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Re-operative Coronary Artery Bypass Grafting: A Review of Changing Pattern and Outcomes

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Abstract

Re-operative coronary artery bypass grafting (CABG) prevalence had markedly changed over the last decades. This change had been also noticed in patients' risk profile and outcomes. The aim of this review is to highlight large multi- and single-center studies investigating the change in pattern, techniques, and outcomes of re-operative CABG globally. It is meant to be a reference that can help cardiac surgeons for a better understanding of our current situation with this challenging operation.

Keywords: Laparoscopy; Bariatric surgery; Sleeve gastrectomy; Leak; Fibrin glue

Introduction

Since coronary artery bypass graft (CABG) surgery was introduced for clinical practice in the 1960s, it has demonstrated its efficiency to improve symptoms and prognosis in patients with the advanced coronary atherosclerotic disease [1]. As CABG patients are getting older and living longer, re-operative CABG surgery has become an integrative part of the cardio-surgical daily practice presenting significant challenges in technical and decision-making aspects [2].

A number of improvements have been made in the pre-, intra-, and postoperative management of re-operative CABG patients over the last decades. These improvements have included technological developments as well as the increased experience of the teams treating these patients (cardiology, anesthesia, intensive care, and surgical teams). Pre-operative imaging with computed tomography is one of the most important pre-operative improvements that have helped much with operative planning [3]. Also, the use of intraoperative transesophageal echocardiography has facilitated placement of retrograde cardioplegia, peripheral cannulation and intra-aortic balloon pump (IABP) [4]. However, the effect of all these improvements on the outcomes of re-operative CABG is masked by the change in the risk profile of the patients. Although the prevalence of re-operative CABG has decreased, the risk profiles of the patients have increased [5-7].

Materials and Methods

Search strategy and study selection

A systematic literature search was performed through PubMed for studies published on outcomes of re-operative CABG. Keywords used in the search included MeSH terms: re-operative coronary artery bypass grafting, incidence, patient characteristics, trend, pattern, and outcome.

The "related articles" function was used to broaden the search and all abstracts, studies, and citations scanned were reviewed. The reference lists of articles found through these searches were also reviewed for relevant articles.

Inclusion and exclusion criteria

The inclusion criteria were: addressing re-operative CABG incidence, patient characteristics, and outcomes. Only the studies with a number of re-operative CABG patients more than 100 patients were included. However, studies comparing deferent techniques of re-operative CABG like: off-pump versus on-pump or thoracotomy versus resternotomy was excluded.

In this review, we present both multi- and single-center studies on trends and outcomes of re-operative CABG **(Table 1)** [8-24].

Table 1 Previous studies of re-operative coronary artery bypass grafting (CABG).

Study	Place	Time interval	Number of re-operative CABG	Percentage of re-operative CABG to overall CABG	Hospital mortality
Ghanta et al. [5]	Multicenter study USA	2000 – 2009	72,322	6% (2000) 3.4% (2009)	6.1% (2000) 4.6% (2009)
Yap et al. [15]	Multicenter study Australia	2001 – 2008	458	3.4%	4.8%
Weintraub et al. [21]	Single center study Emory University Hospital, Atlanta, USA	1975 – 1993	2030		7%
Christenson et al. [23]	Single center study Geneva, Switzerland	1984 – 1994	594	18.8%	9.6%
Noyez et al. [22]	Single center study Nijmegen, Netherlands	1987 – 1998	541		6.7%
Van Eck et al. [16]	Single center study Nijmegen, Netherlands	1987 – 2000	582	8.5%	7.2% (overall) 11% (1987-1991) 6.4% (1992-1995) 4.2% (1996-2000)
Yau et al. [6]	Single center study Toronto, Canada	1982 – 1997	1230	6%	6.8%
Spiliotopoulos et al. [7]	Single center study Toronto, Canada	1990 – 2009	1204	7.2% (1990-1994) 2.2% (2005-2009)	4.7% (1990-1999) 3.8% (2000-2009)
Di Mauro et al. [19]	Single center study Torino, Italy	1994 – 2001	239	6.3%	4.2%
Ngaage et al. [20]	Single center study United Kingdom	1998 – 2006	154	5.6%	4.8% (1999-2001) 2.8% (2002-2006)
Colkesen et al. [18]	Single center study Adana, Turkey	2010 – 2014	109	7.9%	4.6%
Yamamuro et al. [24]	Single center study Cleveland Clinic	1983 – 1993	739 elderly		7.6%
Lytle et al. [11]	Single center study Cleveland Clinic	1988 – 1991	1663		3.7%
Sabik et al. [12]	Single center study Cleveland Clinic	1990 -2003	4,518	21%	4.4%

