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Review

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Surgical revascularization for acute coronary syndromes: a narrative review

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Abstract

Acute coronary syndrome (ACS) comprises a spectrum of disease that includes unstable angina, non-ST-elevation myocardial infarction, and ST-elevation myocardial infarction. Clinical management of patients with ACS has greatly evolved over the last two decades, but ACS remains an important cause of morbidity and mortality in patients with coronary artery disease. This narrative review describes the indication, timing, and approaches to surgical revascularization in the context of ACS. In particular, the review discusses and compares the utilization of off-pump coronary artery bypass grafting (CABG) *vs*. conventional on-pump CABG. Other surgical interventions, such as totally endoscopic coronary artery bypass and hybrid coronary revascularization, are also reviewed.

Keywords: Acute coronary syndromes, coronary artery bypass graft, off pump coronary artery bypass

INTRODUCTION

Acute coronary syndrome (ACS) comprises a spectrum of disease that includes unstable angina (UA), non-ST-elevation myocardial infarction (NSTEMI), and ST-elevation myocardial infarction (STEMI), with distinctions based on symptom severity, electrocardiogram patterns, and degree of myocardial necrosis as reflected by cardiac biomarker levels[1-3]. In-hospital and long-term mortality have improved largely because of improvements in ACS treatment modalities[4-8]. However, ACS remains an important cause of morbidity and mortality in patients with coronary artery disease that is responsible for more than 1 million hospital admissions in the USA annually[9]. Concurrently, indications for surgical revascularization in ACS patients

by coronary artery bypass grafting (CABG) as well as the overall management of ACS patients have evolved a great deal over the last 15 to 20 years[4,10].

INDICATIONS FOR SURGICAL REVASCULARIZATION

For patients with UA or NSTEMI, treatment choices are based on the patient's level of risk as indicated by clinical symptoms, electrocardiogram changes, and cardiac biomarker levels[5]. Based on joint guidelines from the American College of Cardiology and American Heart Association, CABG is recommended as primary treatment for patients with significant left main disease or left main equivalent (i.e. significant proximal left anterior descending and proximal left circumflex stenosis) and for patients unresponsive to maximal nonsurgical treatment (Class of Recommendation: I & Level of Evidence: A)[10]. Surgery is also a reasonable consideration in patients with proximal left anterior descending (LAD) stenosis with 1- or 2-vessel disease, presence of complex coronary lesions, and for patients in whom percutaneous intervention is not feasible[11-13].

For patients experiencing NSTEMI and UA, while indications for CABG *vs.* percutaneous coronary intervention (PCI) are similar to those for patients with stable angina, studies show that high-risk patients with left ventricular systolic dysfunction[14,15], severe 3-vessel disease[16-19], 2-vessel disease involving the proximal LAD, or diabetes mellitus[20-22] should be considered for CABG. Existing guidelines affirm the indications for high-risk patients given the increased chances of long-term survival[23,24]. In contrast, the survival benefits of CABG are much more modest in lower-risk patients. Thus, these patients should only be considered for early surgery if they are willing to accept the short-term risks associated with surgical revascularization in exchange for potentially improved functional status.

The accepted first-line treatment for STEMI is PCI or systemic thrombolysis. However, CABG is performed in up to 5% of STEMI cases[25]. In particular, surgery is indicated among patients with good surgical targets but whose hemodynamic instability results in a complicated or failed angioplasty; after a failed fibrinolysis; who have persistent, refractory ischemia; who show evidence of mechanical or valvular disease; who are in cardiogenic shock; or who have life-threatening ventricular arrhythmias and either severe stenosis or multivessel disease[10]. There is also class II evidence that CABG may be appropriate as primary intervention in patients for whom PCI failed, and it can also be considered in patients with evidence of severe left main or multivessel disease with poor left ventricular function or diabetes.

PROGNOSIS

Despite improvements over time, in-hospital mortality for patients with acute myocardial infarction (AMI) in the USA remains at 5% and is even higher among STEMI patients who undergo either PCI or emergency CABG[26-30]. Additionally, NSTEMI patients undergoing surgical intervention have a poorer prognosis than their non-ACS counterparts[31], and the hospital level 30-day risk-standardized mortality rates for patients discharged with AMI remains at approximately 16%[32]. Outcomes for CABG are also worse in patients with ACS than in patients without ACS[4,33]. The preoperative troponin I level has been promoted as the strongest independent predictor of short-term death[1,31].

OFF-PUMP CABG

The advent of off-pump CABG (OPCABG) - which avoids cardiopulmonary bypass and its associated risks - brought the promise of reducing operative risk while producing long-term outcomes that were as good as or better than those of on-pump surgery[34-36]. Several studies have since shown short-term outcomes comparable to those of on-pump CABG[37,38], as well as lower rates of atrial fibrillation, less need for blood transfusions, less renal and neurocognitive dysfunction, and shorter hospital stays in mixed-risk patient

populations[39]. Furthermore, OPCABG is associated with improved resource utilization and increased cost-effectiveness[36,40].

