total graft occlusion at 10 years [4]. Despite this high failure rate, SVG remain the most commonly used conduit for CABG surgery.

PCI has challenged the superiority of CABG surgery for multi-vessel disease. The use of drug-eluting stents (DES) in particular has provided a less invasive option for revascularization with faster return to normal activities and lower risk of complications. Restenosis rates and stent thrombosis of DES in non-LAD lesions are markedly lower than non-LAD SVG with rates less than 10% and 1%, respectively [5]. In addition, stenting of SVG after thrombosis introduces technical changes with higher peri-procedural rates of complications and in-hospital mortality than stenting of native arteries [4, 6]. Despite data that suggests improved outcomes with many patients including diabetics and those with left main and complex multi-vessel coronary artery disease (CAD) [2], trends continue toward increased PCI over CABG.

The strategy of HCR attempts to capitalize on the superior LIMA-LAD patency rates as well as the minimally invasive PCI approach thus eliminating the need for additional venous or arterial conduits. Patients with multi-vessel disease with significant proximal LAD disease with other lesions suitable for PCI in the left main, left circumflex, or right coronary artery territories are appropriate candidates for HCR [7]. In addition, patients with lack of suitable conduits, prior sternotomy, severe ascending aortic disease, or coronary arteries not amenable for bypass may be suitable HCR candidates. Patients generally not deemed HCR candidates

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and thus deferred to conventional CABG include those with chronic total occlusions, highly calcified segments, and diffusely diseased and bifurcation coronary lesions [7]. Table 1 summarizes the clinical and angiographic findings that should be taken into consideration when discussing the option for HCR. Discussions regarding treatment options are best facilitated by a multi-disciplinary approach including both an interventional cardiologist and cardiac surgeon.

	PCI	CABG	HCR
Angiographic Characteristics			
Unprotected Left Main Disease	no	yes	yes
Intra-myocardial LAD	yes	no	no
Complex LAD lesion	no	yes	yes
Complex non-LAD lesions	no	yes	no
Comorbidities			
Advanced Age	yes	no	yes
LVEF <30%	no	yes	yes
Diabetes mellitus	no	yes	yes
Renal insufficiency	no	yes	yes
Severe chronic lung disease	yes	no	no
Prior left thoracotomy	yes	yes	no
Prior sternotomy	yes	no	yes
Limited vascular access	no	yes	no
Lack of available conduits	yes	no	yes
Severe aortic calcification	yes	no	yes
Contraindication for dual anti-platelet therapy	no	yes	no

Table 1. Recommendations for Candidates for Hybrid Coronary Revascularization Versus Conventional Coronary Revascularization [2, 21]

3. Strategies and surgical approach

3.1. Surgical approaches

Minimally invasive cardiac surgery seeks to eliminate two invasive components of conventional CABG: cardiopulmonary bypass (CBP) and sternotomy. The development of stabilizer technology in the early 1990s made available off-pump CABG with the potential advantages of less blood loss, lower incidence of neurologic complications, and less pulmonary complications [8]. In conjunction with sternal sparing incisions as well as robotic techniques, a minimally invasive off-pump option for LIMA-LAD revascularization offers the key to optimizing the HCR option. The techniques described below and in Table 2 discuss the current options for minimally invasive surgical approaches to LIMA-LAD revascularization highlighting key features of the various techniques.

	Thoracic Access	**LIMA Harvest**	**Anastomosis**	**Single Lung ventilation**	**CPB**	**Advantages/Disadvantages**
OPCAB (Off-pump CABG)	Midline Sternotomy	Direct Vision	Direct vision with stabilizers	Not Required	No	Avoids risks associated with CBP
MIDCAB (Minimally invasive direct coronary artery bypass grafting)	Left-sided thoracotomy or lower partial sternotomy	Direct Vision	Direct Vision	Improves exposure but not required	Not required but can be performed by femoral cannulation	Avoids aortic cross-clamping and manipulation
Endo-ACAB (Endoscopic atraumatic coronary artery bypass graft surgery)	Limited rib sparing left-sided thoracotomy	Robotic or Thoracoscopic	Hand-Sutured	Required when robot is used	Not required	Decreased morbidity from thoracotomy incision yet allows for hand-sewn anastomosis
TECAB (Totally endoscopic coronary artery bypass graft surgery)	Thoracoscopic	Robotic	Robotic intracorporeal anastomosis	Required	Not required	Minimally invasive, however very technically challenging

