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Original research

Right internal mammary artery versus radial artery as second arterial conduit in coronary artery bypass grafting: A case-control study of 1526 patients

Shahzad G. Raja*, Umberto Benedetto, Anand Jothidasan, Raju Krishnam Jujjavarapu, Uchenna Franklin Ukwu, Fabio De Robertis, Toufan Bahrami, Jullien A. Gaer, Mohamed Amrani, on behalf of the Harefield Cardiac Outcomes Research Group

Department of Cardiac Surgery, Harefield Hospital, London, United Kingdom

HIGHLIGHTS

- Arterial grafts improve long-term outcomes in coronary artery bypass grafting (CABG).
- Radial artery (RA) is preferred over right internal mammary artery (RIMA) for CABG.
- RIMA is underutilised due to perceived operative risk and sternal wound issues.
- This largest clinical study to date validates short-term safety of RIMA.
- This study also confirms superiority of RIMA over RA in the long-term.

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ABSTRACT

Objective: Additional arterial grafts such as the right internal mammary artery (RIMA) or the radial artery (RA) have been proposed to improve long term outcomes in coronary artery bypass grafting (CABG). RA is largely preferred over RIMA as it is less technically demanding and there is a perception that bilateral IMA usage increases the risk of sternal wound complications. However, there is a paucity of direct comparison of the two conduits to guide surgeons to choose the best second arterial conduit for CABG. **Methods**: A propensity score adjusted analysis of patients undergoing multiple arterial grafting with RIMA ($n = 747$) and RA ($n = 779$) during the study period (2001–2013) was conducted to investigate the impact of the two strategies on early and late outcomes. **Results**: RIMA did not increase the incidence of postoperative complications including deep sternal wound infection ($P = 0.8$). Compared to the RIMA, the RA was associated with an increased risk for late mortality (Hazard Ratio [HR] 1.9; 95% confidence interval (CI) 1.2–3.1; $P = 0.008$) and repeat revascularization (HR 1.5; 95% CI 1.0–2.2; $P = 0.044$). A trend towards an extra risk for late mortality from RA over RIMA was observed among diabetic (HR 3.3; 95% CI 1.1–9.7) and obese patients (HR 2.1; 95% CI 0.8–5.46). **Conclusions**: RIMA as a second conduit did not increase the operative risk including sternal wound complications and improved long term outcomes including overall survival when compared to RA. This advantage was stronger among diabetic and obese patients. These findings strongly support RIMA as the first choice second arterial conduit in CABG. Further randomized studies with angiographic control and long-term follow-up are needed to address this issue.

Coronary artery bypass grafting (CABG) is a well-established therapy for patients with multivessel coronary disease, with excellent short- and long-term outcomes [1]. This is best illustrated by studies comparing percutaneous coronary interventions with surgical revascularization, where CABG continues to offer enhanced freedom from re-intervention and improved event-free survival [2,3]. However, the success of CABG, the gold standard for the treatment of multivessel coronary artery disease, is limited by poor long-term vein-graft patency [1,4,5]. By contrast, the left internal mammary artery (LIMA) has been

* Corresponding author.
E-mail addresses: drrajashahzad@hotmail.com, drsgraja@gmail.com (S.G. Raja).

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demonstrated to have superior graft patency rate and has provided excellent clinical results [6,7] suggesting that the use of multiple arterial conduits for CABG may be beneficial for long-term results [1,8–10].

Despite increasing recognition that multiple arterial conduits improve long-term outcomes following CABG, the quest for the second best arterial conduit to supplement LIMA continues [11]. Over the past decade, right internal mammary artery (RIMA) and radial artery (RA) have emerged as the most likely contenders for this slot. The use of RIMA as a second arterial graft has been shown to improve long-term survival as well as provide superior freedom from re-intervention when compared with single-LIMA strategy [12,13]. Bilateral IMA use is, however, still limited because of the increased operative time, the potentially increased morbidity rate, and the technical complexity of the operation [14]. On the other hand, RA due to being larger and easier to work with than the RIMA; easier to harvest; and not associated with sternal wound infection (SWI) [15,16] is largely preferred over RIMA. Despite, these aforementioned merits and demerits of RIMA and RA there is a paucity of direct comparison of the two conduits to guide surgeons to choose the best second arterial conduit for CABG.

The present study was undertaken to investigate the impact of RIMA or RA as the second conduit on early and late outcomes following multiple arterial grafting.

