The Radial Artery: A Forgotten Conduit

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We reviewed the published literature on the clinical and angiographic outcome of radial artery (RA) grafts and on the comparison between the RA and the other conduits used in coronary operations. The RA is a better graft than the saphenous vein and comparable to the right internal thoracic artery (RITA); moreover, the RA seems a better choice than the RITA in patients at risk of sternal or pulmonary complications. We conclude that the RA should be preferred to the saphenous vein and considered at least equivalent to the RITA as the second conduit during every elective coronary artery bypass procedure.

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Since its reintroduction in coronary operations in the 1990s, a large amount of information regarding the morphometry, pathology, and vasoreactivity of the radial artery (RA) as well as large clinical series and long-term angiographic data have become available. Despite that, this conduit seems to have been somewhat forgotten by the surgical community, and recent data suggest that the RA is used in less than 6% of all coronary artery bypass grafting (CABG) procedures [1]. This review article summarizes the current evidence on the RA as a bypass conduit and defines the role of the RA in coronary artery operations.

Material and Methods

In September 2014 the PubMed database was searched using the definition "radial artery coronary surgery," "radial artery patency," "radial artery versus saphenous vein," and "radial artery versus right internal thoracic artery." Relevant abstracts were reviewed, and the function "related articles" was used for all included manuscripts. A reference cross-check was performed for all selected studies. More than 1,600 papers were selected. After exclusion or duplicate publications, follow-up of the same cohort of patients, and nonrelevant papers, 650 studies were selected. Exclusion of the RA clinical series with fewer than 300 cases, RA angiographic series with fewer than 200 studies, and papers confirming previous results led to the 63 references quoted in the present review.

Results

Angiographic and Clinical Observational Studies of RA Grafts

Table 1 summarizes the results of angiographic studies that included more than 200 patients. Amano and colleagues [2] described a series of 213 patients who underwent repeat angiography for clinical or study purposes 1.5 years postoperatively with an overall RA patency rate of 93%. Shah and colleagues [3] reported 91% patency rate at 3 years. In an often-cited paper from Cleveland Clinic, Khot and colleagues [4] had an alarming 51.3% RA patency rate at 565 days of follow-up in 310 patients who underwent postoperative angiography for symptoms, but, because the study was limited to symptomatic patients, a major selection bias was evident in this series. The Melbourne group [5] reported 89% patency rate among 1,108 RA patients at 48.3 $\pm$ 40 months postoperatively, and Tranbaugh and colleagues [6] described 82% patency rate at 8.1 years in 278 patients restudied for symptoms. More recently, Achouh and coauthors [7] reported 82.8% 7-year patency in a cohort of 351 patients.

In all angiographic studies, the major determinant of RA graft patency was by far a high degree of stenosis severity of the target vessel, which was probably due to the detrimental effects of chronic native competitive flow on an artery with a high spastic tendency in the early postoperative period. Maniar and associates [8] were the first to show how the early patency rate of RA grafts was significantly worse for target vessels with stenosis of 70% or less compared with 90% or greater (relative risk, 1.7; $p < 0.001$). All subsequent investigations on this issue confirmed these findings [9, 10]. The quality of distal runoff also plays an important role, whereas chronic antispastic therapy, site of inflow or the distal anastomosis, and use or not of cardiopulmonary bypass do not affect long-term RA graft patency [11–13].

In summary, current evidence suggests that the long-term angiographic patency rate of RA grafts is excellent if the target vessel exhibits a severe stenosis (Fig 1). Table 2 summarizes the main results of the published clinical studies that included more than 300 patients.

Chen and colleagues [14] were the first to report a large clinical series; in a multicenter study involving more than 900 RA patients, they reported a 2.3% operative mortality in the absence of ischemia or motor dysfunction in the operated-on hands. In a cohort of 6,646 RA graft cases, Tatoulis and colleagues [16] reported excellent early outcomes, with an operative mortality of 0.9% and

