

# World Journal of *Meta-Analysis*

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## Complete revascularization reduces adverse outcomes in patients with multivessel coronary artery disease

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### Abstract

#### AIM

To investigate the influence of complete and incomplete revascularization (ICR) in patients with multivessel coronary artery disease undergoing coronary artery bypass or percutaneous coronary intervention.

#### METHODS

We searched PubMed using the keywords "complete revascularization", "incomplete revascularization", "coronary artery bypass", and "percutaneous coronary intervention". We selected randomized controlled studies (RCT) and observational studies only for review. The main outcomes of interest were mortality, myocardial infarction (MI) and repeat revascularization. We identified further studies by hand searching relevant publications and included those that met with the inclusion criteria in our final analysis and performed a systematic review.

#### RESULTS

Ten studies were identified, including 13327 patients of whom, 8053 received complete revascularization and 5274 received ICR. Relative to ICR, CR was associated with lower mortality (RR: 0.755, 95%CI: 0.66 to 0.864,  $P = 0.765$ ,  $I^2 = 0.0\%$ ), lower rates of MI (RR: 0.759, 95%CI: 0.615 to 0.937,  $P = 0.091$ ,  $I^2 = 45.1\%$ ), lower rates of MACCE (RR: 0.731, 95%CI: 0.668 to 0.8,  $P = 0.453$ ,  $I^2 = 0.0\%$ ) and reduced rates of repeat coronary revascularization (RR: 0.691, 95%CI: 0.541 to 0.883,  $P = 0.0$ ,  $I^2 = 88.3\%$ ).

#### CONCLUSION

CR is associated with lower rates of adverse outcomes. CR can be used as a standard in the choice of any particular revascularization strategy.

**Key words:** Complete revascularization; Percutaneous coronary intervention; Coronary artery bypass grafting;

## Incomplete revascularization

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**Core tip:** Completeness of revascularization has been documented to have lesser adverse post-operative/post-procedural outcomes as compared to incomplete revascularization (ICR). We conduct a systematic review with meta-analysis to analyze the outcomes in patients undergoing CR vs ICR, using any or both techniques. Ten studies were identified, including 13327 patients of whom, 8053 received CR and 5274 received ICR. CR is associated with lower rates of mortality, MI, repeat coronary revascularization procedures, and MACCE. Subgroup analysis also showed reduced rates of adverse events. CR can be used as an aim for any myocardial revascularization procedure.

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## INTRODUCTION

Complete revascularization arose from early studies on coronary artery bypass grafting (CABG) surgery whereby some studies demonstrated that patients who were completely revascularized enjoyed a mortality benefit over those who were incompletely revascularized<sup>[1-3]</sup>. Data from the coronary artery surgery study (CASS) registry show that patients with multi-vessel coronary artery disease (CAD) and severe angina that received three or more grafts had better survival relative to patients who received one or two grafts<sup>[4]</sup>. Although CR is often easier to achieve with CABG than with percutaneous coronary intervention (PCI), with recent developments in percutaneous transluminal coronary angioplasty procedures, such as the new era of drug eluting stents (DES), the previous barriers of PCI in the treatment of multi-vessel disease are no longer insurmountable, and favorable outcomes have been recorded across multiple centers using this revascularization approach<sup>[5]</sup>.

Different established standards are used to determine the degree of completeness of revascularization. Conventionally, perfusion districts are divided into three areas according to the supply of the coronary artery branches namely the left anterior descending (LAD), the left circumflex (LCX) and the right coronary artery (RCA). The most commonly used definition across studies is the (1) anatomical definition, and was used in 90% of the studies included in our meta-analysis. According to this definition, CR has been achieved if all diseased arterial segments with a vessel size (greater/equal to 1.5 mm for a graft and 2.0-2.25 mm for a stent) with at least

one significant stenosis greater than or equal to 50% receive a graft or a stent. A second definition of CR is (2) numerical whereby the number of distal anastomoses is greater or equal to the number of diseased coronary segments/systems and was used in 10% of the studies included in our meta-analysis. Other definitions include the (3) functional definition whereby all ischemic myocardial territories are grafted (or stented); areas of old infarction with no viable myocardium are not required to be perfused, the (4) score-based definition whereby the stenosis in different vessels is scored and different weights are given to different vessels according to number of myocardial segments supplied (A residual score of 0 is usually considered equivalent to CR) and the (5) physiology-based definition whereby all coronary lesions with fractional flow reserve of less than equal to 0.75-0.80 receive a graft or stent.

Due to procedural difficulties associated with each technique (CABG and PCI), complete revascularization is not always achieved. Previous studies have tried to assess the outcomes following incomplete revascularization (ICR). However, since there is no specific definition for ICR, which is essentially defined as "failure to achieve complete revascularization", it lacks objectivity as it relies on post-procedural classification of CR by the treating surgeon/physician. The SYNTAX trial, which used a more accurate method to determine the completeness of revascularization (patients were categorized as incompletely revascularized when the number of diseased segments that were treated did not match the heart team decision), and the BARI trial reported no increase in adverse outcomes in incompletely revascularized patients.