1. Methods

1.1. Study population

The study was conducted in accordance with the principles of the Declaration of Helsinki. The local ethical committee approved the study, and the requirement for individual patient consent was waived. We retrospectively analysed prospectively collected data from the institutional surgical database (PATS; Dendrite Clinical Systems, Ltd, Oxford, UK) from April 2001 to May 2013. The PATS database captures detailed information on a wide range of preoperative, intraoperative, and hospital postoperative variables (including complications and mortality) for all patients undergoing CABG in our institution. The data is collected and reported in accordance with the Society for Cardiothoracic Surgery in Great Britain & Ireland database criteria. The database is maintained by a team of full-time clinical information analysts, who are responsible for continuous prospective data collection as part of a continuous audit process. Data collection is validated regularly.

Patients included in the final analysis met the following criteria: a) first time isolated CABG; b) $\geq$2 grafts received; c) surgical strategies included single LIMA for the left anterior descending (LAD) artery and the radial artery for non LAD targets with or without additional saphenous vein grafts (RA group) or the use of the bilateral internal mammary arteries with or without additional saphenous vein grafts (RIMA group).

1.2. Operative technique

Grafting strategy, choice of conduits and harvesting technique was influenced by surgeon's preference in accordance with the universally recognized indications and contraindications. All interventions were performed via a midline sternotomy. Left and right IMA were harvested with minimal trauma as pedicled or skeletonised grafts and treated with papaverine solution prior to use. Great saphenous vein was harvested using open technique or vein stripper prior to 2007 and endoscopically from then onwards. RA was harvested from the non-dominant arm and treated with a flushing solution that consisted of verapamil hydrochloride 5 mg, nitroglycerin 2.5 mg, 20 mL of blood, and 2000 U of heparin.

Conventional CABG on CPB was performed at 34 °C. CPB was instituted with single two-stage right atrial cannulation and an ascending aorta perfusion cannula. Standard bypass management included membrane oxygenators, arterial line filters, and non-pulsatile flow of 2.4 l/min/m^2, with a mean arterial pressure greater than 50 mm Hg. The myocardium was protected by using intermittent antegrade cold blood cardioplegia (4:1 blood to crystalloid ratio). Anticoagulation was achieved using 300 U/kg of heparin. If required, heparin was supplemented to maintain the activated clotting time above 480 s and was reversed by protamine at the end of the procedure.

For off-pump CABG the heart was stabilised using a suction–irrigation tissue stabilisation system. A deep pericardial retraction suture helped position the heart for grafting. Anticoagulation was achieved with 150 U/kg of heparin. If required, heparin was supplemented to maintain the activated clotting time above 250 s and was reversed by protamine at the end of the procedure. Blood pressure was continually optimised during the procedure, and the mean arterial pressure was maintained above 50 mm Hg by repositioning the heart and by intravenous fluids or selective use of vasoconstrictors, or both.

1.3. Postoperative management

All patients received intravenous nitroglycerin (0.1–8 μg kg^{-1} min^{-1}) infusions for the first 24 h unless hypotensive (systolic blood pressure < 90 mm Hg). Choice of inotropic agents was dictated by the haemodynamic data. Other routine medications included daily aspirin and resumption of cholesterol-lowering agents and β-blockers unless contraindicated. All diabetic patients were commenced on an insulin infusion immediately after surgery to maintain normoglycaemia. Dose of insulin infusion was adjusted according to the patients' blood glucose level in accordance with an institutional protocol. Insulin infusion was stopped once regular oral hypoglycaemics and subcutaneous insulin therapy was commenced. Calcium channel blockers were not prescribed in the postoperative period for patients with RA grafts due to lack of evidence for their efficacy.

1.4. Pre-treatment variables and study end-point

The effect of the RA over the RIMA was adjusted for the following 24 pre-treatment variables: age, female gender, prior NYHA functional class III–IV, history of congestive heart failure (HxCHF), prior myocardial infarction (MI) prior percutaneous coronary intervention (PCI), diabetes mellitus (DM), hypertension, hypercholesterolaemia, current smoking, chronic obstructive pulmonary disease (COPD), cerebrovascular accident (CVA), peripheral vascular disease (PVD), history of atrial fibrillation (AF), left main stem (LMS) disease, left ventricular ejection fraction (LVEF) less than 50%, renal impairment defined as a serum creatinine more than 200 mmol/l, body mass index $\geq$30, non-elective indication, preoperative use of intra-aortic balloon pump (IABP), surgery performed by resident, number of grafts, incomplete revascularization and the use of cardiopulmonary bypass.

The short-term outcomes investigated were: the incidence of superficial and deep sternal wound infection (SWI) as defined by the Centers for Disease Control and Prevention [17], postoperative CVA, need for renal replacement therapy (RRT), reintubation for acute respiratory failure, re-exploration for bleeding, postoperative atrial fibrillation (POAF) and operative mortality (within 30 days).