International Journal of Medicine
pISSN 1468-3814 | eISSN 2667-7008
https://theinternationalmedicine.com/

Original Researcher Article DOI: 10.61336/im/26-2-12

The Use of The Radial Artery for Coronary Revascularization: Technique and Current Concepts

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Received: January 14, 2026
Revised: February 17, 2026
Accepted: February25, 2026
Published: March 04, 2026

Abstract

Background: The radial artery (RA) was introduced in 1971 as a conduit for coronary artery bypass grafting (CABG). It initially was associated with high occlusion rates. Later advances in harvesting techniques, perioperative pharmacological management, and improved patient and target vessel selection have led to renewed interest in the RA as a durable arterial graft.

Methods: This review narrates the anatomical considerations, surgical harvesting techniques, operative strategies, pharmacological measures for reducing risk, and current clinical evidence related to the use of the RA in coronary revascularization.

Results: Contemporary studies demonstrate superior mid- and long-term patency rates of the RA compared with saphenous vein grafts, particularly when used to bypass coronary arteries with high-grade stenosis. The RA can be used as aorto-coronary graft, a composite Y or T graft, or as an extension graft, with sequential anastomotic techniques further expanding its applicability. Large randomized trials and meta-analyses suggest improved clinical outcomes and reduced graft failure with RA use.

Conclusion: The RA is a reliable arterial conduit for coronary artery bypass surgery. It offers long-term patency and favourable clinical outcomes.

Keywords: Coronary artery bypass grafts, coronary artery bypass grafting, Ischemic heart disease, Radial artery.

INTRODUCTION

The use of radial artery (RA) as a coronary artery bypass graft (CABG) conduit was started by Carpentier in 1971.[1]Due to a high occlusion rate, there was a temporary avoidance of this technique. The revival of the RA as a CABG graft was by Acar in 1989.[2] These initial failures were because of poor selectionand harvesting techniques, which led to endothelial damage. There was also a lack of understanding of the underlying physiology of RA.[3-5]The RA has now emerged as an important arterial graft for coronary bypass surgery. Five-year patency rates in more recent studies are better than 85%. Long-term patency of the RA graft is influenced by patient selection, appropriate choice of target coronary vessels, and operative technique. Advancements in harvesting techniques, with preservation of the endothelium and vasodilatation of the thick muscular media, avoidance of ischemia, and refined implantation techniques have resulted in improved graft patency.[3,6]

The use of RA has expanded the options for arterial revascularization. It can be used alongside Internal thoracic artery (ITA) for arterial coronary revascularization. The advantages for the RA are bilateral availability in selected patients, sufficient conduit length, and excellent handling characteristics for constructing anastomoses. It is also resistant to kinking, and avoidance of leg wounds allows rapid ambulation.

Surgical anatomy

For surgeon harvesting the RA, anatomy can be remembered by the following phrase: “two muscles, two nerves, and two branches (Fig.1, Table.1).The radial artery lies within a fascial plane bordered by two muscles: the brachioradialis muscle (BRM) and the flexor carpi radialis muscle (FCRM). The two nerves, the lateral antebrachial cutaneous nerve (LABCN) and the superficial radial nerve (SRN), are vulnerable during dissection, and a correct knowledge of their anatomy can prevent neural injury. The two branches, the recurrent radial artery (RRA) and the superficial palmar artery (SPA) define the proximal and distal limits of the RA harvest respectively.[5,19]

The brachial artery divides into the radial and ulnar arteries 1 cm below the level of the elbow joint. The radial artery runs in the proximal two-thirds of the anterior compartment of the forearm and continues below the brachioradialis muscle. In the distal one-third, it emerges to be covered only by skin, superficial fascia, and deep fascia (Figure 1, 2). It lies in turn on the tendon of the biceps, supinator, pronator teres, flexor digitorum superficialis, flexor pollicis longus, pronator quadratus, and the lower end of the radius. The radial artery terminates in a deep and superficial carpal arch[3-5](Figure 3).
Anatomic variations may result in hand ischemia if overlooked during harvest. A high origin occurs in approximately 14% of patients, and in 9% of patients, the superficial brachial artery is present. There are variations in the anastomosis around the wrist and hand. In approximately 6% of patients, the RA is the dominant supply to the hand. The modified Allen test is essential prior to RA harvesting. However, harvesting the RA in the presence of a high bifurcation of the superficial palmar branch or poor communication between ulnar and radial contributions to the superficial and the deep carpal arches may cause hand ischemia[5] (Figure 4a and 4b).

