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The variable origin of the lateral circumflex femoral artery: a meta-analysis and proposal for a new classification system

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The lateral circumflex femoral artery (LCFA) is responsible for vascularisation of the head and neck of the femur, greater trochanter, vastus lateralis and the knee. The origin of the LCFA has been reported to vary significantly throughout the literature, with numerous branching patterns described and variable distances to the mid-inguinal point reported. The aim of this study was to determine the estimated population prevalence and pooled means of these anatomical characteristics, and review their associated clinical relevance. A search of the major electronic databases was performed to identify all articles reporting data on the origin of the lateral circumflex femoral artery and its distance to the mid-inguinal point. Additionally, an extensive search of the references of all relevant articles was performed. All data on origin, branching, and distance to mid-inguinal point was extracted and pooled into a meta-analysis. A total of 26 articles (n = 3731 lower limbs) were included in the meta-analysis. Lateral circumflex femoral artery most commonly originates from the deep femoral artery with a pooled prevalence of 76.1% (95% confidence interval 69.4–79.3). The deep femoral artery-derived lateral circumflex femoral artery was found to originate with a mean pooled distance of 51.06 mm (95% confidence interval 44.61–57.51 mm) from the mid-inguinal point. Subgroup analysis of both gender and limb side data were consistent with these findings. Due to variability in the lateral circumflex femoral artery's origin and distance to mid-inguinal point, anatomical knowledge is crucial for clinicians to avoid iatrogenic injuries when performing procedures in the femoral region, and thus radiographic assessment prior to surgery is recommended. Lastly, we propose a new classification system for origin of the lateral circumflex femoral artery. (Folia Morphol 2017; 76, 2: 157–167)

Key words: evidence-based anatomy, common femoral artery, lateral circumflex femoral artery

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INTRODUCTION

The lateral circumflex femoral artery (LCFA) is a laterally running branch of the deep femoral artery (DFA), or less frequently, the common femoral artery (CFA) [1, 30, 31]. It most often arises from the root of the DFA and passes between divisions of the femoral nerve, posteriorly to the sartorius and rectus femoris muscles. The LCFA subsequently divides into its ascending, descending and transverse branches [32].

The LCFA, along with the medial circumflex femoral artery (MCFA), supplies the proximal femoral epiphysis at birth. The LCFA then regresses at 3 years of age, leaving only the MCFA and its branches to supply the entire femoral epiphysis and proximal femoral epiphyseal plate [18]. In adults, the LCFA primarily supplies blood to the head and neck of the femur, greater trochanter, vastus lateralis, and the knee [32].

The LCFA is used in a diverse number of clinical procedures, including aortopopliteal bypass [10, 29], anterolateral thigh flaps [33] and coronary artery bypass grafting [8], giving its normal and variant anatomy a high degree of clinical significance. Furthermore, its branches may also be used in various procedures, for example its ascending branch is often used for vascularised iliac transplant, and its descending branch can be used as a collateral for an obstructed superficial femoral artery (SFA) [12, 32].

Significant differences in the arterial origins of the LCFA exist in the literature. It has been reported that the LCFA originates from the DFA in 64% [9] to 90% of individuals [21], and from the CFA in 4% [7] to 35% [28] of studied subjects. Other rarer variations in the origin of the LCFA have been reported in the literature, including branches from the external iliac artery [8] or the SFA [6]. Variations also exist in the origin of the ascending (La) and descending (Ld) branches of the LCFA. These branches commonly originate from the LCFA, but have been reported in numerous cases to originate from the CFA [7], DFA [20] or SFA [8]. Additionally, variations in the distance of the LCFA to the mid-inguinal point [25, 32] have also been reported, providing relevant clinical information for interventional procedures involving the LCFA.

Due to the large reported degree of variation in the origin of the LCFA, the aim of our study was to determine an accurate population prevalence estimate of the various LCFA branching patterns and formulate a new classification system to provide simplicity to the multitude of reported origins of the LCFA.

MATERIALS AND METHODS

Search strategy

In order to recognise all articles containing relevant data, which can be used in the meta-analysis, a broad search through several electronic databases (PubMed, EMBASE, Scopus, ScienceDirect, Web of Science, SciELO, BIOSIS, and CNKI) was performed through July 2015. During the search the following search terms were used: femoral head circulation, femoral head blood supply, femoral neck circulation, femoral neck blood supply, superior gluteal artery, inferior gluteal artery, medial femoral circumflex artery, lateral femoral circumflex artery, superficial femoral artery, deep femoral artery, retinacular arteries, extracapsular arterial ring of femoral neck, intracapsular arterial ring of femoral neck, arteries of the round ligament, posterior superior nutrient artery, posterior inferior nutrient artery, piriformis branch of the inferior gluteal artery, and profunda femoris. No date and language restrictions were applied.

Additionally, a reference search of all included studies was conducted in order to identify any further relevant articles. During the entirety of this meta-analysis the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were strictly followed (Supplement S1. PRISMA 2009 checklist — see journal website, supplementary file).

