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Macroscopic Characteristics Of Dorsalis Pedis Artery In Human Cadavers: A Cross Sectional Study In North East India

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Abstract:
Background*: The dorsalis pedis artery (DPA) is the largest artery of foot distal to ankle joint. It is the main source of blood supply and very frequent to advertise variations. The study aimed to enrich knowledge of the anatomy of DPA by outlining its origin, course and branching patterns and termination.*
Materials & Methods*: A Cross Sectional descriptive type of tudy was conducted at Dept of Anatomy, AGMC in 2 years of duration from 2020-2022 with 50 preserved cadavers (lower limb of adult & stillborn babies from Obs. & Gynae. Dept, AGMC). 100 dissected lower limbs have been studied for the origin, course, branching pattern, termination of DPA and recorded through charts, table, and photographs.*
Results*: In present study, DPA was found to have, normal course and branching pattern- in 60% cadavers (out of 100 limbs). Variation in origin was found in 5% (out of 40 limbs), variation in course was found in 10% (out of 40 limbs) and variation in branching pattern was seen in 40% (out of 100 limbs). Variations are classified as Type A,B,C,D,E,F,G,H, I where Type D is new variation which was not yet published in any previous literature. Absent of DPA - 5% (out of 40 limbs) 6. Absent of Arcuate - 36% (out of 100 limbs). The findings of study have been compared and correlated closely with available literature.*
Conclusions*: Understanding of possible DPA variations should be very much significant to clinicians to decide whether the absence of pulse of DPA is due to pathology of vessels or the artery variation and so before surgery it is advisable to have pre-operative angiography for any abnormality to avoid unnecessary surgical risk.*
Keywords*: Dorsalis Pedis artery, Arcuate artery, Peripheral arterial disease, Variation.*

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I. Introduction

A sound knowledge of Anatomy of arterial supply in lower limb is necessary for all angiographers, vascular surgeons and reconstructive surgeons who operate upon the foot region. The anatomical study of the arteries of the foot is necessary for further advances in arterial reconstruction. Such reconstruction often avoids amputation in cases of arterial trauma resulting from industrial and automobile accidents, as well as in patients with diabetes and severe ischemia of the lower limbs[1]. The lower limb in man is specially designed for locomotion and weight bearing. The foot being the extreme end of lower limb is vulnerable to injuries especially in diabetic patients. The healing process of wounds depends on an effective arterial supply. Foot may also succumb to ischemic changes if arterial supply is compromised due to atherosclerosis, diabetes mellitus or Berger's disease[2]. As the largest artery distal to the ankle joint, the dorsalis pedis artery is the main source of blood supply to the dorsum of foot[3]. It is the continuation of anterior tibial artery distal to the ankle. It courses straight on the medial side of the dorsum giving branches and then dips into the sole to complete the plantar arterial arch. The variation of branching pattern of arteries, accessory arteries, aberrant arteries are commonly observed. Dorsalis pedis artery is an easily accessible artery for assessing pedal pulsation[4]. The most preferred site for palpation of dorsalis pedis artery is against the navicular bone, however it can be palpated from midpoint between the malleoli to the proximal end of first intermetatarsal space. A diminished or absent dorsalis pedis pulse usually suggest vascular insufficiency. However, a congenitally non palpable dorsalis pedis pulse may found in healthy person. It is absent, unilaterally, or bilaterally, in 2-3 % of young healthy individuals[5]. The anatomical basis for the absence of its pulsation is the change in the arterial branching patterns and deviant course with small caliber. The dorsalis pedis flap is one of the most common used in flap surgery. Knowledge of the vascular anatomy is key to ensure the safety and reliability of flap surgery. More recently dorsalis pedis fascio cutaneous flaps are used in the reconstruction of oral cavity defects in cases of oral cancers patients[6]. The

arterial system of the foot has attracted anatomist and surgeons for many years because of its importance and extreme variability[7]. This artery serves as an important vascular landmark on the dorsum of foot and is prone to exhibit variations8. Knowledge of variations will be useful in deciding whether absence of pulse is due to thrombosis of vessels or abnormal course or absence. Aberration of the usual anatomic pattern of origin, branching and anastomosing pattern are thus of prime importance in surgical operative techniques[9]. Many anatomical reference books provide a standardized anatomical location of the arteries of the foot; however, it is important to recognize that there are variations of anatomy, which are crucial to consider during a clinical assessment[10]. As variation in dorsalis pedis artery is common, it is essential to have a sound knowledge about the artery.

