



# International Journal of Medical Research & Health Sciences

[www.ijmrhs.com](http://www.ijmrhs.com)

Volume 3 Issue 2 (April - Jun)

Coden: IJMRHS

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ISSN: 2319-5886

Received: 12<sup>th</sup> Dec 2013

Revised: 18<sup>th</sup> Jan 2014

Accepted: 20<sup>th</sup> Jan 2014

Research Article

## A STUDY ON RADIAL ARTERY IN CADAVERS AND ITS CLINICAL IMPORTANCE

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### ABSTRACT

As the radial artery is the second most commonly used graft in coronary bypass (CABG) surgery (internal thoracic artery first most common) and for transcatheter coronary interventions (angioplasty), cardiac surgeons should have thorough knowledge about the normal anatomy and possible variations of it before these cardiac procedures. **Methods:** 50 radial artery specimens (both right and left sided) were studied by dissection method in 25 cadavers (20 male and 05 female). The data were tabulated in Microsoft excel and analysed by using Statistical Package for Social Science (SPSS 17<sup>th</sup> version). Mean, Proportion, Standard deviation and Unpaired 't' test were applied for analysing the data obtained. **Results & conclusion:** Radial artery in all the specimens take origin from brachial artery at or just below the elbow joint in the cubital fossa, running superficially and laterally, giving radial recurrent, many collaterals, radial carpal and superficial palmar branches; total mean length of artery from origin to wrist joint is  $20.63 \pm 1.96$  cm; mean luminal diameter at its termination 2 cm proximal to styloid process just above the wrist joint is  $2.14 \pm 0.28$  mm. This study revealed anomalies like tortuosity (30%) in distal 1/3<sup>rd</sup> segment and radio-ulnar loops were not found in any specimens.

**Keywords:** Radial artery, Coronary bypass graft, Transcatheter coronary interventions (Angioplasty), Internal thoracic artery.

### INTRODUCTION

Graft patency is a fundamental predictor of long term survival after coronary bypass graft (CABG) surgery. Given its proven survival benefit, left internal thoracic artery to left anterior descending artery (LITA-LAD) grafting has become a fundamental part of CABG. This grafting also led to increased use of other arterial conduits, of which radial artery is most popular (second most common next to internal thoracic artery)<sup>1</sup>. In 1973, Carpentier suggested the use of radial artery as a conduit for coronary bypass graft surgery.<sup>2</sup> Even though radial artery had been abandoned in early 1970's due to high rate of graft failure in post-operative period, but due to the latest concepts of total arterial revascularisation in coronary bypass surgery in

1989, it has been proved that radial artery is as good as an internal thoracic artery in CABG due to histological similarities.<sup>3</sup>

Radial artery is nowadays commonly used for transcatheter coronary interventions (angioplasty) compared to transfemoral or transbrachial technique due to the lower risk access site related complications. Lower risk is because of the radial artery being superficial; haemostasis can be easily achieved just by local compression.<sup>4</sup> Harvesting radial artery for CABG<sup>5</sup> or during transcatheterisation does not cause any damage as there are no large veins or nerves exist nearby it and even does not cause ischemia in hand as

there exist collateral circulation by palmar arches (ulnar artery).<sup>4</sup>

Normally, the radial artery is a smaller terminal branch of the brachial artery, arises at the level of neck of radius in the cubital fossa. It runs superficial compared to the ulnar artery, (another terminal branch of brachial artery). During its course, at the beginning, it gives one radial recurrent artery which takes part in anastomosis around the elbow joint; it also gives numerous small collateral or muscular branches which supplies nearby muscles and finally giving a palmar carpal branch in the lower part of the forearm. It leaves the forearm by turning posteriorly and enters the anatomical snuffbox. Just before it leaves, gives a superficial palmar branch which completes the superficial palmar arch along with the ulnar artery.<sup>6</sup>

It is also observed that accessing radial artery in some cases of transcatheter intervention fails due to its anatomical variations. Therefore, anatomy and its variations should be studied systematically for guiding the cardiologists in transcatheter coronary interventions and in coronary bypass surgery as a graft.

