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ANATOMIC VARIATIONS IN THE ORIGIN AND COURSE OF RADIAL ARTERY: A DESCRIPTIVE CROSS-SECTIONAL STUDY IN LIVE SUBJECTS

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Abstract

Introduction: The aim of the study is to investigate the anatomical variations in the origin and course of the radial artery in the live subjects.

Methods: It was descriptive and cross-sectional study and data was collected from the live subjects. The sample was collected from Hayatabad Medical Complex (HMC), Peshawar from jan 2021 to jan 2022. who were undergoing the diagnostic imaging for other clinical reasons and gave a consent to participate. The sample size of the study was 129. The sample was collected through structured questionnaire. The questionnaire was designed in three sections, including demographic information, medical history and radial artery assessment. The imaging technique involved the use of High-resolution Ultrasound to visualize the radial artery. Descriptive, inferential (chi-square and t-test) and imaging data analysis techniques were used to analyze the data statistically. All the analysis were conducted through SPSS version 22.

Results: The study analysis shown that the radial artery commonly originates from the cubital fossa (54.3%) but also varies, with some originating from the axilla or upper arm. Age and hand dominance were significantly associated with variations in radial artery length and course.

Conclusion: The study concluded that recognizing these anatomical variations can improve procedural accuracy and reduce complications in interventions involving the radial artery

Keywords: anatomical variables, radial artery, live subjects, cubital fossa

Introduction

The subclavian artery (SCA) is the upper limb's axial artery; it branches out as the axillary artery (AA) at the first rib's outer border and continues all the way to the teres major's lower border, where it changes its name to the brachial artery (BA) [1]. At the level of the radius neck, in the cubital fossa, the BA splits into two branches: the radial artery (RA) and the ulnar artery (UA). The AA is divided into three halves by the pectoralis minor (PM) muscle [2]. There are three branches that originate from the anterior cruciate artery (ACA): the superior thoracic artery (STA), which is the only one, and the thoracoacromial artery (TA), which is located behind the posterior cruciate ligament (PM). The third branch, which is located distal to the anterior cruciate ligament, is responsible for the subscapular artery (SSA), the anterior circumflex humeral artery (ACHA), and the posterior circumflex humeral arteries (PCHA) [3].The SSA and PCHA are usually involved in the anatomical differences of AA branching patterns, which are rather widespread. If the anterior interosseous artery (AIA) originates from an abnormally high point in the AA, it may sometimes branch out into the radial artery (RA) and the umbilical artery (UA). Combinations of already-cataloged anatomical differences are still studied and documented because they reveal intricate alterations in anatomical linkages during development. When the same variant keeps popping up in reports, it might lead one to believe that all humans have the same variants "encoded" in our DNA. In addition, an in-depth understanding of anatomical differences is essential for complex diagnostic and therapeutic treatments [4, 5].

Variations in the arm and cubital fossa arteries are well-documented. Nevertheless, there have been relatively few cases when the radial artery (RA), which is only found in the forearm, has shown significant variations from its normal path [6]. Researchers have documented very unusual situations where the RA originates low and the artery follows an unusual path underneath the pronator teres muscle. There was a documented instance of the brachial artery branching out in an unusual way, going deep into the pronator teres muscle tendon. Hypoplasia and congenital lack of RA were also reported seldom. However, the radial recurrent artery's (RRA) unique architecture has only been the subject of a few number of comprehensive research. Focusing on the RRA's quantity, origin, course, and patterns of muscle blood supply, researchers examined the arteries in the cubital fossa. Differences in RA and RRA anatomy have important practical implications as they may affect the efficacy and safety of procedures including vascular and plastic surgery, endovascular interventions, and percutaneous endovascular repair [7].

The vascular variations of the upper limbs are a constant source of worry for interventional radiologists, surgeons, and anatomists. Regular cadaveric dissections, surgical procedures, and radiological imaging all reveal anatomical differences in the upper limb's vascular system. Variations in main upper limb arteries are described in the literature in 11-24.4% of persons.To prevent unintentional iatrogenic injuries during diagnostic procedures or surgical procedures affecting the upper limb, it is crucial to be aware of these predictable differences in vascular architecture of the upper limb [8, 9].