There is discrepancy between the results of different studies concerning the superiority of CR over ICR. In our meta-analysis, we aim to determine whether CR, is associated with improved post-procedural outcomes. In a subgroup analysis, we also investigate the mid/long-term outcomes of CR, along with outcomes in a > 60 years old patient population.

## MATERIALS AND METHODS

We identified four types of studies on the PubMed database: Randomized controlled trials, observational studies, controlled clinical trials and clinical trials. The study was conducted in March 2016, using the keywords "coronary artery bypass", "percutaneous coronary intervention", "complete revascularization", "incomplete revascularization". The total number of records identified was fifty-four. We limited our search to the specific above-mentioned study types. Six of these studies met with our inclusion criteria. Through Hand-search (a methodological approach previously validated), we searched through journals related to our subject-matter and identified relevant studies and also searched the latter's references. An additional four manuscripts were selected using the above-mentioned method<sup>[6]</sup>. A total of

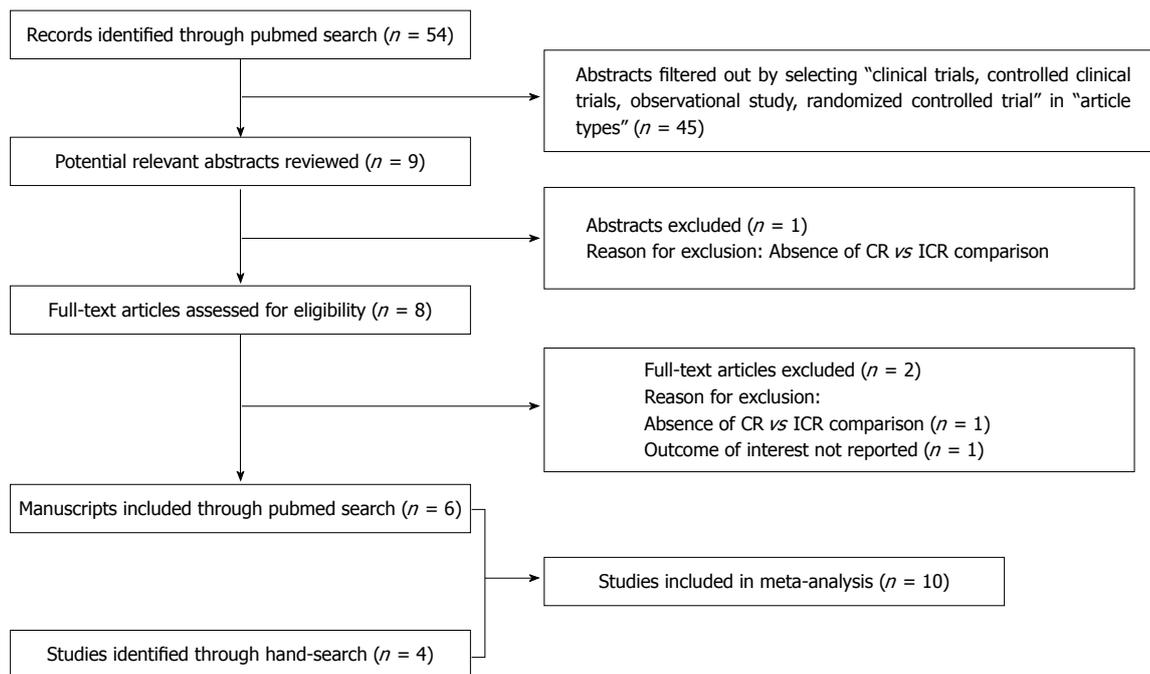


Figure 1 Flow diagram of literature search and study selection. ICR: Incomplete revascularization.

ten studies were included in our final analysis.

### Data sources and study search strategy

We included two types of studies in our meta-analysis, namely randomized controlled trials and observational studies in which: (1) Patients with multi-vessel CAD were enrolled for either CABG or PCI; (2) the outcomes of interest between CR and ICR were compared using any of the definitions of CR (see introduction for definitions of CR used); and (3) the outcomes included the primary outcome of interest and/or the secondary outcomes. We excluded studies in which: (1) multiple grafts were used for treatment of multi-vessel CAD without any reference to CR and/or ICR; (2) PCI was used for the treatment in the setting of ST-elevation acute myocardial infarction (MI); (3) outcomes of interest were not reported unless there was reference to CR and ICR; (4) the patients included were undergoing repeat CABG surgery; and (5) the sample size was small (< 100 patients).