II. Material And Methods

A descriptive observational cross-sectional study was conducted for 2 years from 2020-2022 in dissection hall at Dept. of Anatomy of AGMC on human cadavers. Through census sampling a sample size of 100 of free formalin fixed lower limbs from human cadaver has been decided for study. The study was approved by the Institutional Ethics Committee, AGMC. All the lower limbs of embalmed adult male and female cadavers along with preserved donated stillborn babies, available in Dept of Anatomy, AGMC were included in the study. Lower limb with deformity, any fracture or any crush injuries leads to damage on dorsum of foot and Presence of ischemic features like ulcers, gangrene on the limb were excluded. The compartment of leg and dorsum of foot were dissected along with tracing of the arterial tibial artery and DPA. Short longitudinal incision was made at the midline of lower down from the level of ankle joint on the dorsal aspect till the level of web space. Branches of DPA were exposed after reflecting the extensor digitorum brevis muscle and traced down the origin, course and branching patterns and termination of the dorsalis pedis artery. The artery was colored for proper identification of variation and course and photograph has been taken and data was collected day to day work. In case of variations in the course and branching pattern of DPA, the posterior compartment was explored and all data has documented in a Performa where all necessary information were recorded. Descriptive statistics like frequency, percentage and expressed in text, graphs, pictures. Microsoft excel version 10 was used to analyzed the data.

III. Result

Lower limbs of 50 preserved (adult and donated still born babies) cadavers were dissected in dissection hall for study purposes. Collected data were analyzed with the use of descriptive statistics. Incidences of variations were calculated as percentages and frequency. The result was plotted in the form of photographs, diagrams, tables, and graphs which were compiled in Microsoft Word Document 2019. Then whole outcome of present study was compared with the works of previous workers which was taken from related journals through previous year. The findings and results of this existing studies were classified under below headings showing with results on bar diagram (**Chart 1**):

1. Normal course and branching pattern- 60% (out of 100 limbs)
2. Variation in Origin- 5% (out of 40 limbs)
3. Variation in course- 10% (out of 40 limbs)
4. Variation in branching pattern- 40% (out of 100 limbs)
5. Absent of DPA- 5% (out of 40 limbs)
6. Absent of AA- 36% (out of 100 limbs)

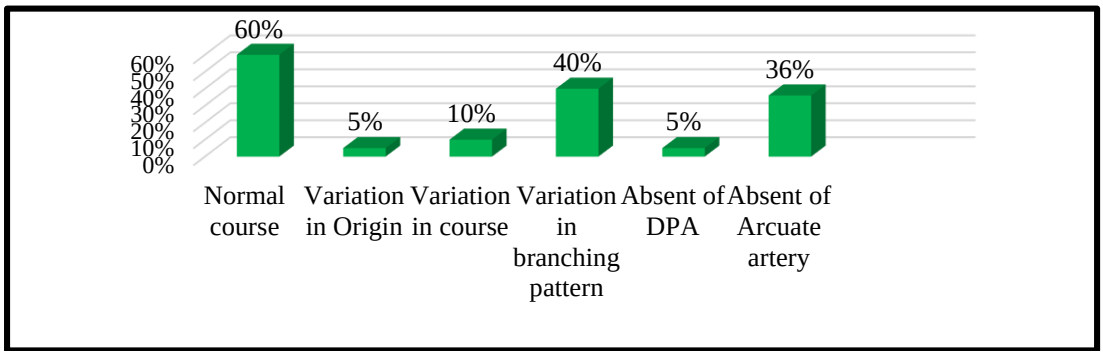

Chart 1: Bar Diagram Showing Variation of Dorsalis Pedis Artery

Normal course and branching pattern: The DPA divide into mainly two branches. The large branch is the first dorsal metatarsal artery (FDMA) that disappears between the two heads of the first interosseous space. A small size arcuate artery (AA), runs transversely across dorsum of foot and divides into 2 to 4 dorsal

metatarsal arteries (DMA). In the present study in 60% cases the anterior tibial artery (ATA) continued as DPA. The artery has crossed between the extensor hallucis longus medially and extensor hallucis brevis laterally. It has lateral tarsal artery (LTA), medial tarsal artery (MTA), arcuate artery (AA), and first dorsal metatarsal artery and continued as deep planter artery after piercing the first dorsal interosseous muscle. So, it was found that around 60 lower limbs specimens, out of 100 sample (lower limbs), had normal course arising from anterior tibial artery and has given all the above said branches in **(Figure 1: Type A).**

