# Deep femoral artery branching by MDCT in a Turkish population and its potential clinical implications

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## SUMMARY

The deep femoral artery and its branches are vital for the arterial circulation of the lower extremity. The aim of the current study is to obtain morphometric and morphological data on the deep femoral artery and its branches and to investigate their clinical importance in the Turkish population. Morphometric measurements of the deep femoral artery and femoral artery were performed. The diameters of the femoral artery and deep femoral artery were measured in the axial plane. Classification was made according to the size of these diameters. A morphological classification was obtained by examining the variations of the deep femoral artery branches.

The distance from the origin of the deep femoral artery to the midpoint of the inguinal ligament was 39.56 ± 8.52 mm, and the distances from the origin of the lateral circumflex femoral artery to the medial circumflex femoral artery were 17.15 ± 4.79 mm and 12.52 ± 4.58 mm, respectively. The study results show that there was a significant difference between genders in terms of the diameters measured. In the classification made by using the diameters, Type D (39%) had the highest rate, whereas Type C had the lowest rate (7.3%). According to the morphological classification, Type I (52.1%) was the most common in all individuals, and Type V and Type VII (2.3%) were the least common. Our study includes both morphometric and morphological information about the femoral artery and deep femoral artery of the Turkish population. We consider that the current study will be useful for cardiologists, interventional radiologists, orthopedists, and regional surgeons in clinical practice.

**Key words:** Femoral artery – Lateral circumflex femoral artery – Medial circumflex femoral artery – Classification – Computed tomography

## INTRODUCTION

The external iliac artery continues as the femoral artery (FA) after the inguinal ligament (IL). The FA is the main artery responsible for supplying the lower extremity. The thickest branch of the FA is the deep femoral artery (DFA). Several variations can be seen in the morphology of the FA and its branches. The course and anatomical

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variations of the vessels of the lower extremities have attracted the attention of anatomists and surgeons for a long time (Prakash et al., 2010; Nasr et al., 2014; Manjappa and Prasanna, 2014; Rajani et al., 2015; Łabętowicz et al., 2019). The cause of these variations, which are based on the formation of unusual channels from the primary capillary plexuses, is usually embryological. Arterial patterns may occur as appropriate channels develop and others recede and disappear (Sanudo et al., 1993; Łabętowicz et al., 2019).

As treatment with endovascular techniques has increased, precise knowledge of vascular anatomy and its variations has become crucial. Due to its wide diameter, the FA is preferred as the primary access site by angiographers performing invasive cardiac and peripheral vascular procedures (Schnyder et al., 2001; Yu et al., 2020). Information about the anatomical variants of the FA and its branches is important for clinicians in procedures such as transluminal stenting, angioplasty and embolectomy in peripheral occlusive arterial diseases, evaluation of arterial status in trauma, imaging of vascular malignancies and identification of arterial diseases. Also, this information is valuable for orthopedists performing total hip replacements and trochanteric or intertrochanteric osteotomy (Łabętowicz et al., 2019; Sudarshana and Chaudhary, 2020).

The DFA, medial circumflex femoral artery (MCFA), and lateral circumflex femoral artery (LCFA) are used in vascular, orthopedic, plastic and reconstructive surgery (Choy et al., 2013; Tzouma et al., 2020). The LCFA and its branches are used for anterolateral thigh flaps, aortopopliteal bypass, coronary artery bypass graft, and extracranial-intracranial bypass surgeries. The MCFA may be exposed to iatrogenic injuries during hip joint surgery and flap plastic surgery, resulting in femoral head necrosis. Therefore, knowledge of variation about the length and origin of the DFA and its branches can help prevent complications during or after surgical procedures (Fukuda et al., 2005; Üzel et al., 2008; Tomaszewski et al., 2016; Vuksanović-Božarić et al., 2018; Tzouma et al., 2020).

In line with all this information, it is seen that both morphological and morphometric data of the FA and its branches are clinically very important. Therefore, in our study, the aims were to obtain data on the FA and to reveal the morphological and morphometric differences by gender and/or side.

## MATERIAL AND METHODS

In this study, the files of 630 patients were retrospectively scanned: these patients had been admitted to the Department of Radiology in Necmettin Erbakan University, Meram Faculty of Medicine, between August 2008 and March 2021, and the data of 130 (70 male, 60 female) individuals were included in the study. The study was approved by the Institutional Ethics Committee. In the study, images obtained by a Multidetector Computed Tomography (MDCT) device (Sensation 64, Siemens, Erlangen, Germany) with the parameters of KV: 120, Effective MaS: 50-170, MAS: 86, Pitch 1.4, Rotation speed: 0.5 sec, Detector area: 1.2 mm, Slice thickness: 1.5 mm were used. The images obtained from MDCT were reconstructed and analyzed on a MacBook Air (13-inch, 2017) laptop computer running macOS Big Sur (Version 11.2.3) and using the OsiriX Lite (V. 12.01.1) software. Images were transferred from MDCT in DICOM format to a folder on the computer via an external disk. Then, the measurements were taken on axial and 3D images in the OsiriX Lite software. All measurements were made by the same person and the results were given in millimeters (mm). Poor image quality, lack of contrast material and arterial aneurysm were our exclusion criteria. In addition, double DFA was detected on the right side of a female individual, and that extremity was excluded from the study. Because if we had included both DFAs in both distance and diameters, we could have obtained erroneous results by not following our methodology. In our study, the mean age was found as 50.33 ± 20.90 years (18-88) in males and 60.17 ± 17.76 years (18-86) in females.

The distances between the origin of the DFA from the midpoint of the anterior superior iliac spine and the pubic tubercle (midpoint of the IL) (Fig. 1a), between the origin of the LCFA originating the DFA and the origin of the DFA (Fig. 1b) and between the origin of the MCFA originating the DFA and the origin of the DFA (Fig. 1c) were measured.

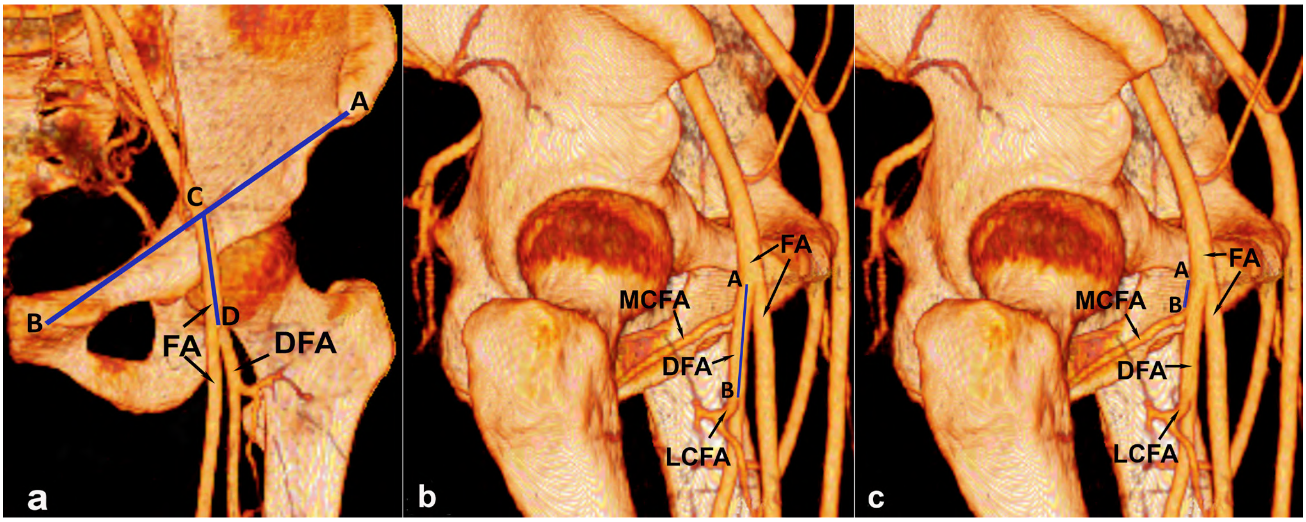


**Fig. 1.-** Three-dimensional volume-rendering CT reconstruction showing the length measurements: **a.** A left lower limb showing the distance between the origin of the DFA from the midpoint of the anterior superior iliac spine and the pubic tubercle (The distance between points C-D) (Observed from the anterior). **b.** A right lower limb showing the distance between the origin of the LCFA originating the DFA and the origin of the DFA (The distance between points A-B) (Observed from the lateral). **c.** A right lower limb showing the distance between the origin of the MCFA originating the DFA and the origin of the DFA (The distance between points A-B) (Observed from the lateral). (FA: Femoral artery, DFA: Deep femoral artery, MCFA: Medial circumflex femoral artery, LCFA: Lateral circumflex femoral artery).

The FA diameter at the level of the IL in the axial plane was noted (Fig. 2a). The FA diameters in the axial plane just before and after the separation of the DFA from the FA were measured (Figs. 2b,2c). The origin of the DFA in the axial plane was recorded.

### Morphometric classification of femoral artery

In our study, the classification proposed by Kawashima et al., (2021) according to the size of the FA and DFA diameters and the presence or absence of an ectopic side branch (ESB) deviating from the FA was used. Morphometric types according to Kawashima et al., (2021) are as follows:

Type A: DFA diameter ≥ FA Diameter just after the separation of the DFA from the FA.

Type B: DFA diameter < FA Diameter just after the separation of the DFA from the FA and the presence of originating ESB before originating the DFA from the FA.

Type C: DFA diameter < FA Diameter just after the separation of the DFA from the FA and the presence of an ESB originate the FA bifurcation.

Type D: DFA diameter < FA Diameter just after the separation of the DFA from the FA and the absence of ESB.