For performing the modified Allen's test, hand hygiene is important. The procedure is explained to the patient. The patient is seated comfortably with hands supine. The radial and ulnar arteries are compressed at once while the patient repeatedly opens and closes the hand until palmar blanching is achieved. Pressure over the ulnar artery is released, and radial artery compression is maintained. Rapid return of palmar colour within 10 seconds indicates adequate ulnar artery perfusion, while persistent pallor indicates insufficient collateral flow, which contraindicates radial artery harvest. Excessive extension of the hand is to be avoided, as it can indicate false-positive results. The test is unreliable in patients unable to cooperate with instructions.[5,6,19]

A Doppler examination of the RA is also recommended pre -harvest to specifically look for size and any calcification in the RA.[17-19]The clinical Allen test may not be sufficient to assess the hand collateral flow in at least 5% of patients due to anatomic variations. The Echo Colour Doppler technique is a safer and more objective preoperative non-invasive evaluation[17].Using pulse oximetry along with the Allen test is the alternative method which places a pulse oximeter on the thumb before compression to see baseline saturation and waveform readings. The examiner compresses both arteries till the waveform disappears and the oxygen saturation reaches zero. After which, pressure on the ulnar artery is released, and waveform and saturation are recorded. If values match with the baseline, adequate collateral flow is indicated.[18]

Open RA Harvest technique:
Successful RA harvesting requires identification of significant anatomical landmarks, preservation of the sensory innervation to the volar forearm, and proper handling of the RA branches. Adherence to a “no-touch” technique improves the patency and durability of the RA conduit.[4-6,19]

For preparation, the arm is prepped circumferentially, which is then draped, and secured to an arm board that is positioned not more than 90 degrees with respect to the operative table. When combined mammary artery and RA are harvested, it is important to harvest each mammary artery along with the contralateral RA.

When only one RA is harvested, the non-dominant arm is preferred.[5]
During positioning for the Coronary artery bypass surgery (CABG), the arm is rotated and abducted at 90 degrees and placed on an arm board. The full forearm and arm are prepped and draped. A linear incision is made along the volar aspect of the forearm extending 2 cm below the midpoint of the elbow crease to approximately 2 cm above the wrist crease, where the radial pulse is felt (Figure 5). Proximally, the radial pulse is identified within the inverted V formed by the biceps tendon laterally and the bicipital aponeurosis medially. This inverted V corresponds to where RRA branches off from RA.[5]
After incision through skin and subcutaneous tissue, the fascia overlying RA is incised as RA becomes a subcutaneous structure emerging from beneath the belly of BRM in the mid-forearm. The RA pedicle lies between the brachioradialis muscle laterally and the flexor carpi radialis medially. Proximally, the fascia is divided with electrocautery, separating the BRM and the FCRM (Figure 6). The fascia is divided distally with scissors due to the close proximity of the RA.[5,19]

Two cutaneous nerves during RA harvest are the lateral antebrachial cutaneous nerve (LABCN) and the superficial radial nerve (SRN), which supplies cutaneous innervation to the volar forearm, portions of the thumb, and the dorsum of the hand. The LABCN lies in the superficial fascia over the BRM and accompanies the cephalic vein. LABCN retracts from view after the intervening fascia between the BRM and the FCRM is divided. The SRN runs laterally, in proximity to the RA.

RA and its venae comitantes are mobilized using the “no-touch technique”, to minimize spasm. Intraoperative confirmation of hand perfusion may be done for extra precaution with digital plethysmography.[5,17,19]
The RA pedicle is mobilized to within 1 cm of the bifurcation of the brachial artery (BA) and doubly clipped and divided. The upper end of RA is surrounded by a confluence of large veins from the forearm, which needs mobilization to identify the proximal end of RA. The interosseal artery (IA) is preserved as it originates from the ulnar artery. If it is seen coming

off proximal RA, it is preserved by clipping RA distally to it. Distal RA is mobilised proximal to the origin of the superficial palmar artery (SPA) and divided 2 cm proximal from wrist joint to preserve collateral circulation. Avoidance of the distal wrist area improves patient comfort. During dissection, care is taken to keep the RA moist using diluted heparinised blood papaverine spray.[5]

RA gives rise to intervening perforating branches that supply the forearm and hand. The majority of these branches arise from the dorsal hemi-circumference of RA, with anteriorly arising branches being very uncommon. Proximally under the BR muscle, more than 4 branches are found. Distally, where RA is subcutaneous, it contains more than twice as many branches and present most numerous near the wrist. The shorter distal branchwhich is more delicate than the proximal branch, make their identification and dissection more difficult.(Figure 7).[5]

