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The First Preferred Second Choice Conduit For Coronary Artery Revascularization - A Review Article On Radial Artery Conduit Usage In Cabg

Poorna Chandhar, Subrata Pramanik, Manju Gupta, Anubhav Gupta, Rimy Prashad, Nootan Hadiya, Ashish S. Tyagi, Kritikalpa Behera
M Ch Ctvs Resident, Vardhman Mahavir Medical College And Safdarjung Hospital, New Delhi, Ind
Assistant Professor, Ctvs, Vardhman Mahavir Medical College And Safdarjung Hospital, Delhi, Ind
Professor, Ctvs, Vardhman Mahavir Medical College And Safdarjung Hospital, New Delhi, Ind
M Ch Ctvs Resident, Vardhman Mahavir Medical College And Safdarjung Hospital, New Delhi, Ind

Abstract
Confounding factors, including preferences for coronary target grafting, reconstruction procedures, medication regimens, patient variances, and post-operative time limit direct comparisons of coronary bypass conduits. Certain aspects of a patient, such as age, gender, drugs, or coexisting conditions, should have an equivalent impact on conduits. When comparing conduits in a group setting, bias is minimized when all patients receive all three comparison conduits, as opposed to some patients receiving only one or none.
This study aims at reviewing current practises in preferring of radial artery conduits in coronary artery bypass grafting as compared to other vascular conduits. With AHA guidelines grading usage of Radial artery as vascular conduit for coronary artery revascularisation as Class I indication, the ulterior motive of choosing RA conduit after LITA (Left Internal Thoracic Artery) in CABG is obtaining long-term patency post revascularization for better quality of life.

Keywords: *conduits in CABG, radial artery conduits, radial artery and LIMA, radial artery and other autologous conduits, coronary artery revascularization.*

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I. Introduction And A Historical Note

Carpentier initially used radial artery conduit for CABG in 1971 but abandoned due to high tension for spasms and early occlusion [11]. Graft occlusion occurred in one-third of the initial series of recipients. This led Carpentier to declare that until this physiological issue was resolved, RA should not be used as a graft. He proposed that the denervated vessel's spasm was the cause of the obstruction of this arterial conduit [2]. In 1989, follow-up on 14 patients with CT coronary angiography by Carpentier encouraged patency rates of RA conduit.

In 1992, once physiology of RA was understood, RA graft came to forefront. There have been many discussions concerning the best conduit for coronary artery bypass surgery (CABG), such as bilateral versus single internal thoracic artery grafts (LITA) or the radial artery (RA), due to concerns about the long-term efficacy of saphenous vein grafts (SVG) [7–15]. According to available data, the LITA remains the primary source of positive long-term results, particularly in those under 70 years without diabetes, unquestionably solidifying its position as the first-choice graft. One unchanging claim remains: LITA-to-LAD is the best and maybe the only significant graft used in coronary surgery [7,8]. By practicing RA harvesting for 49 years and learning when not to utilize this conduit rather than how to use it, Dr. Carpentier's legacy of adopting RA was continued [8–14]. The preparation method was modified by harvesting the RA "en bloc" with the satellite veins and administering an antispasmodic medication (Diltiazem).

II. Conduits For CABG

Both venous and arterial conduits have been utilized to create coronary revascularization to ensure long-term patency. Saphenous vein, Internal Thoracic Arteries (ITA), radial artery (RA), and gastroepiploic artery (GEA) were four conduits showed promising patency. In 2011, the ACCF/AHA guidelines for CABG surgery [20] proposed using arterial grafts for anastomosis to the left anterior descending artery (LAD). Though its caliber is a good fit for LAD diameter, the left IMA has only sometimes been favored graft for LAD; this changed in the 1980s. It has been demonstrated that left IMA to LAD anastomoses had high patency rate of up to 95% to 98% after 20 years post-CABG. SVGs exhibited lower patency and higher mortality rate compared with those of IMAs with occlusion rate up to 50% as early as ten years after implantation [21].

Ten years and beyond follow up for saphenous vein conduit in CABG experienced a higher rate of failure because of venous intimal hyperplasia [22]. Angiographic studies show that SVGs can experience atherosclerosis in addition to intimal thickening; only 38% to 45% of SVGs remain patent after ten years, representing a 2% attrition rate from the first to the seventh post-operative year [23].

The RAPCO (Radial Artery Patency and Clinical Outcome) experiment, the RAPS (Radial Artery Patency Study), and other studies' findings have greatly influenced the decision to use the RA as a bypass conduit [24]. After a follow-up that lasted longer than five years following surgery, the RAPS showed that RA was superior to SVG [25].

