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Anatomical Study: Anatomical Variations of Dorsalis Pedis Artery and Its Correlation with Clinical Assessment

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ABSTRACT

The dorsalis pedis artery, the distal continuation of the anterior tibial artery, is a key landmark for pulse assessment, vascular access, and reconstructive procedures of the foot. Its anatomical variability, however, may complicate clinical examination and contribute to diagnostic uncertainty. **Objectives:** To describe the anatomical configurations and morphometric features of the DPA and to determine how these variations influence clinical pulse palpability. **Methods:** A descriptive cross-sectional study was conducted at Khyber Medical College, Peshawar, from March 2024 to August 2025, in collaboration with the Radiology Department at Khyber Teaching Hospital. A total of 103 lower limbs were examined through standardized palpation followed by colour Doppler ultrasonography using a 7.5–10 MHz linear transducer. The artery's origin, course, termination, diameter, and length were documented and classified. Associations between anatomical type and pulse palpability were assessed using Chi-square tests and Cramer's V. **Results:** The DPA was present in all limbs. Type I was the most common pattern (80.6%). Variant origins (Types II, IV, V) accounted for roughly one-fifth of cases. A palpable pulse was detected in 88.3% of limbs, with significantly higher palpability in Type I compared with variant types ($p<0.001$). Pulse palpability did not differ by sex or limb side. **Conclusions:** Although the DPA generally follows a predictable anatomical course, variations are not uncommon and may reduce clinical pulse detectability. Recognition of these variants is important for accurate vascular assessment, imaging interpretation, and surgical planning.

INTRODUCTION

The dorsalis pedis artery (DPA), the distal continuation of the anterior tibial artery, is an essential vascular landmark for bedside assessment of peripheral perfusion and remains one of the routinely examined pedal pulses in clinical practice [1]. Its superficial position on the dorsum of the foot makes it easily accessible for pulse palpation, Doppler assessment, and a range of diagnostic and surgical procedures. Beyond routine vascular examination, the DPA is frequently used for flap planning, grafting, and distal access in complex limb revascularization. Anatomical reliability is therefore assumed in daily practice, yet normal variants may complicate pulse detection or lead to misinterpretation of vascular status [2, 3]. Although the Type I configuration direct continuation of the anterior tibial artery, is the most frequently reported pattern, multiple studies have described high-origin anterior tibial divisions, double-origin vessels, and collateral replacements arising from the peroneal system [4]. These deviations may produce absent or weak palpable pulses despite normal perfusion, contributing to diagnostic uncertainty or unnecessary investigations [5]. Understanding these variations is especially important in

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settings where palpation remains the primary initial assessment tool [5]. Recent advances in noninvasive vascular imaging, particularly high-resolution Doppler ultrasonography and angiographic techniques, have increased the need for precise anatomical mapping of pedal arteries. Accurate identification of the DPA supports safer interventional radiology procedures, optimizes flap donor-site selection, and assists surgeons in planning reconstructive, orthopedic, and vascular interventions [6, 7]. Despite the clinical importance of this artery, regional data documenting its anatomical patterns and their effect on pulse detectability remain limited, especially in populations where vascular assessments are frequently performed by palpation alone. Accordingly, the present study investigates the anatomical configurations and morphometric characteristics of the DPA in a local adult population and examines how these structural variations influence clinical pulse palpability. Using combined physical examination and colour Doppler ultrasonography, the study compares classical and variant arterial patterns to clarify their clinical implications.

In routine clinical practice, absent or diminished dorsalis pedis pulses are often interpreted as indicators of peripheral vascular compromise, despite the possibility of underlying anatomical variations in an otherwise well-perfused limb. There is limited locally generated, imaging-correlated evidence assessing dorsalis pedis artery anatomical variants and their direct impact on clinical pulse palpability, highlighting the need for population-specific evaluation.This study aimed to enhance anatomical understanding, reduce misinterpretation of absent pedal pulses, and improve accuracy in vascular assessment and surgical planning.