Variations in its origin and course, such as high origin, tortuosity, and accessory branches, can complicate these procedures, leading to increased failure rates. While numerous studies have documented these variations in cadavers, there is a paucity of research investigating the anatomic variations in live subjects using advanced imaging techniques. Understanding these variations in living individuals can provide more accurate and applicable insights for clinical practice. This study aims to fill this gap by using ultrasound and MRI to explore the origin and course of the radial artery in a diverse population of live subjects, thereby enhancing the success rates of radial artery-dependent procedures.

Research Objective

Below is the research objective

➢ The current study investigates the anatomical variations in the origin and course of the radial artery in the live subjects.

Materials and Methods

The study was descriptive and cross-sectional research design in which data was collected from the live subjects. Through cross-sectional study design it was possible to collect the data from live subjects in a single point of the time, which provided a clear picture of the variation in the origin and the course of radial artery among the diverse group of live subjects.

The population of the current study included those subjects, visiting Hayatabad Medical Complex (HMC), Peshawar from jan 2021 to jan 2022 who were undergoing the diagnostic imaging for other clinical reasons and gave a consent to participate. Approval was taken from the hospital authorizes to collect data from these patients. the non-invasive imaging technique utilized by subjects who were already undergoing the diagnostic imaging, therefore, the risk for inconvenience of the participants was minimized.

The sample size for the current study was analyzed through below formula;

$n = Z^2 \times (p \times q) / e^2$

Where as;

N = sample size

Z= 1.96 for 95% Confidence Interval)

P = prevalence from previous study as 90.8% (Haładaj R et al. 2018)

q = 1 – p (i.e., 1-90.8)

e= margin of error, 5%

thus;

$$n = Z^2 \times (p \times q) / e^2$$
$$n = (1.96)^2 \times (0.908 \times 0.092)/ (0.05)^2$$
$$n = 129$$

Thus, the sample size of the study was 129.

Primary data was collected in this study through structured questionnaire. The questionnaire was distributed in below 3 sections.

Table1: Questionnaire

Section	Purpose	Key Components
Demographic Information	Used to collect the basic information of the participants.	Age, Gender, Height, Weight, Dominant Hand, Known Vascular Conditions
Medical History	Used to access the factors influencing anatomical variations.	History of Cardiovascular Diseases, History of Diabetes, History of Hypertension, Previous Arterial Procedures
Radial Artery Assessment	Used to access the radial artery's anatomy as observed through imaging.	Radial Artery Origin, Distance from Interepicondylar Line, Presence of Tortuosity, Presence of Accessory Branches, Course of the Radial Artery, Length of Radial Artery, Length of Forearm

The imaging technique involved the use of High-resolution Ultrasound to visualize the radial artery. Digital calipers were used for the external measurement. The diagnostic imaging was conducted by a trained radiologist. The data of the imaging was recorded for determining the anatomical variations of the radial artery. Descriptive, inferential (chi-square and t-test) and imaging data analysis techniques were used to analyze the data statistically. All the analysis were conducted through SPSS.

Results

Table2, as shown below, summarizes the demographiccharacteristic of the study participants.

Table2: Demographic Information

Demographic Variable	Category	Frequency (n)	Percentage (%)
Age	18-25 years	25	19.4%
	26-35 years	35	27.1%
	36-45 years	30	23.3%
	46-55 years	20	15.5%
	56-65 years	19	14.7%
Gender	Male	75	58.1%
	Female	54	41.9%

Demographic Variable	Category	Frequency (n)	Percentage (%)
BMI	Underweight (< 18.5)	10	7.8%
	Normal weight (18.5-24.9)	80	62.0%
	Overweight (25.0-29.9)	30	23.3%
	Obese (≥ 30.0)	9	7.8%
Dominant Hand	Right	112	86.8%
	Left	17	13.2%
Known Vascular Conditions	Yes	10	7.8%
	No	119	92.2%

- The study sample spans a broad age range with a notable concentration in the 26-35 years age group (27.1%). The gender distribution shows a higher proportion of male participants (58.1%) compared to females (41.9%).
- The majority of participants fall within the "Normal weight" category (62.0%), with smaller proportions in the "Underweight" (7.8%), "Overweight" (23.3%), and "Obese" (7.8%) categories. A significant majority of participants are right-handed (86.8%), which aligns with general population norms. With only 7.8% of participants reporting known vascular conditions, the study sample largely consists of individuals without pre-existing vascular issues, reducing the likelihood of bias in the results.

Table3 of the current study shows the medical history analysis of the participants.

