DOI: 10.7860/IJARS/2022/52770.2788

Original Article

Anatomy Section

A Cadaveric Study of Radial Artery and Cephalic Vein in Forearm and Hand: A Guideline for Radio-cephalic Arteriovenous Fistula Planning

ARPITA MAHAJAN[1], SANSKRITI SHASHANK[2], P MUTHUKRSHNAN[3], RANJANA VERMA[4], SHAYAMA KUMARI RAZDAN[5]

ABSTRACT

Introduction: The creation and maintenance of uninterrupted Haemodialysis (HD) is dependent on the quality and reliability of vascular access. The native Radio-cephalic Arteriovenous Fistula (RCAVF) is the vascular access of choice for HD in patients with end stage renal diseases. A thorough understanding of the vascular anatomy is critical in selecting the site for the RCAVF that provides the flow rates necessary for the development of an optimal outflow vein. The widespread use of the doppler ultrasound has facilitated the identification of vessels that are suitable for fistula construction.

Aim: To analyse the surgical anatomy of radial artery and cephalic vein in the front of forearm and dorsum of hand, pertinent to RCAVF planning.

Materials and Methods: A cross-sectional cadaveric of 30 formalin preserved upper limbs specimens of adult human cadavers was done in the Department of Anatomy, Hamdard Institute of Medical Sciences, New Delhi, India, (n=22 limbs) from August 2016 to April 2018 and Government Institute of Medical Sciences, Greater Noida, Uttar Pradesh, India (n=8 limbs) from November 2018 to November 2019. The external diameter of radial artery, cephalic vein and distance between radial artery and cephalic vein were measured at mid forearm, front of wrist and Anatomical Snuff Box (ASB). Measurements were taken with sliding vernier caliper to an accuracy of 0.01 mm. All the measurements were tabulated separately for right and left-side. The data was analysed using Microsoft excel. Descriptive statistics like mean, standard deviation (SD) and range were evaluated for all the parameters collected. The paired t-test was applied to compare the right and left-side measurements.

Results: Amongst 30 formalin preserved specimens of upper limbs of human cadavers analysed, the diameter of radial artery was 3±0.26 mm on the right-side and 2.87±0.24 mm on the left-side and of cephalic vein was 2.5±0.59 mm on the right-side and 2.9±0.33 mm in ASB. The distance between radial artery and cephalic vein were 2.5 ±0.59 mm on the right-side and 2.9±0.33 mm on the left-side which was minimum in ASB. The distance between radial artery and cephalic vein was maximum at wrist (4.02±0.76 mm and 4.2±0.71 mm on the right and left hand).

Conclusion: The fistula formation in ASB may give better results as the radial artery and cephalic vein are closer as compared to wrist and midforearm with reasonable diameter. Additionally, it would also provide long segment of vein for arterialization.

Keywords: Anatomical snuff box, End stage renal disease Haemodialysis, Mid forearm, Vascular access, Wrist

INTRODUCTION

The RCAVF creation was proposed first by Brescia MJ et al., in 1966 was a ground-breaking technique that transformed vascular access formation and use [1]. The creation and maintenance of uninterrupted HD would reduce patient's morbidity and costs, which is dependent on the quality and reliability of vascular access [2]. There are multiple types of arteriovenous fistula, though native RCAVF has higher patency rates and lower risk of complications when compared to prosthetic RCAVF and central venous catheters. The different types of RCAVFs are radio-cephalic fistula, brachio-cephalic fistula or brachio-basilic transposition, out of which radio-cephalic fistula is considered as gold standard. The Kidney Disease Improving Global Outcomes Guidelines and the European Best Practice Guidelines, both recommended wrist radio-cephalic fistula as the first option for RCAVF creation [3-5]. The RCAVF is a prototype HD access with small incidence of infection and distal ischemia. It can be created anywhere in forearm and hand like front of forearm, wrist and in the ASB on the dorsum of the hand.