METHODS

This descriptive cross-sectional study was conducted from March 2024 to August 2025 at the Department of Anatomy, Khyber Medical College, Peshawar, in collaboration with the Department of Radiology at Khyber Teaching Hospital. The Institutional Research and Ethical Review Board (IREB) of Khyber Medical College/Khyber Teaching Hospital approved the protocol (Certificate No. 167/DME/KMC). The study was conducted in accordance with the principles of the Declaration of Helsinki (2013 revision), and written informed consent was obtained from all participants before examination. Participant anonymity and confidentiality were ensured, and participation was voluntary with the option to withdraw at any time without affecting clinical care. Adult volunteers and patients temporarily attached to the Anatomy Department and Radiology Unit for teaching ultrasound or minor musculoskeletal assessments were invited to participate. A non-probability consecutive sampling approach was used, enrolling all eligible adults during the study period. Individuals aged 18 years or older with no history of peripheral vascular disease, major trauma, deformity, or previous foot surgery, and with normal skin colour and temperature of the feet, were included. Exclusion criteria were diabetes mellitus, known vascular disorders, visible surgical scars over the dorsum of the foot, active infection, significant oedema, or pregnancy. The sample size was calculated using the formula for estimating a single population proportion: $n = Z^2 \times p \times (1 - p) / d^2$, where Z is the value corresponding to a 95% confidence level (1.96), p is the expected proportion of anatomical variation, and d is the allowable error. Previous reports suggested dorsalis pedis artery (DPA) variations in approximately 20–25% of individuals, and p was set at 0.22 with d at 0.09 [8], yielding a minimum sample of 95 limbs. To increase precision and compensate for potential data loss, 103 limbs were finally included. All examinations were performed in a quiet room with ambient temperature maintained at approximately 22–24°C. Participants were examined in the supine position with the ankle slightly dorsiflexed and the feet at heart level, and were allowed to rest for at least 10 minutes before assessment. The DPA pulse was first sought by palpation lateral to the tendon of extensor hallucis longus and recorded as palpable or not palpable. The same examiner used light fingertip pressure in a standardized manner to avoid artificially occluding the artery. When the feet felt cold, they were gently covered until the skin temperature normalized before palpation. Following clinical examination, colour Doppler ultrasonography was performed using a 7.5–10 MHz linear-array transducer to confirm the presence and course of the DPA. Because the DPA is a superficial vessel on the dorsum of the foot, this frequency range provided sufficient resolution and depth penetration to delineate its origin, course, and branching pattern. For participants with greater soft-tissue thickness, depth, and gain settings were adjusted, and the probe was gently angled until a clear colour and spectral Doppler signal was obtained; no limb was excluded because of inadequate visualization. The origin, course, termination, external diameter, and total length of the DPA were documented. Anatomical variations of the DPA were categorized using the modified classification which recognizes Types I (continuation of the anterior tibial artery), II (high origin), IV (double origin), and V (collateral replacement). Each morphometric measurement was taken three times by the same examiner, and the mean value was used for analysis to minimize intra-observer variability. Independent reviewers confirmed the palpation findings, and an experienced radiologist performed all Doppler examinations. A pilot evaluation of ten limbs showed complete inter-observer agreement for pulse

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palpability (κ = 1.0). All data were analyzed using IBM SPSS Statistics version 26.0. Continuous variables such as age, height, weight, and arterial measurements were summarized as means and standard deviations. Categorical variables, including sex, side, DPA type, and pulse palpability, were described as frequencies and percentages. Because these variables are categorical, χ^2 tests with Cramer's V were used to examine associations and effect sizes between DPA type and pulse palpability, as well as between palpability and demographic factors (sex and side). A p-value of less than 0.05 was considered statistically significant.