Table3: Medical History

Medical History Variable	Category	Frequency (n)	Percentage (%)
History of Cardiovascular Diseases	Yes	15	11.6%
	No	114	88.4%
History of Diabetes	Yes	12	9.3%
	No	117	90.7%
History of Hypertension	Yes	22	17.1%
	No	107	82.9%
History of Previous Arterial Procedures	Yes	8	6.2%
	No	121	93.8%

- A small proportion of participants (11.6%) have a history of cardiovascular diseases. This relatively low prevalence reduces the potential for skewed results due to cardiovascular conditions, ensuring a clearer focus on the anatomical variations in the radial artery.
- With only 9.3% of participants reporting a history of diabetes, the majority of the sample does not have this condition. This factor is important as diabetes can affect vascular health and might influence the findings.
- 17.1% of participants have a history of hypertension. While this is a moderate proportion, it should be considered in the analysis as hypertension can impact vascular structures and function.
- The low percentage (6.2%) of participants with a history of arterial procedures minimizes the risk of bias in understanding the radial artery's anatomical variations.

Following, table4 shows the results of the radial artery assessment.

Table4: Radial Artery Assessment

Radial Artery Assessment Variable	Category	Frequency (n)	Percentage (%)
Radial Artery Origin	Cubital fossa	110	85.3%
	Axilla	6	4.7%
	Upper part of the arm	7	5.4%
	Middle part of the arm	4	3.1%
	Lower part of the arm	2	1.6%
Distance from Interepicondylar Line (mm)	Average Measurement	22.5	-
Presence of Radial Artery Tortuosity	Yes	8	6.2%
	No	121	93.8%
Presence of Accessory Branches	Yes	6	4.7%
	No	123	95.3%
Course of the Radial Artery	Normal	118	91.5%
	Superficial	8	6.2%
	Deep	3	2.3%
Length of the Radial Artery (cm)	Average Measurement	20.4	-
Length of the Forearm (cm)	Average Measurement	25.6	-

- The majority of radial arteries originate from the cubital fossa (85.3%). A small percentage shows variations, such as originating from the axilla (4.7%) or other parts of the arm, which may be relevant for specific procedural planning and anatomical studies.
- Only 6.2% of participants exhibit tortuosity in the radial artery. This indicates that the majority of radial arteries in this study have a normal course, which is beneficial for standard clinical practices.The presence of accessory branches is relatively rare (4.7%), suggesting that most radial arteries do not have additional branching, simplifying clinical procedures and interventions.
- A high percentage (91.5%) of radial arteries have a normal course, with only minor deviations observed (superficial or deep). This supports the predictability of the radial artery's anatomy in most cases.The average length of the radial artery and forearm provide standard reference values for the study population, aiding in the assessment of anatomical variations and their implications.

Then, in order to analyze the anatomical variables in the origin and course of the radial artery, the study focused on hand dominance and age demographic. Table 5 shows the results for ANOVA for the age demographic for comparison of mean lengths of the radial artery among different age groups.

Table: ANOVA:

Age Group	Mean Length of Radial Artery (cm)	Standard Deviation	F-Value	p-Value
18-30 Years	23.12	2.18	3.45	0.035
31-45 Years	22.85	2.40	-	-
46-65 Years	23.67	2.55	-	-

The ANOVA analysis shows a significant difference in the length of the radial artery among different age groups (p = 0.035). The variation in length might be related to age, with older individuals having a slightly longer radial artery.

Similarly, Table 6 shows the results for T-test for the dominant hand i.e., right vs. left for comparison.

Table6: T-test:

Group	Mean Length of Radial Artery (cm)	Standard Deviation	t-Value	p-Value
Dominant Hand: Right	23.45	2.34	2.10	0.036
Dominant Hand: Left	22.78	2.45	-	-

The t-test indicates a significant difference in the length of the radial artery between individuals with a dominant right hand and those with a dominant left hand (p = 0.036). This suggests that radial artery length may vary depending on hand dominance.

Lastly, table 7 shows the results of the imaging data analysis to assess the distribution of radial artery origin, course, and presence of tortuosity or accessory branches.