### Study selection

Our initial search using the keywords: Complete revascularization, ICR, coronary artery bypass, PCI yielded fifty-four citations on PubMed. Using the filter for article types, we selected clinical trials, controlled clinical trials, observational studies and randomized controlled trials only. Of the fifty-four citations, nine citations remained, and the abstracts from these nine citations were reviewed. Of these, one abstract was excluded due to absence of comparison between complete and ICR. The remaining eight full text manuscripts were reviewed for eligibility. Of these eight manuscripts, six met with our inclusion criteria. We hand-searched references cited in

relevant publications and an additional four manuscripts that fit our inclusion criteria were included. A total of ten studies were selected and included in this meta-analysis (Figure 1).

### Data extraction

The data was extracted by Merveesh L Auchoybur using standardized extraction forms. Extracted information included study design, method of revascularization and definition of CR used by each study, follow-up time, patient characteristics pre-operatively, and outcomes relevant to this meta-analysis. The subjects were divided into two groups, namely the complete revascularization group for those subjects who received complete revascularization and the ICR group for those subjects who were not completely revascularized. In studies where complete revascularization through CABG and PCI were reported separately, the sum total of completely revascularized patients was used for the complete revascularization group and the remaining patients were added to the ICR group.

### Outcomes

The primary outcome used in this systematic study was all-cause mortality. Secondary outcomes were MI and repeat revascularization. Major adverse cardiovascular and cerebral events were also analyzed where present.

### Methodological quality

In this meta-analysis, both  $\chi^2$  based *Q*-statistic test and *I*<sup>2</sup> test were considered to assess the heterogeneity across studies, and *P*-value less than or equal to 0.05 was considered significant. *I*<sup>2</sup> is a description of the variation present across studies that is due to heterogeneity

**Table 1 Studies included in meta-analysis**

Ref.	Type of search	Method of revascularization	Study design	Year	Definition of CR used	Follow-up (yr)
Bell <i>et al</i> <sup>[24]</sup>	Hand	PCI	Post hoc analysis, non-RCT	1990	Anatomical	2.2
Approach/catherine Mclellan <i>et al</i> <sup>[25]</sup>	Hand	PCI	Post hoc analysis, non-RCT	2005	Anatomical	9
ARTS II/Sarno <i>et al</i> <sup>[26]</sup>	PubMed	CABG/PCI	Post hoc analysis, non-RCT	2010	Anatomical	5
ARTS trial/van den Brand <i>et al</i> <sup>[14]</sup>	PubMed	CABG/PCI	Post hoc analysis, RCT	2002	Anatomical	1
SYNTAX trial/Farooq <i>et al</i> <sup>[27]</sup>	PubMed	CABG/PCI	Post hoc analysis, RCT	2013	Anatomical	4
BARI/Bourassa <i>et al</i> <sup>[28]</sup>	PubMed	CABG/PCI	Post hoc analysis, RCT	1999	Anatomical	5
Bourassa <i>et al</i> <sup>[29]</sup>	Hand	PTCA	Post hoc analysis, non-RCT	1998	Anatomical	9
Head <i>et al</i> <sup>[30]</sup>	PubMed	CABG/PCI	Post hoc analysis, RCT	2012	Anatomical	3
BARI 2D/Schwartz <i>et al</i> <sup>[31]</sup>	PubMed	CABG/PCI	Post hoc analysis, non-RCT	2012	Numerical	5.3
Mohammadi <i>et al</i> <sup>[32]</sup>	Hand	CABG	Post hoc analysis, non-RCT	2012	Anatomical	5.4 ± 3.0

CABG: Coronary artery bypass grafting; PCI: Percutaneous coronary intervention; CR: Complete revascularization; RCT: Randomly controlled trial.

**Table 2 Characteristics of patients undergoing complete revascularization**

Ref.	Prevalence of CR (%)	Mean age (yr)	Previous MI	No previous MI	Diabetes	No diabetes	Hypertension	No hypertension
Bell <i>et al</i> <sup>[24]</sup>	41.0	60.0	122	234	46	319	148	217
Approach/catherine Mclellan <i>et al</i> <sup>[25]</sup>	66.9	62.1	802	506	244.6	1063.4	725.94	582.06
ARTS II/Sarno <i>et al</i> <sup>[26]</sup>	72.5	61.5	149	688	163	674	440	397
ARTS trial/van den Brand <i>et al</i> <sup>[14]</sup>	77.2	61.0	385	498	143.93	739.07	-	-
SYNTAX trial/Farooq <i>et al</i> <sup>[27]</sup>	61.8	65.3	521	1088	429.6	1179.4	759.45	849.55
BARI/Bourassa <i>et al</i> <sup>[28]</sup>	65.4	61.3	612	584	204.52	991.48	578.86	617.14
Bourassa <i>et al</i> <sup>[29]</sup>	17.4	56.6	62	70	15.05	116.95	55.97	76.03
Head <i>et al</i> <sup>[30]</sup>	59.9	64.9	328	713	300	438	702	356
BARI 2D/Schwartz <i>et al</i> <sup>[31]</sup>	37.9	61.21	-	-	-	-	-	-
Mohammadi <i>et al</i> <sup>[32]</sup>	82.1	82.1	224	167	107.92	283.08	286.21	104.79