RESULTS

The study evaluated 103 limbs from adult participants with a mean age of 43.27 ± 11.36 years. Most participants were male (66.0%), with average anthropometric measures of 165.52 cm in height, 66.23 kg in weight, and a BMI of 24.24 ± 3.42 kg/m^2. Right limbs accounted for 37.9% of assessments and left limbs for 62.1%, indicating a well-distributed sample (Table 1).

Table 1: Demographic Characteristics of the Study Population (n=103)

Variables	Category	n (%) / Mean ± SD
Age (Years)	–	43.27 ± 11.36
Sex	Male	68 (66.0%)
	Female	35 (34.0%)
Height (cm)	–	165.52 ± 6.90
Weight (kg)	–	66.23 ± 8.68
BMI (kg/m^2)	–	24.24 ± 3.42
Side Examined	Right	39 (37.9%)
	Left	64 (62.1%)

Among the 103 limbs assessed, most DPAs (87.4%) followed a normal superficial course, with smaller proportions showing a deep (6.8%) or tortuous (5.8%) trajectory. The artery most frequently continued as the first dorsal metatarsal artery (59.2%), followed by the arcuate (23.3%) and lateral tarsal arteries (17.5%). Mean dimensions were 3.05 ± 0.53 mm in diameter and 8.48 ± 1.05 cm in length, indicating generally uniform anatomy with a minority of morphological variations (Table 2).

Table 2: Anatomical and Morphometric Findings of the Dorsalis Pedis Artery (n=103)

Variables	Category	n (%) / Mean ± SD
Presence of DPA	Present	103 (100.0%)
Origin of DPA	Type I – Continuation of AnteriorTibial Artery	83 (80.6%)
	Type II – High Origin from ATA	15 (14.6%)
	Type IV – Double Origin	3 (2.9%)
	Type V – Collateral Replacement	2 (1.9%)
Course of DPA	Normal (Superficial)	90 (87.4%)
	Deep Course	7 (6.8 %)
	Tortuous	6 (5.8 %)
Termination Pattern	First Dorsal Metatarsal Artery	61 (59.2%)
	Arcuate Artery	24 (23.3%)
	Lateral Tarsal Artery	18 (17.5%)
External Diameter (mm)	–	3.05 ± 0.53 (2.02–4.32)
Length (cm)	–	8.48 ± 1.05 (6.27–11.25)

The DPA pulse was palpable in 88.3% of limbs, with only 11.7% showing an absent pulse. A strong association was found between arterial origin and palpability (χ^2 = 28.6, p<0.001), as Type I arteries had the highest detection rate (96.4%) while variant types more frequently lacked a palpable pulse. This moderately strong correlation (Cramer's V = 0.527) indicates that anatomical variation significantly affects clinical pulse detection (Table 3).

Table 3: Association Between Anatomical Variation of the Dorsalis Pedis Artery and Pulse Palpability (n=103)

DPA Types	Palpable, n (%)	Not Palpable, n (%)	Total, n (%)	χ^2 (df)	p-value	Cramer's V
Type I – Continuation of the anterior Tibial Artery	80 (96.4%)	3 (3.6%)	83 (80.6 %)	–	–	–
Type II – High Origin from the Ata	9 (60.0%)	6 (40.0%)	15 (14.6 %)	–	–	–
Type IV – Double Origin	1 (33.3%)	2 (66.7%)	3 (2.9 %)	–	–	–
Type V – Collateral Replacement	1 (50.0%)	1 (50.0%)	2 (1.9 %)	–	–	–
Total	91 (88.3%)	12 (11.7%)	103 (100 %)	28.6 (3)	<0.001*	0.527

* Pearson Chi-square = 28.599, df = 3, p < 0.001 (significant). Cramer's V = 0.527 → moderately strong association between DPA type and pulse palpability

Pulse palpability did not differ significantly by sex or limb side, with both variables showing non-significant χ^2 values. This demonstrates that demographic and laterality factors do not affect the detectability of the dorsalis pedis artery pulse (Table 4).

