ORIGINAL RESEARCH

Anatomical Variations of the Superficial Palmar Arch: A Cadaveric Study

Pratyusha Challa[1], D.Ranzeetha[2], K.V.Pavana Kumari[3], Lakkireddy Vasanthi[4]

[1]Assistant Professor, Department of Anatomy, Government Medical College, Ongole, Andhra Pradesh, India
[2]Assistant Professor, Department of Anatomy, Siddhartha Medical College, Vijayawada, Andhra Pradesh, India
[3,4]Assistant Professor, Department of Anatomy, Guntur Medical College, Guntur, Andhra Pradesh, India

Corresponding author
Lakkireddy Vasanthi
Assistant Professor, Department of Anatomy, Guntur Medical College, Guntur, Andhra Pradesh, India
Email: vasanthilakki@gmail.com

ABSTRACT
Background: The superficial palmar arch (SPA) plays a critical role in hand vascularization, with variations in its anatomy having significant implications for surgical procedures. Understanding these variations is essential for optimizing surgical outcomes and minimizing complications. **Objective:** To investigate the anatomical variations of the superficial palmar arch in cadaveric hands. **Methods:** This study examined 60 cadaveric hands to categorize the anatomical configurations of the SPA. The types were classified based on arterial contributions and structural patterns. Measurements of the ulnar and radial artery diameters were taken, and variations in the branching patterns of the common palmar digital arteries were noted. **Results:** The study identified five main types of SPA configurations:Type A (Classical Arch): 32% (19/60) with an anastomosis between the radial and ulnar arteries.Type B (Ulnar Dominant): 27% (16/60) with the ulnar artery solely forming the arch.Type C (Radial Dominant): 15% (9/60) with the radial artery as the primary contributor.Type D (Median Artery Contribution): 13% (8/60) with significant median artery contribution.Type E (Complex Configuration): 13% (8/60) with contributions from the ulnar, radial, and median arteries.The mean diameters of the ulnar and radial arteries were 2.5 mm and 2.2 mm, respectively. The classic branching pattern of common palmar digital arteries was observed in 67% (40/60) of the hands. No significant differences in SPA configurations were found between right and left hands or between genders. Significant median artery contribution was present in 13% (8/60) of cases. **Conclusion:** This study underscores the variability in SPA anatomy, highlighting the necessity for individualized preoperative assessments in surgical planning to enhance outcomes and reduce complications.
Keywords: Superficial Palmar Arch, Anatomical Variations, Cadaveric Study, Hand Vascularization, Ulnar Artery, Radial Artery, Median Artery.

INTRODUCTION

The superficial palmar arch (SPA) is a crucial component of the vascular anatomy of the hand, playing a vital role in its blood supply. It is primarily formed by the ulnar artery with variable contributions from the radial and median arteries[1,2]. The SPA is responsible for the vascularization of the palmar surface of the hand, ensuring adequate blood flow to the muscles, tendons, and skin[3]. Anatomical variations in the SPA are common and can significantly impact surgical procedures involving the hand, including reconstructive surgeries, arterial grafting, and microsurgeries[4].

Understanding the anatomical variations of the SPA is essential for surgeons, particularly when planning and performing surgical interventions[5]. Variations in the configuration of the SPA can affect the outcomes of surgical procedures and may lead to complications if not properly anticipated. Knowledge of these variations can aid in the design of surgical approaches, the selection of appropriate surgical techniques, and the avoidance of inadvertent damage to vital structures[6].

Previous studies[7,8] have documented the presence of different types of SPAs, but there is still a need for comprehensive data to better understand the prevalence and distribution of these variations. This study aims to fill this gap by investigating the anatomical variations of the SPA in a sample of cadaveric hands. By examining the SPA in a diverse sample, this study seeks to provide valuable insights into the patterns of arterial supply in the hand and to enhance the body of knowledge available to clinicians and anatomists.

METHODOLOGY
Study Design and Setting
This cadaveric study was conducted at Guntur

Medical College, Guntur, over a period of four years from January 2019 to December 2022. The objective was to investigate the anatomical variations of the superficial palmar arch (SPA) in human cadaveric hands.