Table 2. Surgical Techniques Used for LAD Revascularization During Hybrid Coronary Revascularization

MIDCAB: Minimally invasive direct coronary artery bypass(MIDCAB) grafting refers to an off-pump minimally invasive LIMA-LAD revascularization performed through a small left-sided thoracotomy in the fourth or fifth interspace. Costal cartilage removal or rib disarticulation is sometimes necessary for visualizing. Cardiac stabilization and LAD harvest is performed directly through the wound and does not require endoscopic or robotic skills to master the LAD harvest. Surgeon comfort with off-pump techniques is critical as well as experience with sternal sparing incisions. Single-lung ventilation is optimal for exposure; however chest cavity insufflation is not necessary. A slightly larger thoracotomy incision can allow exposure for harvest of bilateral internal mammary arteries.

Large series published since 1994 have validated short-term LAD-LIMA patency rates of this technique at 95%–97% [8]. The advantage of this technique lies in the avoidance of CBP and aortic manipulation as an off-pump strategy; however, no data exists to suggest differences in

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post-operative pain or pulmonary complications from conventional CABG [8]. MIDCAB may have decreased bleeding and infection rates compared to traditional sternotomy, however the need for a thoracotomy incision for the technique has prompted further exploration into various thoracoscopic and robotic techniques to capitalize on the advantages of minimally invasive strategies as discussed in the following.

Endo-ACAB: Endoscopic atraumatic coronary artery bypass (Endo-ACAB) refers to the thoracosocpic or robotic identification of the LAD with LIMA mobilization without violating the integrity of the chest wall (Figure 1). A directed, non-rib spreading or limited rib spreading thoracotomy is then employed for a hand-sewn LIMA-LAD anastomosis on the beating heart. Robotic LIMA mobilization requires single-lung ventilation and insufflation to create space in the anterior mediastinum to facilitate LIMA harvest. After the LIMA is taken down, a pericardial incision is made for identification of the LAD. A small (4–5cm) anterior thoracotomy without disarticulation of costal cartilage is then made to introduce an endoscopic stabilizer via an arm port, which allows for LAD stabilization and hand-sewn anastomosis.