The knowledge and understanding of the anatomy of radial artery and cephalic vein in forearm and hand is necessary for creating an efficient RCAVF. The radial artery is a continuation of the brachial artery which normally starts 1 cm distal to the flexion crease of the elbow and descends along the lateral side of the forearm. In upper part of forearm, it is overlapped by brachio-radialis and in lower part covered only by the deep fasciae, superficial fascia and skin. At wrist, it is palpable between flexor carpi radialis and the anterior border of the radius. At wrist, it gets entry into palm through first dorsal interosseous space and winds dorsally to reach ASB (which is bounded laterally by abductor pollicis longus and extensor pollicis brevis and medially by extensor pollicis longus) on the dorsum of hand. The cephalic vein forms in superficial fascia over the ASB from the radial side of the dorsal venous plexus and is closely related to digital branches of superficial branch of radial nerve. In the ASB, radial artery is crossed by cephalic vein superficially. It runs proximally over the lower lateral aspect of the radius, where it is easily visible and then curves proximally from the radial side of the forearm to gain its ventral aspect. It appears in front of elbow where it is connected to basilic vein by median cubital vein [Table/Fig-1] [6].

Review of literature revealed that the course, diameter and thickness of the wall of radial artery and cephalic vein are important for creation and maintenance of long-term patency of RCAVF. Evolution of ultrasound use has made easy identification of several functional parameters like thickness of arterial wall, calcification, stenotic lesions and velocity of blood flow in addition to size of the vessels. These factors do not represent contraindications to

the creation of AVF although they can render surgery more difficult and influence its outcome [7]. The decision to construct fistula in forearm and hand is mainly based on the diameter of radial artery and cephalic vein. Although there are numerous Ultrasonography (USG) studies on the diameter of radial artery and cephalic vein but ultrasound measurement of non augmented forearm venous diameters may have low reproducibility [8]. Secondly, there is paucity of literature regarding this issue in the cadavers. A thorough understanding of the vascular anatomy is critical in selecting the site for the arteriovenous anastomosis that provides the flow rates necessary for the development of an optimal outflow vein. The present Cadaveric study aimed to outline the surgical anatomy of radial artery and cephalic vein in the front of forearm and dorsum of hand pertinent to RCAVF planning, thus help radiologists and surgeons while making decision for RCAVF creation.

MATERIALS AND METHODS

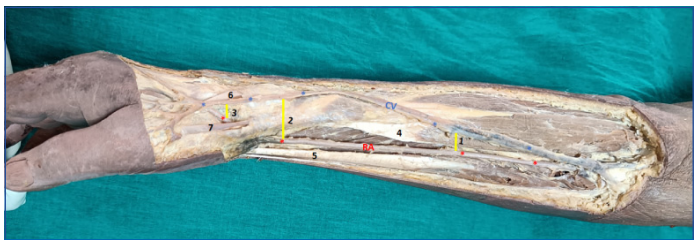
The descriptive cross-sectional cadaveric study was done on 30 formalin preserved upper limbs of human cadavers, obtained from the Department of Anatomy, Hamdard Institute of Medical Sciences and Research, New Delhi from August 2016 to April 2018 (22 limbs) and in Government Institute of Medical Sciences, Greater Noida from November 2018 to November 2019 (08 limbs). Out of 30 limbs, 15 limbs were of right-side and 15 were of left-side and gender of specimen was not taken into consideration.

Inclusion criteria: Formalin fixed Cadavers without any gross pathology of upper limb which were used during their undergraduate teaching were included in the study.

Exclusion criteria: Damaged limbs in the region of forearm and dorsum of hand were excluded from the study.