A meta-analysis of randomized control studies revealed similar findings, with RA showing a reduced rate of adverse cardiac events compared to SVG and a greater rate of patency at ten years of follow-up [26]. Another type of arterial graft that permits revascularization and exhibits patency rates of 91%, 80%, and 62% at 1, 5, and 10-year follow-ups is the GEA. Despite this, its use is less common due to its increased susceptibility to spasms and the requirement for a small laparotomy during harvesting [27].

Vascular biology has recently offered a potential explanation for the underlying variations in graft conduit's success. These findings have swiftly spread to affect the surgeon's reasoning when selecting conduits.

III. Factors Affecting RA Patency

Indications. True graft patency needs to be accurately reflected by most angiographic investigations primarily focused on symptoms. When evidence of myocardial ischemia is used as the basis for angiography, the rate of graft occlusion is roughly quadrupled [9]. This also applies to RA grafts, where patients with no symptoms have an occlusion rate at seven years of 12%, but those with clinical or ECG/scintigraphic evidence of ischemia had a rate of 26% [6].

Coronary artery target. Regardless of the kind of graft - venous or arterial - target coronary artery is a potent predictor of patency [6–11]. The left coronary artery's diagonal and obtuse marginal branches are most patency-rate-highest conduits implanted after the left anterior descending coronary artery, whose substantial run-off includes the perforators. The right coronary artery has the lowest patency rate because its region is primarily restricted to the thin right ventricular myocardium [6].

Target coronary artery's size directly affects the radial arterial conduits' patency [10,11,12,13]. Targets of right coronary artery have statistically lesser RA graft patency than those on left coronary artery [14]. 10 year patency rates of RA grafts dropped to 92%, 82%, and 78% for diagonal, obtuse marginal, and right coronary arteries respectively [6]. Sample sizes of RA grafts anastomosed to LAD were too small to infer statistical analysis.

It has been established that one of the primary reasons RA graft failure occurs is competitive flow. Moderately stenosed targets had worse anastomotic patency than vessels with critical stenosis [4, 15,16]. Nevertheless, there is disagreement over whether stenosis at 70% or 90% qualifies as "critical" [17]. According to Maniar's study, the mean degree of stenosis for patent anastomoses was 82% in contrast to 71% for occluded anastomoses, suggesting a critical range where flow competition occurs [17].

In contrast to all conduits used for surgical myocardial revascularization, particularly with internal thoracic artery, RA has thick muscular wall and only limited elastic tissue in its media [8]. Abundant muscular component causing hyperspastic attitude is anatomic background of radial artery in both in vivo and in vitro. Thus, necessity to prevent RA spasms by pharmacological intervention has been emphasized by many authors and current era excellent patency rates.

IV. Anatomy And Cellular Composition

Employing veins rather than arteries is more successful due to their inherent variances. The adult IMA is a flexible artery with a 1.9 to 2.6 mm diameter and a wall thickness varying from 180 to 430 mm [28].

The tunica media comprises thin layer of collagen-encased vascular smooth muscle cells (VSMCs) positioned between elastic layers and circumferentially aligned. In 50% of instances, intima had some neointima along with VSMCs and endothelium [29].

The SVG's big diameter spans from 3.1 to 8.5 mm, while its wall thickness varies from 180 to 650 mm (11). Type I collagen envelops the longitudinally oriented VSMCs in the media and adventitia and the circumferentially orientated VSMCs. The adventitia and media exhibit elastic laminates, while the intima have a multilayered configuration sculpted by collagen and VSMCs. Additionally, the intima exhibits intimal thickening, typically seen during implantation, and takes up less than 25% of the vein's cross-sectional area [30].

The RA features multiple fenestrations on a single-layer elastic lamina. It features a narrow intima with mild to moderate hyperplasia and a thick tunica media with many VSMCs (12). Its wall thickness typically ranges from 254 to 529 mm, and its tunica media contains 18.84% elastic fibers [31]—the Sequential Grafting (4.4). Due to the more distal run-off, sequential grafting is known to boost patency. Compared to grafts with a single anastomosis, sequential RA conduits exhibit more excellent patency (91% against 82% after seven years) [6]. On rare occasions, the graft's distal or proximal ends stay patent while the remainder becomes nonfunctional (occlusion or string) [5,32].

V. RA And Right Internal Thoracic Artery

The RA has advantages over proper internal thoracic artery (RITA). A flexible conduit, allows it to be used for all coronary targets. Additionally, it can be harvested simultaneously with LITA, reducing operating hours. Potential atheromatous changes of RA more common than LITA, restricts radial artery grafting as primary conduit.