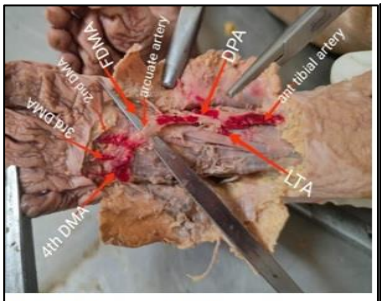

Fig 1: Type A: Showing normal origin, course of DPA and branching patterns in 60% limbs

Fig 3: Anterior tibial artery deviated to lateral side given variation in course of DPA in around 10% of limbs

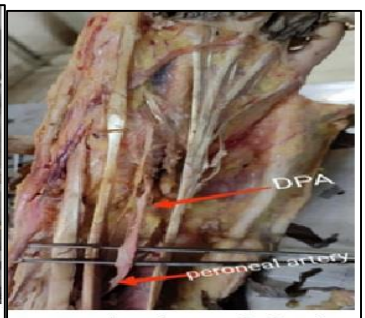

Fig 2: Showing variation in origin of DPA from peroneal artery in 5% limbs

Variations in origin: In 2 specimen the DPA arose from the peroneal artery. The anterior tibial artery was hypoplastic, the perforating branch of peroneal artery continued as the dorsalis pedis artery. Fibular/ peroneal artery arise from posterior tibial artery 2.5 cm distal to popliteus. After giving off the perforator, the posterior tibial artery entered the sole and divided into medial and lateral planter arteries. The perforator branch of peroneal artery passes through the opening in the interosseous membrane descended under cover of extensor digitorum longus and peroneus tertius and then between extensor hallucis longus and EDL and anastomosed with anterior malleolar branch of anterior tibial artery. Lastly it entered sole as deep plantar artery **(Figure 2).** So, in present study variable origin of DPA is around 5% cases.

Variation in course: DPA extends from the midpoint between the two malleoli to the proximal end of the 1st intermetatarsal space. In 4 specimens (10%), DPA had a lateral variation away from the midline, passes forwards along the lateral side of the dorsum of foot **(Figure 3).** In all cases, DPA deviated laterally in the proximal aspect and then returned to the first dorsal inter- metatarsal space in the distal aspect. It crossed inferior extensor retinaculum, below extensor digitorum longus and finally reached the proximal end of the intermetatarsal space.

Variation in branching pattern: 40 limbs have variation in branching patterns. In review of literature has been found that branching patterns of DPA which have varied explanations. As no textbook mentioned standard categories of different patterns except normal branching patterns so classification of branching patterns of DPA has arranged in present study as TYPE A to Type I.

In present study, it has been labelled normal pattern as TYPE-A, where all foresaid branches of DPA i.e., LTA, MTA, AA, FDMA were as per standard description. Branching pattern of DPA were observed and grouped as per their morphological appearance. 8 different patterns of branching DPA were found through this study. The anomalous branching patterns of the DPA was observed in 40% of cases. Accordingly, those were grouped as TYPE A, B, C, D, E, F, G, H, I with regards to the variation in branching pattern of DPA (**Figure 4**). **Type A**: Normal branching pattern of DPA. In present study, 60% cases have normal branching patterns which has given all branches as mentioned in textbooks **(Figure1)**. **Type B**: In the present study, 12 cases (30%) had branching patterns of this type where 2nd DMA directly arises from DPA and 3rd and 4th DMAs arises from LTA. The dorsalis pedis artery in its course provided medial tarsal artery, FDMA, 2nd DMA **(Figure 5a). Type C**: In the present study, 8cases (20%) had branching pattern of this type where FDMA directly arises from DPA and 3rd and 4th DMAs were given by LTA **(Figure 5b).** AA was absent. **Type D**: In the present study, 6cases (15%) had branching pattern of this type where 2nd DMA directly arises from LTA **(Figure 5c).** AA was absent. **Type E**: In the present study, 4cases (10%) had branching pattern of this type where DPA has arcuate artery arising at Cuneonavicular joint rather than its normal position at tarsometatarsal joint **(Figure 5d). Type F**: In the present study, 6 specimens (15%) had same branching pattern where DPA was found to have short straight course and divided into medial and lateral branches. The medial branch has been continued as FDMA and joined the plantar arch. The lateral branch coursed obliquely towards the head of the other metatarsal bones and gave off 2nd, 3rd and 4th metatarsal arteries. AA was absent. These medial and lateral branches were named as dorsalis arteria medialis and dorsalis arteria lateralis (**Figure 5e). Type G**: In the present study, in 2 cases (5%) DPA was hypoplastic, it terminated just below ankle into two terminal branches; MTA and LTA. AA was