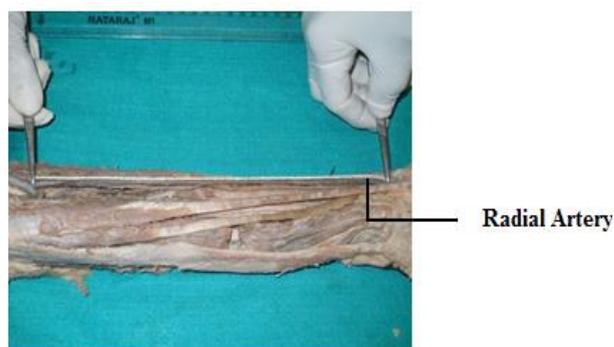
## MATERIALS & METHODS

After the approval of the Institutional Ethical Committee, Azeezia Medical College, Meeyannoor, Kollam Dist, Kerala state, a total of 50 radial artery specimens (25 right sided and 25 left sided) from 25 adults embalmed human cadavers (20 males and 05 females) with an average of 35-60 years, from 2008-2013 in the Department of Anatomy were studied.

In the cadavers, brachial and ante brachial regions were dissected as per the Cunningham's Manual Methods<sup>7</sup> of Dissection. Radial artery was traced from its origin to the termination at the wrist.

The specimens were numbered from 01-50. Each radial artery was studied with respect to its origin, termination, branches and variations or any anomalies like radio-ulnar loops, tortuosity or any other. Total length of the artery was measured from its origin to termination by nylon thread and measuring that thread length using a long scale.

After dissecting the artery from its entire course and studying, papaverine is injected in the distal segment of the artery and cross sectional luminal diameter of artery at the termination point 2cm proximal to styloid process just above the wrist was measured in millimetres using digital calliper.



**Fig 1: Measurement of radial artery with thread.**

As radial artery is the second most common graft used for coronary bypass surgery, the measurement of luminal diameter of the radial artery should be studied to guide the cardiac surgeons to know at what level, it should be grafted to the coronary artery (same corresponding luminal diameter level) to bypass the block.



**Fig 2: Electronic Digital Calliper used for the study.**

All the measurements and observations were recorded and tabulated. After the procedures, all the specimens were preserved in 10% formalin solution. The radial artery even though most commonly takes origin as a branch from brachial artery just at or below the elbow joint, sometimes may take origin directly from the axillary artery above the elbow joint (high origin) or sometimes may absent congenitally in which ulnar artery and its branches will supply the territory of the radial artery. The radial recurrent artery, which is an usual important branch of the radial artery, may come directly from brachial artery or from ulnar artery. The radial artery, which usually terminates as a superficial palmar branch in the hand, sometimes there may not be any branch by its & therefore, no contribution of it in forming the palmar arches in the hand.

## STATISTICAL ANALYSIS:

Data were collected from 50 embalmed adult human cadaveric specimens (05 female and 20 male) belonging to both right and left sides and entered in Microsoft excel and analysed by using Statistical Package for Social Science (SPSS 17th version).

Mean, Proportion, Standard deviation and Unpaired 't' test were applied for analysing the data obtained.

## RESULTS

The present study includes dissection of 50 specimens of radial artery to observe the possible variations - origin, course, branches, total length, luminal diameter

distally, its termination and any other anomalies that may disrupt the transcatheter coronary interventions. All these observations were recorded and tabulated as follows. The data collected was computerised and analysed by using Statistical Package for Social Science (SPSS 17<sup>th</sup> version).