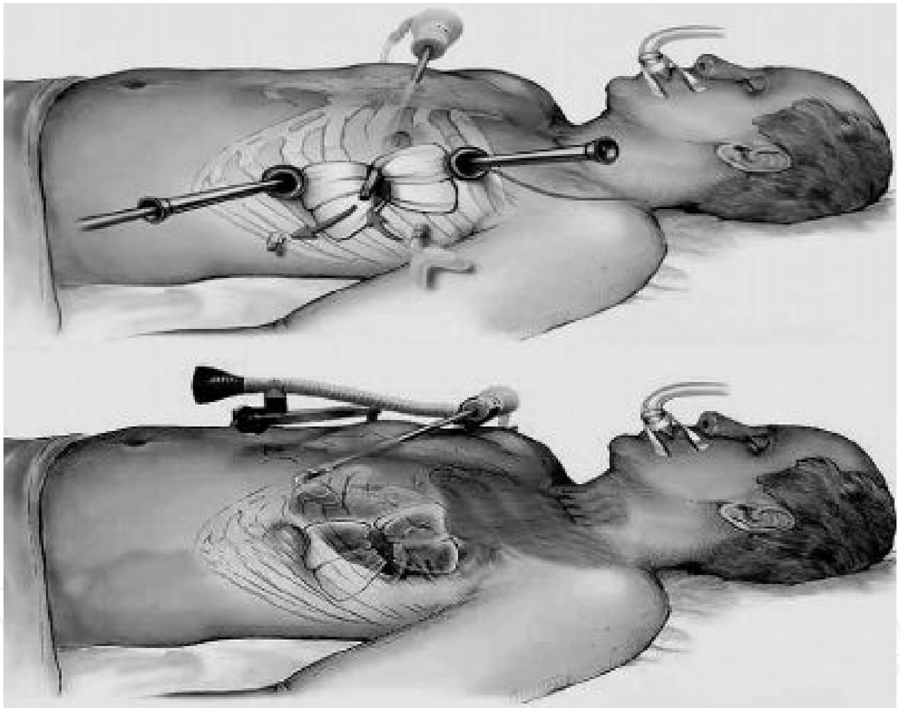

Figure 1. EndoCab technique as described above.

Multiple case series have reported excellent LIMA-LAD patency rates with thoracoscopic Endo-ACAB approaches. In new smaller series with robotic Endo-ACAB approaches, routine post-operative angiography has demonstrated no decline in LIMA-LAD patency rates. In Kiaii's series of 58 patients who underwent one-stage robotic Endo-ACAB HCR, the average length of stay in the ICU and hospital were 1 and 4 days, respectively, leading the authors to suggest benefit to patients in terms of post-operative surgical morbidity and recovery time using more minimally invasive technology [9].

TECAB: Totally endoscopic coronary artery bypass grafting (TECAB) utilizes a robotically sewn, intracorporeal anastomosis, which negates the need for even a small thoracotomy. This technique was first explored on an arrested heart during CBP; however, the associated complications of CPB have led most robotic surgeons to employ an off-pump TECAB. The operation itself is technically challenging without widespread adoption of this technique owning to the need for robotic technology and surgeon expertise.

One of the largest series published in 2012 reported on 226 patients with 5-year outcomes [10]. Perioperative results were consistent with the standards of open CABG. The authors report a dramatically decreased time to recovery owning to the lack of need for sternal precautions. In the 10 cases requiring conversion to thoracotomy, these patients averaged 2- day longer hospital stays with increased ventilator time and return to normal activities [10]. Overall results in other case series support the safety and feasibility of this technique; however, Harskamp reports that only approximately one-third of HCRs from 2011–2013 reported in the Society of Thoracic Adult Cardiac Database utilize robotic technology [11]. Expansion of the TECAB approach is currently limited by the cost and learning curve associated with the implementation of robotic technology.

Graft Assessment: Off-pump (OP) and minimally invasive techniques for LAD-LIMA grafting have appropriately been scrutinized with regard to patency rate outcomes compared to the classical on-pump CABG via a midline sternotomy. The recent Randomized On/Off Bypass (ROOBY) trial as well as other smaller trails have demonstrated that the patency rates of LIMA-LAD grafts between off-pump coronary artery bypass (OPCAB) and conventional CABG were similar (95.3 and 96.2, respectively) [12]. As the HCR approach relies upon the durability and integrity of this anastomosis, the ability of the surgeon to assess the LIMA-LAD graft intra-operatively becomes increasingly important. In fact, the European Society of Cardiology (ESC) and the European Association for Cardio-Thoracic Surgery (EACTS) recommends graft evaluation before leaving the operating room [13].

Graft assessment includes the traditional methods such as inspection, palpation, electrocardiography (ECG), and echocardiography (ECHO). Other methods include conventional coronary angiography, which is the gold standard, transit-time flow measurement (TTFM), and intra-operative fluorescence imaging (IFI). As the causes of early graft failure are often technical, this technology seeks to eliminate these errors by objectively evaluating graft function. Certainly, a clear advantage of single stage HCR with CABG followed by PCI lies in the opportunity for angiographic graft assessment with readily available operative access for reintervention; however, when angiographic assessment is not available, the most commonly utilized technique among cardiovascular surgeons over the last decade has become TTFM. Retrospective studies have demonstrated the ability of TTFM to detect grafts with impaired flow thus predicting graft failure within 6 months after CABG [14]; however, little is known about how TTFM relates to long-term graft patency and patient survival.