absent and all DMAs were given by plantar arch **(Figure 5f). Type H**: In the present study, in 1 case (2.5%) LTA and AA were absent. Lateral side of dorsum of foot is supplied by planter arch **(Figure 5g). Type I**: In the present study, in 1 case (2.5%) Anterior tibial artery divides into a larger lateral tarsal artery and a smaller dorsalis pedis artery **(Figure 5h)**. DPA continues downwards over talas, navicular, cuneiform bones and then between 1st and 2nd metatarsal bones, it gives off FDMA. MTA and AA were absent. In present study, all the variations of DPA were found already in different literature**.** Only **type D** variation in present study which was not yet found in any literature those were reviewed through earlier studies.

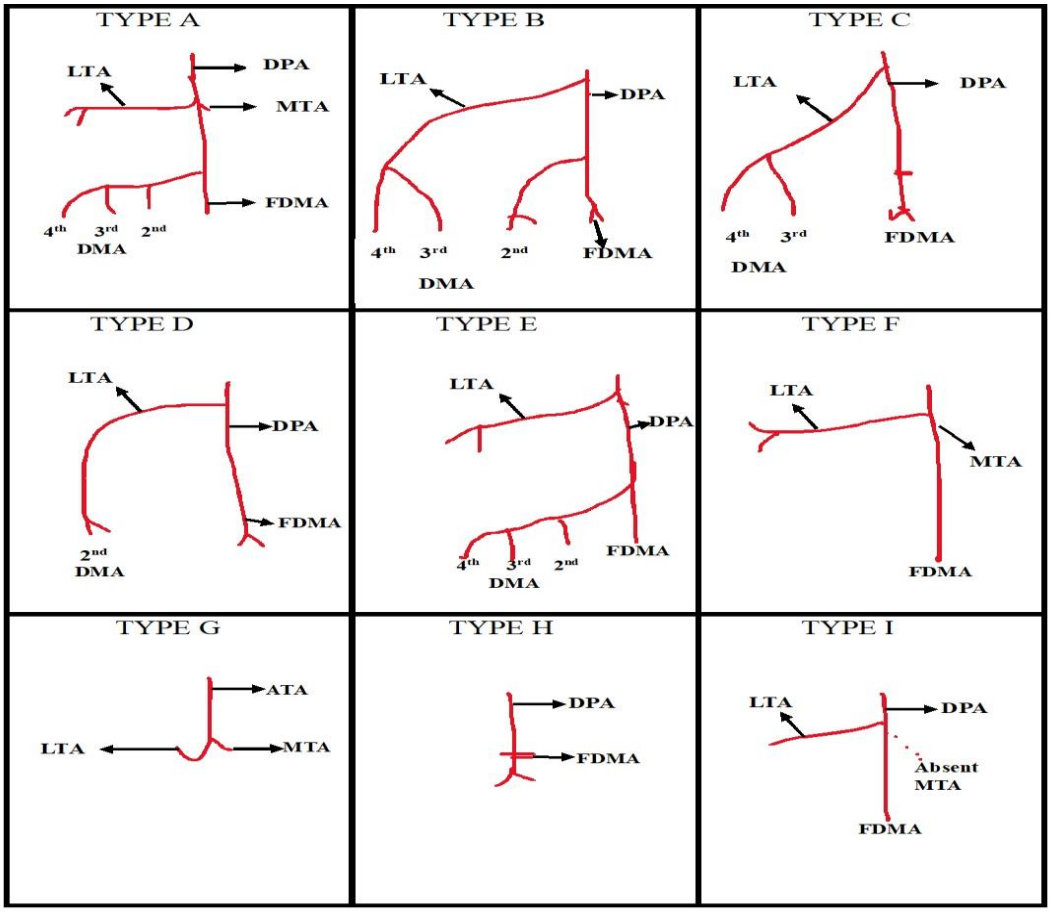

Figure 4: Schematic diagram of branching patterns of DPA

Absence of Dorsalis pedis artery: Out of 40 limbs, 2 limbs (5%), dorsalis pedis artery was absent (Type G). The anterior tibial artery bifurcated into two terminal branches as medial and lateral tarsal artery in front of ankle joint. The caliber of the artery was very small. It ended by giving lateral tarsal branch which supplied lateral aspect of dorsum of foot. Here DPA and FDMA were completely absent. Further course of the artery is not traceable, so beyond the ankle there was absence of DPA. The lateral planter artery is larger and became the main source of dorsum of foot. **Absence of Arcuate artery:** In 36% cases (out of 100 limbs specimen) arcuate artery was absent. In type B, C, D, F, G, H, I; there was absent of arcuate artery. Type B has no AA, 2nd DMA arises from directly DPA and 3rd and 4th from LTA. In type C and type D, in absence of AA, dorsum of foot is supplied by LTA. In type F, G, H, I in absence of arcuate artery, arterial supply of dorsum of foot is provided by planter arch.