Results and Discussion

Incidence

Coronary reintervention after CABG has been common over the last decades. Sabik and colleagues actively followed up 26,927 primary CABG patients at Cleveland Clinic. They found that patients' freedom from reintervention was 73%, 60%, and 46% at 15, 20, and 25 years after the first operation respectively. This means that more than half of primary CABG patients will have coronary reintervention if they lived for 25 years after the operation [8]. In order to adjust potential long-term benefits of CABG for attrition by death, Blackstone and Lytle examined the outcome of primary CABG patients at Cleveland Clinic also in light of three competing time-related events: death, reoperation, and percutaneous transluminal coronary angioplasty (PTCA). Their 12 years follow-up showed 58.6% of the patients were alive and without reintervention, while 26.6% were dead, 8.1% had PTCA, and 6.8% had re-operative CABG [9]. In van Domburg and colleagues' 30-year follow-up study of 1041 primary venous CABG, coronary reinterventions were performed in 36% of the patients. 29.6% had re-operative CABG and 14.2% had PTCA. However, reintervention after 20 years was only PTCA [10].

Older studies showed increase in prevalence of re-operative CABG like Lytle and colleagues' study that mentioned marked increase in incidence of reopertaive CABG compared with previous cohorts (436 patients from 1967 to 1978, 439 patients from 1979 to 1981, 625 patients from 1982 to 1984, 1009 patients from 1985 to 1987, and 1663 patients from 1988 to 1991) [11]. The largest single-center study on re-operative CABG was done by Sabik and colleagues at Cleveland Clinic from 1990 to 2003 including 4,518 reoperations. Although the change in incidence of re-operative CABG was not mentioned in the study, one can notice from their presented tables that the number of re-operative CABG had decreased from around 500 in 1990 to around 200 in 2002 [12].

In contemporary studies; Ghanta and colleagues used the Society of Thoracic Surgeons (STS) Adult Cardiac Surgery

Database from 2000 to 2009 to analyze characteristics and postoperative outcomes of 72,322 isolated re-operative CABG patients from 1035 institutions. The percentage of re-operative to overall CABG volume decreased from 6.0% in 2000 to 3.4% in 2009 [5]. Also, Spiliotopoulos and colleagues in Toronto General Hospital institution had done the most recent largest single-center study of changing pattern of re-operative CABG, including 1204 re-operative CABG patients from 1990 to 2009. The results showed that the prevalence of re-operative CABG had drastically decreased from 7.2% during 1990 to 1994 to 2.2% during 2005 to 2009 [7].

The decrease in the prevalence of re-operative CABG even with the large number of patients who had previous CABG can be attributed to multiple factors. The marked increase in the prevalence of previously performed PCTA on the native arteries or the grafts of re-operated on patients provides an obvious explanation for this downward trend of re-operative CABG [7]. Other factors that might have led to higher patients' freedom from re-intervention include: improved surgical technique during primary operation using internal thoracic artery (ITA) to the left anterior descending artery (LAD) as a standard strategy, more effective risk factor control, and optimal medical therapy with statins and antiplatelet medications [13,14].

Patient characteristics

The characteristics of re-operative CABG patients usually show older age, more comorbidities, and worse presentation compared to primary CABG patients, that was shown in Ghanta's study of STS database. On the other hand, comparing the characteristics of re-operative CABG patients in 2009 with 2000 showed no significant change in age or gender. However, comorbidities like diabetes, hypertension, renal failure, chronic obstructive pulmonary disease, hypercholesterolemia, and cerebrovascular disease were more prevalent in 2009 than in 2000. Also, patients in 2009 had a worse presentation like congestive heart failure, left main disease, and myocardial infarction. 5 Spiliotopoulos and colleagues showed in their study the deterioration in the pre-operative risk profile of re-operative CABG patients over the years from 1990 to 2009. As the patients during the second decade had been significantly older, with larger body surface area, and with a higher incidence of diabetes, dyslipidemia, and hypertension. Moreover, pre-operative atrial fibrillation, cerebrovascular accidents, left main stenosis, and peripheral vascular disease had been significantly more frequent. On the other hand, the mean interval between the first operation and the redo one had significantly increased in the second decade [7].

Another multicenter study of re-operative CABG was done by Yap and colleagues using the Australasian Society of Cardiac and Thoracic Surgeons (ASCTS) Cardiac Surgery Database. The study included isolated CABG patients from 2001 to 2008. 458 patients underwent re-operative CABG. The risk profile of re-operative patients was significantly worse than primary patients due to a higher prevalence of elderly patients, patients with unstable angina, peripheral vascular disease, and higher New York Heart Association class, worse left ventricular function, previous myocardial infarction, complete heart block, and more emergency operations. Similar results were shown in Sabik's study at the Cleveland Clinic [12,15].

Van Eck and colleagues studied the change in profiles of 582 re-operative CABG patients from 1987 to 2000 in Netherlands. They divided the patients into three groups according to the date of the operation. Patients of the latest group showed a significant increase in mean age, kidney disease, and previous PTCA. Also, the time period between both operations had increased significantly, as well as, the number of patients with patent IMA graft [16].