Table 4: Association Between Pulse Palpability, Sex, and Side (n=103)

Variables	Category	Palpable, n (%)	Not Palpable, n (%)	Total, n (%)	χ^2 (df)	p-value	Cramer's V
Sex	Male	60 (88.2%)	8 (11.8%)	68 (66.0%)	0.003 (1)	0.960	0.005
	Female	31 (88.6%)	4 (11.4%)	35 (34.0%)			

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Side Examined	Right	35 (89.7%)	4 (10.3%)	39 (37.9%)	0.12 (1)	0.731	0.034
	Left	56 (87.5%)	8 (12.5%)	64 (62.1%)			

* All tests are Pearson Chi-square (2 × 2 tables); Fisher's exact p > 0.05 in both comparisons.

This study demonstrates that the DPA most commonly originates as a Type I vessel with a superficial and consistent course, explaining the high palpability observed in most limbs. In contrast, variant origins were associated with reduced pulse detection, as reflected in markedly lower palpability rates compared with Type I (96.4% vs. 60%, 33.3%, and 50%). This pattern aligns with the significant association between origin type and palpability (χ^2 = 28.6, p<0.001; Cramer's V = 0.527), underscoring the clinical relevance of anatomical variation for vascular assessment and surgical planning. The X-axis shows the four anatomical patterns (Types I, II, IV, and V), while the Y-axis depicts the percentage of limbs with palpable or non-palpable pulses. The clustered bars highlight the markedly higher palpability in Type I arteries compared with the variant types (Figure 1).

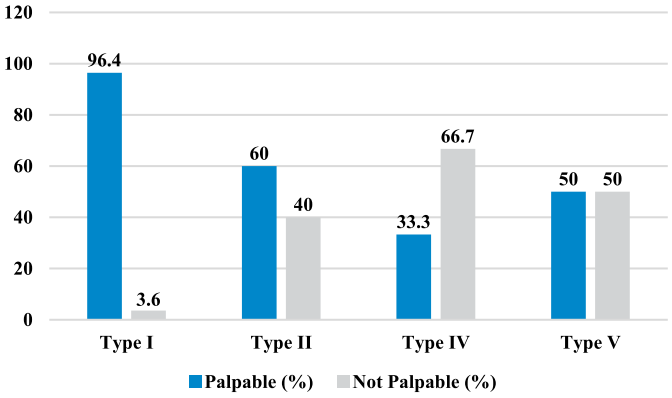

Figure 1: Distribution of DPA Origin Types and Their Corresponding Pulse Palpability in 103 Limbs