Study Procedure

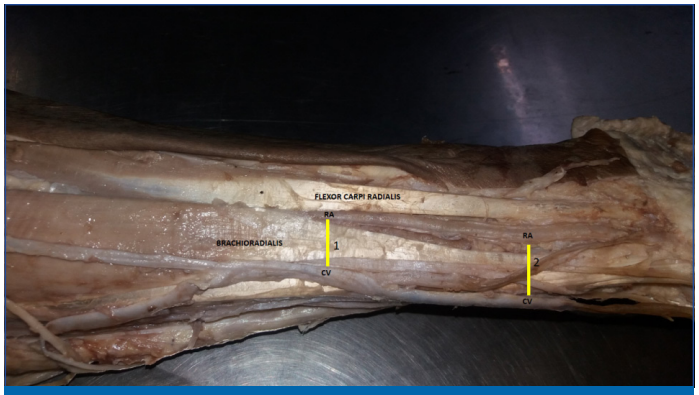
Each upper limb was carefully dissected using a skin incision on the dorsum of hand and radial aspects of the front of forearm reaching upto the elbow. Cephalic vein was dissected in superficial fascia in dorsum of hand and radial side of forearm till cubital fossa and major tributary closest to the radial artery was considered for measurements for RCAVF creation. The radial artery was identified in the cubital fossa and its course was followed from its emergence at the medial border of brachioradialis till styloid process in the front of forearm. On the dorsum of hand, cephalic vein, tendons of Abductor Pollicis longus (APL), Extensor Pollicis Brevis (EPB) and Extensor pollicis longus (EPL) were cleaned and radial artery was identified in the ASB. The external diameter of radial artery, cephalic vein and distance between radial artery and cephalic vein, was measured at three places [Table/Fig-1-3].



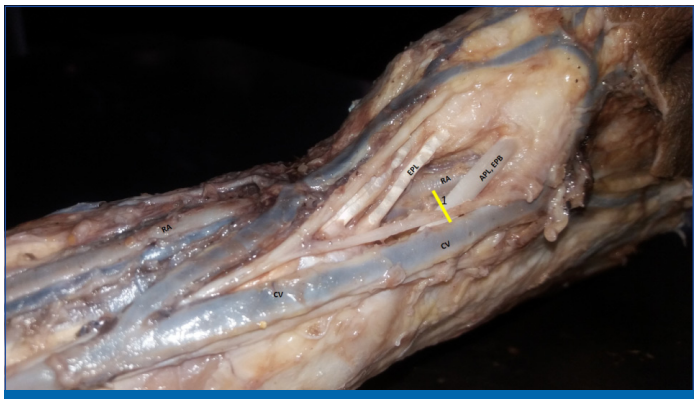
[Table/Fig-1]: Cadaveric dissection of front of forearm and dorsum of hand showing measurements taken in the present study.
RA & red asterix (*): Radial artery; CV & Blue asterix (*): Cephalic vein; 1: Distance between radial artery and cephalic vein in mid forearm; 2: Distance between radial artery and cephalic vein at wrist; 3: Distance between radial artery and cephalic vein in anatomical snuff box; 4: Brachioradialis; 5: Flexor carpi radialis; 6: Extensor pollicis longus; 7: Abductor Pollicis longus and extensor pollicis brevis

- Mid Forearm (at the level of emergence of radial artery at medial border of brachioradialis) [Table/Fig-1,2].
- Wrist [Table/Fig-1,2]
- ASB [Table/Fig-1,3]

Measurements were taken with sliding vernier caliper to an accuracy of 0.01 mm. Each measurement was taken by two different observers



[Table/Fig-2]: Cadaveric dissection of front of forearm showing measurements taken in the present study.
RA: Radial artery; CV: Cephalic vein, 1: Distance between radial artery and cephalic vein in mid forearm; 2: Distance between radial artery and cephalic vein at wrist; Brachioradialis; Flexor carpi radialis



[Table/Fig-3]: Cadaveric dissection of dorsum of hand showing measurements taken in the present study.
RA: Radial artery; CV: Cephalic vein; 1: Distance between radial artery and cephalic snatomical snuff box; EPL: Extensor pollicis longus; APL Abductor Pollicis longus & EPB: Extensor pollicis brevis

and the average of the two observations was considered to reduce the error rate. All the measurements were tabulated separately for right and left-side.