**Table: 1. Radial artery; a study on cadavers and its clinical importance.**

Total cadaver	25	
Sex of the cadaver	20 Male & 05 Female	
Total specimens	50 (25 right sided & 25 left sided)	
Approx. Age (in years)	35 – 60 Yrs.	
Origin	Above the elbow joint (High origin)	Nil
	At or just below the elbow joint	All the 50 radial artery arises below the elbow joint as a branch of brachial artery
	Absent	Nil
Length (in cm) (from origin to wrist joint)	20.63 ± 1.96cm.( minimum – 16.4 cm & maximum – 23.4 cm)	
Luminal diameter (in mm)(at termination point 2 cm proximal to styloid process, just above wrist)	2.14± 0.28mm.( minimum – 1.6 mm & maximum – 2.6 mm)	
Branches	From upper $\frac{1}{3}$ <sup>rd</sup> segment	In 39 specimens, radial recurrent artery is large arising from radial artery. In 09 specimens radial recurrent artery arising directly from brachial artery and in 02 specimens it arises from ulnar artery. In addition, radial artery gives collateral branches.
	From middle $\frac{1}{3}$ <sup>rd</sup> segment	In 48 specimens, collateral branches supplying the muscles. In 02 specimens, we could not find out any collateral branches
	From lower $\frac{1}{3}$ <sup>rd</sup> segment	All 50 specimens give collateral branches & radial carpal branch. At its termination, all give superficial palmar branch.
Any variations (Anomalies)	Radioulnar loops	In no specimen, loops found.
	Tortuosity	15 specimens radial artery show tortuous at the distal $\frac{1}{3}$ <sup>rd</sup> of forearm. 35 specimens do not show any tortuosity.
	Any other	Nil
Course	49 specimens show normal course i.e. from its origin passes downwards to the wrist with a lateral convexity and is overlapped anteriorly by brachioradialis in the upper part, skin superficial fascia and deep fascia in the lower part. Posteriorly, it is related to tendon of biceps and supinator in the upper part. Medially, pronator teres proximally and flexor carpi radialis distally (where the radial pulse is felt lateral to this tendon), and laterally brachioradialis and radial nerve. But in 01 specimen, radial artery at its origin passes behind the tendon of biceps. So the tendon may compress the radial artery during muscle action.	

**Table: 2 statistical analysis of 50 samples (both males and females belonging to right and left sides)**

	Distance from interepicondylar line to origin(in cm)	Total length of artery (in cm)	Luminal diameter (in mm)
<b>Samples</b>	50	50	50
<b>Mean</b>	3.39	20.63	2.14
<b>Std.Error of Mean</b>	0.09	0.28	0.04
<b>Std. Deviation</b>	0.63	1.96	0.28
<b>Variance</b>	0.39	3.82	0.08
<b>Minimum</b>	2.40	16.40	1.60
<b>Maximum</b>	5.20	23.40	2.60

The radial artery takes origin at a mean distance of 3.39cm (minimum: 2.4cm, maximum: 5.2cm) from interepicondylar line, with standard deviation 0.63 and standard error of mean 0.089. (Table 2). The mean total length of the radial artery found to be 20.63 ± 1.96cm (minimum: 16.4cm and maximum: 23.4cm)

with standard deviation 1.96 and standard error of mean 0.28. (Table 2)

The mean luminal diameter of radial artery, 2 cm proximal to styloid process is 2.14 ± 0.28mm (minimum: 1.6mm and maximum: 2.6mm), with standard deviation 0.28 and standard error of mean 0.04. (Table 2)

**Table: 3 Statistical analysis of Male samples (40)**

	Distance from interepicondylar line to origin(in cm)	Total length of artery (in cm)	Luminal diameter (in mm)
<b>Samples</b>	40	40	40
<b>Mean</b>	3.57	21.23	2.16
<b>Std.Error of Mean</b>	0.09	0.27	0.04
<b>Std. Deviation</b>	0.56	1.71	0.28
<b>Variance</b>	0.32	2.93	0.08
<b>Minimum</b>	2.80	16.40	1.60
<b>Maximum</b>	5.20	23.40	2.60