CR: Complete revascularization; MI: Myocardial infarction.

instead of chance ( $I^2$  value less than 50% indicates no or little heterogeneity)<sup>[7]</sup>. Weighted relative risk (RR) and its 95% confidence interval were calculated to evaluate the effect size. A fixed effect model using Mantel-Haenszel method were used to combine values from studies when heterogeneity was absent, otherwise, a random-effects model using the DerSimonian and Laird method was used<sup>[8]</sup>. Egger’s test and inverted funnel plots were utilized to provide a diagnosis of publication bias<sup>[9]</sup>. Automatic “zero cell” correction was used for studies with no events for a particular outcome. All analyses were performed using Stata version 11.1 software (Stata, College Station, TX, United States). All statistical evaluations were made assuming a two-sided test with a significance level of 0.05, unless stated otherwise.

## RESULTS

### Study and patient characteristics

The list of the ten studies that met with our inclusion criteria are listed in Table 1. Of the studies included, four were RCTs and six were non-RCTs. All the RCTs reported both CABG and PCI as revascularization strategies. Of the six non-RCTs included, three reported PCI, two reported both CABG and PCI simultaneously, and one reported CABG only. Of the studies comprising our analysis,

nine use an anatomical definition of CR and one uses a numerical definition of CR. The current analysis includes 13327 patients of whom, 8053 (60.4%) received complete revascularization (CR) and 5274 (39.6%) received ICR. The mean age of the patients undergoing CR was 63.6 years, 20.5% had diabetes mellitus, 39.8% had suffered from previous MI, 43.5% had hypertension (Table 2). The mean age of the patients undergoing ICR was 65.1 years, 22.4% had diabetes mellitus, 46.1% had previously suffered from MI, and 52.6% had hypertension (Table 3). The mean follow-up time of the patients was 4.9 years.

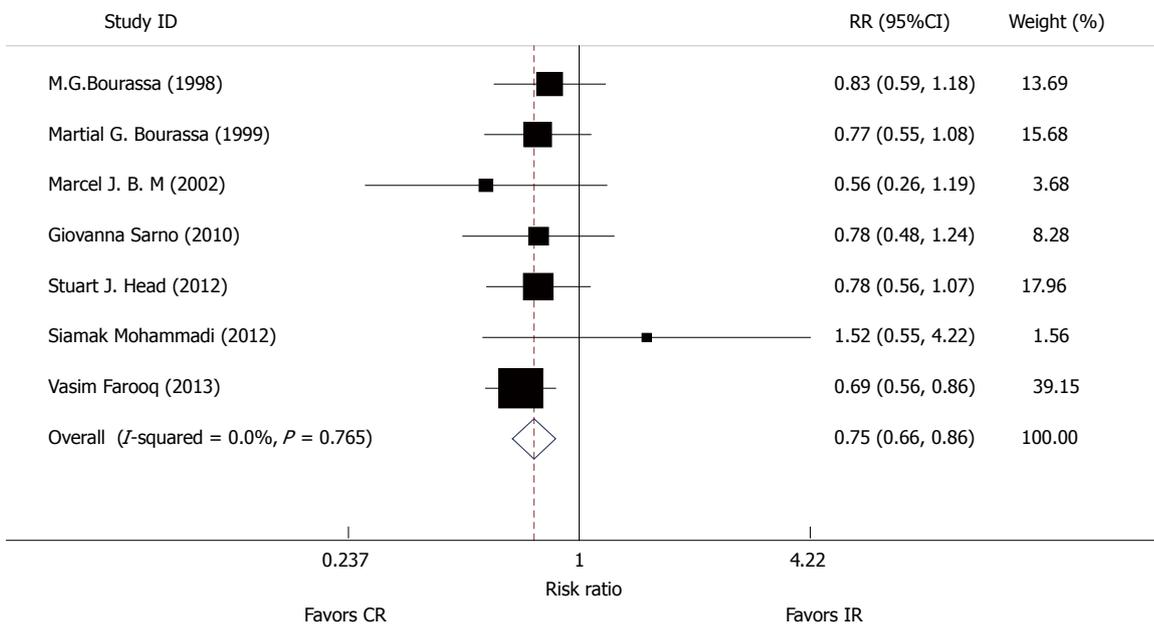
### Mortality

Of the ten studies included, eight reported mortality and were used for this analysis. CR is associated with reduced overall mortality relative to ICR (RR: 0.755, 95%CI: 0.66 to 0.864,  $P = 0.765$ ,  $I^2 = 0.0\%$ ) (Figure 2). In a subgroup analysis: Mid-term follow-up of < 5 years shows that CR has lower mortality (RR: 0.710, 95%CI: 0.595 to 0.847,  $P = 0.701$ ,  $I^2 = 0.0\%$ ). Long-term follow-up of > 5 years is associated with reduced mortality (RR: 0.824, 95%CI: 0.669 to 1.016,  $P = 0.660$ ,  $I^2 = 0.0\%$ ). In the age group of > 60 years, CR is associated with reduced mortality (RR: 0.742, 95%CI: 0.641 to 0.859,  $P = 0.706$ ,  $I^2 = 0.0\%$ ) (Figure 3).