Several different methods exists o deal with these RA branches. For example, electrocautery alone, sharp dissection with clips, a combination of electrocautery and clips, and ultrasonic dissection. The preferred method is the combined use of electrocautery and clips because it allows rapid vessel harvesting and the reliability of controlling larger branches. In this approach, a clip is used to secure the branch adjacent to the veins, and electrocautery is used to divide the vessel distally towards the surrounding tissue. Although heat generation from electrocautery is a concern, injury can be minimized by keeping the electrocautery current low (20 Watts).[19]

RA should never be grasped directly. Method for retracting RA is to gently roll it with papaverine-soaked gauze to one side while managing its branches. RA must not be stretched to improve exposure, as it can cause separation of the intima from the vessel wall.[5]

After all branches are divided and RA is fully mobilized, the distal segment is clamped to confirm retrograde pulsatile flow from ulnar collateral circulationalong with the presence of a trace on pulse oximetry. Once adequate collateral flow is established, the artery is securely ligated distally with heavy silk and divided. The proximal end is then ligated and transacted in the same manner. A 2-mm flexible olive-tip cannula is carefully inserted into the proximal artery, which is flushed with a vasodilator heparinised diluted blood solution using minimal pressure. The composition of this solution is outlined in Table 2. The vessel is subsequently stored in the same solution until use, although it may alternatively be left in situ until implantation is required.[5]

After the RA is harvested, complete hemostasis is achieved and re-checked. Wound is packed and the arm is covered with sterile drapes. At the completion of the CABG and after protamine is administered - wound is closed. This is done in its most superficial layers only without a drain. The deeper fascial layers are left unclosed to reduce the risk of compartment syndrome and nerve injury. The arm should not be tied with a crepe bandage but a simple dressing is done. Intra and post op the vascularity of the hand is continuously monitored with a pulse oximeter and routine hourly visual and palpatory assessment of the hand and forearm. Alternatively RA may be harvested using a Harmonic scalpel to facilitate haemostasis and minimize trauma.[5,19]

Endoscopic radial artery harvesting (ERAH)

ERAH[19] can be performed using either an open or a closed system. Open systems allow endoscopic exposure without pressurized CO_2, whereas closed systems use controlled CO_2 insufflation through a sealed access port to enhance visualization.

A 3-cm longitudinal incision is made over RA, ending 1 cm proximal to the wrist crease. The artery and venae comitantes are identified, and the overlying fascia is divided proximally to allow scope entry. A sterile tourniquet is applied after distal exposure is completed, inflated to 75 mmHg above systolic pressure (maximum 200 mmHg), and maintained for less than 60 minutes to create a bloodless field.

A bullet-tipped dissector and blunt-tipped trocar are introduced, the trocar balloon inflated to seal the incision, and CO_2 insufflated at 3–5 L/min (10–12 mmHg). Blunt dissection frees RA and its venae comitantes as a pedicle, avoiding direct contact with the artery and minimizing traction. Dissection proceeds proximally to the antecubital fossa.

Following dissection, a fasciotomy of the brachioradialis–flexor carpi radialis fascia is performed. Side branches are divided using cautery while a vessel cradle maintains separation from the artery. Once debranching is complete, a small proximal incision is made, the pedicle retrieved, and the graft ligated and divided proximally and distally. The artery is cannulated and flushed. The tunnel is reinspected endoscopically after tourniquet release to ensure haemostasis. Incisions are closed, sterile dressings applied, and the forearm loosely wrapped.

Pre, intra and post- operative pharmacological (anti-spastic) management:
An ideal antispastic protocol should fulfil the following criteria: (1) excellent antispastic (vasorelaxant) effect; (2) maximal preservation of the vascular endothelial function; (3) readily used preoperatively and (4) no major side effects. A number of protocols are used.

Preop– Tab Diltiazem 15-30 mg TDS unless contraindicated

Intraop: a continuous infusion of IV Diltiazem (the loading dose is 0.05 mg/kg followed by a continuous infusion of 0.15 to 0.2 $\mu g \cdot kg^{-1} \cdot min^{-1}$) is given unless there is bradycardia or hypotension. Liberal spraying is done with papaverine solution (60 mg of papaverine per 60 mL of saline solution) during harvesting. After harvesting the graft is kept in a warm blood-papaverine solution till used. After harvest – cannulate proximal end with an olive tip cannula and gently flush the RA with a clear solution with the distal end unclamped to remove any possible blood clots. Inspection of the graft is now performed with gentle hydrostatic dilation of the RA using a solution of heparinised blood and papaverine (60 mg of papaverine per 60 mL of blood).