STATISTICAL ANALYSIS

Data collection was done with Microsoft (MS) excel software. Categorical data were presented as mean and percentage. Descriptive statistics like mean, Standard Deviation (SD) and range were evaluated for all the parameters collected. The paired t-test was applied to compare the right and left-side measurements. If the p-value is <0.05, the comparison was considered statistically significant.

RESULTS

The external diameter of radial artery was 4 mm±0.75 mm and 3.8 mm±0.76 mm, respectively on the right and left-side of forearm. In the front of wrist, the diameter was 3.6 mm±0.58 mm and 3.16 mm±0.17 mm on the right and left hand (p-value 0.006). In the ASB, the diameter of radial artery was 3 mm±0.26 mm on the right-side and 2.87 mm±0.24 mm on the left-side [Table/Fig-4]. The external diameter of cephalic vein was 4.5±0.67 mm and 4.2±0.71 mm, respectively on the right and left-side of forearm. In the front of

Serial no.	Site	External diameter of radial artery (in mm)				p-value
		Right		Left		
		Mean±SD	Range	Mean±SD	Range	
1	Mid forearm	4±0.75	3-5.4	3.8±0.76	3-5.7	0.18
2	Wrist	3.6±0.58	3-5	3.16±0.17	3-3.5	**0.006**
3	ASB	3±0.26	2.5-3.4	2.87±0.24	2.5-3.2	0.08

[Table/Fig-4]: Measurement of external diameter of radial artery in forearm, wrist and Anatomical Snuff Box (ASB). Values are presented as mean±SD and range. The paired t-test was applied for the statistical analysis.
*The difference was considered as statistically significant if the p-value is less than 0.05

wrist, the diameter was 2.5±0.52 mm and 2.6±0.60 mm on the right and left hand. In the ASB, the diameter of cephalic vein was 2.5±0.59 mm on the right-side and 2.9±0.33 mm on the left-side [Table/Fig-5]. The distance between radial artery and cephalic vein 2.57±0.43 mm and 2.6±0.60 mm respectively on the right and left-side of forearm. In the front of wrist, the distance was 4.02±0.76 mm and 4.2±0.71 mm on the right and left hand. In the ASB, the distance between radial artery and cephalic vein was 2.5±0.59 mm on the right-side and 3±0.36 mm (p-value=0.015) on the left-side [Table/Fig-6].

Serial no.	Site	Mean external diameter of cephalic vein (mm)				p-value
		Right		Left		
		Mean±SD	Range	Mean±SD	Range	
1	Mid forearm	4.5±0.67	3.5-5.5	4.2±0.71	4.4-5.7	0.07
2	Wrist	2.5±0.52	2-4	2.6±0.60	1.6-4	0.28
3	ASB	2.5±0.59	1.5-3.3	2.9±0.33	2.4-3.5	0.08

[Table/Fig-5]: Measurement of external diameter of Cephalic Vein in forearm, wrist and ASB. Values are presented as mean±SD and range. The paired t test was applied for the statistical analysis.
*The difference was considered as statistically significant if the p-value is less than 0.05

Serial no.	Site	Mean distance between radial artery and cephalic vein (mm)				p-value
		Right	Left	Right	Left	
		Mean±SD	Range	Mean±SD	Range	
1	Mid forearm	2.57±0.43	1.7-3.4	2.6±0.60	1.8-3.6	0.39
2	Wrist	4.02±0.76	2.8-5.5	4.2±0.71	3.3-5.7	0.25
3	ASB	2.5±0.59	1.5-3.3	3±0.36	2.5-3.6	**0.015**

[Table/Fig-6]: Measurement of the distance between radial artery and cephalic vein in forearm, wrist and ASB. Values are presented as mean±SD and range. The paired t-test was applied for the statistical analysis.
*The difference was considered as statistically significant if the p-value is less than 0.05

DISCUSSION

Therapeutic options for patients suffering from end-stage renal disease have improved enormously over the last decades and can be divided into three categories: HD, peritoneal dialysis and kidney transplantation. Transplantation remains the treatment of choice however, dearth of donor organs results in the compulsion of performing temporary dialysis therapy, of which HD is carried out in the majority of patients. Formation of a vascular access on the upper arm may result in high flow but may be associated with distal ischemia [9,10]. The guidelines recommend a distal location for RCAVF, although having high non maturation rates [3,4,11,12]. The RCAVF is ideal for HD as it has lesser frequencies of infection and distal ischemia and it also spares proximal veins for future access use.