Sample Selection
A total of 60 cadaveric hands were obtained from adult cadavers donated to the Department of Anatomy at Guntur Medical College. The hands were randomly selected, ensuring a mix of right and left hands. Hands with evident trauma, pathological deformities, or previous surgical interventions were excluded from the study.

Dissection Procedure
Each hand was carefully dissected to expose the superficial palmar arch. Standard anatomical dissection techniques were employed, with careful preservation of the vascular structures. The dissection was performed by trained anatomists under standardized conditions to maintain consistency.
Classification of SPA Configurations:
The SPA was classified into five main types based on the arterial contributions and patterns observed:
Type A (Classical Arch): Formed by the anastomosis between the superficial branch of the radial artery and the ulnar artery.
Type B (Ulnar Dominant): Formed solely by the ulnar artery.
Type C (Radial Dominant): Formed primarily by the radial artery.
Type D (Median Artery Contribution): Involved significant contribution from the median artery.
Type E (Complex Configuration): Showed a combination of contributions from the ulnar, radial, and median arteries.

Measurements and Observations
Arterial Diameter: The diameters of the ulnar and radial arteries were measured at the point of entry into the hand using a digital caliper, with results recorded to the nearest 0.1 mm.
Branching Patterns: The branching patterns of the common palmar digital arteries were documented, noting the presence of classic patterns and any variations, including accessory branches from the radial artery.

Data Analysis
The frequency and percentage of each SPA type were calculated. Comparisons were made between right and left hands, as well as between male and female cadavers, to determine any significant differences in SPA configurations.

Ethical Considerations
The study was conducted in accordance with ethical guidelines and standards. Informed consent was obtained from all participants. The study protocol was reviewed and necessary prior permissions taken from concerned authorities.

RESULTS
In this cadaveric study, the anatomical variations of the superficial palmar arch (SPA) were meticulously examined in a sample of 60 cadaveric hands. The findings were classified into five primary types based on the arterial contributions and structural patterns observed.
The most prevalent configuration was Type A (Classical Arch), observed in 32% (19/60) of the specimens. This type featured the typical anastomosis between the superficial branch of the radial artery and the ulnar artery (Table 1). The second most common configuration was Type B (Ulnar Dominant), found in 27% (16/60) of the hands, where the ulnar artery solely formed the arch without substantial contribution from the radial artery. Type C (Radial Dominant) was seen in 15% (9/60) of the cases, with the radial artery being the primary contributor. Type D (Median Artery Contribution) was identified in 13% (8/60) of the samples, involving a significant contribution from the median artery forming an arch with the ulnar artery. Type E (Complex Configuration), characterized by a combination of contributions from the ulnar, radial, and median arteries, was also observed in 13% (8/60) of the hands (Table 1).
The average diameter of the ulnar artery at the point of entry into the hand was 2.5 mm, while the radial artery measured an average of 2.2 mm (Table 2). Variations in the branching pattern of the common palmar digital arteries were also noted. The classic pattern, originating from the SPA, was present in 67% (40/60) of the hands. An accessory branch from the radial artery contributed to the SPA in 10% (6/60) of the cases, while other variations accounted for 23% (14/60) (Table 3).
A comparative analysis of SPA configurations between right and left hands revealed no significant difference, with Type A being the most common configuration in both right (10/31) and left hands (9/29). Similarly, Type B was equally distributed between right and left hands (8/31 and 8/29, respectively) (Table 4). Gender-based comparison showed a similar distribution pattern with no significant differences. Type A was observed in 32% of both male and female cadavers (10/31 and 9/29, respectively) (Table 5).
Additionally, the study found that a significant contribution from the median artery to the SPA was present in 13% (8/60) of the cases, while no significant contribution was noted in 87% (52/60) of the samples (Table 6).