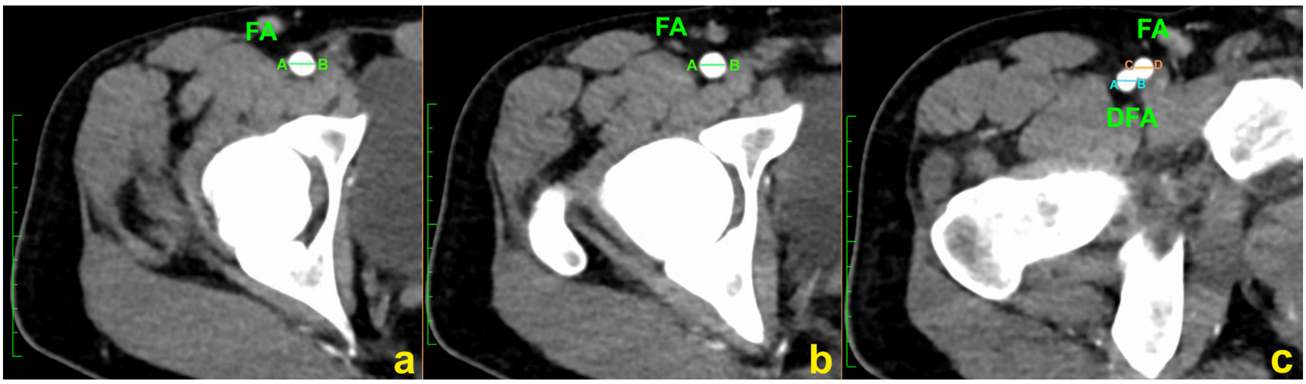


**Fig. 2.-** Showing the diameters in the axial plane: **a.** A right lower limb showing the diameter of the proximal FA (at the level of the IL). **b.** A right lower limb showing the diameter of the FA just before the separation of the DFA from the FA. **c.** A right lower limb showing the diameter of the DFA and the diameter of the FA just after the separation of the DFA from the FA. (IL: Inguinal ligament, FA: Femoral artery, DFA: Deep femoral artery, MCFA: Medial circumflex femoral artery, LCFA: Lateral circumflex femoral artery).

## Morphological classification of femoral artery

In our study, a modified classification given below was obtained using Adachi's (1928) classification:

Type I: The DFA originates from the FA. The MCFA and LCFA originate separately from DFA.

Type II: The DFA originates from the FA. The MCFA originates from the FA, and the LCFA originates from the DFA.

Type III: The DFA originates from the FA. The LCFA originates from the FA, and the MCFA originates from the DFA.

Type IV: The DFA, MCFA, and LCFA originate from the FA separately.

Type V: The DFA and the descending branch of the LCFA originate from the FA separately. The MCFA and the ascending branch of the LCFA originate from the DFA.

Type VI: The DFA originates from the FA. The MCFA and LCFA originate from a common trunk originating from the FA.

Type VII: The DFA, MCFA and the descending branch of the LCFA originate from the FA separately. The ascending branch of the LCFA originates from the DFA.

Type VIII: The DFA and LCFA separately originate from the FA. There is no MCFA.

In our study, the side of origin from the FA of the DFA was also examined. DFAs originating from the posterolateral (P-L), posterior (P), lateral (Lat), posteromedial (P-M), medial (Med), and anterolateral (A-L) aspects of the FA were recorded. In addition, the artery from which the MCFA and LCFA originate (FA or DFA) was examined.

In our study, descriptive statistical analysis was performed with IBM SPSS Statistics 21.0. The independent-samples t-test was used to compare all measured values by gender, and the paired-samples t-test was employed to compare the individuals' right and left values.

# RESULTS

The mean ± SD values of the measurement scores of all, male and female individuals in our study are given in Table 1 and Table 2. Although the data obtained from males were higher than those of females in terms of all measurement parameters, only the differences in diameters were significant between males and females (Table 2). Besides, there was no significant difference between the right and left side values (Table 1) ($p<0.05$).

**Table 1.** Total and gender and right-left values of length measurements (mm).

| Measurements | Total | | Male | | Female | | p | Right | | Left | | p |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | Mean±SD | N | Mean±SD | N | Mean±SD | | N | Mean±SD | N | Mean±SD | |
| **Distance between the origin of the DFA from the midpoint of the IL** | 259 | 39,56 ± 8,52 | 140 | 40,13 ± 8,58 | 119 | 38,89 ± 8,44 | 0,245 | 129 | 39,58 ± 8,71 | 130 | 39,53 ± 8,37 | 0,960 |
| **Distance between the origin of the LCFA originating the DFA and the origin of the DFA** | 214 | 17,15 ± 4,79 | 84 | 17,55 ± 5,48 | 100 | 16,69 ± 3,86 | 0,188 | 107 | 17,01 ± 4,28 | 107 | 17,28 ± 5,28 | 0,684 |
| **Distance between the origin of the MCFA originating the DFA and the origin of the DFA** | 167 | 12,52 ± 4,58 | 140 | 12,85 ± 3,97 | 83 | 12,19 ± 5,13 | 0,350 | 79 | 12,65 ± 4,41 | 88 | 12,41 ± 4,75 | 0,732 |

**FA:** Femoral artery, **DFA:** Deep femoral artery, **IL:** Inguinal ligament, **N:** Number of samples measured, **SD:** Standart deviation, (p<0,05).

**Table 2.** Total and gender and right-left values of diameters (mm).

| Measurements | Total | | Male | | Female | | p | Right | | Left | | p |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | Mean±SD | N | Mean±SD | N | Mean±SD | | N | Mean±SD | N | Mean±SD | |
| **FA Diameter (at the level of the IL)** | 259 | 7,78 ± 1,21 | 114 | 8,11 ± 1,04 | 119 | 7,04 ± 1,28 | <0,001 | 129 | 7,78 ± 1,19 | 130 | 7,79 ± 1,22 | 0,972 |
| **FA Diameter (just before the separation of the DFA from the FA)** | 259 | 6,67 ± 1,26 | 140 | 7,07 ± 1,11 | 119 | 6,21 ± 1,27 | <0,001 | 129 | 6,67 ± 1,21 | 130 | 6,68 ± 1,31 | 0,983 |
| **FA Diameter (just after the separation of the DFA from the FA)** | 259 | 5,48 ± 1,19 | 140 | 5,87 ± 1,08 | 119 | 5,01 ± 1,15 | <0,001 | 129 | 5,45 ± 1,13 | 130 | 5,50 ± 1,26 | 0,757 |
| **DFA Diameter** | 259 | 5,18 ±1,31 | 140 | 5,46 ± 1,25 | 119 | 4,85 ± 1,31 | <0,001 | 129 | 5,20 ± 1,28 | 130 | 5,16 ± 1,35 | 0,849 |

**FA:** Femoral artery, **DFA:** Deep femoral artery, **IL:** Inguinal ligament, **N:** Number of samples measured, **SD:** Standart deviation, (p<0,05).

In our study, four morphometric types were observed according to the classification suggested by Kawashima et al. (2021). Among these types, the most common one was Type D (39%). In type D, the diameter of the DFA was smaller than the diameter of the FA (below DFA), and there was no ESB. Type B (29%) was the second most common type, in which the diameter of the DFA was smaller than the diameter of the FA (below DFA), and there was ESB originating from the FA. In Type A (24.7%), the third most common type, the diameter of the DFA was larger than the diameter of the FA (below DFA). The least detected type was Type C (7.3%) in which, the diameter of the DFA was smaller than the diameter of the FA (below DFA), and there was ESB originating from the FA bifurcation (Table 3) (Figs. 3-6).

In addition, in this study, eight types were examined according to the morphological classification made according to Adachi (1928), but six types were found. Type VI was not observed in the study, because the MCFA and LCFA did not originate from a common trunk. Besides, since there were no individuals without MCFA in our study, we did not encounter Type VIII. Type I (52.1%) was the most common one among the types obtained in the morphological classification. In this type, the LCFA and MCFA originated from the DFA. Type II (29.8%) was the second most common type in which the MCFA originated from the FA, while the LCFA originated from the DFA. The third most common type was observed to be Type III (10.4%) in which, the LCFA originated from the FA, while the MCFA originated from the DFA. The incidence of Type IV was found to be 3.1%. In this type, the DFA, LCFA, and MCFA were separately originated from the FA. The least detected types were Type V (2.3%) and Type VII (2.3%). In Type V, the descending branch of the LCFA originated from the FA, while the ascending branch of the

**Table 3.** Total and gender and right-left values according to morphometric classification (%).

| Study | Type | Male % (N) | Female % (N) | Right % (N) | Left % (N) | Total % (N) |
|---|---|---|---|---|---|---|
| **Morphometric classification** | Type A | 21,4 (30) | 28,6 (34) | 24 (31) | 25,4 (33) | 24,7 (64) |
| | Type B | 33,6 (47) | 23,5 (28) | 31,8 (41) | 26,1 (34) | 29 (75) |
| | Type C | 7,9 (11) | 6,7 (8) | 6,2 (8) | 8,5 (11) | 7,3 (19) |
| | Type D | 37,1 (52) | 41,2 (49) | 38 (49) | 40 (52) | 39 (101) |