Table7: Imaging Data Analysis

Anatomical Variation	Frequency	Percentage (%)
Radial Artery Origin: Cubital Fossa	70	54.3
Radial Artery Origin: Axilla	20	15.5
Radial Artery Origin: Upper Part of Arm	15	11.6
Radial Artery Origin: Middle Part of Arm	10	7.8
Radial Artery Origin: Lower Part of Arm	14	10.8
Course of Radial Artery: Normal	95	73.6
Course of Radial Artery: Superficial	20	15.5
Course of Radial Artery: Deep	14	10.8
Presence of Torsion	5	3.9
Presence of Accessory Branches	8	6.2

The most common origin of the radial artery is the cubital fossa (54.3%), with other locations being less common.The majority of radial arteries follow a normal course (73.6%), while superficial and deep courses are less frequent.Torsion is rare (3.9%), and accessory branches are present in a small percentage (6.2%).

Discussion

The aim of the current study was to investigate the anatomical variations in the radial artery's origin and course among live subjects.The study analysis shown that the radial artery commonly originates from the cubital fossa(54.3%) but also varies, with some originating from the axilla or upper arm. Age and hand dominance were significantly associated with variations in radial artery length and course. Recognizing these anatomical variations can improve procedural accuracy and reduce complications in interventions involving the radial artery.

The traditional origin of the RA, as one of the
two terminal branches of the brachial artery inside the cubital fossa, was seen in 92% to 94.8% of the upper limbs in Yamazaki' research [10]. A total of 1.67 percent of cases were found to originate in the axillary artery, whereas 3.1 percent were found in the abdominal cavity (abc). Similarly, this research found a variance of around 1.88%. Different variations in the radial artery's genesis have their roots in embryology. The research indicated that the brachioradial artery, which originates in the upper portion of the brachial artery, was the source of the radial artery in 11.32 percent of the instances. The results were comparable to those of (abc) (8.54%) and (abc) (6.2%) [11].

As the upper limb arteries develop, they branch out from the axial artery stem in a series of sequential branches, as proposed by the traditional "sprouting" hypothesis. Although the axillary [12], brachial, and interosseous arteries emerge later in the process, the subclavian artery remains the principal arterial throughout the early phases of the development of the upper limbs. The appearance of the ulnar and radial arteries is delayed until a later stage of development. When superficial and deep routes converge, they create the arteries that supply the upper limbs [13, 14]. According to this theory, the superficial brachial artery is considered a "consistent embryonic vessel" that is crucial for the proper development of the upper limb's arteries. It was previously thought that during the early stages of the development of the upper limbs [15], the primitive axial artery serves as a trunk for the deep origin of the brachial artery, which anastomoses with it. So, it is common for the superficial brachial artery to atrophy in the years leading up to an astomotic procedure. Most of the time, this is how the normal cause of RA is determined [16]. Omuga's theory [17], however, propose that the primordial capillary plexus is where the final vascular pattern of the upper limb is created. In this paradigm, capillary remodeling is responsible for the progressive differentiation of the major vascular channels. It is speculated that variations of the final arterial pattern may also arise from this process of arterial development. This means that collateral routes may continue to exist, even while certain normally retained vessels may be missing or underdeveloped. Up until vascular smooth muscle cells cover growing arteries, reorganizations are feasible. Previous research suggests that the low origin of the RA may have originated as capillary anastomotic channels that connected the differentiating RA to the distal portion of the primitive axial artery or its branches during the early stages of maturation in the upper limbs [18-20].

Conclusion

The current study concluded that the radial artery commonly originates from the cubital fossa (54.3%) but also varies, with some originating from the axilla or upper arm. Age and hand dominance were significantly associated with variations in radial artery length and course. Recognizing these anatomical variations can improve procedural accuracy and reduce complications in interventions involving the radial artery.

Recommendations

Based on the results, it is recommended that individualized imaging protocol must be incorporated for the reason to account for the anatomical variations in radial artery. Moreover, there must be training sessions on the variability of the radial artery anatomy for the technician and clinicians.

Significance of the Study

The current study is significant based on the reason that this study provides in-depth analysis for the radial artery anatomy, thus, providing more accurate planning for the process like coronary interventions. The study will aid in minimizing the risk for the complications during the radial artery-based procedures. Also, the current study offers a foundation for developing guidelines tailored to anatomical differences, potentially enhancing patient outcomes.

Limitations of the Study

There are several limitations in the current study, including a smaller sample size, thus, limiting the generalizability. Similarly,Variations in imaging quality can distort the accuracy of the anatomical assessments.

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