TTFM relies on the principles of transit-time ultrasound technology. The surgeon can obtain both quantitative data of average blood flow volume and several calculated derivatives of the flow of blood in the graft displayed in waveform. TTFM cannot, however, differentiate physiologic conditions accounting for low blood flow versus technical quality of a surgical anastomosis. While clear cut-off values for graft revision have not been set, a mean flow <15ml min $^{-1}$ for grafts to the left coronary system and less than 20ml min $^{-1}$ for grafts to the right coronary system were predictive of failure. A pulsatility index (PI) greater than 0.5 is predictive of graft failure. Another important value is the diastolic flow percentage (DF%) or diastolic flow divided by total flow through the graft. This value should be greater than 50% for all grafts and territories and ideally greater than 65%. When the PI and DF% both demonstrate adequate measurements, the graft can be objectively presumed adequate [15]. Figure 2 demonstrates the intra-operative TTFM tracings utilizing the MediStim ASA technology, which is one of the more commonly utilized flowmeters.

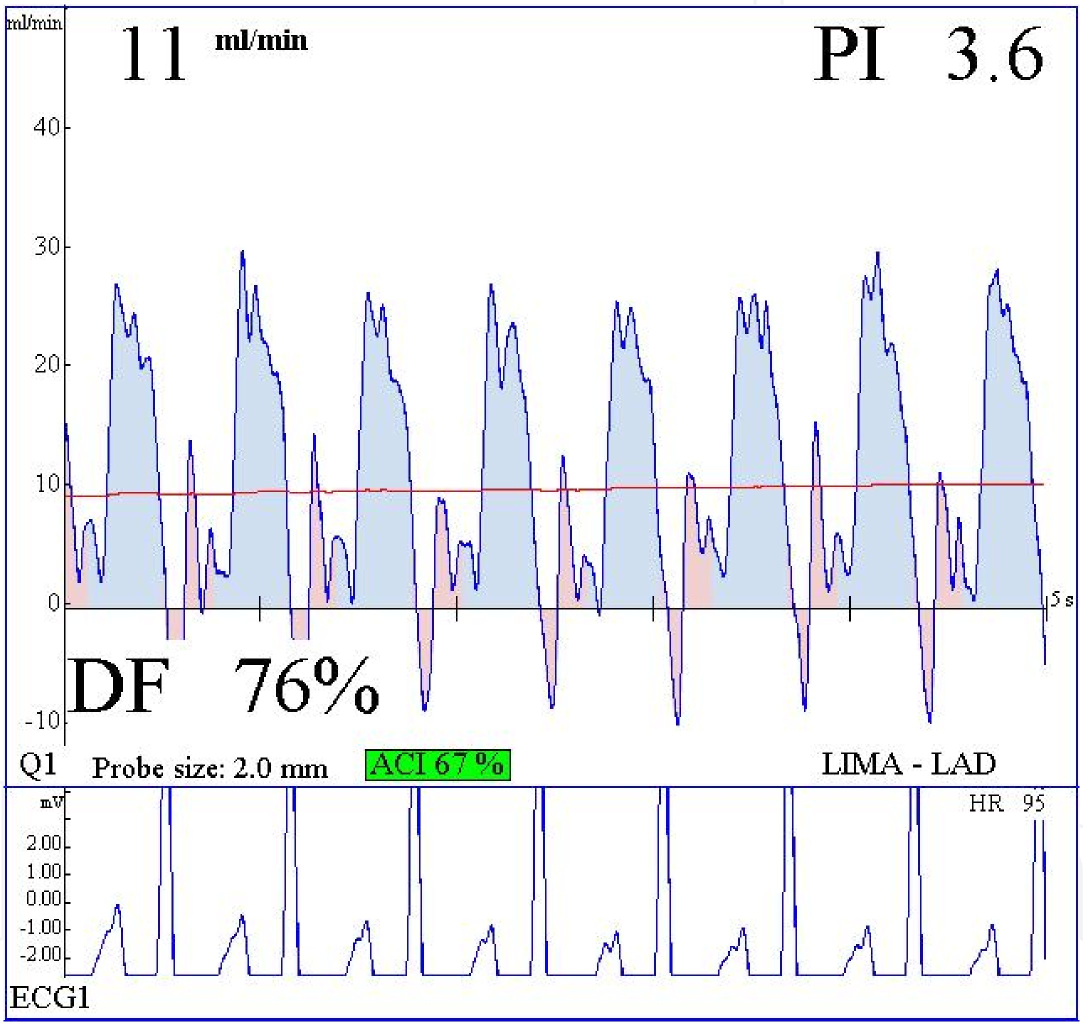

Figure 2. Transit Time Flow Assessment.

3.2. Timing strategies

HCR began in the 1990s as a staged procedure with LIMA-LAD revascularization performed first followed by PCI. The use of DESs and anti-platelet therapy as well as the use of hybrid operating room suites has introduced questions as to the most optimal timing for open and

PCI revascularization. Currently, three options for timing strategies exist: PCI followed by CABG, CABG followed by PCI, and one-stage hybrid HCR. Each option introduces different benefits and challenges, and at this time no clear consensus exists on the optimal strategy for timing of revascularization (Table 3). Patient characteristics, operator skill, and availability of facilities should be considered when choosing the most appropriate approach.

One-Stage HCR	**Two-Stage HCR**	
Simultaneous CABG and PCI	**CABG then PCI**	**PCI then CABG**
Advantages:	**Advantages:**	**Advantages:**
Ability to study LIMA-LAD graft	Ability to study LIMA-LAD graft	Pre-operative angiographic imaging of LIMA size