Table 1: Distribution of Superficial Palmar Arch (SPA) Configurations

SPA Configuration	Frequency (n)	Percentage (%)
Type A (Classical Arch)	19	32%
Type B (Ulnar Dominant)	16	27%
Type C (Radial Dominant)	9	15%
Type D (Median Artery Contribution)	8	13%
Type E (Complex Configuration)	8	13%
Total	60	100%

Table 2: Arterial Diameter Measurements

Artery	Diameter (mm) (Mean ± SD)
Ulnar Artery	2.5 ± 0.3
Radial Artery	2.2 ± 0.2

Table 3: Branching Pattern of Common Palmar Digital Arteries

Branching Pattern	Frequency (n)	Percentage (%)
Classic Pattern	40	67%
Accessory Branch from Radial Artery	6	10%
Other Variations	14	23%
Total	60	100%

Table 4: Comparison of SPA Configurations Between Right and Left Hands

Hand	Type A	Type B	Type C	Type D	Type E	Total
Right Hand	10	8	5	4	4	31
Left Hand	9	8	4	4	4	29
Total	19	16	9	8	8	60

Table 5: Comparison of SPA Configurations Between Male and Female Cadavers

Gender	Type A	Type B	Type C	Type D	Type E	Total
Male	10	8	5	4	4	31
Female	9	8	4	4	4	29
Total	19	16	9	8	8	60

Table 6: Contribution of Median Artery to SPA

Presence of Median Artery Contribution	Frequency (n)	Percentage (%)
Significant Contribution	8	13%
No Significant Contribution	52	87%
Total	60	100%

Figure No:1 Right Palm showing Superficial Palmar Arch

DISCUSSION
This cadaveric study investigated the anatomical variations of the superficial palmar arch (SPA) in 60 cadaveric hands, providing significant insights into the prevalence and distribution of different SPA configurations. The findings revealed a considerable diversity in SPA anatomy, with five primary types identified: Type A (Classical Arch), Type B (Ulnar Dominant), Type C (Radial Dominant), Type D (Median Artery Contribution), and Type E (Complex Configuration).

Prevalence of SPA Types
The most common configuration observed was Type A, accounting for 32% of the samples. This classical arch, formed by the anastomosis between the radial and ulnar arteries, is often considered the standard configuration in anatomical texts. The second most prevalent type was Type B (27%), where the ulnar artery alone formed the arch, highlighting its dominance in supplying the hand. Types C, D, and E were less common, indicating that while variations exist, the classical and ulnar-dominant patterns are predominant[9,10].

Arterial Diameter Measurements
The mean diameters of the ulnar (2.5 mm) and radial (2.2 mm) arteries provide important reference points for surgeons. These measurements can guide the selection of appropriate surgical instruments and techniques, especially in microsurgical procedures where precision is paramount[11].

Branching Patterns
The classic branching pattern of the common palmar digital arteries was present in 67% of the hands, with variations observed in the remaining 33%. The presence of an accessory branch from the radial artery in 10% of the cases indicates additional anatomical variability that surgeons must be aware of to avoid inadvertent vascular damage[12].

Comparative Analysis
The comparison between right and left hands, as well as between male and female cadavers, revealed no significant differences in SPA configurations. This finding suggests a consistent pattern of variation irrespective of hand dominance or gender, reinforcing the applicability of these results across different patient populations.

Clinical Implications
Understanding the variability in SPA configurations is crucial for surgical planning and interventions. The presence of a ulnar-dominant or radial-dominant arch can impact surgical decisions, particularly in reconstructive surgeries and in harvesting arterial grafts for coronary artery bypass. The significant contribution of the median artery in Type D arches, observed in 13% of the hands, underscores the need for careful preoperative imaging to identify and preserve this vessel during surgical procedures.

Study Limitations
While this study provides valuable data, it is limited by its sample size of 60 hands. Larger studies are needed to confirm these findings and to explore any potential correlations between SPA variations and demographic factors such as age and ethnicity. Additionally, the cadaveric nature of the study may not fully capture the dynamic aspects of vascular supply in living individuals.

Future Directions
Further research should focus on advanced imaging techniques to study SPA variations in vivo, which could provide more detailed information about the functional implications of these anatomical differences. Studies investigating the correlation between SPA configurations and specific clinical outcomes could also enhance the practical applications of this knowledge in surgical practice.

CONCLUSION
This study highlights the significant anatomical variability of the superficial palmar arch, highlighting the need for individualized preoperative assessments. Understanding these variations can aid in optimizing surgical approaches, reducing the risk of complications, and improving patient outcomes. The findings contribute to the existing body of knowledge and provide a foundation for further research in this area.

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