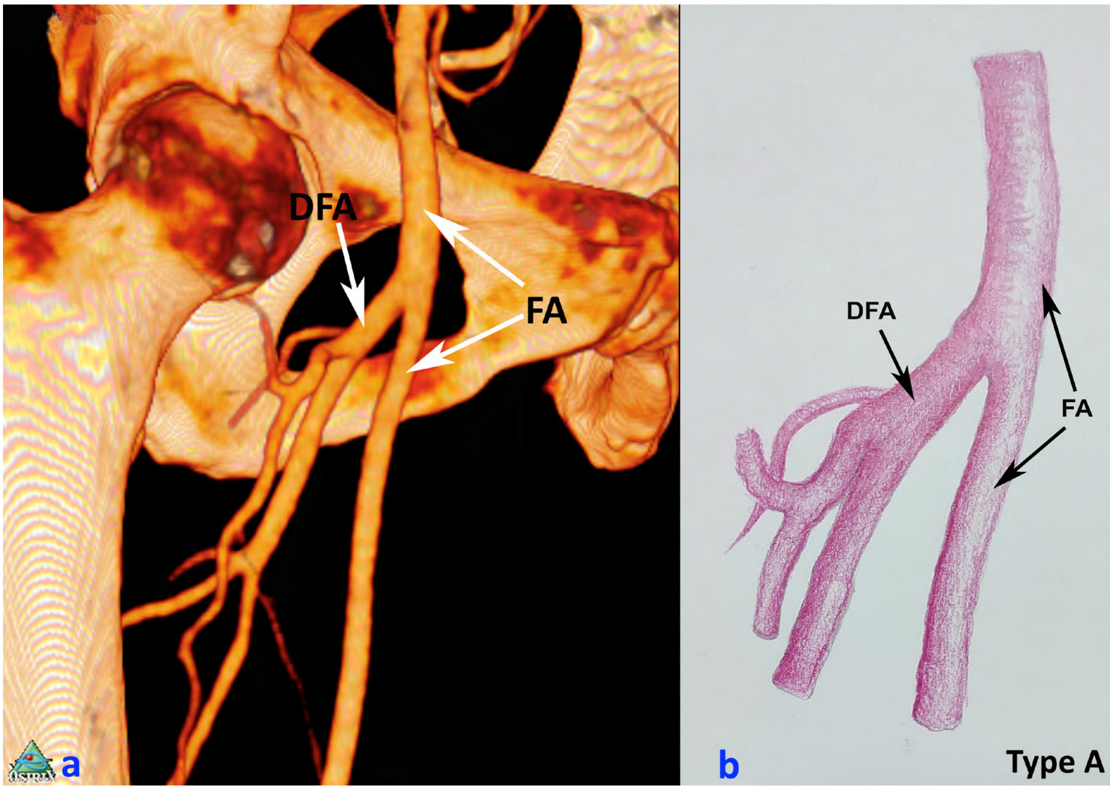


**Fig. 3.-** A right lower limb showing the image of Type A (Observed from the anterolateral). **a:** Three-dimensional volume-rendering CT reconstruction showing the image of Type A. **b:** The schema showing the image of Type A **(**DFA diameter ≥ diameter of FA just after the separation of DFA from FA) (FA: Femoral artery, DFA: Deep femoral artery).

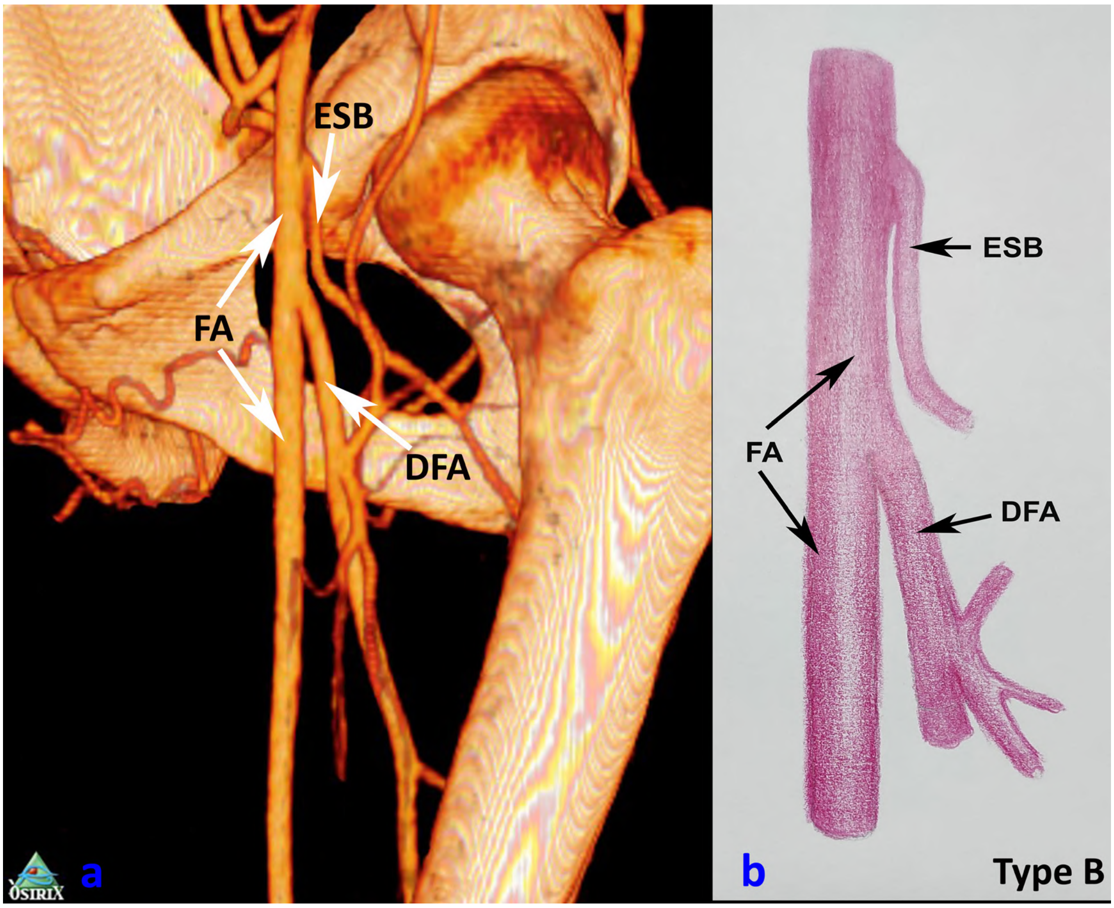


**Fig. 4.-** A left lower limb showing the image of Type B (Observed from the anterolateral). **a:** Three-dimensional volume-rendering CT reconstruction showing the image of Type B. **b:** The schema showing the image of Type B (DFA diameter < diameter of FA just after the separation of DFA from FA and presence of originating ESB before originating DFA from FA) (FA: Femoral artery, DFA: Deep femoral artery, ESB: Ectopic side branch).

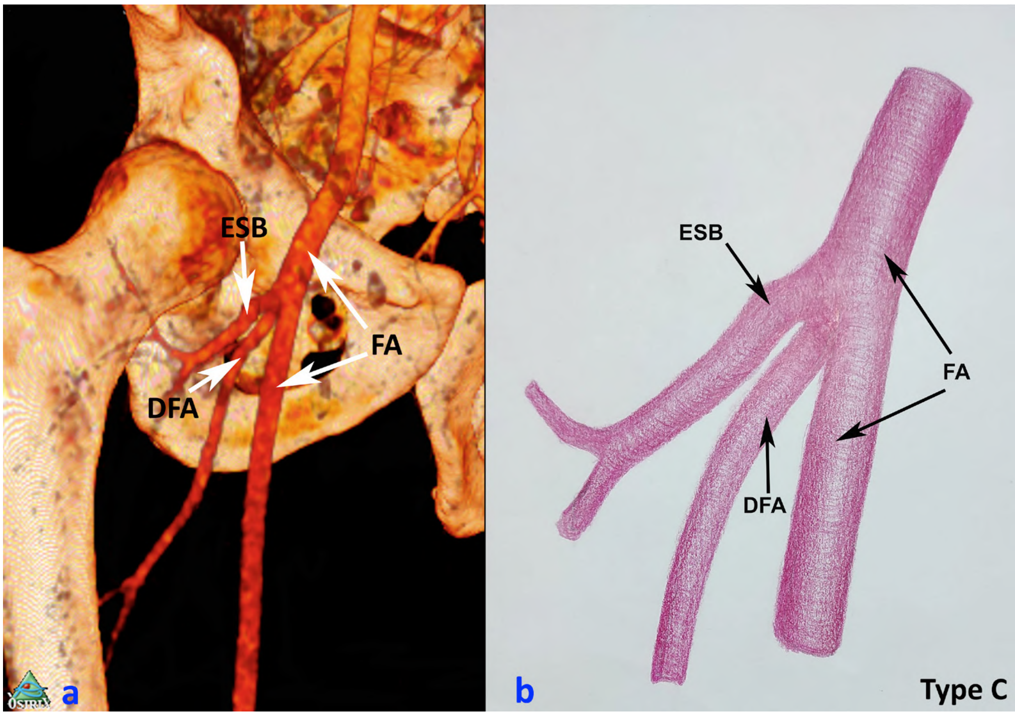


**Fig. 5.-** A right lower limb showing the image of Type C (Observed from the anterolateral). **a:** Three-dimensional volume-rendering CT reconstruction showing the image of Type C. **b:** The schema showing the image of Type C (DFA diameter < diameter of FA just after the separation of DFA from FA and presence of an ESB originating the FA bifurcation) (FA: Femoral artery, DFA: Deep femoral artery, ESB: Ectopic side branch).