Protected LAD to allow PCI to high-risk non-LAD lesions	Protected LAD to allow PCI to high-risk non-LAD lesions	Lower risk of ischemia during CABG given non-LAD territory revascularization
Single anesthetic exposure	Reduced risk of post-surgical bleedingas no need for anti-platelet therapy post CABG	Useful in acute coronary syndromeswith non-LAD culprits
Can convert to conventional CABG if PCI fails	After LIMA-LAD revascularization, asymptomatic patients may require no further intervention	If stents unsuccessful, conventional CABG has to be subsequently performed
Single procedure reduces cost and hospital length of stay		
Disadvantages:	**Disadvantages:**	**Disadvantages:**
Requires hybrid suite	Risk of ischemia during CABG in non-LAD lesions	No ability to angiographically evaluate LIMA-LAD anastomosis
Increased risk of post-operative bleeding due to need for anti-platelet after surgery	Unsuccessful PCI may lead to need for surgical reintervention	Increased peri-operative bleeding due to need for anti-platelet therapy
Risk of stent thrombosis due to post-operative inflammatory state		Potential for LAD territory ischemia between stages
CKD patients exposed to dual nephrotoxic insults with surgery and PCI contrast use		Higher risk of stent thrombosis due to inflammatory response of CABG and potential need to hold anti-platelet therapy
High degrees of coordination needed between teams		

Table 3. Advantages and Disadvantages of One and Two-Staged HCR Procedures

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One-Stage HCR: Simultaneous CABG and PCI: The advent of hybrid operating room suites has introduced the option for simultaneous CABG and PCI. This approach allows for complete revascularization before leaving the operating room. Routine imaging of the LIMA-LAD anastomosis is also available before chest closure. More aggressive percutaneous approaches can be taken to otherwise challenging lesions given the safety net of open revascularization options. The patient benefits from a single anesthetic exposure and decreased hospitalization time. One ongoing concern however is the post-operative risk of bleeding given the need for dual anti-platelet therapy after DES placement in conjunction with incomplete heparin reversal. Concerns also exist regarding the relationship of the inflammatory response in the post-operative setting and risk for acute stent thrombosis.