Borger [33] was first to assess the clinical advantages of integrating IMA to LAD graft using RA instead of RITA from the left. While there was a reduced incidence of perioperative myocardial infarction than in the RITA group, it is noteworthy that patients in the RA group were older and had more multiple risk factors, including low ejection fraction, diabetes, and NYHA class [33]. The evidence thus showed that, throughout the three-year study period, using the RA as a conduit for CABG provided superior protection against cardiac death and other cardiac events like myocardial infarction, readmission, and repeated revascularization [34]. This is in comparison to using the RITA conduit.

Only the randomized RAPCO (Radial Artery Patency and Clinical Outcomes) experiment compared RA and RITA. At the 6-year follow-up, the study found no changes in the patency rates of the two conduits and a nonsignificant trend toward improved event-free survival for RA [70]. There is conflicting evidence, typically due to significant methodological or sample size limitations, regarding the relationship between graft patency and composite cardiac outcomes, such as rehospitalization rate, based on follow-up from retrospective cohort studies [35].

Comparable mortality was found in one comparative meta-analysis involving clinical outcomes; however, the RA was associated with a decreased incidence of cardiac events, including myocardial infarction, heart failure, and ischemia (RR: 0.49; 95% CI: 0.28 to 0.87; P = 0:014) [36-38].

VI. RA Compared To Other Conduits :

Vein against RA

It is unlikely that intimal hyperplasia will be the cause of graft failure in the early post-operative months; instead, acute graft thrombosis is a recurring mechanism. Because of its better hemodynamic properties, RA is most likely less prone to thrombosis than saphenous veins [39].

Its diameter matches the coronary arteries proportionately, as it is just 20% larger than the target vessel [40]. Furthermore, this RA is offered without valves and maintains a similar diameter from the proximal to the distal end, if not somewhat less. On the other hand, the vein's diameter is 50% more than the target coronary artery's [40], frequently resulting in a noticeable discrepancy. In addition, the saphenous vein lumen has valves and varies in diameter at the level of its collateral branches. Its diameter grows from the proximal to the distal end of the vein. This somewhat unfavorable hemodynamic characteristic explains a higher thrombosis rate compared to the RA graft.

For CABG operations, seven RCTs [9–14, 75, 76] have examined the use of RA and saphenous vein graft (SVG). Individuals who got RA had far higher patency rates when the follow-up period was extended beyond the first year following surgery when compared to individuals who were handled with SVG [8]. According to two trials, RA recipients had a decreased incidence of clinical events [8].

According to the results of the Randomised Artery Patency Study (RAPS), meta-analyses, and observational studies, patients who underwent radial artery use were significantly protected against graft occlusion over one year compared to those who received saphenous vein grafts [8, 9, 13, 41].

Males and Females experience equal radial artery graft occlusion rates one year after the procedure. However, women experience a two-fold higher saphenous vein graft occlusion rate than males [42].

Compared to vein grafts, radial artery patency is higher in patients with diabetes and non-diabetes at one year [8, 43]. However, the Copenhagen Arterial Revascularization Randomised Patency and Outcome experiment, or CARRPO, a randomized angiographic study conducted a year following total arterial revascularization, was unable to find any differences in graft patency when compared to traditional single IMA with vein grafting [44].

A developing graft disease affects saphenous veins, causing calcification of the vascular wall, intraluminal accumulation of atheromatous debris, and increased intimal hyperplasia. Only 60% of vein grafts remain patent after ten years, and half have an atheromatous process in the anatomy of their vessels [45]. In contrast, all long-term investigations have shown that the 10-year patency rate of RA grafts surpasses 80%.

The results of the randomized clinical trial Radial Artery versus Saphenous Vein Patency (RSVP) showed that, at five years, radial artery grafts placed on a stenosed branch of the circumflex coronary artery had a considerably higher patency rate than saphenous vein grafts [46].

RA versus ITA

Most series found that the LITA graft had a higher patency rate than the RA graft [3-6, 47-49]. To develop an accurate assessment, the interpretation of angiographic data must consider additional factors contributing to graft failure and the kind of conduit investigated. The target vessel's size influences the LITA's patency; grafts placed on the LAD have the best patency, while the right coronary target anastomosis has the lowest patency [50]. The graft occlusion rate for vessels with less than 60% stenosis is four times higher than that of arteries with 80% stenosis, indicating that LITA grafts are similarly susceptible to competitive flow [51,52].

RA versus Gastroepiploic Artery

The Gas-troepiploic Artery (GEA) conduit was systematically used for CABG grafting, as documented in seminal articles published more than thirty years ago by Suma et al. [53]. The GEA demonstrated a favorable load-flow ratio [54] and a low risk of developing severe atherosclerotic degeneration [55].