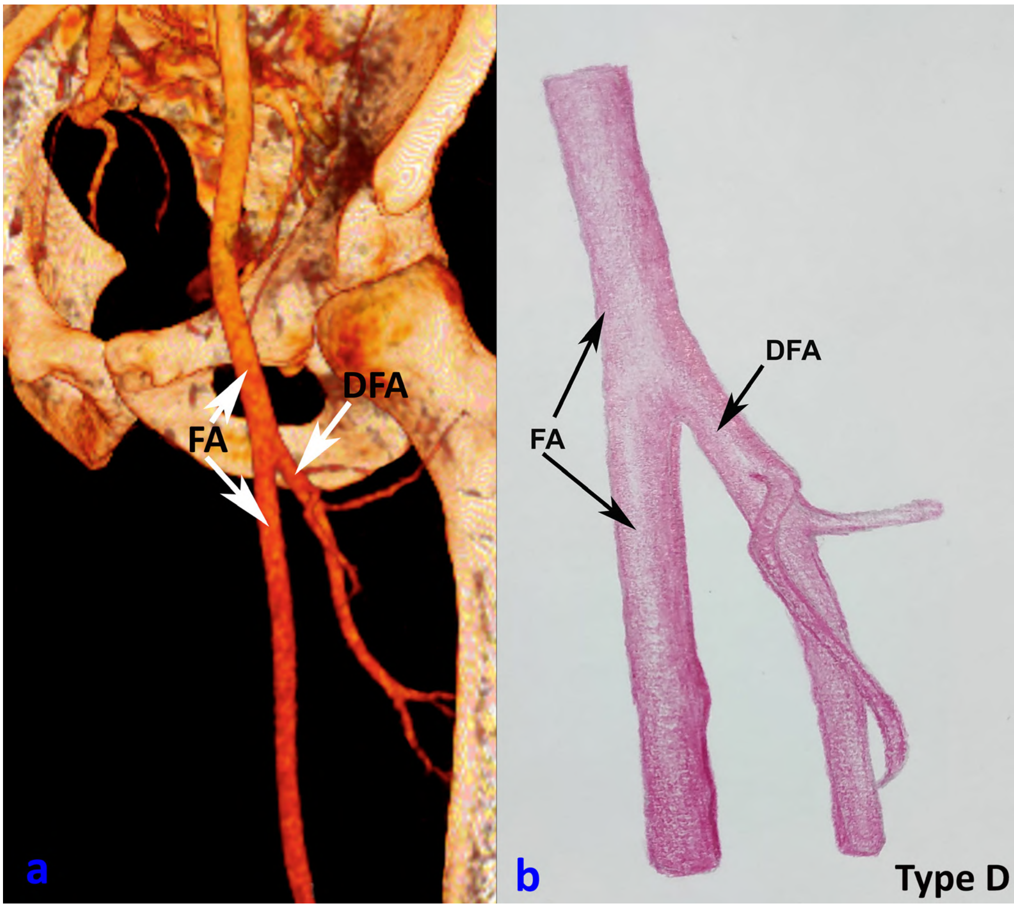


**Fig. 6.-** A left lower limb showing the image of Type D (Observed from the anterolateral). **a:** Three-dimensional volume-rendering CT reconstruction showing the image of Type D. **b:** The schema showing the image of Type D (DFA diameter < diameter of FA just after the separation of DFA from FA and absence of ESB) (FA: Femoral artery, DFA: Deep femoral artery, ESB: Ectopic side branch).

MCFA and LCFA originated from the DFA. In Type V, the descending branch of the LCFA and MCFA originated from the FA separately, while the ascending branch of the LCFA originated from the DFA (Table 4) (Figs. 7-12).

In all individuals, it was observed that the DFA branched from the FA the most from the posterolateral side (72.6%) and the least from the anterolateral side (0.4%) (Table 5). It was determined that 64.9% of the MCFA originated from the DFA, while 85.8% of the LCFA originated from the DFA (Table 6). In our study, it was observed that all LCFAs and MCFAs branching from the FA originated from under the inguinal ligament. In addition, circumflex arteries were not observed to originate from any artery other than the FA and DFA.

**Table 4.** Total and gender and right-left values according to morphological classification (%).

| Study | Type | Male % (N) | Female % (N) | Right % (N) | Left % (N) | Total % (N) |
|---|---|---|---|---|---|---|
| Morphological classification | Type I | 47,2 (66) | 58 (69) | 50,4 (65) | 53,9 (70) | 52,1 (135) |
| | Type II | 33,5 (47) | 25,2 (30) | 32,6 (42) | 26,9 (35) | 29,8 (77) |
| | Type III | 11,4 (16) | 9,2 (11) | 9,3 (12) | 11,5 (15) | 10,4 (27) |
| | Type IV | 2,9 (4) | 3,4 (4) | 2,3 (3) | 3,9 (5) | 3,1 (8) |
| | Type V | 1,4 (2) | 3,4 (4) | 2,3 (3) | 2,3 (3) | 2,3 (6) |
| | Type VI | 0 | 0 | 0 | 0 | 0 |
| | Type VII | 3,6 (5) | 0,8 (1) | 3,1 (4) | 1,5 (2) | 2,3 (6) |
| | Type VIII | 0 | 0 | 0 | 0 | 0 |

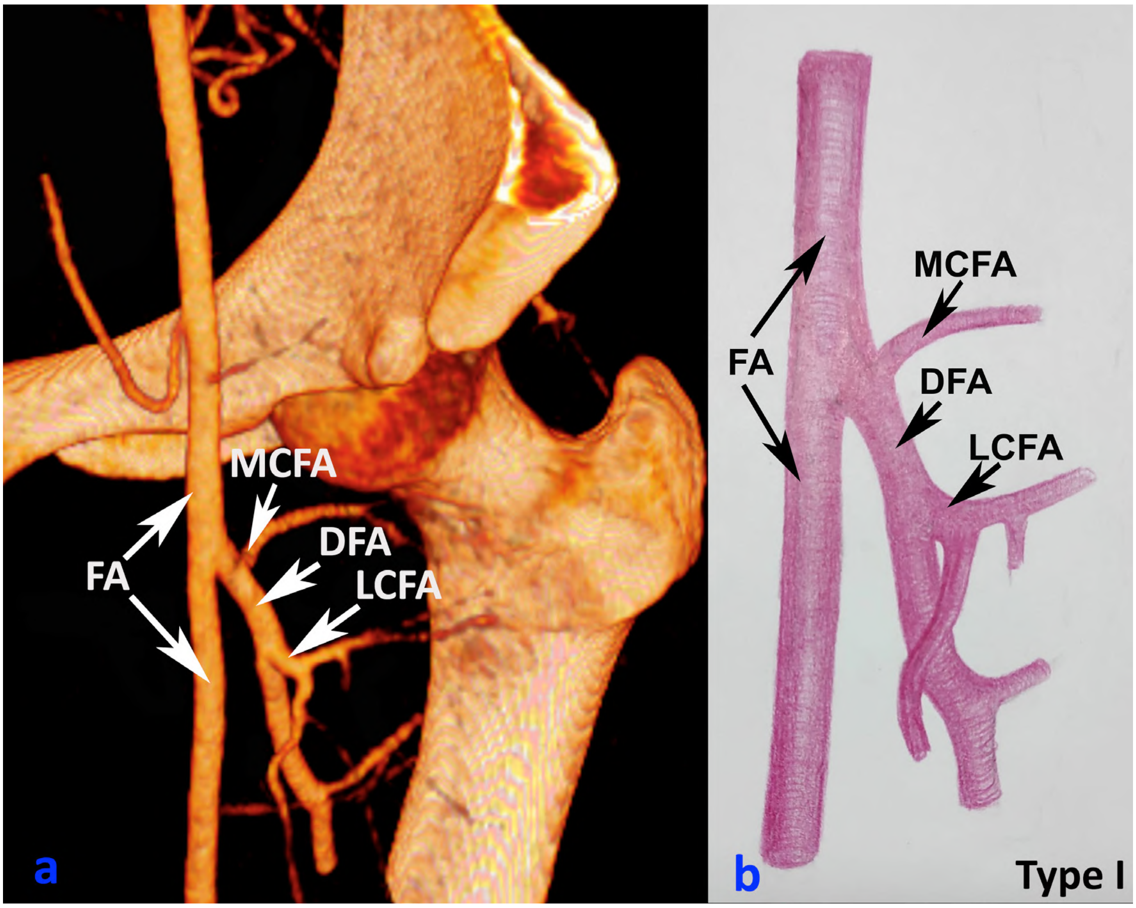


**Fig. 7.-** A left lower limb showing the image of Type I (Observed from the anterolateral). **a:** Three-dimensional volume-rendering CT reconstruction showing the image of Type I. **b:** The schema showing the image of Type I (MCFA and LCFA originate separately from DFA) (DFA: Deep femoral artery, MCFA: Medial circumflex femoral artery, LCFA: Lateral circumflex femoral artery).

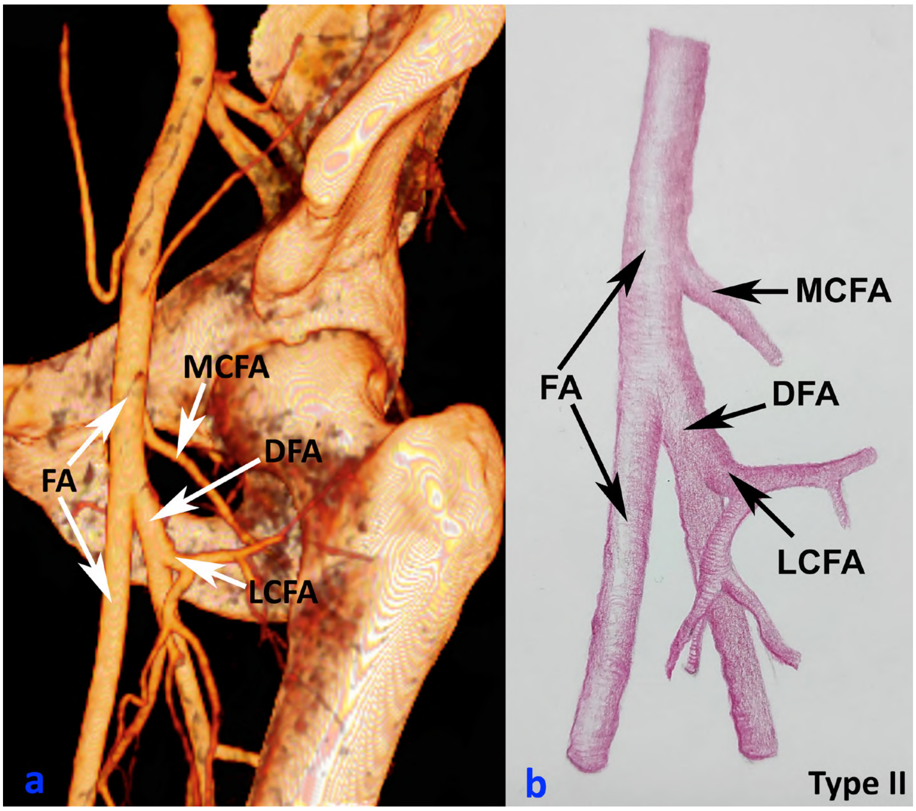


**Fig. 8.-** A left lower limb showing the image of Type II (Observed from the anterolateral). **a:** Three-dimensional volume-rendering CT reconstruction showing the image of Type II. **b:** The schema showing the image of Type II **(**MCFA originates from FA and LCFA originates from DFA) (FA: Femoral artery, DFA: Deep femoral artery, MCFA: Medial circumflex femoral artery, LCFA: Lateral circumflex femoral artery).

