

Saphenous vein graft vs. radial artery graft searching for the best second coronary artery bypass graft



Hilal Ali Al-Sabti ^{a,*}, Adil Al Kindi ^a, Khalid Al-Rasadi ^b, Yajnavalka Banerjee ^b
Khamis Al-Hashmi ^c, Ali Al-Hinai ^d

^a Department of Surgery, Sultan Qaboos University Hospital; ^b Department of Clinical Biochemistry, Sultan Qaboos University Hospital; ^c Department of Clinical Physiology, College of Medicine and Health Sciences, Sultan Qaboos University; ^d Department of Medicine, College of Medicine

^{a-d} Muscat

Coronary artery bypass grafting (CABG) was first used in the late 1960s. This revolutionary procedure created hope among ischemic heart disease patients. Multiple conduits are used and the golden standard is the left internal mammary artery to the left anterior descending artery. Although all approaches were advocated by doctors, the use of saphenous vein grafts became the leading approach used by the majority of cardiac surgeons in the 1970s. The radial artery graft was introduced at the same time but was not as prevalent due to complications. It was reintroduced into clinical practice in 1989. The procedure was not well received initially but it has since shown superiority in patency as well as long-term survival after CABG. This review provides a summary of characteristics, technical features and patency rates of the radial artery graft in comparison with venous conduits. Current studies and research into radial artery grafts and saphenous vein grafts for CABG are explored. However, more studies are required to verify the various findings of the positive effects of coronary artery bypass grafting with the help of radial arteries on mortality and long-lasting patency.

© 2013 Production and hosting by Elsevier B.V. on behalf of King Saud University.

Keywords: Coronary artery bypass grafting (CABG), Arterial grafts, Saphenous vein vs. radial artery, Radial artery graft patency, Radial artery graft spasm, RA graft long-term outcome

Disclosure: Authors have nothing to disclose with regard to commercial support.

Received 15 May 2013; revised 31 May 2013; accepted 8 June 2013.
Available online 19 June 2013

* Corresponding author. Address: Department of Surgery, Sultan Qaboos University Hospital, PO Box 38, Al-Khod, Muscat 123, Oman.
E-mail address: alsabti@hotmail.com (H.A. Al-Sabti).



P.O. Box 2925 Riyadh – 11461KSA
Tel: +966 1 2520088 ext 40151
Fax: +966 1 2520718
Email: sha@sha.org.sa
URL: www.sha.org.sa



1016–7315 © 2013 Production and hosting by Elsevier B.V. on behalf of King Saud University.

Peer review under responsibility of King Saud University.
URL: www.ksu.edu.sa
<http://dx.doi.org/10.1016/j.jsha.2013.06.001>



Production and hosting by Elsevier

Abbreviations and Acronyms

CABG	=	Coronary Artery Bypass Grafting
CAD	=	Coronary Artery Disease
RA	=	Radial Artery
LIMA	=	Let Internal Mammary Artery
RIMA	=	Right Internal Mammary Artery

Introduction

Many risk factors can lead to an occlusion of the coronary arteries of the heart in which the blood supply demand equation is imbalanced, leading to what is known as coronary artery disease (CAD). The most common etiology behind this is atherosclerosis, in which fats are deposited in the arterial walls, causing them to thicken. Occlusion of the coronary arteries increases the subject's risk of myocardial infarction. There are three main treatment options for CAD: medical treatment, percutaneous cardiac intervention or coronary artery bypass grafting (CABG), which is a surgical treatment directed to restore the flow of blood to the heart. The selection of the graft conduit is important to the success of CABG, since the coronary conduit's patency is directly linked with a normal postoperative course and an improved long-standing patient survival [1]. The most commonly used graft was the saphenous vein (particularly the great saphenous vein) and is still in use. However, due to the success story of the left internal mammary artery LIMA, total arterial revascularization has gained much importance for coronary bypass graft surgery. These arterial grafts also have an added benefit of a better long-term patency rate and survival, [2,3] but such observational studies do not take into consideration the risk of mediastinitis which is a major risk factor. Further when comparing the two arterial grafts used after the LIMA, the radial artery (RA) and right internal mammary artery (RIMA), most of the studies could not show any superiority of either grafts. With the RA, risk of infection remain less and it is longer and the risk of injury is less in redo surgery. Premature vein graft failure along with blockage is the most significant drawback of saphenous vein grafts. Nonetheless, in spite of everything, vein grafting remains a fundamental aspect of heart surgeries. This review offers a comparison between the saphenous vein graft and the radial artery graft.