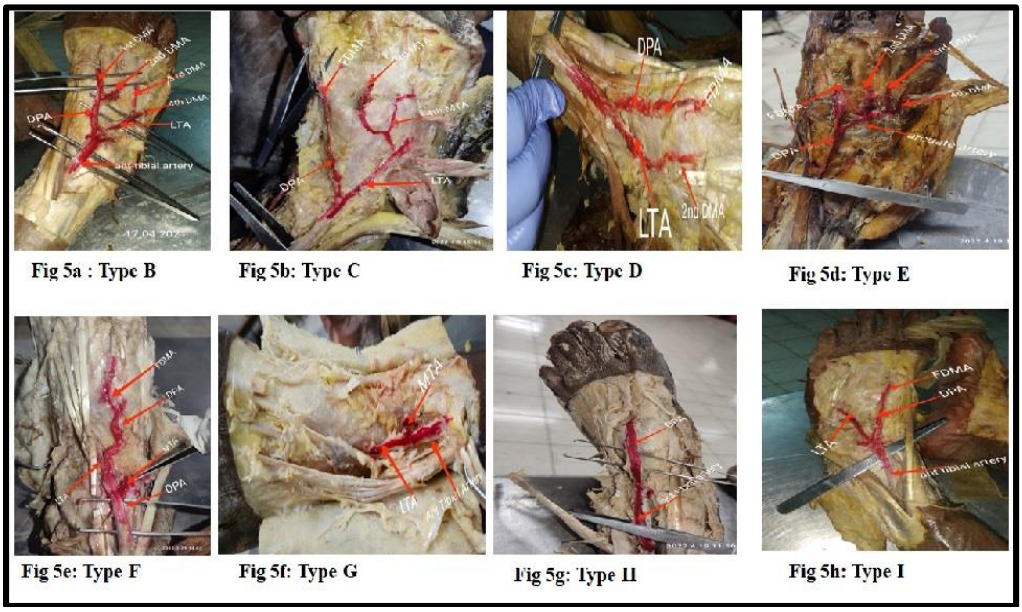

Fig 5a : Type B | Fig 5b: Type C | Fig 5c: Type D | Fig 5d: Type E

Fig 5e: Type F | Fig 5f: Type G | Fig 5g: Type H | Fig 5h: Type I

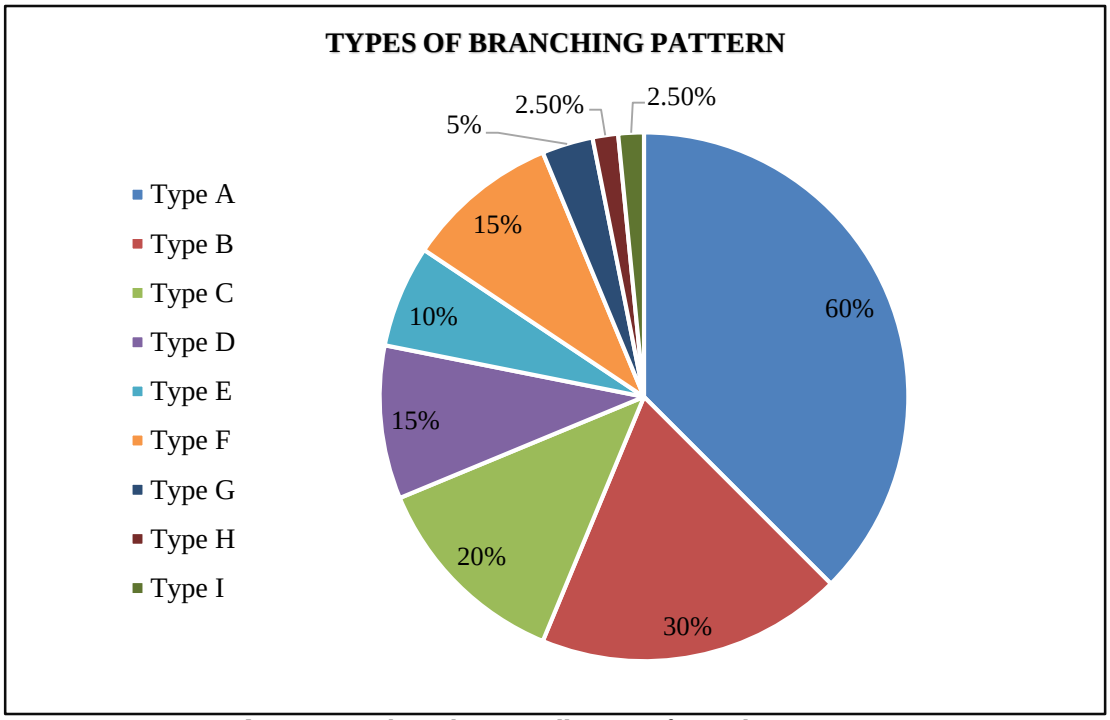

Chart 2: Pie Chart Showing All Types of Branching Patterns

IV. Discussion

DPA is very interesting, informative, attracting, important study topic for many Anatomist, Vascular & Foot surgeons, Plastic surgeons, Radiologist and Physicians for its variable vascular patterns in the foot. The DPA is a constant embryonic vessel that plays an important role in the normal arterial morphogenesis of the lower limb[12]. Depending on the functional dominance and development of multiple and plexiform sources of vessels and anastomoses between of those arterial patterns of lower limbs has found regression and divergence of some vessels in the mode of origin and course from the principal vessels. So, their development explains why the anomalies and variation of the blood vessels of lower limbs happens. The dorsalis pedis artery is noted for its variation[13]. The present study was undertaken to study in details variation in the origin, course, and branching pattern of DPA in 100 lower limbs specimens by intricate dissection method.

In our study, normal pattern of DPA were found 60% cases where other study has also shown almost very nearer results (Table 1). Vijayalaksmi et al[4] have shown normal branching pattern in 56% cases, Rajeswari