An alternative is the Verapamil plus nitroglycerin (VG) solution: (GW HE (**Guo-Wei He)** or UHK – univ of Hong Kong protocol) Concentration of approximately 30 µmol/L of verapamil and NTG in an isotonic solution of pH 7.4.
The components are:
- Verapamil hydrochloride, 5 mg;
- Nitroglycerin (NTG), 2.5 mg;
- Heparin, 500 unit;
- 8.4% $NaHCO_3$, 0.2 mL;
- Ringer's solution, 300 mL.

It is used for spraying and for storage

Post-operative: IV Diltiazem is continued till oral medications are started. To prevent RA spasm, patients are prescribed Tab Diltiazem 30 mg TDS or Tab Amlodipine 5 – 10 mg OD for 1 year, unless contraindicated. Other medications (antiplatelet, nitrates, beta blockers, statins etc) are as per standard post CABG protocol.

Exclusion criteria for RA use:
- Negative Allen test ie inadequate ulnar collateral flow
- RA stenosis
- RA plaque or calcification as seen by Doppler ultrasonography
- h/o vasculitis or Raynaud's disease/ phenomenon
- Chronic renal failure on hemodialysis (as RA may be needed for an AV fistula)
- Diffuse calcification noted during harvesting
- Diameter < 2 mm
- Trans RA coronary angio-gram (CAG) – for at least 3 months – check always with Duplex scan in such cases and in elderly
- Less than 80% stenosis in target coronary artery

Complications: The overall incidence of local complications including wound infection or dehiscence and permanent neurological deficits after RA harvesting is <1%, and reports of ischemic hand complications are exceedingly rare.[4]

Surgical strategy:
RA is used as a standard aorto-coronary bypass.[3,4]Many surgeons prefer the routine use of a RA Y or T graft with the left internal thoracic artery. Other variations include an end-to-end suture technique, particularly with the right internal thoracic artery to extend its application to the posterior descending or posterolateral branches.

Grafting technique:
Distal anastomoses
The number of vessels targeted by RA may be extended through the use of one or more sequential anastomoses. These are performed in parallel when there is sufficient graft length or as a diamond-shape when RA and the target vessel lie at a right angle. Distal anastomoses can be performed using cardiopulmonary bypass or off-pump techniques.

Standard anastomoses
Surgeons may have their own techniques of performing the distal anastomosis. Principles are similar which includes preparation of the distal end of RA by removal of surrounding fat, collateral veins and any adventitial bands. RA is divided obliquely at 45 degree and enlarged to match the size of coronary arteriotomy. Selection of disease-free segment of native

CA is desirable. Accurate intimal approximation reduces risk of platelet deposition and thrombus formation. A forehand parachute technique is simpler. Commencing opposite the surgeon, anastomosis is completed at the end nearest the surgeon. For accurate placement of the apical sutures exposure is done by leaving the last 2 or 3 loops loose and also using the adjacent sutures for retraction to insert the apical sutures.

Sequential anastomoses

Parallel: Sequential anastomosis using RA are popular. An adequate length of radial graft is required, especially when a parallel grafting technique is used. Sequential grafting provides proper use of RA conduits. It is vital to select the optimal sites on target arteries. Alignment of graft should not be compromised.

For sequential anastomosis, incisions in the native CA and the grafts are performed in the longitudinal direction. For in-parallel anastomosis, the length is to be generous, similar to that for a distal anastomosis. Suturing is commenced away from the surgeon – Figure 9. The anastomosis is performed within the lumen, or preferably, on the external aspect of the anastomosis. Suturing from the outside of the artery avoids inverting and exposing cut edges of the native coronary artery and the graft.

Diamond: The diamond technique minimizes the length of conduit required. The anastomosis is modified by restricting the length of the anastomosis to approximately twice the diameter of the native coronary artery, thus avoiding distortion. (Figure 10)

Proximal anastomoses:

Proximal anastomoses are performed with the ascending thoracic aorta with 6-0 prolene after a 3.6 mm punch is used to create a round hole. Alternatively, RA is used as a composite 'Y' graft with an internal thoracic artery or with another segment of RA. An extension graft using RA and in-situ right internal thoracic artery is a useful method of reaching postero-lateral and post-descending branches on the right side. The proximal anastomosis with the aorta is performed at a site of convenience. Extensive calcification, atherosclerotic disease or inadequate graft length are limiting factors for aorto-radial artery anastomosis.

'Y' or 'T' -Graft: RA 'Y'graft is sutured to the left internal thoracic artery before cannulation or before off-pump coronary artery bypass. It is anastomosed at the level of the pericardial reflection or where the LIMA crosses the pulmonary artery when it is placed on the heart – Figure 11. The pulmonary valve is the ideal position for the "T" graft. It provides a consistent point of reference when constructing the graft and importantly it maintains the straight lie of the LIMA to LAD graft, thus preventing kinking.