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Abbreviations and Acronyms

AMI = acute myocardial infarction
CABG = coronary artery bypass graft
CX = circumflex coronary artery
ITA = internal thoracic artery
LAD = left anterior descending
RA = radial artery
RAPCO = radial artery patency and clinical outcomes
RAPS = radial artery patency study
RCTs = randomized controlled trials
RITA = right internal thoracic artery
RSVP = Radial Artery Versus Saphenous Vein Patency
SV = saphenous vein
TEP = transradial endovascular procedures

perioperative myocardial infarction of 0.8%, and concordantly, Al-Ruzzeh and coauthors [17] had 0.6% operative mortality and 0.5% perioperative myocardial infarction in a series of 600 consecutive RA cases. In 2012 Achouh and colleagues [7] reported 80.3% and 92.7% freedom from death and cardiac death, respectively, among 563 RA patients at 9.2 years of follow-up, and the following year Tranbaugh and colleagues [6] reported 99%, 96%, 89% and 75% survival at 1, 5, 10, and 15 years, respectively, in a large cohort of 1,851 RA patients. Finally, the Mayo Clinic group [20] found 93% survival at 5 years and 78% at 10 years.

To summarize, with all the limitations of case series, the current literature suggests that excellent early and late clinical results can be achieved using the RA for CABG.

Studies Comparing RA and Saphenous Vein

Several studies compared the RA with other venous or arterial conduits. The most frequent comparison has been with the saphenous vein (SV). The results of the randomized trials and the meta-analyses on this topic are summarized in Table 3.

Goldman and associates [21] reported lack of clinical or patency benefit in the first postoperative year comparing 366 RA and 367 SV patients. The Radial Artery Versus Saphenous Vein Patency (RSVP) trial investigators, at a longer follow-up of 5 years, had a significantly better patency rate for RA grafts and no difference in crude mortality, which was the only clinical end point considered in the study [22]. The Radial Artery Patency Study (RAPS) trial confirmed better late patency for RA vs SV grafts, with a tendency toward a lower incidence of adverse clinical events (death, myocardial infarction, repeat coronary revascularization) in the RA group (0.7% vs 2.5%) [23, 24]. The Radial Artery Patency and Clinical Outcomes (RAPCO) trial interim analysis found no difference in death, myocardial infarction, repeat revascularization, or angiographic patency, but a tendency for lower target vessel revascularization among RA patients (0.9 vs 3.6%; $p = 0.21$) [25, 26]; however, definitive trial results are still awaited.

Regarding meta-analysis, Benedetto and colleagues [27] in 2010 did not find a difference in patency rates between RA and SV at early follow-up (22 months), but a subsequent meta-analysis with longer follow-up (56 months) reported comparable mortality but significantly lower occlusion rates for RA than for SV grafts [28]. Concordantly, Athanasiou and associates [29], in a pooled analysis of 35 studies, showed better results for the RA at midterm and long-term (odds ratio [OR], 2.06 and 2.28 for patency).

After the RAPS 5-year results were published, this meta-analysis was updated by Deb and coworkers [24], who confirmed reduced occlusion rates of the RA beyond 5 years (OR, 0.52) [24]. Similar results were obtained by Cao and colleagues [30], who analyzed five randomized controlled trials (RCTs) comparing RA and SV graft angiographic outcomes at different intervals and described a significantly lower rate of graft failure for the RA after 4 years (OR, 0.17). Zhang and coauthors [31], in a recent analysis of six trials including more than 1,800 RA grafts, reported reduced cardiac death, myocardial infarction, and repeat coronary operation and better late graft patency for RA vs SV grafts (OR, 0.72, 0.68, 0.27, and 0.52 respectively). Finally, Benedetto and colleagues [32] in a network meta-analysis of angiographic RCTs comparing the SV with all the arterial conduits used for CABG and including 2,780 patients, found that the use of venous grafts was associated with a fourfold (OR, 1.67 to

Table 1. Angiographic Results of the Observational Studies Assessing the Patency Rate of Radial Artery Grafts and Including More Than 200 Patients

First Author	Year	Grafts/Patients With Angiographic Control (%)	Follow-Up	RA Patency Rate (%)
Amano [2]	2001	44.8	18 mo	93
Shah [3]	2005	NA[a]	1,100 d	91
Khot [4]	2004	NA[a]	565 d	51.3
Tatoulis [5]	2009	7.8	48.3 mo	89
Tranbaugh [6]	2012	22.6	8.1 y	82
Achouh [7]	2012	43	7 y	82.8
Maniar [8]	2002	13.5	27.1 mo	70

[a] These were studies limited to patients who underwent postoperative angiographic control.

NA = not applicable; RA = radial artery.