Need for change

Saphenous vein graft failure remains a considerable economic and clinical burden. Although greater use of the left internal mammary artery (LIMA) has led to a better long-term outcome, the mainstream of bypass procedures continues to use the saphenous vein. Prior to the vein graft, patency is enhanced by preventing damage at the time of implantation, careful surgical practice, and pertinent utilization of antithrombotic therapy. No surgical method or pharmacological intervention has yet been demonstrated to put off late occlusion, which is a consequence of the evolution of smooth muscle cell proliferation of intimal vascular and superimposed atheromatous alterations. Recent literature describes the use of antiplatelet therapy, but that is still in need of further evidence-based science [4].

There has been a striking increase over the past few years in the understanding of the vessel wall biology and the humoral and cellular outcomes of the process of smooth muscle cell proliferation of the vascular intima. This is become possible mainly via the improvement and use of molecular biological methods. Although pharmacological therapies to avoid hyperplasia of intimal vessels are yet to be appraised, it is again the novel run of approaches made probable by molecular biology that offer the most promising outlooks for treatment. One such approach is the use of radial artery grafts instead of saphenous vein grafts.

Comparison between saphenous vein graft and radial artery graft

The radial artery has long been supported as a prospective graft for CABG. Intrinsic anatomical and convenient features mean that this conduit is technically beneficial compared with other arterial grafts, such as the right internal mammary artery (RIMA).

Characteristics of saphenous vein graft

The saphenous vein is the large, superficial and subcutaneous vein of the leg. This graft has been in use for many years. The vein grafts are placed in a reversed position to allow free blood to flow via the venous valves. The only problem with this graft is the patency. The saphenous vein graft

(SVG) remains patent for more than a ten-year period in only a very small number of people [5].

Characteristics of the radial artery

The average length of the radial artery graft makes it appropriate for approaching myocardial areas. The lumen diameter is larger than others venous and arterial grafts. It shows good correspondence and size match to most of the recipient coronary vessels. It is easily harvested by endoscope or openly [6]. The thick muscular wall of the radial artery is suitable for both coronary and aortic anastomoses. Its harvesting does not impede ambulation and wound infection is uncommon.

Preoperative preparation of the radial artery

Before performing a surgical procedure, a modified Allen's test is carried out in all patients prior to operation.

In this test, the patient is asked to make a tight fist. The examiner tightly compresses the ulnar and radial arteries at the wrist. The patient is then asked to slowly open his wrists. As soon as the pressure over the ulnar artery is released, a hyperaemic response may show the presence of sufficient collateral circulation via the radial and ulnar arteries. This hyperaemic response is extended in the thumb, hand and thenar eminence [7]

Harvesting procedure

The harvest site is usually the non-dominant extremity. It is essential to examine the entire hand before harvesting. A curvilinear incision, running parallel to the medial border of the brachioradialis muscle is made, extending 2 cm below the antecubital crease to the wrist [8]. The following structures are incised.