**Table 3 Characteristics of patients undergoing incomplete revascularization**

Ref.	Prevalence of CR (%)	Mean age (yr)	Previous MI	No previous MI	Diabetes	No diabetes	Hypertension	No hypertension
Bell <i>et al</i> <sup>[24]</sup>	41.0	60.0	122	234	46	319	148	217
Approach/catherine Mclellan <i>et al</i> <sup>[25]</sup>	66.9	62.1	802	506	244.6	1063.4	725.94	582.06
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SYNTAX trial/Farooq <i>et al</i> <sup>[27]</sup>	61.8	65.3	521	1088	429.6	1179.4	759.45	849.55
BARI/Bourassa <i>et al</i> <sup>[28]</sup>	65.4	61.3	612	584	204.52	991.48	578.86	617.14
Bourassa <i>et al</i> <sup>[29]</sup>	17.4	56.6	62	70	15.05	116.95	55.97	76.03
Head <i>et al</i> <sup>[30]</sup>	59.9	64.9	328	713	300	438	702	356
BARI 2D/Schwartz <i>et al</i> <sup>[31]</sup>	37.9	61.21	-	-	-	-	-	-
Mohammadi <i>et al</i> <sup>[32]</sup>	82.1	82.1	224	167	107.92	283.08	286.21	104.79

CR: Complete revascularization; MI: Myocardial infarction.



**Figure 2 Pooled analysis with risk ratio and 95%CI for the occurrence of total mortality.** Boxes are relative risk estimates from each study. The horizontal bars are 95%CI. The size of the box is proportional to the weight of the study in the pooled analysis. CR: Complete revascularization.

**MI**

Of the ten studies, seven reported MI and were used for this analysis. CR is associated with reduced rates of post-operative MI as compared to ICR (RR: 0.759, 95%CI: 0.615 to 0.937, *P* = 0.091, *I*<sup>2</sup> = 45.1%) (Figure 4). In a subgroup analysis: mid-term follow-up of < 5 years group, occurrence of MI is less with CR as compared to ICR (RR: 0.608, 95%CI: 0.484 to 0.763, *P* = 0.388, *I*<sup>2</sup> = 0.0%). Long-term follow-up of > 5 years shows that CR is associated with reduced rates of MI (RR: 0.894, 95%CI: 0.731 to 1.095, *P* = 0.419, *I*<sup>2</sup> = 0.0%). In the age group of > 60 years, CR is associated with reduced MI (RR: 0.758, 95%CI: 0.589 to 0.974, *P* = 0.053, *I*<sup>2</sup> = 54.1%).

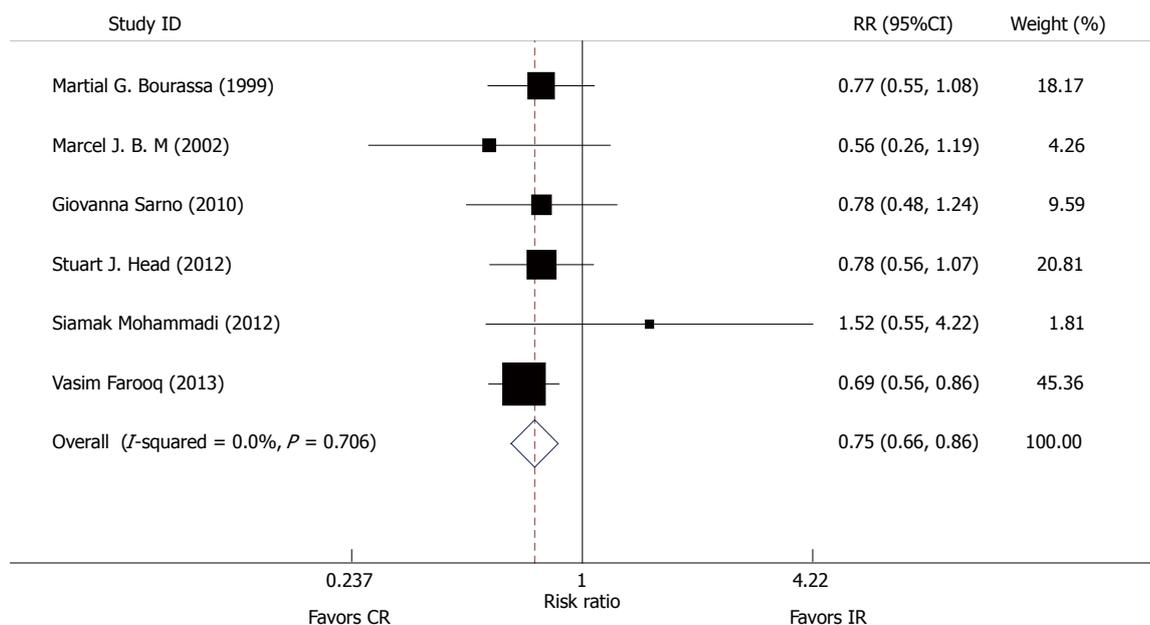
**Repeat coronary revascularization**

Of the ten studies, six reported repeat revascularization and were consequently used in this analysis. CR is associated with reduced rates of revascularization (PCI