A forehand technique commencing as high as possible in the left internal thoracic artery is preferable. Placement of the corner sutures in the 'heel' is facilitated by suturing from within the artery. If the anastomosis is located inferiorly on the left internal thoracic artery, it is commenced distally (Figure 12,13). The proximal RA is fashioned obliquely for the 'Y' anastomosis. An additional suture may be required in the acute angle of the 'Y' to avoid excessive angulation at the site of the anastomosis.

A small incision is made on the thoracic wall side of the internal thoracic artery pedicle with a stab blade, and this is extended with a Pott's scissor to a length of 3 to 4 mm. The RA is divided obliquely and anastomosed end-to-side with a continuous 7-0 or 8-0 polypropylene suture. When the anastomosis is placed proximally, it is simpler to commence the anastomosis at the proximal end of the left internal thoracic artery incision.

Extension graft: A RA extension from the in-situ right internal thoracic artery is useful for grafting the posterior descending, posterolateral or even the distal circumflex branches (Figure 14.). Complete arterial grafting using internal thoracic and radial artery grafts is readily achieved using on or off-pump coronary artery techniques.

RESULTS:

An average patency of 85% at 5 years of the RA has been noted. (Figure15)

Table 1: Key anatomic structures: the rule of two's [19].

Muscles & tendons	Nerves	RA branches
Brachioradialis	Lateral antebrachial cutaneous	Recurrent radial
Flexor carpi radialis	Superficial radial	Superficial palmar

Table 2: Contents of radial artery solution[19]

Content	**Dose**
Normosol R	250ml
Heparin	2,500 units
Patient's blood	60ml
Papaverine	60mg

Table 3: Existing techniques to overcome spasm of radial artery

Authors	**Topical**	**Systemic**	**Postoperative oral**
Acar et al	Papaverine+ blood	Diltiazem	Diltiazem
Dietl et al	Papaverine diltiazem if spasm is noted	Diltiazem	
Reyes et al	Papaverine 60 mg + 60 ml blood	Diltiazem	
He et al	Verapamil+ nitroglycerin	Nicardipine	One calcium antagonist
Esmore	Verapamil+ nitroglycerin	Nitroglycerin	
Tatoulis	Papaverine	Nitroglycerin	Amlodipine

Table 4: RA patency for CABG: Summary of published data[6]

Authors	RA conduit used	RA conduit reassessed	Original grafts reassessed (%)	Angiographic patency	Follow-up (y)
Acar et al.	910	64	7	83	5.6±1.1
Possati et al.	325	62	19	87	4.9±0.5
Iaco et al.	164	91*	47	95	4.0±2.3
Tatoulis et al.	8420	280 (369*)	3	90	1.2±0.9
Possati et al.	91	84	92	88	8.8±0.8
Khot et al	–	310	–	51	1.5±1.4

*Numbers represent anastomoses reassessed.

Table 5: Randomized Trails with Sample size > 100 grafts comparing patency of RA with SVG

Trial/Year	**Number of Grafts Restudied**	**Mean follow up**	**Main finding**
RSVP/2008	134	5 yrs	Better patency rate for RA (p=0.004)
VA/2011	266	1yr	No difference in patency (p=0.98)
RAPS/2012	269	7.7 yrs	Better patency rate for RA (p=0.002)

RA= radial artery, RAPS= Radial Artery Patency Study, RSVP= Radial Artery Versus Saphenous Vein Patency trail, VA= Veterans Affairs trial.

Table 6: 2021 ACC/ AHA recommendations for Bypass Conduits in CABG[39].

Recommendations for Bypass Conduits in Patients undergoing CABG		
COR	LOE	Recommendations
1	B-R	1. For isolated CABG procedures, the RA is favored over the SV for bypassing the second most significant stenosed non-LAD vessel to enhance long-term cardiac results
1	B-NR	2. For patients undergoing CABG requiring revascularization of the LAD, use of an internal mammary artery (IMA), preferably the left is recommended to enhance survival and lower the risk of recurrent ischemic events.
2a	B-NR	3. In selected patients undergoing CABG, bilateral IMA grafting may provide improved long-term cardiac outcomes.