- Skin
- Subcutaneous tissue
- Fascial sheath

Care should be taken to prevent injury to the lateral cutaneous nerve of the forearm. After this, retraction of the flexor carpi radialis and brachioradialis and muscles are carried out. The complete radial artery course becomes visible from the tendons of the biceps to the styloid process of radial bone. The easiest point at which to start radial artery pedicle dissection is the middle segment of the forearm, where the radial artery comes out from underneath the brachioradialis muscle. The radial artery pedicle is carefully moved to pick it

up from its muscular bed. Upward traction is applied to the pedicle. When the radial artery pedicle is entirely mobilized, the distal and proximal ends of the pedicle are arranged for separation. A silk suture is located around the radial pedicle throughout its length where the radial styloid process of radial bones meets the radial pedicle. The ligation of the distal end of the radial artery is performed. The stump of the remaining radial artery is palpated to check pulsation and confirm the collateral circulation of the ulnar artery [8]. After that, the proximal end of the radial artery pedicle is planned. The pedicle is picked up perpendicularly to the forearm; it is then ligated with a 2-0 silk suture, and separated. The harvested radial artery graft is scrutinized to ensure all side branches are firmly ligated. The complete radial artery pedicle graft is then enclosed in papaverine-soaked gauze.

The haemostasis of the radial artery harvest location is accomplished using electrocautery. The wound on the forearm is closed prior to the systemic administration of heparin. The deep fascia of the forearm is sutured using a 2-0 polyglycolic suture. The skin is sutured with the help of a running 4-0 polyglycolic suture. The placement of drains is not necessary unless moderate drainage continues in spite of haemostasis [8].

Comparative review

Many aspects should be considered when comparing the different conduits used in grafting and these are discussed below.

Among the different CABG conduits, the left internal mammary artery has the longest patency rate and is associated with an improvement in survival. The saphenous vein graft has the advantage of being long and easy to handle, and has been found to require less transfusion compared to the bilateral internal mammary artery. The issue with this graft is that the patency rate is not as good as that of the left internal mammary artery. The radial artery was first used by Carpentier in 1971. Its use was stopped two years later because of a 35% incidence of narrowing and occlusion due to spasm, intimal hyperplasia after endothelial denudation and due to trauma of skeletonization. It was revived in 1989 by Acar and his group after modifying the harvesting techniques.

Apart from the Cleveland study published in 2004, which showed poor results for the radial artery compared to other grafts, the results of

other studies have been very favorable towards the radial artery.

In a systematic review and meta-analysis published in 2011, it was shown that the early results for the graft patency of the radial artery are comparable to those for the saphenous vein graft. However, in the longer term, the radial artery shows definite patent superiority. This is most likely to be due to many factors, such as the handling of the conduit, the distal anastomosis, distal bed quality and also the degree of stenosis. The review showed beyond doubt that in the medium and long terms, the radial artery is more effective in patency. The biological nature of the radial artery in terms of resistance to atherosclerosis is reflected in the better patency rate [9].

The 2004 Radial Artery Patency Study included 561 patients [10]. Each patient served as their own control in grafting a vein or radial artery in the opposite territory in either the right coronary artery (RCA) or the circumflex artery (Cx), while all patients received the left internal mammary artery to the left anterior descending artery. An angiogram was done in 440 patients and it was found that one year after CABG, 8.2% of radial artery grafts and 13.6% of saphenous vein grafts were completely occluded ($P = 0.009$). The string sign was found in 7% of the radial artery grafts, while it was present in only 0.9% of the vein grafts. This study also revealed that absence of severe native vessel stenosis is a risk factor for RA occlusion and that the patency of RA in both Cx and RCA is the same. It was also found that RA occlusion is similar between males and females, while SV occlusion is greater in females. Radial artery occlusion is lower than SV occlusion in diabetics and peripheral vascular disease is associated with higher risk of RA graft failure. The RA vs. SVG Patency (RSVP) trial was a single center, prospective randomized trial that examined the five-year patency rate. The study enrolled 142 grafted patients and 105 had angiograms at five years. This revealed graft patency of 98.3% for RA compared to 86.4% for SV. Graft narrowing was found in 10% of patients in RA compared to 23% in SV [32].

Another study conducted by Modine et al. assessed the use of radial artery grafts in older patients (65 years and above). They evaluated 261 patients aged 65–93 who had received coronary artery bypass grafting surgery from 1998 to 2001. Different grafts were given in addition to the saphenous vein and the radial artery. After the surgery, and after thorough evaluation, this study determined that the use of radial artery grafts in patients aged 65 years and above is practical,

harmless, and does not increase death risk or morbidity [11].