Two-Stage: PCI Followed by CABG: This option confers several advantages. In revascularizing the non-LAD lesion first and thus providing collateralization, the potential risks of ischemia during LAD occlusion are minimized. PCI firstly also provides the interventional cardiologist a safety net should revascularization be unsuccessful percutaneously. The most important benefit of this approach occurs in the setting of acute coronary syndrome with a non-LAD culprit. The acutely affected lesion may be stented followed by LAD revascularization at a later time. This strategy does however introduce the difficulty of the need for anti-platelet therapy with DES. Even brief discontinuation of anti-platelet therapy can risk stent thrombosis; however this must be weighed with intra-operative bleeding risk. Investigation is underway regarding the use of newer anti-platelet agents and potential decreased bleeding risk. It again should be noted that the pro-inflammatory trauma from surgery could also put new stents at risk for thrombosis.

Two-Stage: CABG Followed by PCI: This strategy has become the most widely adopted one for HCR. With PCI post-CABG, the concern for surgical bleeding while on anti-platelet therapy is negated. Like hybrid HCR, LIMA-LAD graft patency can be confirmed during PCI angiography. Pre-PCI protection of the LAD also provides the interventional cardiologist the option to approach lesions that would perhaps have otherwise been at higher risk. This includes both left main lesions and diagonal bifurcation lesions [8]. For the minimally invasive surgeon, the unrevascularized collateral lesions could manifest as intra-operative ischemia. Careful attention must be paid to hemodynamics during insufflation, and the use of peripheral CPB should be considered if needed. In the scenario of a PCI complication or failure, this approach could necessitate a return to the operating room with emergent CABG. The optimal time frame for PCI following CABG remains unclear. Some teams opt for PCI during the index hospitalization and thus avoid patient discharge with an incomplete revascularization, however other teams propose a more extended period of waiting from 1 to several weeks. Economic factors also become an increasing concern given questions of reimbursement.

Overall, no clear optimal timing strategy has been clearly defined. While some studies demonstrate increased post-operative bleeding risks on dual-anti-platelet therapy, others suggest that the minimally invasive surgical approaches negate this risk traditionally associated with sternotomy. Harskamp's analysis of recent STS data suggests that the need for post-operative transfusion was actually lower in the one-stage procedure group with comparable reoperation for bleeding [11]. This analysis also reports that patients undergoing one-stage procedures were more likely to have peripheral vascular disease and stroke history compared to other groups [11]. Further studies are needed to outline the specific clinical scenarios and patient characteristics, which should dictate the timing of CABG and PCI. Certainly, cost analysis and patient preferences will also factor into future decision-making regarding timing strategies.

Anti-platelet management: As discussed, the use of anti-platelet therapy is a complicated balance of post-surgical bleeding versus risk of acute stent thrombosis. Currently, no guidelines exist to define the optimal strategy. This question of anti-platelet therapy poses two questions regarding the order of staging as well as timing of initiation of therapy. Different authors have reported their experience with varying strategies and outcomes. In cases of two staged procedures with CABG first, most authors performed CABG on aspirin alone followed by a second anti-platelet agent greater than 4 h post-operatively after ensuring that there were no bleeding complications [16]. In the two stage procedures, which performed PCI first, anti-platelet therapy was begun before PCI and continued uninterrupted during CABG. In one-stage procedures, the most common strategies administered anti-platelet therapy after undergoing the LIMA-LAD graft, just before its completion, or immediately after PCI. Others administered anti-platelet therapy at the induction of anesthesia or in the pre-operative area owning to the fact that maximal platelet inhibition occurs 4–24 h after administration [16]. None of these strategies differed in reported rate of acute stent thrombosis [5]. In some studies, the rate of blood transfusion was actually lower in the HCR group as was the need for reoperation for bleeding [11]. Newer anti-platelet agents that are more potent and have a faster onset of action and reversal have also been employed; however, there is currently no data to support the use of these new agents in HCR.