COR - Class of Recommendation, LOE- Level of evidence, B-R (Randomized), B-NR(Non Randomized)

Patency of RA *vs.* SVG over the short and long-term:

- Four systematic reviews have compared graft patency of RA and SVG. A 2010 meta-analysis of five RCTs showed similar failure rates of RA and SVG (14.1% vs. 14.6%) at a mean follow-up of 22 months[20]

- A large pooled analysis by Athanasiou and colleagues, including 3678 RA and 7506 SVG from 35 studies, demonstrated no difference at short term patency but significantly better RA patency at medium- (one to five years) and long- (greater than five years) term follow-up.[21]
- A metanalysis by Hu and colleagues focusing on non-LAD targets showed significantly reduced risk of occlusion of RA grafts at a mean follow-up of 56 months.[22]

Data from five randomized trials analysed by Cao and colleagues showed no difference in graft occlusion at one year, although RA grafts had a higher incidence of the string sign. By four years, RA grafts demonstrated significantly lower occlusion rates and higher perfect patency, with no difference in string sign compared with SVG.[23]

- Overall, RA patency was 90.2% beyond 1 year and 80% at 5 to 7 years follow-up and is similar to other reports.[42,43]

Extensive evidence shows that degree of stenosis in the native coronary artery is key determinant of both the short- and long-term patency of the RA. When stenosis is less than 70-80%, competitive flow can significantly compromise graft durability.[24,25]Visual assessment of coronary narrowing is often unreliable compared with objective measures such as fractional flow reserve. In addition, competitive flow is greater in larger-caliber vessels; for example, a 70% lesion in a 4-mm artery produces substantially more residual flow than the same degree of stenosis in a 2-mm vessel.

- Three large RCTs have compared RA and SV graft patency in CABG (Table 5). The two trials with follow-up beyond 1 year showed significantly higher patency with RA grafts. A pooled analysis by Gaudino et al evaluated six RCTs involving 1,036 patients. At a mean follow-up of five years, RA grafting was associated with fewer adverse cardiac events and a significantly lower risk of graft occlusion compared with SV grafts. Extended analyses also demonstrated improved clinical outcomes at 5 and 10 years when the RA was used to revascularize the most important non-LAD target vessel.[26,27]
- In a large network meta-analysis of nearly 150,000 patients comparing RA, right internal thoracic artery (RITA), and SV as second conduits, SV grafts were associated with higher long-term mortality than both RA and RITA. The risk of deep sternal wound infection was similar between RA and SV and lower than with RITA.[28,29]

Clinical outcomes RA *vs*. SVG:

- Overall, one RCT comparing RA and SVG has demonstrated superior clinical outcomes with RA grafts. RAPS (Radial artery patency study) reported higher rates of death from cardiac causes, non-fatal MI and repeat revascularization with SVG rather than RA grafts during late follow-up.[30]
- In contrast Goldman *et al*. found no difference in death, MI, stroke and repeat revascularization between RA and LSV grafts at one year.[31]
- RSVP trial (Radial artery versus saphenous vein patency) showed no difference in mortality at five years in an older cohort.[32]
- However, several larger propensity-matched registries have reported a survival advantage with RA over SVG, with the greatest benefits seen in diabetic patients.[33-35]

In summary, available evidence suggests that RA and SVG grafts have comparable functional patency during the first post-operative period. Beyond this period, there is robust evidence for higher mid- and long-term patency rates for the RA in comparison to SVG, largely due to progressive attrition of vein grafts over the long-term. This long-term patency of the RA favours substantial improvements in clinical outcomes.

Comparison between the RA and the RITA:

A large RCT showed similar graft patency for RA and RITA.[7] This is also confirmed by a network meta-analysis of nine RCTs, despite no significant trend toward lower functional occlusion with RITA. Observational studies suggest a survival advantage with RITA,[8-10,] whereas randomized data report equivalent outcomes.[7] Interim results from the ART trial showed no difference in mid-term survival between single and bilateral internal thoracic artery grafting. However, post hoc analysis demonstrated that adding the RA significantly reduced major adverse cardiac events.[11]

Site of Proximal Anastomosis: ITA Versus Ascending Aorta

Onorati and colleagues[36]demonstrated comparable baseline hemodynamic and flow reserve between aorta- and internal thoracic artery (ITA)–anastomosed radial artery grafts in 114 patients. In a larger series of 512 cases[37] reported no differences in in-hospital or late outcomes between the two techniques, with similar angiographic patency also confirmed.[38]

The RA usage guidelines + utilisation in specific patient subsets:

Owing to superior patency and possible survival benefit, the use of an additional arterial conduit (RA or RITA) to supplement a left internal thoracic artery–to–left anterior descending artery graft is a Class IIa recommendation in European guidelines for multivessel CABG.[12] In 2011 American College of Cardiology/American Heart Association guidelines, multiarterial grafting received a Class IIB recommendation.[13] In 2016, the Society of Thoracic Surgeons clinical practice guidelines assigned a Class IIA recommendation. The 2021 American College of Cardiology (ACC) and American Heart Association (AHA) guidelines recommend the use of RA as a conduit in CABG over SVGs, particularly for the second most important target vessel, after the left anterior descending artery.[39] (Table 6).