Engoren et al. (2012) likewise examined the long-term effects of receiving a radial artery graft in comparison with a saphenous vein graft [12]. They reviewed 2,120 patients over the years from 1996 to 2007 who underwent CABG and received different grafts, including radial artery and saphenous vein grafts. This study compared the twelve-year survival rate and clearly concluded that radial artery grafts are much better for elderly people [12].

Numerous studies on the mortality and morbidity of RA grafts point towards a better outcome with this graft. Radial artery grafts are also found to improve survival compared to saphenous vein grafts six years after CABG [10]. Graft patency is the chief predictor of long-term endurance and survival.

Tranbaugh and colleagues evaluated their institution's 14-year experience with radial artery grafting to decide whether adding a second arterial conduit, i.e. the RA, would enhance long-standing survival of the patients after CABG [13]. They conducted a retrospective study of 4,271 successive patients. Among these patients, many were suffering from a number of other diseases. The survival rate turned out to be very good, while patency was found to be equal to that for the saphenous vein. RA patency rate was 80.7%. [13,14].

Wagner and his conducted research to determine cost as well as quality of life in patients who were given radial artery grafts and saphenous vein grafts. Their study showed that radial artery grafts took longer, while there was no difference in quality of life and cost in comparison with saphenous vein grafts [15].

Georghiou and colleagues also worked to determine the long-term patency of radial artery grafts in comparison with the patency of saphenous vein grafts [16]. After reviewing several studies, they put forward a conclusion that in terms of patency, saphenous vein grafts lag behind radial artery grafts. They also stated that surgeons can use radial artery grafts with confidence as a second arterial graft for bypass, predominantly in patients having a tight native-vessel stenosis [16].

Hu and Zhao compared the effectiveness of the saphenous vein and the radial artery in coronary bypass grafts. Grafts were used for non-left anterior descending coronary arteries [17]. This study concluded that the radial artery is probably the second best option for a graft [17]. They also shown that the radial artery has fewer cardiac re-

lated events compared to the right internal mammary artery.

A study by Goldman et al. compared the one-year radial artery graft patency against saphenous vein grafts in patients going through an elective CABG. A total of 733 patients were studied. Among these, 366 received radial artery grafts, while 367 received saphenous vein grafts [18]. They received follow up every three months. Angiography was performed one week after surgery, before their hospital discharge and then one year later. No difference in patency was found between the two types of graft [18]. This study also explored the differences in patency rate on the basis of the surgical intervention patients received. They showed that the patency of the saphenous vein was quite low in patients who underwent endoscopic vessel harvesting, while the one-year saphenous vein graft patency was found to be high in patients who underwent surgery on pump [18]. This study also found radial artery grafts to have more string signs than saphenous vein grafts. Nevertheless, the disease in the artery had arisen due to the degree of stenosis. The radial artery graft patency showed no differences in patency based on endoscopic harvesting. Similarly, on-pump or off-pump surgery had no effect on the patency of radial artery grafts [18]. One major finding of this study was that after one year radial artery grafts were more patent relative to the patency of saphenous vein grafts, even in diabetic patients.

There are numerous prominent reports showing short- and long-term radial artery graft patency after coronary artery bypass graft surgery. Radial artery graft patency is based on a number of factors. The process of harvesting the radial artery should be carried out meticulously [19] and the conduit handled gently. The patency of the radial artery graft has almost always been lower than that of the internal mammary artery [19]. Many studies reveal that the patency rate of the radial artery graft in comparison with the saphenous vein and internal mammary artery grafts, is mid-way between the two. The rationale for an arterial graft failure is reportedly due to poor overflow as a result of several factors a small coronary artery, grave distal atherosclerosis, competitive flow or the lack of sufficient viable myocardium [20]. Competitive flow from the coronary artery may diminish graft flow, leading to atrophy in the arterial graft, with resultant narrowing in the caliber size of the radial artery graft. All arterial revascularization is linked to considerably better twelve-year survival on par with saphenous vein CABG surgery, especially

for patients with three-vessel disease [21]. The totality of revascularization of causal coronary disease is important for increasing the long-term advantages of arterial-only grafting [21].