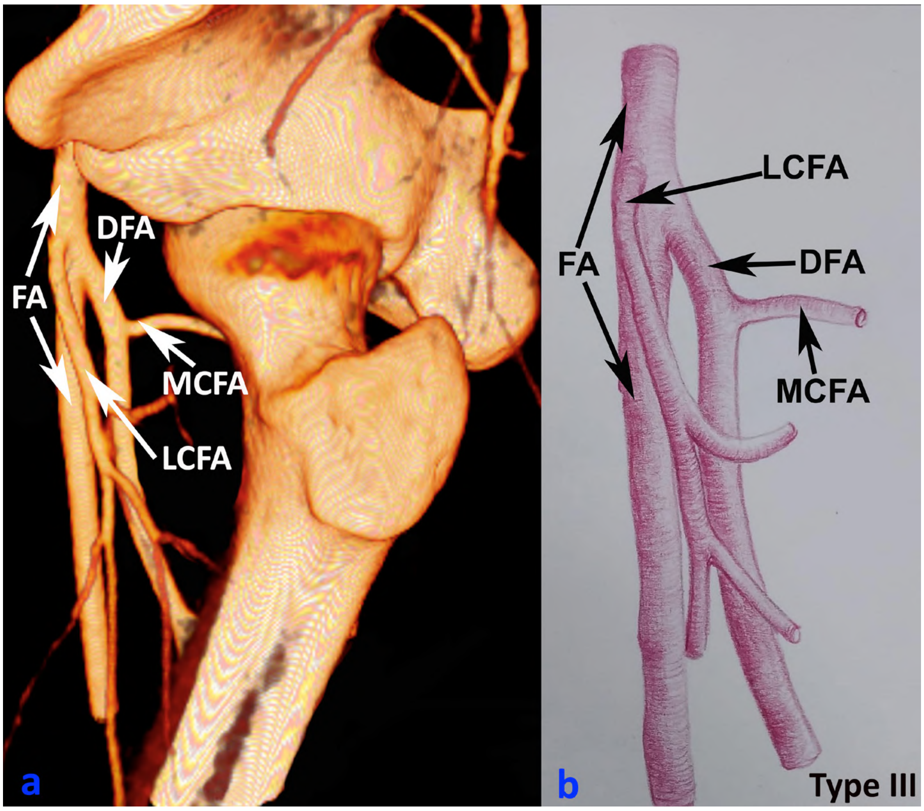


**Fig. 9.-** A left lower limb showing the image of Type III (Observed from the lateral). **a:** Three-dimensional volume-rendering CT reconstruction showing the image of Type III. **b:** The schema showing the image of Type III (LCFA originates from FA, MCFA originates from DFA) (FA: Femoral artery, DFA: Deep femoral artery, MCFA: Medial circumflex femoral artery, LCFA: Lateral circumflex femoral artery).

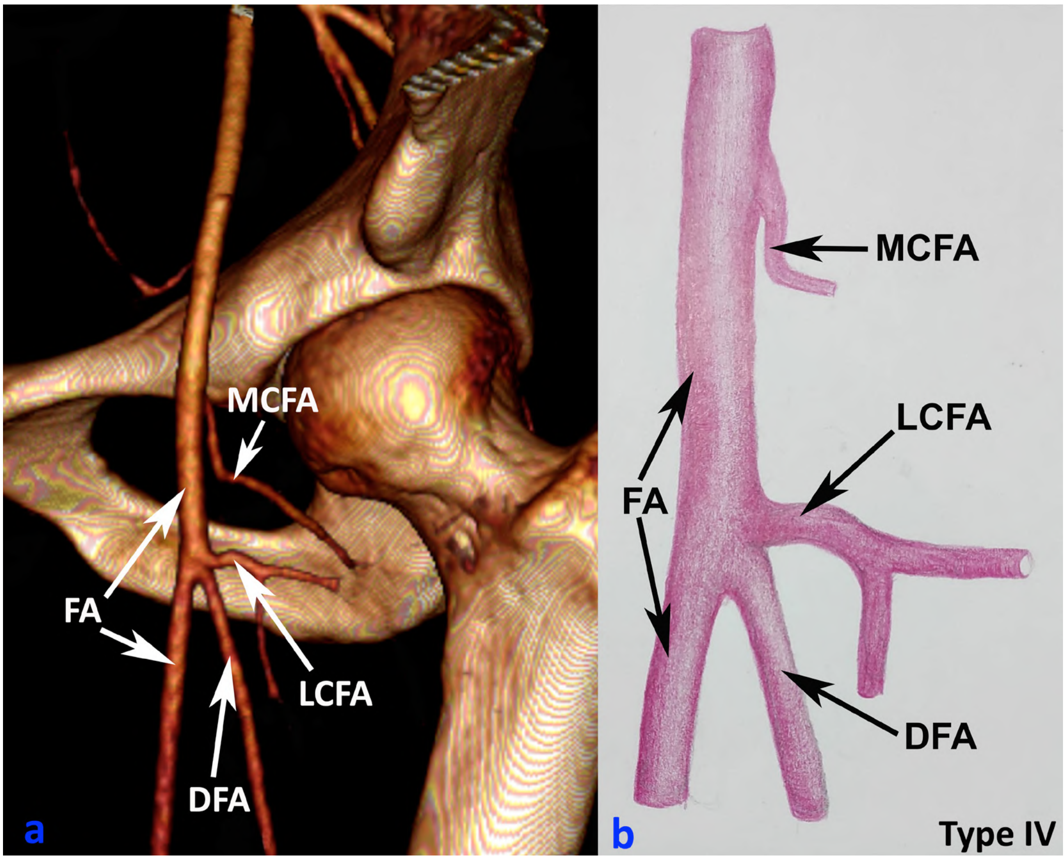


**Fig. 10.-** A left lower limb showing the image of Type IV (Observed from the anterolateral). **a:** Three-dimensional volume-rendering CT reconstruction showing the image of Type IV. **b:** The schema showing the image of Type IV (DFA, MCFA, and LCFA originate from FA separately) (FA: Femoral artery, DFA: Deep femoral artery, MCFA: Medial circumflex femoral artery, LCFA: Lateral circumflex femoral artery).

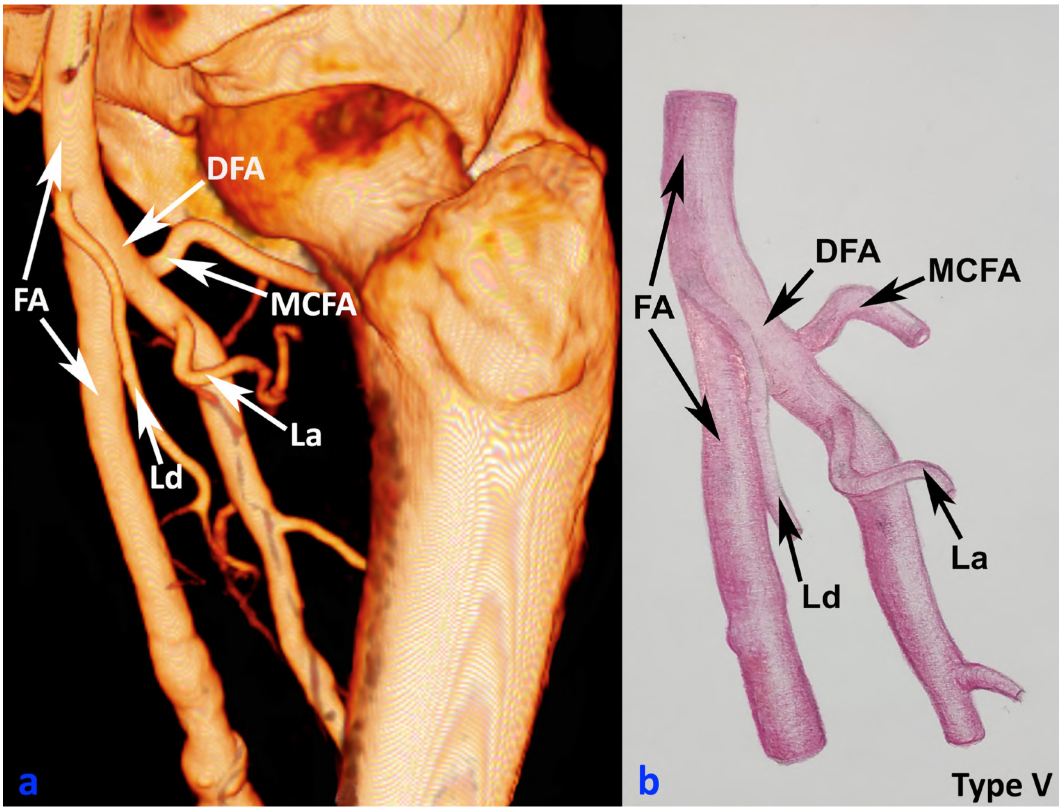


**Fig. 11.-** A left lower limb showing the image of Type V (Observed from the lateral). **a:** Three-dimensional volume-rendering CT reconstruction showing the image of Type V. **b:** The schema showing the image of Type V (DFA and the descending branch of LCFA originate from FA separately. MCFA and the ascending branch of LCFA originate from DFA) (FA: Femoral artery, DFA: Deep femoral artery, MCFA: Medial circumflex femoral artery, LCFA: Lateral circumflex femoral artery).