Eligibility assessment

Eligibility for inclusion into the meta-analysis was assessed by two independent reviewers. All cadaveric or radiographic studies containing extractable anatomical data concerning the LCFA origin in humans were included into the analysis. All reviews, case reports, case series, letters to the editor, and conference abstracts were excluded. Additionally, studies with incomplete or non-extractable data, studies concerning limbs with congenital hip and femur pathologies, and studies conducted on animals were excluded from the meta-analysis. All manuscripts in languages other than those spoken fluently by the authors were translated by medical professionals fluent in both the language of the original article and English. Any differences in opinions among the reviewers concerning the eligibility of articles were solved by a consensus among all the authors following email consultation with the authors of the original study, when possible.

Data extraction

All relevant anatomical data including prevalence of the various origins of the LCFA, prevalence of the various types of CFA origins of the LCFA, and the mean distance of the various origins of the LCFA to the mid-inguinal point (MIP) were extracted individually by two reviewers. In the event of any discrepancies in the data, the authors of the original study were contacted via email for clarification. Morphometric data obtained from any foetal studies were excluded from the analysis.

Statistical analysis

To determine the multi-categorical pooled prevalence of the LCFA origins, the extracted data was pooled into a meta-analysis using MetaXL analysis version 2.0 EpiGear Pty Ltd (Wilston, Queensland, Australia). For morphometric anatomical data, pooled means were calculated using Comprehensive Meta-Analysis version 3.0 by Biostat (Englewood, New Jersey, USA). A random effects model was applied for all analyses. The χ^2 test and Higgins I^2 statistics were used to assess heterogeneity between the included studies. For the χ^2 test, significant heterogeneity among studies was indicated by a p-value of < 0.10. The I^2 statistic was interpreted as follows: 0% to 40% might not be important; 30% to 60% might indicate moderate heterogeneity; 50% to 90% may indicate substantial heterogeneity; and 75% to 100% may represent considerable heterogeneity [14].

To probe for sources of heterogeneity, subgroup analyses based on type of study, geography, gender, and side were conducted. Additionally, a sensitivity analysis was performed by restricting inclusion to only studies with ≥ 100 lower limbs. To compare results between subgroups, confidence intervals were used. Statistically insignificant results were considered in cases of overlapping confidence intervals between the two or more compared groups [13].

Establishment of a classification system

For the establishment of a simple classification system for the origin of LCFA, the authors set an a priori threshold level of a minimum 1% pooled population prevalence of a variant origin in the overall analysis, for it to be eligible for inclusion into the classification system. For any sub-variant origins not represented in the overall analysis (i.e. various types of CFA origins of the LCFA), eligibility for inclusion was determined by multiplying the pooled prevalence of the particular sub-variant by the pooled prevalence of its main variant representative in the overall analysis. If the calculated value was ≥ 1%, the sub-variant origin would be deemed eligible for inclusion as an independent variant in the new classification system.

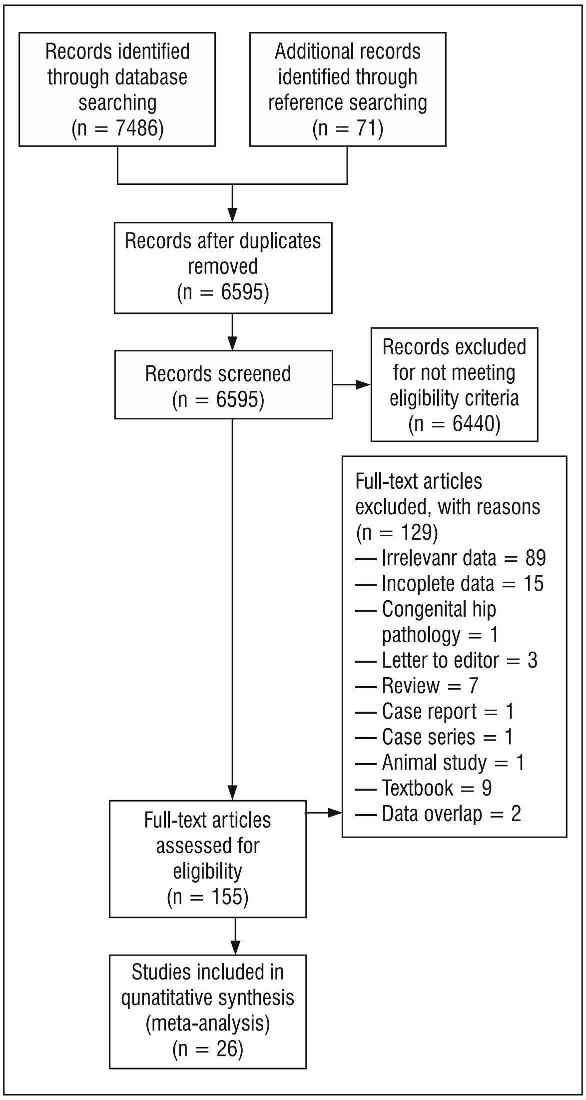

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart of the study identification process of studies included in the meta-analysis.