4. Outcomes

Multiple case series from single institution experiences have been published on HCR since the first report in 1996. This includes a population of over 3,000 patients [16]. Data from these series suggest that in experienced hands, the safety profile of HCR is excellent. Multiple studies comparing outcomes after HCR versus CABG and multi-vessel disease have also been published (Table 4). Among cohort studies, the single-stage HCR was most commonly employed. Across these studies, age averaged around 60 years with a male predominance. Left ventricular ejection fraction (LVEF) was preserved or mildly reduced in the majority of patients. With the exception of data from Leacche et al., overall in-hospital mortality, stroke and reoperation for bleeding rates were comparable and low [0% to 2.6%). The outlier reported by Leacche et al. was among the high SYNTAX-HCR group with a reported in-hospital mortality of 23% leading the authors to suggest that HCR should be approached with caution in patients with high (≥33] SYNTAX scores [17]. These reports collectively suggest that HCR may be a comparable option to CABG in patients with non-LAD lesions accessible by PCI.

Table 4. Studies Comparing Outcomes After HCR Versus CABG or PCI in the Drug Eluting Stent Era [5, 22]

Author, Year Type of Study	N	Surgical Technique	Timing of PCI	Age, years	Male, %	LVEF %	SYNTAX Score	In-Hospital Mortality	Follow-Up Period	Survival
Shen et al., 2013 Retrospective, matched cohort study (propensity matched) Recruitment: 2007-2010 (23)	141 HCR 141 CABG 141 PCI	Lower partial mini-sternotomy CABG (on and off pump)	One Stage	62±9.9 62.4±7.8 61.7±10.3	88.7 90.1 87.2	62.7±7.1 62.6±8.0 62.1± 9.3	27.6±7.9 28.2±9.4 26.0±8.2	N/A	30 days	99.3% 97.2% 96.5%
Leacche et al., 2013 Retrospective cohort study (group stratification) Recruitment: 2005-2009 (17)	80 HCR SYNTAX≤32 (67) SYNTAX>32 (13) 301 CABG SYNTAX≤32 (226) SYNTAX>32 (75)	OP 22% OP 31% OP 15% OP 16%	One Stage	62 (32-85) 74 (32-84) 63 (32-89) 62 (32-83)	79 62 75 83	50 (20-70) 50 (20-65) 55 (10-80) 50 (10-70)	N/A	****	30 days	N/A
Bachinsky et al., 2012 Prospective cohort study, no matching Recruitment: 2009-2011 (24)	25 HCR 27 CABG	OP MIDCab (Robotic) 100% OP CABG (thoracotomy)	One Stage	63.2±10.5 66.78±10.7	80 59	55.3±10.4 51.48±12.0	33.52±8 34.89±8.2	0% 4%	30 days	100% 96%
Halkos et al., 2011 Retrospective matched cohort study (propensity matching) Recruitment: 2003-2010 (25)	147 HCR 588 CABG	OP EndoACAB OP CABG	Surgery and PCI within 2-3 day (137); One stage (10)	64.3±12.8 64.3±12.5	38.1 28.6	54.7±8.7 54.6±8.7	N/A	0.7% 0.9%	3.2 years	5-year survival: 86.8% 84.3%
Vassiliades et al., 2009 Retrospective cohort study (no matching, propensity score adjustment) Recruitment: 2003-2007 (26)	91 HCR 4175 CABG	OP EndoACAB OP CABG	85 CABG first 6 PCI first	64.7±13.7 62.8±11.7	40.7 37.3	51.5±9.4 50.9±12.7	N/A	0% 1.8%	3 years	94.0% 89.2%
Zhao et al., 2009 Retrospective cohort study (no matching) Recruitment: 2005-2007 (27)	112 HCR 20 CABG	Reversed-J inferior sternotomy OP CABG	One Stage	63 (32-85) 63 (32-89)	71 76	50 (15-70) 54 (10-72)	N/A	2.6% 1.5%	N/A	N/A
Reicher et al., 2008 Prospective, matched cohort study (propensity matching) 2005-2006 (28)	12 HCR 26 CABG	OP MidCab OP CABG (sternotomy)	CABG first	62±10 64±10	80 83	31 (EF <40%) 27 (EF <40%)	N/A	0% 0%	30 days	100% 100%
Kon et al., 2008 Matched prospective cohort study, unclear matching method Recruitment: 2005-2006 (29)	15 HCR 30 CABG	OP MidCab OP CABG (sternotomy)	One Stage	61±10 65±10	73 63	47±14 45±14	N/A	0% 0%	12 mo.	100% 100%