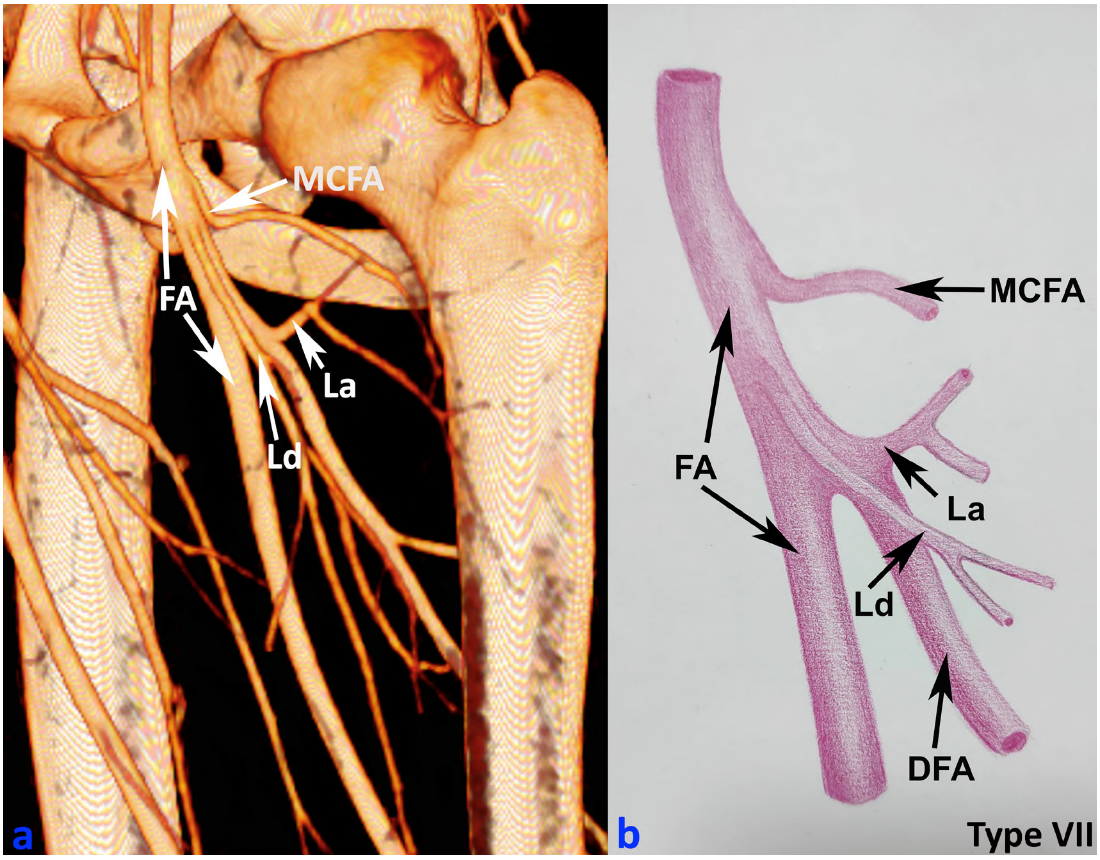


**Fig. 12.-** A left lower limb showing the image of Type VII (Observed from the anterolateral). **a:** Three-dimensional volume-rendering CT reconstruction showing the image of Type VII. **b:** The schema showing the image of Type VII (DFA, MCFA, and the descending branch of LCFA originate from FA separately. The ascending branch of LCFA leaves DFA) (FA: Femoral artery, DFA: Deep femoral artery, MCFA: Medial circumflex femoral artery, **LCFA:** Lateral circumflex femoral artery).

**Table 5.** Ratios of various positions where the DFA originates from the FA (%).

| Position of DFA origin | Male % (N) | Female % (N) | Right % (N) | Left % (N) | Total % (N) |
|---|---|---|---|---|---|
| **P-L** | 75,7 (106) | 68,9 (82) | 72 (93) | 73,1 (95) | 72,6 (188) |
| **P** | 17,2 (24) | 21 (25) | 18,6 (24) | 19,2 (25) | 18,9 (49) |
| **Lat** | 1,4 (2) | 5,9 (7) | 4,7 (6) | 2,3 (3) | 3,4 (9) |
| **P-M** | 4,3 (6) | 3,4 (4) | 3,9 (5) | 3,8 (5) | 3,9 (10) |
| **Med** | 0,7 (1) | 0,8 (1) | 0,8 (1) | 0,8 (1) | 0,8 (2) |
| **A-L** | 0,7 (1) | 0 | 0 | 0,8 (1) | 0,4 (1) |

**N:** Number of samples measured, **P-L:** Posterolateral, **P:** Posterior, **Lat:** Lateral, **P-M:** Posteromedial, **Med:** Medial, **A-L:** Antero-lateral.

**Table 6.** Findings on which artery originates MCFA and LCFA (%).

| | Direct origins of the MCFA without of a common trunk | | Direct origins of the LCFA without of a common trunk | |
|---|---|---|---|---|
| | **FA** | **DFA** | **FA** | **DFA** |
| **Male** | 40 | 60 | 15 | 85 |
| **Female** | 29,4 | 70,6 | 13,2 | 86,8 |
| **Right** | 38 | 62 | 13,9 | 86,1 |
| **Left** | 32,3 | 67,7 | 14,4 | 85,6 |
| **Total** | 35,1 | 64,9 | 14,2 | 85,8 |

**N:** Number of samples measured, **FA:** Femoral artery, **DFA:** Deep femoral artery, **MCFA:** Medial circumflex femoral artery, **LCFA:** Lateral circumflex femoral artery.

## DISCUSSION

The FA is the main artery supplying blood to the lower extremities. The DFA, on the other hand, is the most important branch of the FA and supplies the femur, hip joint and thigh muscles (Zlotorowicz et al., 2018). Comprehensive knowledge regarding the normal anatomy and variations of the origin and course of the DFA and its circumflex branches is of paramount importance during diagnostic vascular interventions and surgeries. In addition, detailed anatomy knowledge helps reduce the possibility of intraoperative secondary bleeding and postoperative complications (Dixit et al., 2011).

In a study conducted on cadavers, Manjappa and Prasanna (2014) observed that the lowest distance from the origin of the DFA to the midpoint of the IL (31.95 mm) was on the left side. As shown in Table 7, the mean distance from the origin of the DFA to the midpoint of the IL was determined to be 39.56 ± 8.52 mm in our study, which was very close to the result (39.55 mm) reported by Verma et al. (2016). The data of the Sri Lankan (Samarawickrama et al., 2009), Greek (Panagouli et al., 2011), Arabian (Nasr et al., 2014), and Polish (Łabętowicz et al., 2019) populations, which were shown in Table 7, were higher than those found in the current study. It was thought that this variability among the results might be due to racial differences.

The data for the Indian populations were observed to be both lower (Sabnis, 2013; Manjappa and Prasanna, 2014; Murthy et al., 2022) and higher (Sudarshana and Chaudhary, 2020; George and Santhakumary, 2021) than ours (Table 7). This can be explained by the use of different measurement methods. Vuksanović-Božarić et al. (2007) emphasized that the distance from the origin of the DFA to the midpoint of the IL should be known to prevent flap necrosis and to perform safe cardiac catheterizations in plastic and reconstructive surgery practices.

In our study, the distances between the origin of the LCFA originating from the DFA and the origin of the DFA and between the origin of the MCFA originating from the DFA and the origin of the DFA were measured, and the data obtained were compared with the results reported by other researchers (Table 7). The data for the British population (Vazquez et al., 2007) were found to be lower than ours. However, the data of the Arabian (Nasr et al., 2014) and Indian (Prakash et al., 2010) populations were observed to be higher than ours. We think that the reason for this variability may be due to racial differences and the use of different measurement methods. Knowing the original locations and distances of the DFA, MCFA, and LCFA allows the surgeon to identify the vascular pattern and avoid unexpected iatrogenic injuries before performing any invasive procedure (Nasr et al., 2014).

As listed in Table 8, both data of Sabnis (2013) and Chauhan et al. (2015) were larger than our data. This difference may be attributed to the different measurement methodologies employed. The external diameters of the arteries were measured in those studies, whereas the internal (lumen) diameters of the arteries were measured in our study. Kashyap and Kasote (2018) measured the lumen diameter of the FA in their study on cadavers. The results obtained by these researchers were similar to our data. Kawashima et al. (2021) performed diameter measurements with CT before the invasive procedure in the Japanese population in 2021. The comparison revealed that the results obtained in our study were lower than those of the Japanese population (Table 8). We think that this may be linked to racial differences. Kaur et al. (2019) emphasized the importance of knowledge of the mean diameter and location of the FA and its branches when performing clinical interventions in the femoral region and hip joint replacement. We are of the opinion that it would be more accurate to know the lumen diameters rather than external diameters in arterial interventional procedures.