Outcomes

Comparing outcomes in Ghanta's study, postoperative observed mortality for re-operative CABG decreased from 6.1% in 2000 to 4.6% in 2009. But, it remained almost 2.5 times the mortality for primary CABG. This study was limited to STS Adult Cardiac Surgery Database information which captured neither the conduits used in the previous operation nor the interval between it and the current operation. STS database represents 1035 participating institutions with different protocols, teams, and experience. Also, using observed, predicted, and adjusted mortality in comparing the outcomes of re-operative and primary CABG in 2000 and in 2009 might not be enough to avoid the problem of comparing apples and oranges as those patients had different risk profiles. Using propensity scoring and comparing matched pairs instead might have been a more valid comparison [5,17]. In Yap's study, operative mortality for re-operative CABG was 4.8%. While, operative mortality for primary CABG was 1.8%. Using logistic regression model and after adjustment for differences in patient variables, re-operative CABG status remained a predictor of operative mortality [15].

In single-center studies, Spiliotopoulos and colleagues showed in their study that comparing propensity-matched re-operative patients from 1990 to 1999 and from 2000 to 2009 did not show a significant change in operative mortality. However, the mean hospital length of stay had been significantly reduced. Also, their multivariate analysis of risk factors revealed pre-operative shock, congestive heart failure, peripheral vascular disease, and age as independent predictors of operative mortality [7]. Another study was done by Colkesen and colleagues in Adana, Turkey. They compared redo cardiac surgery procedures in general with primary ones including CABG and valve surgeries. They had 109 redo cardiac surgery patients between 2010 and 2014. Hospital mortality of redo patients was 4.6%, while it was 2.2% for primary cardiac surgery patients [18]. Also, Di Mauro and colleagues analyzed early and late outcomes of re-operative CABG between 1994 and 2001. Applying the propensity score, they matched 239 redo patients with 239 primary CABG patients. Early mortality was 4.2% for the redo group and 2.1% for the primary CABG group, without any significant difference. However, off-pump surgery in redo group had a positive impact on lower mortality than on-pump surgery (1.5% versus 5.3%) [19]. Ngaage and colleagues studied the impact of pre-operative symptom severity on the outcomes of re-operative cardiac surgery in

Castle Hill Hospital, United Kingdom. Between 1998 and 2006, they had 154 re-operative CABG patients. Patients were divided into two groups, the first one from 1998 to 2002 and the second group from 2002 to 2006. The operative mortality was 4.8% for the first group versus 2.8% for the second group with no significant difference. Reoperation was not a determining predictor of major adverse postoperative event unlike age, pre-existing atrial fibrillation, duration of extracorporeal circulation, and concomitant valve procedure [20]. In older studies, hospital mortality was higher like in Weintraub and colleagues study of 2030 re-operative CABG patient at Emory University Hospitals, Atlanta, USA between 1975 and 1993. They had hospital mortality of 7%. Also, in Noyez's study in Netherland between 1987 and 1998 hospital mortality of re-operative CABG was 6.7%. In Christenson's study at Geneva, Switzerland 594 patients had re-operative CABG between 1984 and 1994 with hospital mortality of 9.6% [21-23]. In van Eck study, hospital mortality rate after re-operative CABG decreased significantly from 11% in the period from 1987 to 1991, to 4.2% at the period from 1996 to 2000 [16].

As for Cleveland Clinic, it has been one of the largest cardiac centers all over the world; having the highest rates of re-operative CABG they provided the largest single-center studies for the literature over time. Between 1983 and 1993, Yamamuro and colleagues studied the risk factors and outcomes after re-operative CABG in 739 elderly patients (age ≥ 70). At this era, the incidence of re-operative CABG was increasing (26 cases in 1983, 123 cases in 1992). Hospital mortality rates were 7.6% [24]. Lytle and colleagues analyzed the in-hospital mortality of 1663 re-operative CABG patients from 1988 through 1991 to study the influence of arterial grafts on the mortality. In this study, hospital mortality was 3.7%.11 In Sabik's study for re-operative CABG from 1990 to 2003, hospital mortality for patients having re-operative CABG was 4.4%. However, this rate decreased from 6% in 1990 to around 2.2% in 2000. Also, when the patients were stratified by date of operation, multivariable analysis demonstrated that after January 1, 1997, the risk of hospital death was the same in re-operative and primary CABG patients.

Conclusion

For the propensity-matched patients, hospital mortality was still higher after reoperations (4.7%) than after primary operations (2.2%). However, when the propensity-matched patients were stratified by date of operation, multivariable analysis demonstrated that, after 1997 reoperation was not associated with increased risk of death. Then they concluded that surgical experience had neutralized the risk of reoperation attributable to its technical difficulty, while patient characteristics had a greater influence on hospital mortality [12].

The incidence of re-operative CABG has been decreasing over the last decade after reaching its peak in the 1990s. On the other hand, hospital mortality rates after re-operative CABG have been improving overtime despite the fact that the patients' risk profiles have been deteriorating.

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