Due to these unsatisfactory outcomes, the harvesting technique was modified, which clearly showed relatively low patency rates. Suzuki et al. found noticeably improved long-term results (90.2% at eight years) employing skeletonized GEA grafts only for target arteries with stenosis > 90% [56].

Only a few trials are known regarding the safety and efficacy of using GEA instead of RA as the second target conduit for coronary artery bypass grafting [57,58].

Compared to the RA, the circumflex system's short graft length limits its function as a conduit and makes it a less desirable alternative [59,60].

VII. Final Considerations

While there are few contraindications to using RA, there is disagreement on its usage as a graft for the second target vascular. Per the Society of Thoracic Surgeons (STS) review database, less than five percent of CABG had an RA as second conduit. This tendency must be bucked.

Randomized clinical studies have made this trend reversal possible, involving numerous cardiac surgeons from Australia [10, 11, 15] and Europe [8, 9, 12]. Though RA harvest was initially opposed, recent researches gradually softened public opinion on its usage as a second preferred artery conduit.

There is growing consensus [8] about the inclusion of radial artery as direct implant and as composite graft (LIMA-RA - 'Y' anastomosis), as depicted by Royce et al [41]. High-risk cases, like ventricular dysfunction [98] or unstable angina benefitted from RA as second preferred arterial conduit [5, 6].

Furthermore, as shown in series of 910 patients since 1989 [3, 4] and in more recent reports, Out of 57 patients, 52 had RA fully patent when anastomosed sequentially at 9.8 years follow up (91.2% P = 0:08) [5, 6], the site of RA conduit for sequential anastomosis didn't affect late survival benefit.

Even in occluded right coronary artery or left circumflex artery causing myocardial infarction and ischemic mitral regurgitation, RA was effectively used as primary target conduit in CABG [61].

Many patients had restricted mitral annuloplasty combined with papillary muscle approximation linked to CABG utilizing RA [62]. Restrictive mitral annuloplasty employing a double row overlapping suture was linked to myocardial revascularization utilising the RA in cases having substantial distortion of LV with asymmetric tethering, extensive infero-basal scar linked [63].

The use of BITA grafts has long been restricted due to a dogmatic bias regarding the technical challenges of surgery and the impact of the financial consequences associated with sternal wound infection. Despite the multitude of positive studies, this attitude has unfairly extended to the RA during the discussion of complete arterial revascularization.

Having reviewed articles of over 49 years of expertise, the radial artery can be considered an excellent second-choice graft for coronary artery bypass surgery [64-68]. Undeniably, each surgeon can choose the conduit for a CABG operation endoscopically, whether using an open approach or a no-touch technique. A 2009 comparative analysis of 3,000 CABG patients who had open or endoscopic vein graft harvesting option given by surgeons revealed a worse graft survival rate.

The problems above, linked to vascular damage such as venous compression, adventitial stripping, traction, and endothelial damage, were demonstrated to be less prominent in open vein harvesting instances than in endoscopic procedures. According to a more recent randomized clinical trial that compared them in 2019 [68], the incidence of major adverse cardiac events did not significantly differ between these two procedures.

The SVG is harvested using the atraumatic no-touch approach, which yields more excellent graft patency on par with the IMA. Despite their higher risk of experiencing wound problems, patients using the no-touch SVG approach exhibit excellent graft performance compared to endoscopic vein graft harvesting [69].

A prospective randomized trial comparing endoscopic versus open RA harvesting methods revealed no adverse effects on harvested RA length, harvest duration & quality, local complications, or wound epithelialization when analyzing various RA harvesting methods [70]. Contrarily, the GEA can be harvested as skeletonized or pedicled, with skeletonization being likely preferable as it prevents vasoconstriction while maintaining a broader and longer conduit [41].

VIII. Discussion And Future Perspectives

Sufficient function and long-term durability of the conduit used for grafting are determined by their functional and anatomical similarities with the coronary artery. Its length, luminal diameter, wall thickness, and histological characteristics are a few of these characteristics [72]. When opposed to SVGs, arterial grafts seem to meet these requirements better: They are less vulnerable to VSMC migration and proliferation; 2) their endothelium secretes more NO and endothelium-derived relaxing substances, protecting against platelet aggravation; and 3) their structure contains all the components required to maintain systemic arterial pressure.