Kawashima et al. (2021) analyzed CT images of 82 patients and classified the FA morphometrically and reported that they mostly detected Type A (55%). They also stated that during FA cannulation for minimally invasive cardiac surgery, the prolongation of cardiopulmonary bypass time and the presence of Type D are factors predisposing to the development of asymptomatic limb ischemia. In addition to the fact that Type D was the most

**Table 7.** Comparison of distance measurements related to DFA origin with other studies (mm).

| Author | Country | KS | N | T R/L M/F | The distance between the origin of the DFA from the midpoint of the IL | The distance between the origin of the LCFA leaving the DFA and the origin of the DFA | The distance between the origin of the MCFA leaving the DFA and the origin of the DFA |
|---|---|---|---|---|---|---|---|
| **Vazquez et al. (2007)** | England | Ca | 346 | T | | 14,8 | 9 |
| **Samarawickrama et al. (2009)** | Sri Lanka | Ca | 26 | T | 50 | | |
| | | | | R | 55 | | |
| | | | | L | 45 | | |
| **Prakash et al. (2010)** | India | Ca | 64 | T | | 25 | 20 |
| **Panagouli et al. (2011)** | Greece | Ca | 123 | R | 48 ± 15,5 | | |
| | | | | L | 43 ± 15,4 | | |
| **Sabnis (2013)** | India | Ca | 60 | T | 32 | | |
| **Nasr et al. (2014)** | Arabia | Ca | 90 | M | 50,6 ± 1,3 | 21,3 ± 1,6 | 19, 1± 1,4 |
| | | | | F | 48,8 ± 1,5 | 21,3 ± 1,8 | 18,9 ± 1,7 |
| **Manjappa and Prasanna (2014)** | India | Ca | 40 | R | 35,6 | | |
| | | | | L | 31,95 | | |
| **Verma et al. (2016)** | India | Ca | 38 | T | 39,55 | | |
| | | | | R | 37,55 | | |
| | | | | L | 41,55 | | |
| **Łabętowicz et al. (2019)** | Poland | Ca | 80 | T | 43,15 | | |
| **Sudarshana and Chaudhary (2020)** | India | Ca | 50 | T | 41,1 | | |
| **Mogale et al. (2021)** | South Africa | Ca | 90 | T | 38,9 | | |
| | | | | R | 44 | | |
| | | | | L | 36,8 | | |
| **George and Santhakumary (2021)** | India | Ca | 60 | T | 52,2 | | |
| | | | | R | 56,4 | | |
| | | | | L | 48 | | |
| **Murthy et al. (2022)** | India | Ca | 70 | T | 36 ± 1,3 | | |
| | | | | R | 35,8 ± 1,2 | | |
| | | | | L | 35,7 ± 1,3 | | |
| **Our study** | Türkiye | CT | 259 | T | 39,56 ± 8,52 | 17,15 ± 4,79 | 12,52 ± 4,58 |
| | | | | R | 39,58 ± 8,71 | 17,01 ± 4,28 | 12,65 ± 4,41 |
| | | | | L | 39,53 ± 8,37 | 17,28 ± 5,28 | 12,41 ± 4,75 |
| | | | | M | 40,13 ± 8,58 | 17,55 ± 5,48 | 12,85 ± 3,97 |
| | | | | F | 38,89 ± 8,44 | 12,19 ± 5,13 | 16,69 ± 3,86 |

**N:** Number of samples measured, **KS:** Kind of study**, Ca:** cadaver, **MA:** Meta-analysis, **CT**: Computed Tomography, **T:** Total, **R:** Right, **L:** Left, **M:** Male, **F:** Female, **DFA:** Deep femoral artery, **MCFA:** Medial circumflex femoral artery, **LCFA:** Lateral circumflex femoral artery, **mm**: millimeter.

**Table 8.** Comparison of diameter lengths of FA and DFA with other studies (mm).

| Author | T R/L M/F | | Diameter of FA (at the level of the IL) | Diameter of FA (just before DFA leaves FA) | Diameter of FA (just after DFA leaves FA) | Diameter of DFA |
|---|---|---|---|---|---|---|
| **Sabnis (2013)** | T | | 10 | | | 6 |
| **Anjankar et al. (2014)** | R | | | | | 10,6 |
| | L | | | | | 10,9 |
| **Chauhan et al. (2015)** | R | | | | | 7,31 ± 0,21 |
| | L | | | | | 7,12 ± 0,32 |
| | M | | | | | 7,19 ± 0,23 |
| | F | | | | | 7,28 ± 0,32 |
| **Verma et al. (2016)** | T | | | | | 6,69 |
| | R | | | | | 6,88 |
| | L | | | | | 6,5 |
| **Kashyap and Kasote (2018)** | M | R | 7,46 ± 0,97 | | | |
| | | L | 7,43 ± 0,93 | | | |
| | F | R | 6,33 ± 0,68 | | | |
| | | L | 6,29 ± 0,69 | | | |
| **Łabętowicz et al. (2019)** | M | | 12,11 ± 1,24 | 10,91±1,49 | 8,23 ±1,42 | 7,11 ± 1,31 |
| | F | | 9,94 ±1,65 | 9,08 ±1,74 | 6,35±1,32 | 6,42 ± 1,39 |
| **Kawashima et al. (2021)** | T | | 8,9 ± 1,5 | | 6,4 ± 1,2 | 6,4 ± 1,3 |
| | R | | 8,9 ± 1,5 | | 6,5 ± 1,3 | 6,6 ± 1,2 |
| | L | | 8,8 ± 1,4 | | 6,3 ± 1,1 | 6,3 ± 1,3 |
| **Our study** | T | | 7,78 ± 1,21 | 6,67 ± 1,26 | 5,48 ± 1,19 | 5,18 ±1,31 |
| | R | | 7,78 ± 1,19 | 6,67 ± 1,21 | 5,45 ± 1,13 | 5,20 ± 1,28 |
| | L | | 7,79 ± 1,22 | 6,68 ± 1,31 | 5,50 ± 1,26 | 5,16 ± 1,35 |
| | M | | 8,11 ± 1,04 | 7,07 ± 1,11 | 5,87 ± 1,08 | 5,46 ± 1,25 |
| | F | | 7,04 ± 1,28 | 6,21 ± 1,27 | 5,01 ± 1,15 | 4,85 ± 1,31 |

**T:** Total, **R:** Right, **L:** Left, **M:** Male, **F:** Female, **FA:** Femoral artery, **DFA:** Deep femoral artery, **IL:** Inguinal ligament, mm: millimeter.

common (39%) in our study, it is also noteworthy to mention that the rate of Type D (41.2%) was especially high in females. Considering the results obtained in the current study based on the classification of Kawashima et al. (2021), in the Turkish population, more attention should be paid to the risk of the development of lower extremity ischemia in patients (especially in females) with Type D who will undergo FA cannulation.

The morphological types obtained in our study are presented in Table 9 together with the classifications made by various researchers. As listed in Table 9, Type I was the most common type both in the literature and in our study. In addition, Type VI and Type VIII were not detected in our study. Troupis et al. (2013) emphasized the importance of knowing the branching pattern and anatomical variations of the FA according to both its origin and course, since a large number of procedures such as general surgery, orthopedic surgery, vascular surgery, plastic surgery, and invasive cardiology are performed in the femoral region.

In our study, the origin direction of the DFA from the FA was examined. As listed in Table 10, it has been reported in the literature that the DFA originates mostly from the posterolateral direction. It was also observed in our study that the DFA mostly originated from the posterolateral aspect of the FA (72.6%) in line with the literature.

The CT images examined in our study showed that the MCFA originated directly from the FA or DFA. As presented in Table 11, the literature

**Table 9.** Comparison of the obtained types with the corresponding types in other studies (%).

| Author | T R/L M/F | Type I | Type II | Type III | Type IV | Type V | Type VI | Type VII | Type VIII |
|---|---|---|---|---|---|---|---|---|---|
| **Adachi B (1928)** | T | 63,2 | 15 | 14,4 | 3,6 | 2,2 | 0,8 | 0,5 | 0,3 |
| **Massoud and Fletcher (1997)** | T | 81 | 6,4 | 2,8 | 5,9 | 0 | 0,7 | | |
| **Vazquez et al. (2007)** | T | 78,8 | 15,95 | 4,55 | 0,5 | | | | |
| | R | 82,11 | 12,84 | 5,04 | 0 | | | | |
| | L | 75,9 | 19,09 | 4,09 | 0,9 | | | | |
| | M | 75,6 | 18,53 | 4,87 | 0,97 | | | | |
| | F | 81,97 | 13,73 | 4,29 | 0 | | | | |
| **Łabętowicz et al. (2019)** | T | 40 | 15 | 16,25 | 3,75 | | | | |
| **Vuksanović-Božarić et al. (2018)** | T | 66,7 | 10 | 5 | 5 | | | | |
| **Zlotorowicz et al. (2018)** | T | 50 | 31 | 15 | 2 | | 1 | | 1 |
| **Tomaszewski et al. (2016)** | T | 64,6 | 32,2 | | | | 0,4 | | 0,4 |
| **Our study** | T | 52,1 | 29,8 | 10,4 | 3,1 | 2,3 | 0 | 2,3 | 0 |
| | R | 50,4 | 32,6 | 9,3 | 2,3 | 2,3 | 0 | 3,1 | 0 |
| | L | 53,9 | 26,9 | 11,5 | 3,9 | 2,3 | 0 | 1,5 | 0 |
| | M | 47,2 | 33,5 | 11,4 | 2,9 | 1,4 | 0 | 3,6 | 0 |
| | F | 58 | 25,2 | 9,3 | 3,4 | 3,4 | 0 | 0,8 | 0 |