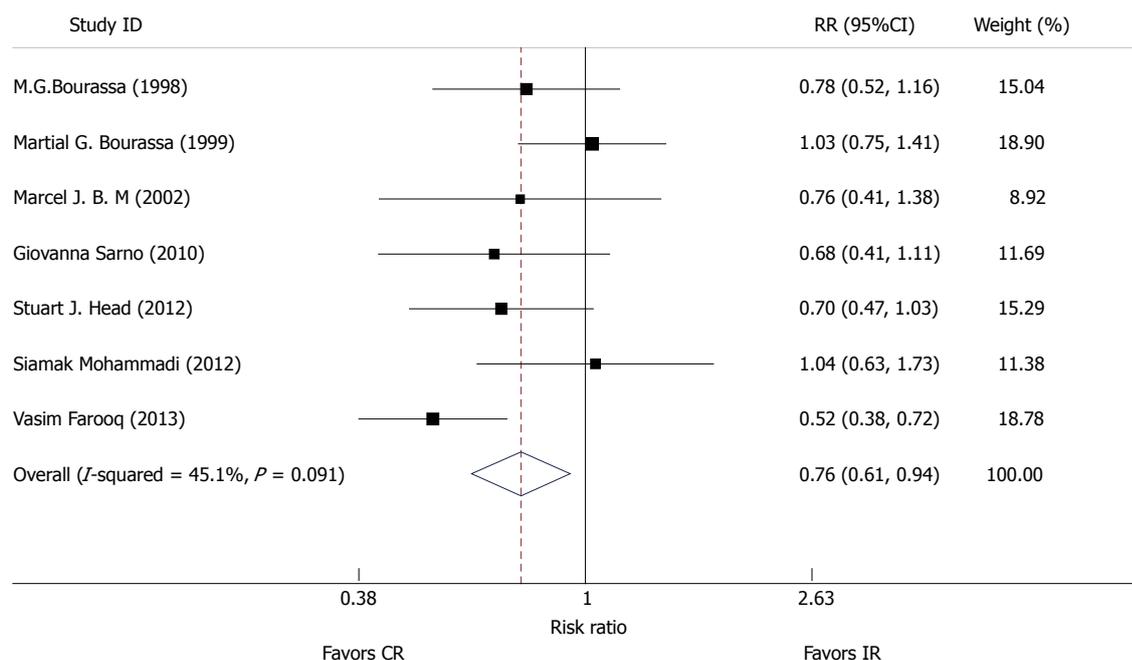
and/or CABG) relative to ICR (RR: 0.691, 95%CI: 0.541 to 0.883, *P* = 0.0, *I*<sup>2</sup> = 88.3%). In a subgroup analysis: Mid-term follow-up of < 5 years shows that CR is associated with less repeat revascularizations (RR: 0.827, 95%CI: 0.651 to 1.052, *P* = 0.323, *I*<sup>2</sup> = 11.6%). Long-term follow up of > 5 years shows that CR is associated with less repeat revascularizations (RR: 0.827, 95%CI: 0.651 to 1.052, *P* = 0.009, *I*<sup>2</sup> = 78.9%). In the age group > 60 years, CR is associated with reduced rates of repeat revascularization (RR: 0.646, 95%CI: 0.484 to 0.863, *P* = 0.0, *I*<sup>2</sup> = 89.2%).

**MACCE**

Of the ten studies, five reported MACCE and were used in this analysis. CR is associated with reduced MACCE relative to ICR (RR: 0.731, 95%CI: 0.668 to 0.8, *P* = 0.453, *I*<sup>2</sup> = 0.0%). In a subgroup analysis of MACCE: Mid-term follow-up of < 5 years shows that CR is associated with lower MACCE rates as compared to ICR



**Figure 3** Pooled analysis with risk ratio and 95%CI for the occurrence of mortality in the > 60 age group. Boxes are relative risk estimates from each study. The horizontal bars are 95%CI. The size of the box is proportional to the weight of the study in the pooled analysis. CR: Complete revascularization.



**Figure 4** Pooled analysis with risk ratio and 95%CI for occurrence of myocardial infarction. Boxes are relative risk estimates from each study. The horizontal bars are 95%CI. The size of the box is proportional to the weight of the study in the pooled analysis. CR: Complete revascularization.