et al[17] in 54.76%, Luckrajh et al[21] in 42.50% cases and Hemamalini et al[11] in 67.5%. On the other hand, EL-Saeed et al[1] reported normal branching pattern in 95%, Vengadesan & Pushpalatha[19] in 90%. George et al[2] in 92% documented a much higher frequency in the prevalence of the standard anatomical course of DPA. This suggests the variability in the branching patterns of DPA. However, the percentage of the normal branching pattern was higher than percentage of the abnormal branching pattern in all studies including present study. Hypoplasia of one of DPA can cause abnormal blood supply to the foot. In present study, it was observed that 5% cases dorsalis pedis artery was originated from perforating branch of peroneal artery instead of anterior tibial artery. Vijayalaksmi et al[4], B Vengadesan et al[24] and Hemamalini et al[11] observed same 5% cases like present study. Kulkarni and Ramesh[14] found variation in origin in 12.10% cases. Anju George et al[2] and Ntuli et al[10] got around 6% cases of variation in origin. In present study, the artery has normal course in 60 cases, but in 10% of limbs, course of DPA is laterally deviated, showed bifurcation just distal to ankle joint, the medial branch continued as dorsalis pedis artery. Kesabi D et al[16] reported in their study lateral variation of DPA and higher bifurcation of anterior tibial artery to form dorsalis pedis at junction of upper 3/4th and 1/4th of leg. In a study of B Vengadasen[24], 5% cases were observed as laterally deviated from its original position. In comparison with recent study in Mamta et al.[8] observed 7.5% and Hemamalini et al[11] got 2.5% in lateral variation of DPA. The navicular bone is a landmark for palpation of the DPA pulse. However present study shown cases where DPA was deviated laterally. This variation suggesting that dorsalis pedis pulse is not always felt lateral to the tendon extensor hallucis longus, it can be deviated laterally without vascular disease. Table 2 showing comparison with other author in branching patterns of DPA. The present study denotes, out of 100 lower limbs, 40 cases are abnormal branching patterns. Type B: Second dorsal metatarsal artery (DMA) originating from the DPA was reported by Rajeshwari et al.[17] in 2.38% cases, and Awari and Vatsalaswamy[18] 10% cases. These patterns resemble Type B branching pattern. EI-Saeed et al[1] also reported 2nd DMA arising from DPA but they have not mentioned the prevalence of the cases. Luckrajh et al[21] showed 7.5% cases of type B. Chepte AP et al[20] found type B pattern in 6.66% cases. In present study, type B pattern was observed around 12 cases (30%). Type C was observed around 5% cases in Chepte AP[20] study, where present study shows around 20% cases where 2nd DMA was absent. In present study, a variation found where LTA giving 2nd DMA. AA is absent. This variation was not found in previous any literature. Around in 6 limbs (15%), there were observed this variation, nomenclature given as TYPE D. Type E: High origin of Arcuate artery was reported by EI-Saeed et al.