**T:** Total, **R:** Right, **L:** Left, **M:** Male, **F:** Female.

**Table 10.** Comparison of various positions where the DFA originates from the FA with other studies (%).

| Author | Country | KS | N | T R/L M/F | P-L (%) | P (%) | Lat (%) | P-M (%) | Med (%) | A-L (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Prakash et al. (2010)** | India | Ca | 64 | T | 50 | 46,9 | | | 3,1 | |
| **Nasr et al. (2014)** | Arabia | Ca | 90 | M | 42 | 24 | 20 | 14 | | |
| | | | | F | 42,5 | 27,5 | 20 | 10 | | |
| **Manjappa and Prasanna (2014)** | India | Ca | 40 | R | 50 | 40 | 5 | | | |
| | | | | L | 70 | 10 | 15 | 5 | | |
| **Anjankar et al. (2014)** | India | Ca | 120 | R | 48,33 | 20 | 18,33 | 13,33 | | |
| | | | | L | 46,67 | 23,33 | 15 | 15 | | |
| **Rajani et al. (2015)** | India | Ca | 66 | T | 53,03 | 10,61 | 18,17 | 13,63 | 3,03 | 1,51 |
| **Sudarshana and Chaudhary (2020)** | India | Ca | 50 | T | 64 | 12 | 22 | | | 2 |
| **George and Santhakumary (2021)** | India | Ca | 60 | R | 60 | 6,67 | 23,3 | 3,33 | 3,33 | 3,33 |
| | | | | L | 66,7 | 6,67 | 20 | 3,33 | 3,33 | 0 |
| **Our Study** | Türkiye | CT | 259 | T | 72,6 | 18,9 | 3,4 | 3,9 | 0,8 | 0,4 |
| | | | | R | 72 | 18,6 | 4,7 | 3,9 | 0,8 | 0 |
| | | | | L | 73,1 | 19,2 | 2,3 | 3,8 | 0,8 | 0,8 |
| | | | | M | 75,7 | 17,2 | 1,4 | 4,3 | 0,7 | 0,7 |
| | | | | F | 68,9 | 21 | 5,9 | 3,4 | 0,8 | 0 |

**N:** Number of samples measured, **P-L:** Posterolateral, **P:** Posterior, **Lat:** Lateral, **P-M:** Posteromedial, **Med:** Medial, **A-L:** Anterolateral, **KS:** Kind of study, **Ca:** Cadaver, **MA:** Meta-analysis, **CT**: Computed Tomography, **T:** Total, **R:** Right, **L:** Left, **M:** Male, **F:** Female. (Rates for MCFAs that directly originate (without a common trunk) are compared)

**Table 11.** Comparison of arteries from which MCFA originates with other studies (%).

| Author | Country | KS | N | T R/L M/F | From DFA (directly) | From FA (directly) |
|---|---|---|---|---|---|---|
| **Massoud and Fletcher (1997)** | USA | Ta | 188 | T | 76 | 22 |
| **Vazquez et al. (2007)** | England | Ca | 438 | T | 83,4 | 16,4 |
| **Prakash et al. (2010)** | India | Ca | 64 | T | 67,2 | 32,8 |
| **Nasr et al. (2014)** | Arabia | Ca | 90 | M | 60 | 22 |
| | | | | F | 57,5 | 27,5 |
| **Manjappa and Prasanna (2014)** | India | Ca | 40 | R | 40 | 50 |
| | | | | L | 60 | 35 |
| **Anjankar et al. (2014)** | India | Ca | 120 | R | 65 | 20 |
| | | | | L | 60 | 23,33 |
| **Al-Talalwah (2015)** | Scotland | Ca | 342 | T | 57 | 15,6 |
| **Ogeng'o et al.  (2015)** | Kenya | Ca | 104 | T | 79,6 | 4,1 |
| **Tomaszewski et al. (2016)** | World | MA | 4351 | T | 64,6 | 33,2 |
| **Verma et al. 82016)** | India | Ca | 38 | T | 73,68 | 26,32 |
| | | | | R | 66,67 | 33,33 |
| | | | | L | 80 | 20 |
| **Vuksanović-Božarić et al. (2018)** | Monte-negro | Ca | 60 | T | 78,3 | 16,7 |
| **Zlotorowicz et al. 82018)** | Poland | CT | 100 | T | 65 | 34 |
| **Kaur et al. 2019)** | India | Ca | 40 | R | 85 | 15 |
| | | | | L | 75 | 25 |
| **Łabętowicz et al. (2019)** | Polonya | Ca | 80 | T | 62,5 | 18,75 |
| **Our study** | Türkiye | CT | 259 | T | 64,9 | 35,1 |
| | | | | R | 62 | 38 |
| | | | | L | 67,7 | 32,3 |
| | | | | M | 60 | 40 |
| | | | | F | 70,6 | 29,4 |

**N:** Number of samples measured, **KS:** Kind of study**, Ta**: Transfemoral aortogram, **Ca:** Cadaver, **MA:** Meta-analysis, **CT**: Computed Tomography, **T:** Total, **R:** Right, **L:** Left, **M:** Male, **F:** Female, **FA**: Femoral artery, **DFA:** Deep femoral artery.
(Rates for LCFAs that directly originate (without a common trunk) are compared)

data similarly indicate that the MCFA directly originates from the FA or DFA. Manjappa and Prasanna (2014) stated that the right-side MCFA mostly originates from the FA, while all other researchers reported that it originates mostly from the DFA. In our study, it was found that the MCFA mostly originated from the DFA and the results of the current study show similarities with previous studies. Accurate anatomy knowledge of the MCFA is important to prevent femoral head necrosis and iatrogenic injuries to this artery during hip joint surgery and flap plastic surgery (Tomaszewski et al., 2016; Tzouma et al., 2020).

In the current study, it was detected that the LCFA originated directly from the FA or DFA. As listed in Table 12, the data obtained in previous studies reveal that the LCFA directly originates from the FA or DFA. Although most researchers have stated that the LCFA directly originates from the DFA, Kaur et al. (2019) reported that the right of the LCFA originates equally both from the

**Table 12.** Comparison of arteries from which LCFA originates with other studies (%).

| **Author** | **Country** | **KS** | **N** | **T R/L M/F** | **From DFA (directly)** | **From FA (directly)** |
|---|---|---|---|---|---|---|
| **Massoud and Fletcher (1997)** | USA | Ta | 188 | T | 80 | 19 |
| **Fukuda et al. (2005)** | Japan | Fa | 262 | T | 81,7 | 17,2 |
| **Vazquez et al. (2007)** | England | Ka | 438 | T | 94,8 | 5,02 |
| **Uzel et al. (2008)** | Türkiye | Ka | 110 | T | 77,3 | 20,9 |
| **Prakash et al. (2010)** | India | Ka | 64 | T | 81,25 | 18,75 |
| **Sinkeet et al. (2012)** | Kenya | Ka | 84 | T | 65,55 | 2,4 |
| **Sabnis (2013)** | India | Ka | 60 | T | 80 | 16,6 |
| **Nasr et al. (2014)** | Arabia | Ka | 90 | M | 74 | 12 |
| | | | | F | 65 | 20 |
| **Manjappa and Prasanna (2014)** | India | Ka | 40 | R | 80 | 20 |
| | | | | L | 70 | 25 |
| **Anjankar et al. (2014)** | India | Ka | 120 | R | 70 | 13,33 |
| | | | | L | 66,67 | 15 |
| **Ogeng'o et al. (2015)** | Kenya | Ka | 104 | T | 66,7 | 33,5 |
| **Verma et al. (2016)** | India | Ka | 38 | T | 84,21 | 15,79 |
| | | | | R | 77,77 | 22,23 |
| | | | | L | 90 | 10 |
| **Vuksanović-Božarić et al. (2018)** | Montenegro | Ka | 60 | T | 83,3 | 8,4 |
| **Kaur et al. (2019)** | India | Ka | 40 | R | 50 | 50 |
| | | | | L | 60 | 40 |
| **Łabętowicz et al. (2019)** | Poland | Ka | 80 | T | 78,75 | 21,25 |
| **Mogale et al. (2021)** | South Africa | Ka | 90 | T | 78,9 | 21,1 |
| | | | | R | 82,2 | 17,8 |
| | | | | L | 75,6 | 24,4 |
| **Our study** | Türkiye | CT | 247 | T | 85,8 | 14,2 |
| | | | | R | 86,1 | 13,9 |
| | | | | L | 85,6 | 14,4 |
| | | | | M | 85 | 15 |
| | | | | F | 86,8 | 13,2 |

**N:** Number of samples measured, **KS:** Kind of study**, Ta**: Transfemoral aortogram, **Fa:** Femoral angiography**, Ca:** Cadaver, **MA:** Meta-analysis, **CT**: Computed Tomography, **T:** Total, **R:** Right, **L:** Left, **M:** Male, **F:** Female, **FA**: Femoral artery, **DFA:** Deep femoral artery.

DFA and FA. In our study, it was observed that the LCFA mostly originated from the DFA (85.8%). It is important to have information about the anatomical variations of the LCFA and its branches, as they are used in aortopopliteal bypass, coronary artery bypass graft, extracranial-intracranial bypass surgeries, and anterolateral thigh flaps (Fukuda et al., 2005; Üzel et al., 2008; Olasińska-Wiśniewska et al., 2017).

Prakash et al. (2010), in their study on cadavers, reported that if the MCFA and LCFA originate directly from the FA, the level of separation of the DFA from the FA would be more distal. For this reason, they emphasized that these anatomical facts should be taken into account before planning different diagnostic and therapeutic interventions for the FA and its branches.

Our study has two limitations. The first is the small sample size included in the study. The second is that the study was conducted in a population in a limited region.

## CONCLUSION

It is necessary to know the morphometric information of the FA and its branches, especially to perform intravenous applications more safely. Information about the branching model and vascular system of the FA and DFA is very important in terms of cardiology, radiology, general surgery, plastic surgery and orthopedic surgery. Our study includes morphological information, as well as morphometric information. Therefore, we believe that it will be of significant use to both clinicians and the literature in this regard.

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