(RR: 0.717, 95%CI: 0.649 to 0.792,  $P = 0.427$ ,  $I^2 = 0.0\%$ ). Long-term follow-up of > 5 years shows that CR is associated with reduced rates of MACCE (RR: 0.799, CI: 0.644 to 0.990,  $P = 0.427$ ,  $I^2 = 0.0\%$ ). In the age group of > 60 years, CR is associated with less MACCE (RR: 0.731, 95%CI: 0.668 to 0.8,  $P = 0.453$ ;  $I^2 = 0.0\%$ ).

## DISCUSSION

The results of our study comparing the outcomes of

CR vs ICR show that CR is associated with a 25% reduction in overall mortality, 24% reduction in MI, 27% reduction in MACCE, and 31% reduction in repeat revascularization procedures. Our findings are quite similar to the paper published by Santiago *et al*<sup>[5]</sup> where they reported a 30% reduction in long term mortality, a 22% reduction in MI, and a 26% reduction in repeat coronary revascularization procedures. Moreover, the results of our subgroup analysis show that independent of the modality of revascularization, CR is associated

with better mid-term (< 5 years), long-term (> 5 years) outcomes and is also associated with lesser adverse outcomes in the > 60 years old patient population.

Conventionally, there are two distinct approaches to coronary artery revascularization, one of them being CABG and the other being PCI. Both of these revascularization strategies have their set of advantages and disadvantages. The advantages of PCI include use of local anesthesia, minimal post-procedural morbidity, and shorter hospital stay. New advancement in the form of DES has also allowed effective treatment of long diffuse stenosed segments. Despite these numerous advantages, PCI remains restricted with respect to its inability to overcome chronic total occlusions, whereby success rates vary and symptomatic failures eventually require CABG. CABG surgery, on the other hand, despite having the ability to overcome chronic occlusions, and necessitating fewer repeat revascularization procedures, is nevertheless associated with substantial postoperative morbidity, longer periods of hospitalization, and a slower return to normal activities. Multiple diseased vessel segments are challenging, requiring multiple grafts and longer operative times which translate into longer periods of CPB, and are associated with higher morbidity<sup>[10]</sup>. Among the main adverse outcomes, PCI is associated with higher rates of MI and repeat revascularization while CABG is associated with higher morbidity and risk of stroke<sup>[11]</sup>. Many variables have to be considered when selecting a patient for any procedure, which might be a cause for dissimilarities between the outcomes from different studies. Although SYNTAX reported a higher incidence of MACCE at 5 years, data concerning the incidence of death, MI and stroke at 5 years was inconsistent between these studies, even in the diabetic subgroup. In SYNTAX there was no significant difference reported at 5 years in any of the individual outcomes of death, MI, or stroke between PCI and CABG in either the diabetic or non-diabetic subgroups<sup>[12]</sup>. On the other hand, in the FREEDOM trial PCI was associated with higher incidence of death and MI with a lower incidence of stroke when compared to CABG<sup>[10]</sup>. Past studies have compared post-procedural outcomes of these two revascularization approaches<sup>[13-15]</sup>. The primary focus of our study is the clinical outcome(s) of complete revascularization as compared to ICR, achieved by any particular method of revascularization, or both methods simultaneously (hybrid procedures), rather than a comparison of CABG vs PCI.

### **Benefits of CR**

The association between CR and lower risk for subsequent cardiovascular events has been documented in some studies in which the benefits of complete revascularization are reduction and often elimination of myocardial ischemia (which has been linked to worse prognosis especially when large), improvement in left ventricular function with preserved ejection fraction in heart failure patients, reduction of arrhythmias,

improved exercise capacity, and better tolerance to future acute myocardial ischemic events<sup>[12,16]</sup>. More importantly, the mortality benefit of CR is independent of revascularization modality and definition of CR used<sup>[17]</sup>. In a study by An Den Brand *et al.*<sup>[14]</sup>, the authors reported that the frequency with which CR was achieved was greater in CABG treated patients (84.1%) as compared to stented patients, despite the potential for equivalent revascularization. Although no difference in mortality or the combined endpoint of death/stroke/MI were seen, overall MACCE rates were significantly higher in the incompletely revascularized stented group, driven by an increased need for CABG within the first year of follow up.

Over the past decades, CABG has evolved to better peri-operative management, more frequent use of arterial grafting and off pump surgery, and development of minimally invasive direct coronary artery bypass grafting (MIDCAB) and robot-assisted totally endoscopic coronary artery bypass (TECAB) grafting as genuine options. PCIs, especially percutaneous transluminal coronary angioplasty (PTCA), initially developed as a strategy in the treatment of single-vessel disease. Currently, particularly with the advent of DES and new devices to treat chronic total occlusions, it is considered an alternative to CABG in the treatment of multiple vessel disease in certain cases<sup>[18,19]</sup>. These improvements in technique have increased the feasibility and practicability of complete revascularization. Although CABG and PCI have their own sets of inclusion and exclusion criteria, overlapping in selection criteria exist, where the decision to proceed with a particular technique is generally made by a heart team, consisting of both cardiac surgeons and cardiologists among others. All other factors excluded, we propose that CR/IR should influence a decision to proceed with any specific surgical approach of coronary artery revascularization.