[1] in 30% cases, and Kaur et al.[26] in 1.66% cases Chepte Ap et al[20] in 3.33% cases. Present study observed high origin of AA in 10% cases. Type F: Vijayalakshmi et al[4] reported 8 cases (16%), kulkarni et al[14] 9.1% cases where DPA run a short straight course before terminating into Lateral and Medial main trunks; medial trunk continuing as DPA and FDMA. Mamatha et al[9] reported around 16% cases, there were present of medial and lateral tarsal artery. In the present study, 1 case (1.66%) had this type of pattern. Type G: DPA was hypoplastic. It was absent in 5% cases. The anterior tibial artery (ATA) ended by giving off tarsal branches beyond which the ATA was untraceable. Mamta[8] reported around 1 case entire artery was absent. Type H: In present study, in 2.5% cases LTA and AA were absent. Chepte AP[20] reported in their study around 1.66% cases of type H. Type I: FDMA was absent in 1 limb (2.5%). Awari and Vatsalaswamy[18] reported 8% cases in which FDMA was absent, Chepta AP[20] et al found 1.66% cases. AA was absent in 36 limbs. In cases of absence of AA, DMAs were supplied by LTA in 26 cases (Type B, C, D) whereas in 10 cases (Types G, F H, I) apart from FDMA all DMAs were given by plantar arch. Dinesh k. patel reported, arcuate artery was absent in 12% cases[6]. Awari PS & Vatsalaswamy P[18] reported 40% cases arcuate artery was absent where,10% cases DMAs arose from mixed sources of DPA & deep plantar arch.

Table 1: Incidence of normal branching pattern of the DPA by different authors in previous literature

Sl. No	Authors	Normal Branching Pattern
1	El- Saeed Et Al 1(2008)	95%
2	Vijayalakshmi Et Al4 (2011)	56%
3	Kulkarni And Ramesh 14(2012)	15.20%
4	Kaur Et Al26 (2013)	90%
5	Rajeswari Et Al17(2013)	54.76%
6	Sarad Kumar5 (2013)	96%
7	Mamata K & Bharati8 (2016)	72.50%
8	Vengadesan And Pushpalatha19 (2017)	90%
9	Luckrajh Et Al21 (2018)	42.50%
10	Ntuli Et Al10 (2018)	36.36%
11	Barot & Koyani22 (2019)	87.5%
12	Gautam & Sintakala23 (2020)	100%
13	B Vengadesan Et Al24 (2020)	90%
14	George Et Al2 (2020)	92%

15	Hemamalini Et Al11 (2021)	67.5%
16	**Present Study**	**60%**

Table 2: Incidence of variation in origin by previous authors

Sl. No	Author	Variation In Origin
1	Vijayalakshmi et al[4] (2011)	8%
2	Kulkarni and Ramesh[14] (2012)	12.10%
3	Kumari and Bharati8 (2016)	4%
4	vari and Vatsalaswamy[18] (2016)	4%
5	Vengadesan and Pushpalatha[19] (2017)	5%
6	Luckrajh et al[21] (2018)	5%
7	Ntuli et al[1] (2018)	6.06%
8	Anju George et al[2] (2020)	6%
9	B Vengadesan et [al24] (2020)	5%
10	Hemamalini et al[11] (2021)	5%
11	**Present study**	**5%**