The quality and diameter of the artery plays a major role in the determining the volume of blood that could flow through the vessel for a given pressure and viscosity of the blood. The quality of the vessel wall becomes less of an issue for a fistula that depend on large calibre arteries (brachial and larger). In this situation, due to the larger diameter and shorter length, flow is more dependent on the diameter of the vessel which is already large (usually >4 mm) and is capable of handling the increased flow required to overcome the loss of resistance caused by RCAVF construction. The size of anastomosis will be another factor that can act as a determinant of the flow. Hence creating a small anastomosis with diameters of 4-5 mm is adequate to provide necessary flow for adequate Arteriovenous Fistula (AVF) maturation placing the distal extremity at a lower risk of vascular compromise [13]. Therefore, the quality and diameter of the artery plays a major role in maturation of AVF. Evaluation of anatomy, diameter and wall quality are critical in vascular access planning for site selection [2].

In the present study [Table/Fig-7] [14-19], the external diameter of radial artery and cephalic vein was maximum in forearm and is gradually decreasing from forearm to ASB. The average diameter of radial artery was 3.9 mm, 3.4 mm and 2.9 mm in forearm, wrist and ASB respectively. Previous maximum studies were done on USG imaging and measurements shown were intraluminal diameter which is low as compared to findings of the present study. In a retrospective study of 64 upper limbs in 55 dialysis patients by Hull JE et al., on the basis of diameter of radial artery and cephalic vein 9 >2 mm and within 1.5 mm of each other, showed radial artery sites were qualified in 47.6% near wrist and 87.9% in forearm [14]. Letachowicz K et al., noted the diameter 2 mm and 1.5 mm at wrist and ASB [15]. Wong V et al., Malovrh M, Silva MB et al., mentioned the radial artery diameter ranging between 1.5 mm to 2 mm but they didn't mentioned the site where measurement was taken [16-18]. Similarly, the diameter cephalic vein was increasing from ASB to forearm in the present study-4.3 mm, 2.5 mm and 2.7 mm in forearm, wrist and ASB respectively. Hull JE et al., observed cephalic vein diameter 2.9 mm and 2.3 mm in forearm and ASB respectively while Letachowicz K et al., noted the diameter 2 mm in both, wrist and ASB [14,15]. Wong V et al., Malovrh M, Silva MB et al., and Ascher E et al., mentioned the cephalic vein diameter ranging between 1.6 mm to 2.5 mm [16-19]. As shown in the result of present study, it has also been observed that average diameter of both radial artery and cephalic vein was more on the right hand and as compared to the left hand. Letachowicz K et al., finally concluded that outcome of vascular access was similar at both wrist and ASB in spite of smaller diameter of vessels at ASB [15].

Author	Radial artery (mm)			Cephalic vein (mm)		
	Forearm	Wrist	ASB	Forearm	Wrist	ASB
Present study (Average of right and left side)	3.9	3.4	2.9	4.3	2.5	2.7
Hull JE et al., 2013 [14]	2.8	-	2.5	2.9		2.3
Letachowicz K et al., 2015 [15]	-	2	1.5	-	2	2
Wong V et al., 1996 [16]	1.6			1.6		
Malovrh M, 1998 [17]	1.5			1.6		
Silva Jr MB et al, 1998 [18]	2.0			2.5		
Ascher et al., 2000 [19]	-			2 .5		

[Table/Fig-7]: Comparison of mean diameter of radial artery and cephalic vein of present study with findings of previous authors [14-19].