In the male specimens, the artery takes origin at a mean distance of 3.57cm (minimum: 2.8cm and maximum: 5.2cm) from interepicondylar line, with standard deviation 0.56 and standard error of mean 0.09. Similarly, the total mean length of the artery is 21.23± 1.71cm (minimum: 16.4cm and maximum:

23.4cm), with standard deviation 1.71 and standard error of mean 0.27. The total mean luminal diameter of the artery is 2.16± 0.28mm (minimum: 1.6mm and maximum: 2.6mm) with standard deviation 0.28 and standard error of mean 0.04. (Table 3)

**Table: 4 Statistical analysis of Female samples (10)**

	Distance from interepicondylar line to origin(in cm)	Total length of artery (in cm)	Luminal diameter (in mm)
<b>Samples</b>	10	10	10
<b>Mean</b>	2.66	18.26	2.06
<b>Std.Error of Mean</b>	0.06	0.18	0.094
<b>Std. Deviation</b>	0.19	0.57	0.29
<b>Variance</b>	0.36	0.32	0.09
<b>Minimum</b>	2.40	17.40	1.60
<b>Maximum</b>	3.00	19.20	2.60

From 10 female samples, it was observed that, the radial artery takes origin at a mean distance of 2.66cm (minimum: 2.4cm and maximum: 3.0cm) from

interepicondylar line, with standard deviation 0.19 and standard error of mean 0.06. Similarly, the total mean length of the artery is 18.26± 0.57cm (minimum:

17.4cm and maximum: 19.2cm) with standard deviation 0.57 and standard error of mean 0.18. The total mean luminal diameter of the artery is 2.06±

0.29mm (minimum: 1.6mm and maximum: 2.6mm) with standard deviation 0.29 and standard error of mean 0.09. (Table 4)

**Table: 5 Statistical analysis of Male and Female comparison**

	Sex	Samples	Mean	Std.Deviation	Std.Error of Mean
<b>Distance from interepicondylar line to origin(in cm)</b>	M	40	3.57	0.56	0.09
	F	10	2.66	0.19	0.06
<b>Total length of artery (in cm)</b>	M	40	21.23	1.71	0.27
	F	10	18.26	0.57	0.18
<b>Luminal diameter (in mm)</b>	M	40	2.16	0.28	0.04
	F	10	2.06	0.29	0.09

**Table: 6 Statistical analysis of Male and Female comparison (applying Unpaired ‘t’ test)**

		Levene’s Test for Equality of Variances		t-test for Equality of Means	t-test for Equality of Means		t-test for Equality of Means	t-test for Equality of Means	
		F	Sig.	t	df	Sig. (2 tailed)	Mean ±SE	Lower	Upper
<b>Distance of origin from Interepicondylar line</b>	Equal variances assumed	5.01	0.30	5.01	48	0.00	0.91±0.18	0.54	1.28
	Equal variances not assumed			8.48	43.5	0.00	0.91±0.11	0.69	1.13
<b>Length of artery</b>	Equal variances assumed	5.27	0.03	5.37	48	0.00	2.97± 0.55	1.86	4.08
	Equal variances not assumed			9.14	44.0	0.00	2.97± 0.32	2.31	3.62
<b>Luminal diameter</b>	Equal variances assumed	0.001	0.97	0.95	48	0.35	0.09± 0.10	-	0.29
	Equal variances not assumed			0.91	13.3	0.38	0.09± 0.10	-	0.32

When Unpaired ‘t’ test is applied (Ref Table 6) to the sex and to the distance of origin of the artery from interepicondylar line, sex and the total length of the artery, sex and luminal diameter of the artery, the distance between the origin of the artery and the interepicondylar line between male and female, found to be highly significant (P = 0.00, which is less than 0.05), total length of the artery among males and females also highly significant (P = 0.00, which is less than 0.05). Highly significant means that there is a difference between males and females with respect to the distance between the origin of the artery from interepicondylar line and the total length of the artery, whereas luminal diameter values found not to be significant (P = 0.35, which is greater than 0.05) and therefore, no sex variation with respect to the luminal diameter.