The present study shows presence of arcuate artery in 60% of cases, in the 36% cases absence of arcuate artery, suggesting that the arcuate artery is not the primary blood supply of foot and absence of it, branches from plantar arch supply to the metatarsal spaces 2-4. Performance of a study on DPA in 30 cadaveric limbs revealed that dorsalis pedis artery was absent in 6.7% of cases, the arcuate artery was absent in 33%[7]. The finding of study is almost of the present study where DPA was absent in 5 % limbs and AA was absent in 36% of cases. Rajeswari et al[17] found 54.76% cases the ATA continued as the DPA, 9.52% cases DPA absent and 16.67% cases DPA failed to provide the arcuate branch. Vijayalaksmi et al[4] has shown absent of DPA in 2% cases. In 10 to12 % of people, the DPA may be too small to palpate or may be away from the normal position or absent. So, if there is failure to detect a dorsalis pedis pulse, it does not always indicate that presence of any arteriosclerotic disease or any arterial trauma but it also can be seen in normal persons too. Table 3 showing briefly compilation of the previous study with the present study. Through all studies, it can assume that variation of DPA has great significance. The present study is reporting type D significant variation which was not reported before. There are few limitations found while conducting the study like due to irregular surface of foot, doing meticulous dissection in foot was troublesome. Present study is cadaveric study and it was not correlated with any other study like Doppler and USG. The caliber of artery has not measured and sexual variation is not explored in this study.

V. CONCLUSION

Variations in anatomy of dorsalis pedis artery are incidentally found in routine dissection. The precise knowledge of vascular anatomy of ankle is indispensable for surgical techniques such as ankle arthroscopy, surgical release of club foot etc. Arterial abnormalities also increase the risk of postsurgical trauma. These days radiologist prefer DPA to femoral artery for performing angiographic studies because of easy accessibility and tiny complications. The added advantage is the patient can be ambulant very fast when compared with femoral artery approach and bleeding can be arrested easily in the DPA. The study has been described the anatomy of DPA by outlining its origin, course, branching pattern, absent of DPA and arcuate artery. Understanding of possible DPA variations should be very much significant to clinicians to decide whether the absence of pulse of DPA is due to pathology of vessels or the arterial variation. So, before surgery it is advisable to have pre-operative angiography for any abnormality to avoid unnecessary surgical risk. This study will enrich the knowledge of anatomy of DPA in doctor's fraternity.

Table 3: Showing compilation of the data available on the variations of DPA in origin, course and branching pattern published in literature till date and comparing them with present study variations

Author name & year	No of cases/ specimen	Normal pattern	Replaced by peroneal artery	Dorsalis Pedis Artery absent	Absent Arcuate artery	Lateral deviation/anomalous course	Branching pattern variations
El Saeed et al[1] (2008)	20	95%			10%	5%	20%
Vijayalakshmi et al[4] (2011)	50	56%	8%	2%	6%		16%
Kulkarni V and Ramesh[14] (2012)	33	15.20%	6%			12.10%	9.10%

Kaur et al[26] (2013)	60	90%					10%
Rajeswari et al[17] (2013)	42	54.76%		9.52%	16.67%		
Kumari and Bharati[8] (2016)	40	72.50%	7.5%	2.5%	5%	7.5%	27.5%
Sharad kumar[5] (2013)	100	96%					4%
Awari & Vatsalaswamy[18] (2016)	50	40%	4%		40%	4%	40%
Sanjoy et al[12] (2016)	50	98%	2%				
Vengadesan & Puspalatha[19] (2017)	40	90%	5%			5%	
Luckrajh et al[21] (2018)	40	42.5%	5%		32.5%	2.5%	50%
Ntuli et al[10] (2018)	33	36.36%	6.06%	6.06%	15.15%		6.6%
Barot & koyni[22] (2019)	40	87.5%		2.5%		10%	12.5%
Goutam & Sintakala[23](2020)	30	80%					
B Vengadesan et al[24] (2020)	44	90%	5%			5%	
George et al[2] (2020)	50	92%	6%	2%			
Hemamalini et al[11] (2021)	40	67.5%	5% bilateral		17.5%	5%	
Present study	100	60%	5%	5%	36%	10%	40%

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Conflicts of Interest**:** There were no such conflicts of interest involved in the study.

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