In the present study [Table/Fig-8] [14,20], distance between the radial artery and cephalic vein was more in wrist as compared to the mid forearm and ASB and mean distance was approximately same in mid forearm and ASB. An anatomic cadaver study demonstrated that the superficial branch of radial artery and adjacent vein were present in the snuffbox in 92% (23/25) of specimens and were a mean of 4±2 mm apart [20]. Hull JE et al., noted more distance between radial artery and cephalic vein in ASB as compared to the wrist found that in 24% cases wrist site is disqualified due to distance between artery and vein [14].

Author	Mean distance between radial artery and cephalic vein (mm)							
	Forearm				ASB			
	Mean±SD		Range		Mean±SD		Range	
	Right	Left	Right	Left	Right	Left	Right	Left
Present study	2.57±0.52	2.6±0.60	2-4.1	1.6-4	2.56±0.59	3±0.36	1.5-3.3	2.5-3.6
Hull JE et al, 2013 [14]	0.50±0.45		0 to 1.4		1.3±1.34		0.09 to 6.9	
Lirk P et al, 2004 [20]	-		-		4±2 mm		-	

[Table/Fig-8]: Comparison of mean distance between radial artery and cephalic vein of present study with findings of previous authors [14, 20].

Limitation(s)

Due to non availability of cadaveric study, it has been compared with USG studies and external diameters of vessels have been

compared with relative internal diameters observed in USG findings. The variations in measurements may also be possible of deflation of vessels in cadaveric specimens.

CONCLUSION(S)

Successful RCAVF creation brings many benefits to dialysis patient and it spares proximal veins for future access use. In the present study, the diameter of radial artery and cephalic vein is maximum at the site of emergence of radial artery underneath the brachio-radialis and it gradually decreases in wrist and ASB. The radial artery and cephalic vein was closest in ASB and mid forearm. So, it can be assumed that distal sites especially ASB would be the better site for making RCAVF creation as it would provide long segment of vein for arterialization after fistula formation and are also associated with lower incidence of infection and distal ischemia.

REFERENCES

[1] Brescia MJ, Cimino JE, Appel K, Hurwich BJ. Chronic hemodialysis using venipuncture and a surgically created arteriovenous fistula. N Engl J Med. 1966;275(20):1089-92.

[2] Shenoy S. Surgical anatomy of upper arm: what is needed for AVF planning. The Journal of Vascular Access. 2009;10(4):223-32.

[3] Vascular Access 2006 Work Group. Clinical practice guidelines for vascular access. Am J Kidney Dis. 2006;48(suppl. 1):S176-247.

[4] Tordoir J, Canaud B, Haage P, Konner K, Basci A, Fouque D, et al. EBPG on vascular access. Nephrol Dial Transplant. 2007;22(suppl. 2):ii88-117.

[5] Sidawy AN, Gray R, Besarab A, Henry M, Ascher E, Silva M Jr, et al. Recommended standards for reports dealing with arteriovenous hemodialysis accesses. J Vasc Surg. 2002;35(2):603-10.

[6] Standring S. The Anatomical Basis of Clinical Practice, Gray's Anatomy. In: Alistair Ross Editor. Pectoral girdle and Upper limb 42nd ed. Scotland: Churchill Livingstone Elsevier; 2021. 949-51.

[7] Malovrh M. The role of sonography in the planning of arteriovenous fistulas for hemodialysis. Semin Dial. 2003;16(4):299-303.

[8] Planken RN, Leiner T, Tordoir JHM. Forearm venous distensibility measurements with ultrasound techniques are poorly reproducible. Am J Kidney Dis. 2007;49(2):347.

[9] Basile C, Lomonte C, Vernaglione L, Casucci F, Antonelli M, Losurdo N. The relationship between the flow of arteriovenous fistula and cardiac output in haemodialysis patients. Nephrol Dial Transplant. 2008;23(1):282-87.

[10] Van Hoek F, Scheltinga MR, Kouwenberg I, Moret KE, Beerenhout CH, Tordoir JH. Steal in hemodialysis patients depends on type of vascular access. Eur J Vasc Endovasc Surg. 2006;32(6):710-17.