Doctors from the Department of Cardiovascular Surgery, Juntendo University Hospital, in Tokyo, Japan also carried out a study on radial artery graft patency between October 2002 and July 2003 [22]. They studied 50 patients who underwent remote coronary artery bypass and received skeletonized radial artery grafts at the Juntendo University Hospital. They were no hospital deaths and no perioperative myocardial infarctions. Eighteen patients with no symptoms and two symptomatic patients underwent coronary angiography one year after the procedure [23]. The two symptomatic patients had occlusion of the radial artery, while all other patients showed an excellent outcome. One of the patients with an occluded RA graft was found to have a history of disease related to peripheral vessels and was also diabetic. Thus, the authors concluded that a skeletonized radial artery graft gives outstanding results [23].

A study by Ikeda et al. evaluated the luminal changes in the radial artery graft that can affect the long-term patency rate of the RA graft. The evaluation was based on four years of study and research [23]. They evaluated 200 patients with RA grafts in coronary artery bypass surgery. They assessed the luminal diameters of the radial artery at different intervals: first at an early stage and then at mid-term periods in a total of 23 patients who underwent mid-term angiographies after a mean follow-up of 27 months [23]. The proximal anastomoses of the RA were the ascending aorta in these patients. The G/N ratio was determined as a ratio of the luminal diameter of the graft to that of the revascularized coronary artery so as to evaluate the luminal discrepancy between the graft and the native artery [23].

Likewise, a study by Acar et al. demonstrated the five-year patency of radial artery grafts following evaluation via angiography. The patency was found to be 83%, while 86% of patients were found to be free of angina [24]. The long-term results of the use of the radial artery by the same group showed a definite superiority of the radial artery compared to other grafts. At seven years, the Acar study showed a patency rate of 83% for the LIMA, 87% for the RIMA, 83% for the RA and 81% for the SVG. They also showed that the RA patency to the Diagonal was 93%, the circumflex was 82.5% and the RCA 77.6% [24]. Despite the RIMA patency rate being higher than the other grafts it was

never reported anywhere else in the literature that RIMA patency rate is higher than LIMA.

In spite of a recognized survival advantage the use of the left internal mammary artery, is utilized less commonly with women than with men. The study by Parolari and colleagues appraised the hypothesis that the radial artery graft is employed less in women than in men, that the radial artery is small in size in women in contrast with men, and that the utilization of the radial artery affects surgical mortality and long-standing survival in women. The study was carried out from 1997 to 2001 on 207 female patients who were undergoing CABG [25]. The authors concluded that long-standing patency of the radial artery as a conduit for CABG is superior to that of grafts of the saphenous vein. It was also found that radial artery grafts improve the five-year survival in women compared to saphenous vein grafts [25].

Hoffman et al. used their institution's 16 year case histories to evaluate clinical outcomes, need for re-intervention and patency for coronary artery bypass grafting after use of the radial artery [26]. Their outcomes showed that patency was 82% for RA, 47% for SV, 85% for LIMA and 80% for RIMA, while overall freedom from catheterization, percutaneous coronary intervention and CABG were 85%, 97%, and 99%, respectively for the radial artery. RA patency was comparable with (LIMA) patency.

Yie and colleagues conducted a study at their institute from 2002 to 2006 investigating patients who had received radial artery grafts for coronary artery bypass surgery. The total number of patients enrolled for the study was 123. Thirty-two months postoperatively, the grafts were checked via angiography. Radial artery graft patency was found to be 92%. This study also revealed that the radial artery conduit is more effective when used for highly stenotic lesions [27].