### **Mid/long-term outcomes**

The short-term, mid-term, and long-term outcomes of a strategy of revascularization are as important to the patient as it is to the doctor, and we consider it a pivotal factor in the decision making process. In our study, we sub-divided the follow-up time at the 5-year mark, and obtained the two sub-groups, namely the mid-term follow-up group (< 5 years) and long-term follow-up group (> 5 years). Statistical analysis was separately performed on each of the subgroups. CR was found to be associated with less mortality, post-op MI, reduced MACCE, and repeat revascularization procedures.

### **> 60 years old**

There has been a gradual increase in the average age of patients now referred for CABG. Contemporary cohorts consist of a greater proportion of octogenarians<sup>[15,20]</sup>. The BARI trial reported no survival disadvantage associated with IR, where non-LAD territories were left ungrafted. Siamak Mohammadi *et al.*<sup>[32]</sup> in their study of octogenarians undergoing CABG reported that short-term and long-term

mortality were not negatively affected by a strategy of ICR during CABG. Due to the greater number of grafted vessels, CR is associated with longer procedural times. This translates into increased duration of general anesthesia, longer cardiopulmonary bypass times, which increase the incidence of negative post-procedural complication and delay discharge from the hospital. Hence, some surgeons have advocated the concept of incomplete "reasonable" revascularization<sup>[21-23]</sup>. The results of our subgroup analysis show that there is a reduction across all negative outcomes associated with CR in patients who are > 60 years old. Despite the general trend in the elderly population, we propose CR as a precautionary measure against leaving potential myocardial regions and graftable target coronary arteries un-revascularized.

### Study limitations

There are several limitations to our meta-analysis. The results are affected by variation in study design, end-point definitions and reporting and possible publication bias. Moreover, our results and analysis are limited to the papers found on the Pubmed database and those added by hand-search.

Our study is concordant with similar studies from the past, whereby CR is associated with lower mortality, reduced post-op MI and MACCE, and lower rates of repeat procedures for revascularization. Furthermore, our study shows that CR is also associated with better mid-term and long-term outcomes, and less adverse outcomes in the > 60 years of age patient population. In our experience, CR acts as a buffer between CABG and PCI, and reduces the adverse outcomes associated with any one particular technique. With this in mind, and as dictated by the patient's condition, the technique with which CR is most likely to be accomplished should be used, and hybrid techniques can be emphasized for complicated cases, thus maximizing the gains from both techniques while minimizing the drawbacks. Given the obvious benefits, CR should be considered as the standard to determine the strategy of revascularization in patients with multi-vessel CAD.

## ARTICLE HIGHLIGHTS

### Research background

Two strategies are used in the treatment of multivessel coronary artery disease (CAD), namely percutaneous coronary intervention with stenting and coronary artery bypass grafting. Previous studies have proved the importance of complete revascularization. However, the extent to which completeness of revascularization influences the outcomes is still unclear.

### Research motivation

Nowadays with new improvements in technology and technique, the feasibility of complete revascularization is less of an issue. Hence, a thorough understanding of how complete revascularization affects post-procedural outcomes is mandatory.

### Research objectives

To investigate the influence and outcomes of complete vs incomplete myocardial revascularization in patients with multivessel CAD.

### Research methods

Database (pubmed) search coupled with hand search was performed for the identification and collection of relevant studies. Filters, inclusion and exclusion criteria were used to ensure quality and homogeneity of studies. Standard tables were used for data extraction. The data was analyzed and subjected to the appropriate tests by a statistician. A systematic review was then performed.

### Research results

Ten studies were identified, including 13327 patients of whom, 8053 received complete revascularization and 5274 received ICR. Relative to ICR, CR was associated with lower mortality (RR: 0.755, 95%CI: 0.66 to 0.864,  $P = 0.765$ ,  $I^2 = 0.0\%$ ), lower rates of MI (RR: 0.759, 95%CI: 0.615 to 0.937,  $P = 0.091$ ,  $I^2 = 45.1\%$ ), lower rates of MACCE (RR: 0.731, 95%CI: 0.668 to 0.8,  $P = 0.453$ ,  $I^2 = 0.0\%$ ) and reduced rates of repeat coronary revascularization (RR: 0.691, CI: 0.541 to 0.883,  $P = 0.0$ ,  $I^2 = 88.3\%$ ).

### Research conclusions

Completeness of revascularization is not mandatory for the treatment of multivessel CAD. The results of our study show that CR is associated with lower rates of adverse outcomes. The results propose that the extent to which a technique can achieve complete revascularization should be a major deciding factor in the choice of any one particular technique.

### Research perspectives

Complete revascularization is an alternative standard to decide the choice of a particular technique of revascularization. With emerging techniques of coronary revascularization, new retrospective cohort studies can be performed. Further research is needed to better understand the benefits of complete revascularization with a particular technique.

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