**** see text

Harskamp et al. published a meta-analysis in 2014 reporting clinical outcomes after HCR in 1,190 patients in single-center registries [18]. This study incorporated six observational studies (one case control and five propensity adjusted) that included adjustments for differences in baseline characteristics. Comparisons of individual components showed no differences in all-cause mortality, MI, or stroke at one year follow-up (odds ratio: 0.49; 95% confidence interval: 0.2 -1.24; p=0.13), however the HCR group demonstrated a higher repeat revascularization rate compared with CABG. These findings were irrespective of the order in which LIMA-LAD graft and PCI were performed.

The only current randomized control trial comparing HCR and CABG was published in 2014 [19]. Two-hundred consecutive patients from a single institution with angiographically confirmed multi-vessel disease involving the proximal LAD and a significant (>70%) lesion in at least one major non-LAD epicardial vessel amenable to both PCI and CABG were randomized in a 1:1 fashion. The primary endpoint was the evaluation of the safety of HCR. The HCR group (n=98) utilized MIDCAB and cobalt chromium DES with a two-stage HCR with PCI performed within 36 h of initial MIDCAB, versus the conventional CABG group (n=102) in which 85.0% of the procedures were performed off-pump. Pre-operative characteristics were similar. Regarding HCR procedures, 6.1% patients were converted to CABG with no adverse early or late outcomes, and HCR was feasible in 93.9% of patients. At 1 year, the two groups had similar all-cause mortality (CABG 2.9% versus HCR 2%; p=NS) and MACE-free survival rates (CABG 92.2% versus HCR 89.8%; p log-rank =0.54). Larger studies are needed to power conclusions regarding long-term mortality data; however, this study suggests that HCR is feasible and safe.

Harskamp et al. recently published a study of practice patterns and clinical outcomes after HCR, in the United States, using the Society of Thoracic Surgeons Adult Cardiac Surgery Database from July 2011 to March 2013 [11]. This analysis demonstrated that HCR represented 0.48% (n=950; staged=809, concurrent=141) of the total CABG volume (n=198,622) over the studied time. HCR was performed in approximately one-third of participating centers (n=361). Interestingly, patients who underwent HCR had high-risk profiles but less extensive coronary disease. There was no statistically significant association between operative approach and operative mortality when comparing the HCR and conventional CABG treatment groups [11].

5. Conclusions

Hybrid coronary revascularization has emerged as a promising technique that combines the superior patency of the LIMA-LAD graft with the superior patency of DES to SVG grafts for non-LAD vessels. As with any new technique, ongoing research will benefit from standardized definitions as well as sub-classification for HCR procedures [20]. Current evidence also lacks direction as to which patient population benefits most from HCR. Current data supports HCR as a feasible alternative to CABG, however, the future of these techniques will rely on improved patient satisfaction, recovery, and financial feasibility. Current reported quality of life assessments 1 year post-operatively are remarkably better in patients undergoing HCR versus OPCAB [5]. Likely reasons include decreased post-operative pain and decreased length of intensive care and hospital stay with quicker return to work and normal activities. Cost analysis have been reported both equal and in favor of HCR; however, these analysis did not examine the hidden cost of construction of a cardiac hybrid operating room as well as training of personal [5]. Further studies are needed to firmly establish improved outcomes and financial benefits of HCR before this novel technique establishes itself as a widespread option in the algorithm of coronary revascularization.

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