**Origin:** All 50 radial arteries observed to take origin from the brachial artery at or just below the elbow

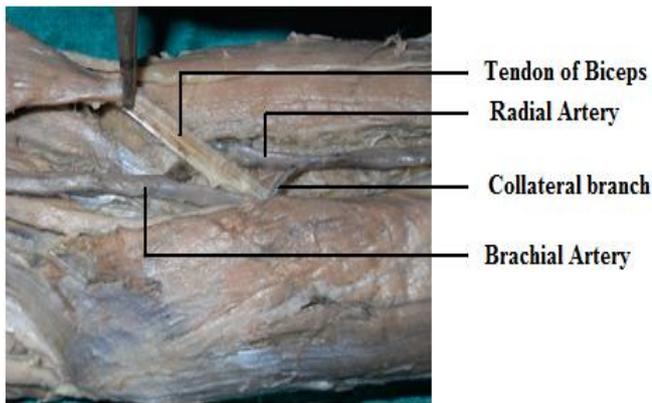
joint in the cubital fossa. No high origin or low origin cases noted. In all the cases, the radial artery originates from brachial artery just below the elbow joint at an overall mean distance of 3.39 ± 0.62cm from an imaginary line joining the two epicondyles (medial & lateral) of the humerus bone (interepicondylar line). In males, it originates at a distance of 3.57±0.56cm and in females, at a distance of 2.66± 0.19cm.

**Length:** Total length of the radial artery from its origin to wrist joint averaged to be 20.63 ± 1.96cm, minimum length being 16.4 cm and maximum length being 23.4 cm. In males, total length averaged to 21.23± 1.71cm and in females, it is measured to be 18.26 ± 0.57cm.

**Luminal diameter:** Luminal diameter of radial artery measured with digital calliper at termination 2 cm proximal to styloid process just above wrist joint, in overall, varying from minimum 1.6 mm to maximum 2.6 mm, and luminal diameter averaged to be 2.14±

0.28mm. In males, luminal diameter averaged to  $2.16 \pm 0.28$ mm and in females, it is measured to be  $2.06 \pm 0.29$  mm.

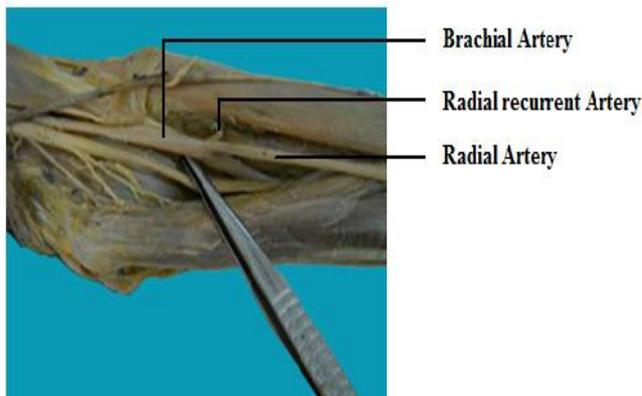
**Course:** Radial artery from its origin passes downwards to the wrist with a lateral convexity and is overlapped anteriorly by brachioradialis in the upper part; skin superficial fascia and deep fascia in the lower part. Posteriorly, it is related to tendon of biceps and supinator in the upper part. Medially, pronator teres proximally and flexor carpi radialis distally and laterally brachioradialis and the radial nerve. In 49 specimens, this normal course of radial artery had been observed. But in 01 specimen, radial artery passes behind the tendon of biceps after arising from the brachial artery. In such a case, the tendon of biceps may compress the radial artery during flexion of elbow joint or supination of forearm.