Use of the RA does not increase sternal wound complications compared with RITA, an important advantage in patients with diabetes or obesity. In diabetics, RA reduces graft occlusion regardless of diabetic status.[14,15] The RA is also beneficial in redo CABG and for distal or multiple targets due to its greater length,[16] and bilateral RA grafting is safe.[40]

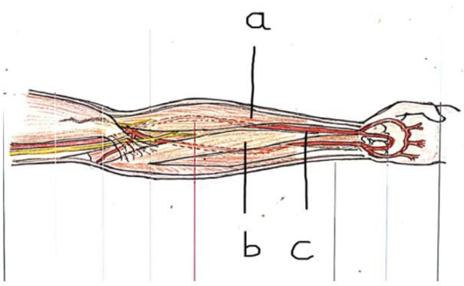

Figure 1: The major arteries and superficial muscles of the forearm. RA lies between the brachioradialis and flexor carpi radialis muscles in the proximal forearm, and beneath the deep fascia in the distal forearm (a- Brachioradialis muscle, b- flexor carpi ulnaris muscle, c- RA).

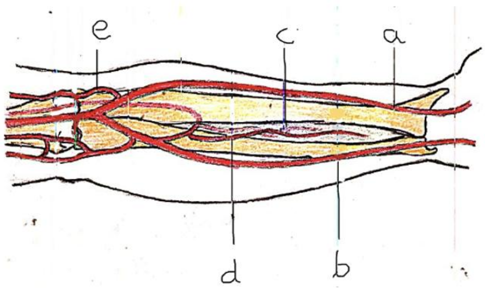

Figure 2 : Arteries of the forearm (a- RA, b- ulnar artery, c- posterior interosseous artery, d- anterior interosseous artery, e-RRA)

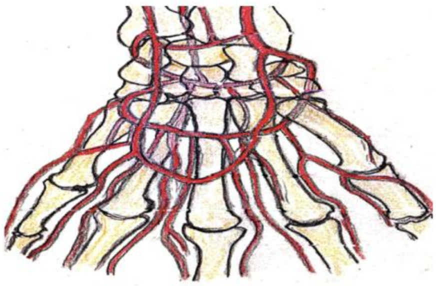

Figure 3: Arteries of the hand showing superficial and deep palmar arches.

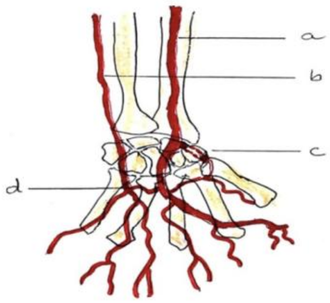

Figure 4a: Anatomic variation of the RA in the forearm and hand. Note absence of the superficial palmar arch and small caliber of the ulnar artery (a- radial artery, b- ulnar artery, c- deep palmar branch of RA, d- deep palmar arch)

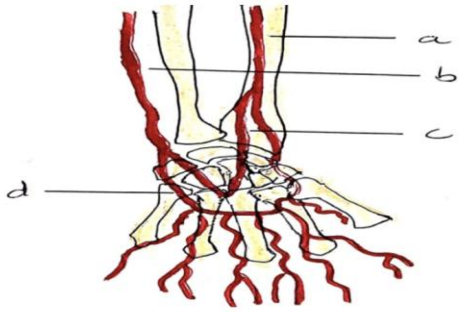

Figure 4b: Anatomic variation of the RA in the forearm and hand. Proximal origin of the superficial palmar branch of the RA (a- RA, b- ulnar artery, c - superficial palmar branch of RA, d- deep palmar arch)

Figure 5: Skin incision for Open RA harvesting

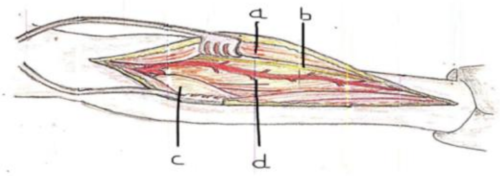

Figure 6: RA once the overlying fascia is opened. (a- brachioradialis muscle, b- superficial radial nerve, c- flexor carpiradialis muscle, d- RA)

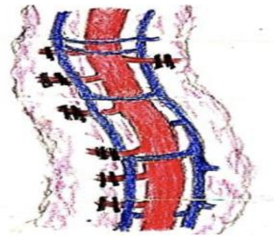

Figure 7: Clipping of the side branches of radial artery.