Side effects after harvesting of radial artery

Despite the frequent use of the radial artery, there is little information about both the effects of its harvesting and arm and hand circulation after the radial artery has been harvested. Severe complications after this procedure noted in some studies include ischemia, gangrene and resting pain. These are the results of artery occlusion. Mild ischemia and claudication, however, are rare, although they do occur in a small number of people. Manabe and colleagues carried out a study to detect the effect on the hands of patients who had undergone radial artery harvesting procedures for

CABG [28]. However, SVC is not free of complications and outcores the RAG. Indian investigators have shown that harvesting of the SV may lead to damage of the lymphatics, nerves and blood vessels. In their study, saphenous vein (SV) harvesting led to a number of cutaneous changes in the legs [29]. The common symptoms and complaints they demonstrated in their study include:

- Pruritus.
- Skin dryness.
- Pigmentary changes.
- Eczematous reaction.
- Impaired sweating.

These problems were treated with the help of H1 antihistamines, topical steroids, emollients etc. [29]. The severe side effects of SV harvesting demonstrated by Ghosh and colleagues include:

- Xerosis.
- Dermatitis.
- Anaesthesia.
- Infection.
- Healing ulcers.
- Cellulitis.
- Vein graft dermatitis.

Zhu and colleagues stated that the (RA) has achieved esteem as a second major conduit for coronary artery bypass surgery despite the relative lack of patient-centred scrutiny of long-standing quality of life following its removal. Therefore, they sought to distinguish the function of the forearm along with symptoms subsequent to RA harvest and compare these to those linked with (SV) extraction [30]. The final verdict by the researchers was that RA harvesting is linked to greater patient satisfaction and less discomfort due to scarring than SV removal. In general, functionality reduces with time, and a small number of patients appear to suffer pain and numbness of the forearm. Nonetheless, this is not dissimilar in comparison to patients who have not undergone artery removal and may consequently be distinct from the outcomes of surgery [30].

Radial artery spasm is the most recurrent complication of CABG. It leads to patient discomfort and decreases the success rate of the procedure. In their study, Song et al. sought to identify variables connected with this problem, for example angiographic characteristics, clinical parameters of the radial artery and factors connected to the process, and to evaluate the clinical results of spasm, both in general and for patency of the radial artery during follow-up [31]. The study

comprised a large number of patients undergoing CABG. Radial artery spasm was noted by means of a scale that reflected the occurrence of pain and the technical intricacy of the process [31]. It was shown that the most common cause of RA graft failure in such patients was thrombosis from platelet dysfunction at the point of focal endothelial damage. The CABG process is mainly decided by two factors: patient hypercoagulability and graft endothelial damage. The authors also noted that early bypass graft failure could also be due to a malpositioned graft. Moreover, if the graft is too long, it might bend or crook. Technical factors linked with utilization of an aortic connector may cause venous grafts to twist [31].

RA grafts are vulnerable to vasospasm, since the RA is a muscular artery with high vasoreactivity. Manifestation is similar to fixed graft stenosis, though the narrowing of the lumen is longer [31]. Nonetheless, the use of intraoperative alpha-adrenergic antagonist solution or calcium channel blockers posteroperatively can overcome cases of graft vasospasm after surgery.

The study by Song et al. also showed graft aneurysms in the radial artery graft. Other complications or side effects associated with radial artery graft demonstrated by this study include:

- Thrombosis and embolization of the bypass graft.
- Formation of fistula in the heart's atrium and ventricle.
- Sudden rupture causing haemopericardium and haemothorax or even death [31].

Conclusion

Certainly, internal thoracic artery grafting is associated with considerably better survival, patency, and rates of re-intervention in comparison with other bypass conduits. The majority of CABG patients experience disease in more than one artery, and require the utilization of supplementary saphenous vein or radial artery conduits. Several studies from different groups of investigators have demonstrated the superiority of the RA over the SV. The evidence from these studies allows us to conclude that radial artery graft is so far the best second option conduit and better than the saphenous vein. The use of the radial artery ensures high patency is easier to harvest and removing it does not alter the supply of blood to the arm. The radial artery is an effective graft that should be used for coronary artery bypass graft surgery. It offers good long-term outcomes and minimal complications.