[11] Sidawy AN, Spergel LM, Besarab A, Allon M, Jennings WC, Padberg FT Jr, et al. The Society for Vascular Surgery: clinical practice guidelines for the surgical placement and maintenance of arteriovenous hemodialysis access. J Vasc Surg. 2008;48(5 Suppl):2S-25S.

[12] Al-Jaishi AA, Oliver MJ, Thomas SM, Lok CE, Zhang JC, Garg AX, et al. Patency rates of the arteriovenous fistula for hemodialysis: a systematic review and meta-analysis. Am J Kidney Dis. 2014;63(3):464-78.

[13] Konner K. Initial creation of native arteriovenous fistulas: surgical aspects and their impact on practice of nephrology. Semin Dial. 2003;16(4):291-98.

[14] Hull JE, Kinsey EN, Bishop WL. Mapping of the snuffbox and cubital vessels for percutaneous Arterial Venous Fistula (pAVF) in dialysis patients. J Vasc Access. 2013;14(3):245-51.

[15] Letachowicz K, Gołębiowski T, Kusztal M, Letachowicz W, Weyde W, Klinger M. The snuffbox fistula should be preferred over the wrist arteriovenous fistula. Journal of Vascular Surgery. 2015;63(2):436-40.

[16] Wong V, Ward R, Taylor J, Selvakumar S, How TV, Bakran A. Factors associated with early failure of arteriovenous fistulae or haemodialysis access. Eur J Vasc Endovasc Surg. 1996;12:207-13.

[17] Malovrh M. Non invasive evaluation of vessels by duplex sonography prior to construction of arteriovenous fistulas for haemodialysis. Nephrol Dial Transpl. 1998;13:125-29.

[18] Silva Jr MB, Hobson RW, Pappas PJ, Jamil Z, Araki CT, Goldberg MC, et al. A strategy for increasing the use of autogenous hemodialysis access procedures: impact of perioperative noninvasive evaluation. J Vasc Surg. 1998;27:302-07.

[19] Ascher E, Gade P, Hingorani A, Mazzariol F, Gunduz Y, Fodera M, et al. Changes in the practice of angioaccess surgery: Impact of dialysis outcome and quality initiative recommendations. J Vasc Surg. 2000;31(1Pt1):84-92.

[20] Lirk P, Keller C, Colvin J, Colvin H, Rieder J, Maurer H, et. al. Unintentional arterial puncture during cephalic vein cannulation: case report and anatomical study. Br J Anaesth. 2004;92(5):740-42.

PARTICULARS OF CONTRIBUTORS:

1. Assistant Professor, Department of Anatomy, Hamdard Institute of Medical Sciences, New Delhi, India.
2. MBBS Student (2nd Professional), JSS Medical College, Mysuru, Karnataka, India.
3. Tutor, Department of Anatomy, Government Institute of Medical Sciences, Greater Noida, Uttar Pradesh, India.
4. Professor, Department of Anatomy, Government Institute of Medical Sciences, Greater Noida, Uttar Pradesh, India.
5. Professor, Department of Anatomy, Hamdard Institute of Medical Sciences, New Delhi, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Ranjana Verma,
F-25, Type VI Quarter, Gautam Buddha University Campus, Greater Noida, Uttar Pradesh, India.
E-mail: ranjanaverma318@gmail.com

PLAGIARISM CHECKING METHODS: [Jain H et al.]

- Plagiarism X-checker: Oct 09, 2021
- Manual Googling: Jan 21, 2022
- iThenticate Software: Mar 13, 2022 (24%)

ETYMOLOGY: Author Origin

AUTHOR DECLARATION:

- Financial or Other Competing Interests: None
- Was Ethics Committee Approval Obtained for this study? NA
- Was informed consent obtained from the subjects involved in the study? NA
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Oct 08, 2021**
Date of Peer Review: **Nov 19, 2021**
Date of Acceptance: **Feb 14, 2022**
Date of Publishing: **Jul 01, 2022**