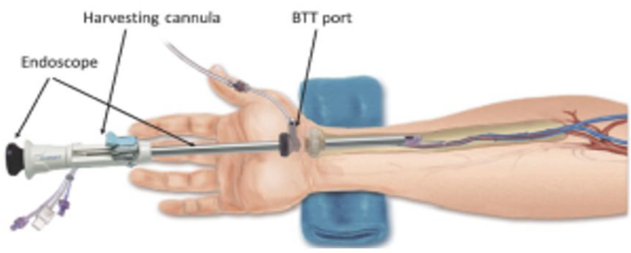

Figure 8: In situ display of the Vasoview System. The components include the 7 mm endoscope, the harvesting cannula and the BTT port (Illustration courtesy of Maquet)

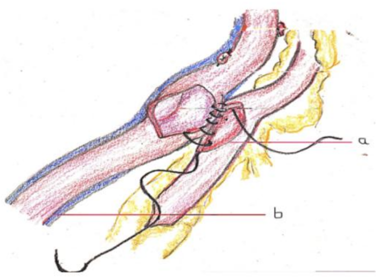

Figure 9: The linear side-to-side sequential anastomosis. (a- target coronary vessel, b- RA conduit)

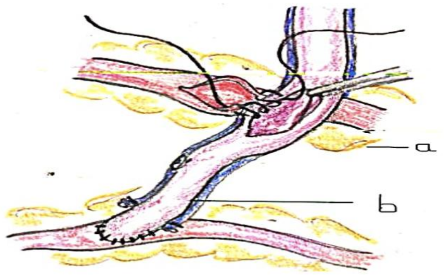

Figure 10: 'Diamond-shape' side-to-side sequential anastomosis. (a- target coronary vessel, b- RA conduit)

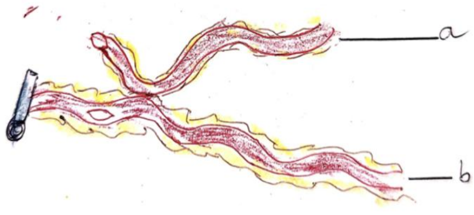

Figure 11: Performing the LIMA – RA Y anastomosis (a- RA, b- Left Internal Mammary

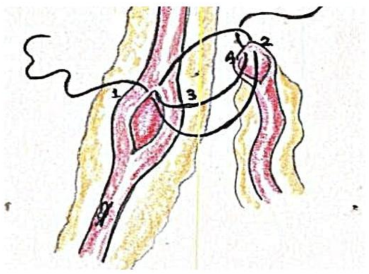

Figure 12 : Technique of Y graft anastomosis between the radial artery and the left internal thoracic artery. When the anastomoses is placed proximally, it is simpler to commence the anastomosis at the proximal end of the left thoracic artery incision

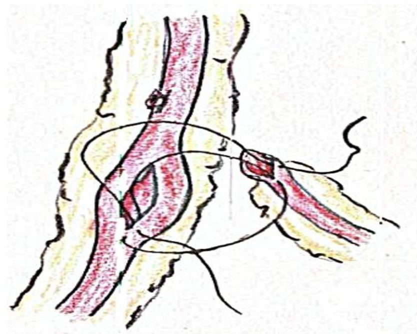

Figure 13: Alternative suture method. If the anastomosis is lower in the internal thoracic artery, it may be commenced at the heel

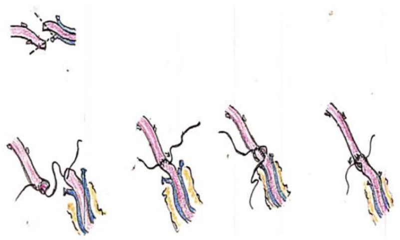

Figure 14: Extension graft. RA is anastomosed to the distal in-situ right internal thoracic artery using an oblique end-to-end anastomosis.

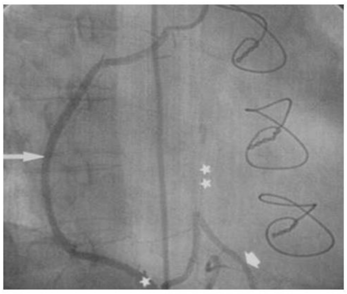

Figure 15: Angiogram: Patent RA(long white arrow) to posterior descending artery (single white star at site of anastomosis) filling up the whole of the right coronary system (short wide arrow). The two white stars show the site of in stent stenosis[41].

CONCLUSION

On the basis of all above data it is recommended that surgeons could confidently use the radial artery as a second coronary artery bypass graft in patients with severe native vessel stenosis.

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