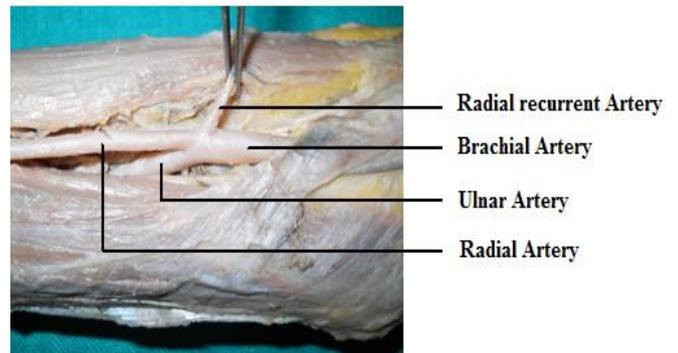
**Fig 3: Radial artery behind biceps tendon**

**Branches:**

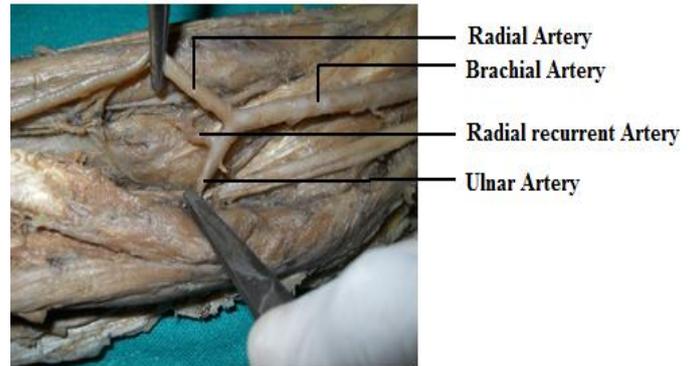
**From upper 1/3<sup>rd</sup> segment:** In 39 specimens, radial recurrent artery is arising from the radial artery, in 09 specimens it is arising directly from the brachial artery and in 02 specimens from ulnar artery, all will be participating in anastomosis around the elbow joint. In addition, radial artery also gives some collateral branches.



**Fig 4: Radial recurrent artery from radial artery**



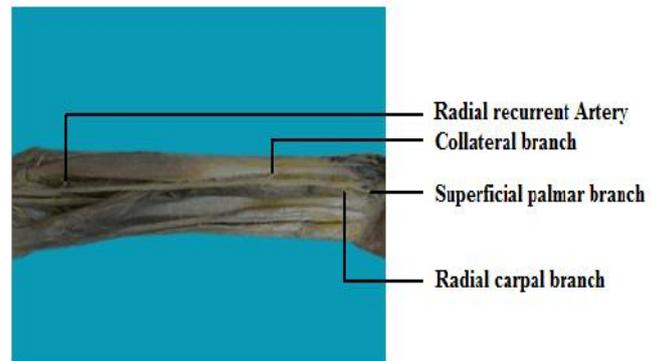
**Fig5: Radial recurrent artery from brachial artery**



**Fig 6: Radial recurrent artery from ulnar artery**

**From middle 1/3<sup>rd</sup> segment:** In 48 specimens, it has been observed that many collateral branches arising and piercing the muscles surrounding and supplying them. In 02 specimens, we could not find out any collateral branches.

**From lower 1/3<sup>rd</sup> segment:** All the 50 specimens showed collateral branches & radial carpal branch arising before termination, and finally giving superficial palmar branch at its termination.



**Fig 7 - Radial artery – Normal branches**

**Anomalies:**

**Radio-ulnar loops:** In all 50 specimens, no radio-ulnar loops connecting radial and ulnar arteries were found.

**Tortuosity:** In 35 specimens, there was no tortuosity found in its entire course from its origin to termination. But, 15 specimens showed tortuosity at the distal 1/3<sup>rd</sup> of forearm.