However, the relative merits of OPCABG and on-pump CABG remain debatable and there has been national decline in the utilization of OPCABG[41]. Randomized trials have demonstrated that short-term death or complications within a month of surgery occurred at similar frequency, but long-term mortality and complications occurred similarly if not at higher rates in patients undergoing OPCABG[42,43]. Meta-analyses have also failed to demonstrate any significant benefit of OPCABG in mortality rates and showed comparable organ protection to conventional methods[44,45].

Another aspect of understanding the comparative advantages of OPCABG[46,47] is that patients who require intraoperative conversion from off-pump to on-pump surgery or abortion of the OPCABG procedure have poorer outcomes compared to patients undergoing successful OPCABG or on-pump operations[48-51]. Additionally, patients who underwent OPCABG generally had fewer anastomoses than their on-pump counterparts, limiting the conclusions that can be drawn about OPCABG in patients with multiple targets and raising concerns about the completeness and effectiveness of revascularization in OPCABG[39,52].

There are limited data regarding primary OPCABG for the treatment of ACS. In two studies, mortality was lower in off-pump *vs.* on-pump procedures (5% *vs.* 24%, $P = 0.015$ and 3.5% *vs.* 5.4%, $P = 0.690$)[53,54]. Additionally, a European study with a cohort of 624 patients demonstrated that stratification and preselection of patients, as well as the timing of the intervention, are crucial considerations for ensuring that only appropriate candidates undergo and derive benefits from the procedure[55]. An updated algorithm to stratify patients and better address the issue of conversion from off- to on-pump CABG has been put forth, which may help to reduce the frequency of off-pump to on-pump conversion in ACS patients[54,56].

OTHER POTENTIAL SURGICAL INTERVENTIONS

It has been approximately two decades since several groups first described endoscopic techniques for less invasive, closed-chest totally endoscopic coronary artery bypass (TECAB) with the da Vinci robotic system[57,58]. After a multicenter trial showed promising results, the US Food and Drug Administration approved robotically-assisted TECAB for non-emergent left internal mammary artery to LAD myocardial revascularization[59]. Subsequently, there has been interest both in traditional arrested-heart TECAB with cardiopulmonary bypass and in beating-heart, off-pump TECAB with the use of endoscopic stabilizers. Although issues have been raised regarding technical challenges and conversion rates[60-62], there are also data that suggest that with appropriate techniques and experience, excellent graft patency rates can be achieved[63].

More recent advancement in this field is hybrid coronary revascularization (HCR), a procedure that combines PCI with OPCABG via minimally invasive entry through an anterolateral thoracotomy[64]. In patients with multivessel and left main disease, HCR has been shown to be comparable to OPCABG performed via midline sternotomy with respect to short- and mid-term outcomes, without significant differences in repeat revascularization rates[64,65].

Although no study has specifically examined the use of TECAB or HCR in the treatment of ACS, they may be alternative techniques to consider as the technology continues to advance and additional data are gathered regarding their outcomes and safety. Currently, only a few medical centers worldwide perform robotic TECAB due to the high complexity of operations, corresponding long learning curves and lack of an endoscopic surgical tradition[66]. Therefore, more evidence is needed to quantify the benefits of HCR as an emerging procedure for ACS.

TIMING OF SURGICAL REVASCULARIZATION

In most patients with ACS who are to undergo CABG surgery, the procedure is postponed for several days to reduce procedure-related risk[8]. The exceptions are patients with life-threatening conditions, such as severe disease or mechanical complications, who undergo early CABG. In another, AMI patients with persistent nonmechanial complications (persistent ischemia, shock), mortality rates when surgical revascularization was performed within 48 h of AMI were 7.7% for on-pump procedures performed because of persistent pain, but were negligible in those done more than 48 h later[67]. Other work looking at patients undergoing CABG after AMI has produced similar numbers and has associated early operation with higher risk in both transmural and non-transmural AMI[68]. There has been some suggestions, however, that even in higher-risk patients, early CABG is associated with very low in-hospital mortality and, therefore, could be considered in appropriate situations[8]. For OPCABG, data suggest that patients taken to the operating room within 6 h from the onset of chest pain are more suitable for off-pump surgery and have a low incidence of conversion to on-pump CABG, which, as mentioned above, carries severe risks and consequences[54].

CONCLUSION

Though the management of ACS has greatly evolved over the last two decades, the condition remains an important cause of morbidity and mortality in patients with coronary artery disease. Surgical revascularization is favored for more complex and high-risk patients. The merits of OPCABG remain debatable, and further study is needed to quantify the benefits of TECAB and HCR as emerging procedures for ACS.

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Dr. Chu serves as an oral board review examiner for The Osler Institute, academic editor for Wolters Kluwer Health, and national proctor for Toray International America, Inc., and the Japanese Organization for Medical Device Development, Inc., none of which have relationship to this manuscript. Dr. Liao, Dr. Bakaeen, and Mr. Joo have no conflicts to disclose.

Patient consent

Not applicable.

Ethics approval

Not applicable.

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