References

- [1] Loop F, Lytle B, Cosgrove D, et al. Influence of the internal mammary-artery graft on 10-year survival and other cardiac events. *N Engl J Med* 1986;314:1-6.
- [2] Taggart DP, D'Amico R, Altman DG. Effect of arterial revascularisation on survival: a systematic review of studies comparing bilateral and single internal mammary arteries. *Lancet* 2001;358:870-5.
- [3] Buxton BF, Komeda M, Fuller JA, Gordon I. Bilateral internal thoracic grafting may improve outcome of coronary artery surgery: risk-adjusted survival. *Circulation* 1998;1(Suppl. 19):III-6.
- [4] Deo SV, Dunlay SM, Shah IK, Altarabsheh SE, Erwin PJ, Boilson BA, et al. Dual anti-platelet therapy after coronary artery bypass grafting: is there any benefit? A systematic review and meta-analysis. *J Card Surg* 2013 Mar;28(2): 109-16.
- [5] Goldman S, Zadina K, Moritz T, Ovitt T, Sethi G, Copeland JG, et al. VA Cooperative Study Group #207/297/364. Long-term patency of saphenous vein and left internal mammary artery grafts after coronary artery bypass surgery: results from a department of veterans affairs cooperative study. *J Am Coll Cardiol* 2004;44:2149-56.
- [6] Anyanwu AC, Saeed I, Bustami M, Ilsley C, Yacoub MH, Amrani M. Does routine use of the radial artery increase complexity or morbidity of coronary bypass surgery? *Ann Thorac Surg* 2001 Feb;71(2):555-9 [discussion 559-60].
- [7] Sajja LR, Mannam G, Sompalli S. Extrafascially harvested radial artery in CABG: technique of harvest, complications, and mid-term angiographic patency. *J Card Surg* 2005 Sep-Oct;20(5):440-8.
- [8] Conklin LD, Ferguson ER, Reardon MJ. The technical aspects of radial artery harvesting. *Tex Heart Inst J* 2001;28(2):129-31.
- [9] Athanasiou T, Saso S, Rao C, Vecht J, Grapsa J, Dunning J, et al. Radial artery versus saphenous vein conduits for coronary artery bypass surgery: forty years of competition-which conduit offers better patency? A systematic review and meta-analysis. *Eur J Cardiothorac Surg* Jul 2011;40(1):208-20.
- [10] Desai ND, Cohen EA, Naylor CD, Fries SE. A randomized comparison of radial-artery and saphenous-vein coronary bypass grafts. *N Engl J Med* 2004;351:2302-9.
- [11] Modine T, Al-Ruzzeh S, Mazrani W, Azeem F, Bustami M, Ilsley C, et al. Use of radial artery graft reduces the morbidity of coronary artery bypass graft surgery in patients aged 65 years and older. *Ann Thorac Surg* 2002 Oct;74(4):1144-7.
- [12] Engoren M, Habib RH, Schwann TA. Late effects of radial artery versus saphenous vein grafting in patients aged 70 years or older. *Ann Thorac Surg* 2012;94(5):1478-84.
- [13] Tranbaugh RF, Dimitrova KR, Friedmann P, Geller CM, Harris LJ, Stelzer P, et al. Coronary artery bypass grafting using the radial artery: clinical outcomes, patency, and need for reintervention. *Circulation* 2012 Sep 11;126(11 Suppl. 1):S170-5.
- [14] Geller CM, Tranbaugh RF, Dimitrova KR, Friedmann P. Bypass grafting radial artery conduits improve long-term survival after coronary artery. *Ann Thorac Surg* 2010;90: 1165-72.
- [15] Wagner TH, Sethi G, Holman W, Lee K, Bakaeen FG, Upadhyay A, et al. Costs and quality of life associated with radial artery and saphenous vein cardiac bypass surgery: results from a veterans affairs multisite trial. *Am J Surg* 2011 Nov;202(5):532-55.
- [16] Georghiou GP, Vidne BA, Dunning J. Does the radial artery provide better long-term patency than the saphenous vein? *Interact Cardiovasc Thorac Surg* 2005 Aug;4(4):304-10.
- [17] Hu Xiang, Zhao Qiang. Systematic comparison of the effectiveness of radial artery and saphenous vein or right