**Fig 8: A tortuous radial artery**

## DISCUSSION

The study of radial artery has gained its utmost importance as it is the second most commonly used graft in CABG and its common use in transcatheter coronary interventions (angioplasty) compared to transfemoral or transbrachial technique due to very less risk of access site related complications.

Bypass surgeries or angioplasty procedures are done to bypass the occluded or nearby occluded coronary arterial segments, to relieve ischemic symptoms, persistent angina or congestive heart failure from severe occlusive diseases of the coronary arteries.

A total of 50 radial artery specimens were studied by the dissection method to know the possible variations pertaining to its origin, length, course, branches, termination and distal luminal diameter 2 cm just above the wrist joint and this study will surely guide the Cardiothoracic surgeons in transcatheter coronary interventions (angioplasty) and harvesting it for coronary bypass surgery as a graft.

A. Rodriguez-Baeza et al<sup>7</sup> in a study, a total of 150 routine dissection of human upper limb from adult cadavers noted 23 cases of variations in brachio-antibrachial arterial pattern among which radial artery was found to take high origin from axillary artery and also from the upper third of brachial artery.

VA Jebara, C Acaret al<sup>3</sup> in 1991 studied radial artery in 40 subjects (30 patients undergoing CABG and 10 adult cadavers) observed that in all the cases artery was originating from brachial artery at or just below the elbow.

Poteat WL<sup>8</sup> reported a case of unilateral absence of the radial artery, which is a very rare variation and there was no deep palmar arch.

M. Rodriguez-Niedenfuhr et al<sup>9</sup>, in their review study explained the embryological reasons and basis for the

variations in the arterial patterns of the human upper limb including radial artery.

Charles JJ<sup>10</sup> also reported the absence of radial artery with an estimated incidence lower than 0.2% in which the radial blood supply territory was supplied by the anterior interosseous or the median artery.

In our present study of 50 specimens, all the specimens of radial artery observed originating from brachial artery at or just below the elbow joint.

Total length of the radial artery from its origin to the wrist joint and the luminal diameter at its termination 2 cm proximal to the styloid process just above the wrist was recorded and found to be similar with previous studies as follows.

**Table: 7. Measurement of length and diameter of radial artery**

Studies	Length (in cm)	Diameter (in mm)	Richness in collateral branches
VA Jebara et al <sup>3</sup>	22.5 ± 1.2	2.7 ± 0.06	+++
Naoyuki Yokoyama et al <sup>4</sup>	-----	2.6 ± 0.5	+++
Byung-su Yoo et al <sup>11</sup>	-----	2.6 ± 0.41	+++
Present study	20.63 ± 1.96	2.14 ± 0.28	+++

VA Jebara et al<sup>3</sup> in their study reported that the radial artery gives off many collateral branches that supply adjacent muscles and the integument of the anterolateral region of the forearm; and noted a large recurrent collateral branch from radial artery near its origin. They found very few collaterals in the upper 1/3<sup>rd</sup> segment and two to three collaterals in distal 1/3<sup>rd</sup>.

In our present study, it has been observed that large radial recurrent artery arising from the radial artery at its origin (upper 1/3<sup>rd</sup>) in 39 specimens and taking part in anastomosis around the elbow joint. In 09 specimens, radial recurrent artery arising directly from brachial artery and in 02 specimens, arising from ulnar artery and finally participating in the anastomosis around the elbow joint. Many collateral branches also seen arising from the upper 1/3<sup>rd</sup> segment. And most of the specimens give collaterals from middle 1/3<sup>rd</sup>. Collaterals along with radial carpal branch found arising from the lower 1/3<sup>rd</sup> segment. All specimens showed the presence of the superficial palmar branch at its termination.