The graft's longevity and patency are determined by its structural biology. When comparing the incidence of atherosclerosis in arteries (IMA, RA, or GEA) following CABG to that of SVG grafts, it needs to be more present and shallow. When the SVG is harvested, it begins to degrade as a conduit; during this process, its adventitial layer is frequently lost and enlarged, causing hypoxia in the artery wall and encouraging early thrombosis and activated platelet [73]. Implanted SVG is subjected to greater arterial pressure, which increases its luminal diameter and shear stress. This causes damage to the endothelial cell (EC) layer, encourages vasospasm, and decreases graft patency [74].

Consequently, neointimal hyperplasia brought on by increased arterial pressure on the vein may result in graft failure in less than a year. During this process, VSMCs proliferate and migrate concurrently, eventually resulting in luminal loss and an increased risk of atherosclerosis [75]. After a year, thrombosis, high risk of plaque rupture and significant atherosclerosis and aneurysmal dilatation are usually cause of graft failure.

These mechanisms arise because the SVG cannot undergo positive re-modeling compared with IMA which has a low VSMC proliferation and migration rate, matrix activation and cellular necrosis [76].

Since artery conduits are thought to have similar biological properties, they would also have comparable functional responses. However, Functional studies have shown that these arteries differ in histology, endothelial function, and contractility.

For instance, during surgical dissection and perioperative procedures, the RA and GEA are more prone to experiencing spasms than the IMA [77]. In vitro, vasospasm can be reversible with calcium channel blockers such as isradipine. Clinical series have indicated that using Ca^{2+} channel blockers following CABG when RA grafts are utilized, is linked to reduced major adverse cardiovascular events and higher graft patency [78]. Even though the IMA is the best conduit for grafting a coronary artery biologically, using a second IMA can occasionally be difficult due to clinical and technical issues.

As long as adequate measures are taken during the perioperative phase to prevent vasospasm, using the RA currently represents a fantastic alternative.

Clinical results showing the superiority of IMA in CABG have been partially explained by a molecular explanation derived from the transcriptional study of human surgically removed IMAs, SVGs, and aortas. In a research examining patients who had isolated CABG, analysis of the transcript expression of proathero-sclerotic and proinflammatory genes in the right and left IMAs was found to be lower than that of the patient's aortic buttons [79].

Certain arterial branches from the same patient do not appear to have the same protective effect against atherosclerosis in the IMAs as the ascending aorta does (49). A study examining IMA resistance to thrombotic occlusion found that IMAs were less susceptible to thrombosis and neo-intima development than SVGs (36). A 10-year follow-up of Dimitrova et al (50) revealed two noteworthy findings based on clinical and angiographical data: 1) a significant patency rates of arteria grafts over vein grafts, 2) delayed atherosclerosis on grafted coronary vessels - arterial conduits compared to venous grafts.

IX. Promulgated Flyers For Radial Artery Conduits

Preoperative Allen test to assess perfusion and collateral ulnar-radial arteries flow is mandatory with the good ulnar flow to choose radial artery graft from non-dominant limb owing to hematoma and neurological complications possibly avoided in CKD patients requiring dialysis/ fistula creation (80).

In patients undergoing isolated CABG, the use of a radial artery is recommended in preference to a saphenous vein conduit to graft the second most important, significantly stenosed, non–LAD vessel to improve long-term cardiac outcomes (81)

Watson and associates (82) summarized the literature on the effect of proximal anastomosis on RA patency in a best-evidence topic paper in 2013. The authors highlighted the heterogeneous and contradictory results reported. They concluded that the evidence suggests that the proximal anastomosis site has little or no effect on RA graft patency.

Historically, calcium channel antagonists and nitrates have been the most popular agents for mitigating RA graft vasospasm. Others, such as papaverine and phenoxybenzamine, have also been used. Papaverine, extensively used as a topical vasodilator in the bath for arterial and venous conduits, was found to have equivalent vasodilatory potency compared with verapamil/nitroglycerine. However, the time of onset was slower and the duration shorter.

There is a higher incidence of an RA "string sign" in patients who did not receive calcium channel antagonists.

X. Conclusion

The radial artery is an attractive vessel for coronary bypass surgery as its length allows it to be used for almost any coronary target or multiple sequential anastomoses. The preferred conduit in CABG is based on understanding each graft's USP, limitations, and patient-centric choices. Radial artery, LIMA conduits are harvested preferably given their better long-term patency. Venous grafts (GSV) however, remains feasible substitutes if circumstances arise. The available options for cardiac surgeon with resurgence in hybrid graft harvesting techniques adds to the armamentarium, yielding in complex cases. The ulterior motive of conduit in CABG is obtaining long-term patent revascularization, for better quality of life. Further understanding and research in surgical prospects may protocolize selection process, thus improving outcomes of CABG.

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