- internal thoracic artery coronary bypass grafts in non-left anterior descending coronary arteries. *J Zhejiang Univ Sci B* 2011;12(4):273-9.
- [18] Goldman S. Radial Artery Grafts vs Saphenous vein grafts in coronary artery bypass surgery: a randomized trial. *AMA* 2011;305(2):167-74.
- [19] Parolari A, Rubini P, Alamanni F. The radial artery: which place in coronary operation?. *Ann Thorac Surg* 2000;69:1288-94.
- [20] Barner HB. Remodeling of arterial conduits in coronary grafting. *Ann Thorac Surg* 2002;73:1341-5.
- [21] Zacharias A, Schwann TA, Riordan CJ, Durham SJ, Shah AS, Habib RH. Late results of conventional versus all-arterial revascularization based on internal thoracic and radial artery grafting. *Ann Thorac Surg* 2009;87(1) [19-26.e2].
- [22] Tanaka H, Narisawa T, Mori N, Masuda M, Kishi D, Suzuki T, et al. The left internal thoracic artery and radial artery compositegraft in off-pump coronary artery bypass grafting. *Ann Thorac Cardiovasc Surg* 2002;8(4):204-8.
- [23] Ikeda M, Ohashi H, Tsutsumi Y, Hige K, Kawai T, Ohnaka M. Angiographic evaluation of the luminal changes in the radial artery graft in coronary artery bypass surgery: a concern over the long-term patency. *Eur J Cardiothorac Surg* 2002 May;21(5):800-3.
- [24] Achouh P, Boutekadjirt R, Toledano D, Hammoudi N, Pagny JY, Goube P, et al. Long-term (5- to 20-year) patency of the radial artery for coronary bypass grafting. *J Thorac Cardiovasc Surg* 2010 Jul;140(1) [73-9, 79.e1-2].
- [25] Parolari A, Dainese L, Naliato M, Polvani G, Loardi C, Trezzi M, et al. Radial artery grafts in women: utilization and results. *Ann Thorac Surg* 2008 Mar;85(3):885-90.
- [26] Tranbaugh RF, Dimitrova KR, Friedmann P, Geller CM, Harris LJ, Stelzer P, et al. Coronary artery bypass grafting using the radial artery: clinical outcomes, patency, and need for reintervention. *Circulation* 2012;126(11 Suppl. 1):S170-5.
- [27] Yie K, Na CY, Oh SS, Kim JH, Shinn SH, Seo HJ. Angiographic results of the radial artery graft patency according to the degree of native coronary stenosis. *Eur J Cardiothorac Surg* 2008 Mar;33(3):341-8.
- [28] Manabe S, Tabuchi N, Tanaka H, Arai H, Sunamori M. Hand circulation after radial artery harvest for coronary artery bypass grafting. *J Med Dent Sci* 2005 Jun;52(2):101-7.
- [29] Ghosh SK, Dermat D, Bandyopadhyay D. Saphenous vein harvesting site dermatoses in eastern India. *Dermatol Online J* 2009;15(7):13.
- [30] Zhu YY, Hayward PA, Hadinata IE, Matalanis G, Buxton BF, Stewart AG, et al. Long-term impact of radial artery harvest on forearm function and symptoms: a comparison with leg vein. *J Thorac Cardiovasc Surg* 2013;145(2):412-9.
- [31] Song BG, Yang HS, Doh JH, Jang H, Kang GH, Park YH, et al. Assessment of coronary artery bypass graft (CABG) patency and graft disease using multidetector computed tomography (MDCT). In: Branislav B, editor. *Coronary angiography – advances in noninvasive imaging approach for evaluation of coronary artery disease*, Newyork: InTech Publisher, InTech North America. ISBN: 978-953-307-675-1.
- [32] Collins P, Webb CM, Chong CF, Moat NE. Radial artery versus saphenous vein patency (RSVP) trial investigators. Radial artery versus saphenous vein patency randomized trial: five-year angiographic follow-up. *Circulation* 2008; 117:2859-64.