Variations and anomalies like radio-ulnar loops, tortuosity etc. were studied in the specimens and reviewed with the previous studies as follows:

**Table: 8. Anomalies of radial artery**

Studies	Radio-ulnar loops	Tortuosity
Naoyuki Yokoyama et al <sup>4</sup>	0.9 %	5.2 % in proximal 1/3 <sup>rd</sup> segment
Byung-su Yoo et al <sup>11</sup>	37.1 %	23.3 %
TS LO, Nolan et al <sup>12</sup>	-----	4.2 % in proximal 1/3 <sup>rd</sup> segment
Present study	Nil	30 % in distal 1/3 <sup>rd</sup> segment of artery

In 49 specimens, normal course of radial artery had been observed. But, in 01 specimen, the radial artery after arising from the brachial artery passes behind the tendon of biceps brachii instead passing anterior to the tendon. In such a case, the tendon of biceps may compress the radial artery during flexion of elbow joint or supination of forearm.

Richard F Brodman, Rosemary Frame et al<sup>5</sup> from their study recommended the use of one or both the radial arteries as additional conduits along with the internal thoracic artery for arterial revascularisation of the coronary arteries because of potential benefit of excellent long term patency, minimal morbidity and mortality associated with the use of radial artery as a graft in CABG and, they found high degree of acceptance of radial artery by both patients and cardiologists; patients experienced less pain and easier ambulation post operatively and length of the hospital stay is shorter for the patients comparatively.

In an angiographic study after CABG surgery by Peter Collins, Carolyn M. Webbet al<sup>13</sup> out of 103 patients, 98.3% radial artery grafts and 86.4% of saphenous vein grafts were patent and graft narrowing occurred in 10% of patent radial arterial grafts and 23% of patent saphenous vein grafts.

In a similar study by Anwar Zacharias, Robert et al<sup>1</sup> concluded that using the radial artery as a second arterial conduit in CABG-LITA-LAD as opposed to vein grafting improves long term outcomes.

In a study by Naoyuki Yokoyama et al<sup>4</sup> recommended for angioplasty, transradial Coronary Interventions (TRI) as they found high success rate with very less stenotic changes without any other precipitating a major cardiac event including death and myocardial infarction. And, no access site related complications developed.

Similarly, in a study by Keimeneij F et al<sup>14-16</sup> reported that transradial artery coronary angioplasty has got

very high prognosis and good result, and no access site related complications.

Other many previous studies also revealed less complication and very less access related site risks using radial artery for transcatheter coronary interventions<sup>17-21</sup>

## CONCLUSION

From the study of total of 50 dissected radial artery specimens (both right and left sided; 20 male and 05 female cadavers) and comparing the present study with the previous works, it can be concluded that the origin of artery takes usually from brachial artery at or just below the elbow joint in the cubital fossa at an average distance of  $3.39 \pm 0.62$ cm from interepicondylar line (male:  $3.57 \pm 0.56$ cm, female:  $2.66 \pm 0.19$ cm) and the total length of the radial artery from its origin to wrist joint is averaged to be  $20.63 \pm 1.96$ cm (male:  $21.23 \pm 1.71$ cm, female:  $18.26 \pm 0.57$ cm); luminal diameter at its termination 2 cm proximal to styloid process just above the wrist joint is  $2.14 \pm 0.28$ mm (male:  $2.16 \pm 0.28$ mm, female:  $2.06 \pm 0.29$ mm)

Radial artery found to have a normal course running superficially and laterally in all the cases giving branches- radial recurrent artery at its origin, many collateral branches supplying surrounding muscles, radial carpal branch before termination and superficial palmar branch at its termination.

Radial arteries anomalies like radio-ulnar loops (Nil) and tortuosity (30%) in distal 1/3<sup>rd</sup> segment are noted in the present study. This concludes that the radial artery can be safely used as a route for transradial coronary interventions (angioplasty) and as a graft in coronary arterial bypass (CABG) surgery. Therefore, the radial artery can be regarded as a useful vascular access site for all the coronary procedures.

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