DISCUSSION

In this investigation, the most common type was the DPA, which continued from the anterior tibial artery (Type I), accounting for 80.6% of the limbs, while variants (Types II, IV, V) made up about 1 in 5 limbs. This distribution is consistent with recent anatomical studies, which report predominance of the classic pattern while also acknowledging, albeit a smaller minority, variants. In a cadaver-based population-level study, Hemamalini and Manjunatha *et al.* noted alternative sources and courses, with origins from 'textbook' locations, which also carry important implications in the hands of the surgeon [8]. At the case level, vascular imaging continues to reveal DPA arising from the peroneal artery and other unusual configurations, indicating variant anatomy is by no means rare and also complicates surface examination or planning access [9]. Clinical implications from your cohort were the associations in origin type with palpable pulse (χ^2 = 28.6; Cramer's V = 0.527). This aligns with modern teachings that the absence of a DPA pulse does not equate to pathology; clinical appreciation involves both the anatomical and physiological. DPA is identified as a peripheral pulse, and variation in anatomy and technique is warranted [10]. Additionally, Doppler sonography is one of the most palpation-equivalent techniques and is increasingly recommended as a first-line, non-invasive test for vascular assessment of the foot and ankle [11]. Current morphometric values align with established imaging ranges for the distal anterior tibial/DPA segment, confirming suitability for Doppler assessment and distal access procedures. These findings are consistent with modern CT angiography and Doppler criteria used for evaluating pedal vessel caliber and hemodynamics [12, 13]. From a revascularization standpoint, the DPA continues to serve as an important distal target or access point, even as therapeutic strategies evolve. Recent multicenter studies have reported favourable outcomes for popliteal-to-distal and pedal bypasses, as well as newer conduit options that support limb salvage in critical ischemia. Ultrasound-guided pedal access, including via the DPA, is now widely used when antegrade routes are not feasible, with evidence supporting its safety and expanding indications [14]. The angiosome concept further highlights that restoring flow to the DPA and first dorsal metatarsal region can meaningfully affect wound healing, as shown in contemporary perfusion-imaging studies [15, 16]. Current finding that sex and side did not affect palpability fits with current bedside guidance: examination reliability hinges on consistent technique and awareness of anatomic course, with Doppler as a rapid adjunct when edema, obesity, or variant paths obscure signals [10]. In diabetes and foot ulcer care settings where DPA assessment is routine, recent international guidelines emphasize a combined strategy of clinical pulses, Doppler/duplex, and, when needed, advanced imaging to direct revascularization and gauge healing potential [17]. The anatomically based, reconstructively related conclusions can be strengthened further. Modern literature continues to validate the adaptability of the FDMA-based flaps originating from the DPA system to repair the hallux and dorsal foot defects. More recent reviews have also pointed out the utility of briefly described, flow-through, perforator flaps, which take advantage of the pneumatically flow-continuous state of the DPA [18, 19]. These multiple, interconnected strands of anatomy, noninvasive testing, imaging, endovascular/bypass tactics, and flap design justify the need and importance of clinical documentation

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of DPA variations and their impact on the palpability demonstrated in this study [20]. The dataset includes clinical palpation and Doppler confirmation, exceeding the calculated minimum sample size and improving internal validity; however, the single-center design and lack of universal angiographic mapping may be limitations in generalizability. Future multicenter studies using standardized duplex ultrasound, CT angiography (CTA), or dual-energy CT (DECT) protocols may improve estimates of prevalence and also clarify the hemodynamic and clinical implications of each anatomical variant. Additionally, the use of consecutive participants from the Anatomy and Radiology Departments introduces an element of convenience sampling, which may limit the representativeness of the study population. This study confirms that while the DPA typically continues from the anterior tibial artery, clinically relevant variants occur in about one-fifth of limbs and are associated with reduced pulse palpability. These anatomical differences help explain instances of absent pedal pulses despite otherwise normal perfusion. The findings support current recommendations to integrate palpation with Doppler or advanced imaging when needed, and they provide useful anatomical guidance for decisions involving pedal access, distal bypass, and flap planning.

The single-center design and use of convenience sampling from Anatomy and Radiology departments may limit the representativeness of DPA variant prevalence. Additionally, the absence of routine angiographic mapping restricted detailed hemodynamic correlation for each anatomical variant. Multicenter studies using standardized duplex ultrasound and CT angiography protocols are recommended to better define the prevalence and clinical impact of dorsalis pedis artery variants.

CONCLUSIONS

This study confirms that the DPA most commonly arises as a direct continuation of the anterior tibial artery, with about one-fifth of limbs showing anatomical variants. These variants were strongly linked to reduced pulse palpability, while sex and limb laterality had no meaningful influence. Recognizing such variations is essential for accurate vascular examination and for interpreting Doppler or imaging findings. A clear understanding of DPA anatomy can help avoid misinterpreting absent pulses and support safer planning in reconstructive and vascular procedures of the foot and ankle.

Authors' Contribution

Conceptualization: SK
Methodology: RUJ, MS, AK, MTS
Formal analysis: FSR, MS
Writing and Drafting: SK, FSR, RUJ, AK, SMTS
Review and Editing: SK, RUJ, MS, AK, SMTS, FSR

All authors approved the final manuscript and take responsibility for the integrity of the work.

Conflicts of Interest

All the authors declare no conflict of interest.

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