RESULTS

Study identification

An overview of the process of study identification is summarised in Figure 1. Extensive searching of all major databases revealed an initial 7486 articles. A further 71 articles were identified through reference searching. One hundred and fifty-five articles were assessed by full text for potential eligibility, of which

Table 1. Characteristics of included studies

Study	Country	Type of study	No. of lower limbs
Manjappa 2014 [19]	India	Cadaveric	40
Nasr 2014 [23]	Egypt	Cadaveric	90
Anwer 2013 [1]	India	Cadaveric	60
Lalovic 2013 [17]	Bosnia and Herzegovina	Cadaveric	42
Peera 2013 [25]	India	Cadaveric	40
Kalhor 2012 [15]	Iran	Cadaveric	35
Sinkeet 2012 [28]	Kenya	Cadaveric	84
del Sol 2011 [4]	Chile	Cadaveric	92
Dixit 2011 [5]	India	Cadaveric	228
Prakash 2010 [26]	India	Cadaveric	64
Uzel 2008 [32]	Turkey	Cadaveric	110
Vazquez 2007 [34]	Spain	Cadaveric	438
Fukuda 2005 [8]	Japan	Imaging (DSFA*)	262
Dixit 2001 [6]	India	Cadaveric	48
Massoud 1997 [21]	USA	Imaging (DSTA*)	188
Goscicka 1990 [9]	Poland	Imaging (Radiogram)	100
Emura 1989 [7]	Japan	Cadaveric	337
Boonkham 1987 [2]	Thailand	Cadaveric	113
Siddharth 1985 [27]	USA	Cadaveric	100
O'Hara 1983 [24]	South Africa	Cadaveric	19
Marcade 1978 [20]	France	Cadaveric	50
Gremigni 1968 [11]	Italy	Cadaveric	100
De Beer 1965 [3]	South Africa	Cadaveric	180
Keen 1961 [16]	South Africa	Cadaveric	280
Ming-Tzu 1937 [22]	China	Cadaveric	150
Williams 1934 [35]	USA	Cadaveric	481

DSFA — digital subtraction femoral arteriography; DSTA — digital subtraction transfemoral aortogram

129 articles were deemed ineligible and 26 articles were included into the meta-analysis. Articles that were not considered eligible included case reports, case series, letters to the editor and reviews.

Characteristics of included studies

The characteristics of included studies are presented in Table 1. Twenty-eight studies (n = 3766 lower limbs) were considered eligible and included in the meta-analysis. The dates of the included studies ranged from 1934 to 2014, and mostly included cadaveric studies, except for the studies by Fukuda et al. [8] (Digital Subtraction Femoral Arteriography), Massoud and Fletcher [21] (Digital Subtraction Transfemoral Aortogram) and Gościcka et al. [9] (Radiogram) which utilised different imaging modalities. The studies also varied geographically and hailed from Asia, Europe, North America and Africa.

Origin of the lateral circumflex femoral artery

Twenty-six studies (n = 3731 lower limbs) reported the prevalence of the various origins of the LCFA (Table 2). Our results showed that the LCFA most commonly originates from the DFA with a pooled prevalence of 76.1% (95% confidence interval 69.4–79.3). The second most common origin of the LCFA was from the CFA in 19.6% of cases, of which 81.8% of these cases arose as a single branch. Detailed results on the various origins of the LCFA are presented in Tables 2 and 3 and illustrated in Figures 2 and 3 (Supplement S2. Forrest plots for origins of the lateral circumflex femoral artery — see journal website, supplementary file).

Table 2. Prevalence of the various origins of the LCFA with subgroup and sensitivity analyses

Population	All	Africa	Asia	Europe	North America	Cadaveric	Imaging	Sensitivity analysis (n ≥ 100 limbs)
Number of studies (no. of legs)	26 (3731)	4 (563)	12 (1467)	6 (840)	3 (769)	22 (3131)	4 (600)	14 3067)
From CFA [%] (95% CI)	19.6 (14.9–23.9)	26.6 (23.0–31.1)	17.8 (11.0–26.0)	18.2 (0.8–41.7)	14.6 (6.1–25.6)	20.2 (16.3–24.7)	16.2 (0–46.2)	16.2 (11.3–21.0)
From DFA [%] (95% CI)	76.1 (69.4–79.3)	72.0 (68.9–77.0)	77.6 (69.3–85.6)	72.3 (37.1–88.6)	81.5 (68.9–90.6)	76.7 (72.8–81.6)	65.3 (16.6–92.1)	80.3 (72.9–83.7)
From SFA [%] (95% CI)	1.0 (0.1–2.5)	0.2 (0–0.6)	9.2 (0–3.8)	2.6 (0–14.2)	0.7 (0–3.8)	0.5 (0–1.6)	7.4 (0–32.1)	1.3 (0.1–3.2)
From EIA [%] (95% CI)	0.3 (0–1.0)	0.2 (0–0.6)	0.3 (0–2.0)	0.3 (0–7.7)	0.1 (0–2.1)	0.3 (0–1.0)	0.3 (0–12.1)	0.2 (0–0.9)
La from CFA, Ld from SFA [%] (95% CI)	0.3 (0–1.2)	0.2 (0–0.6)	0.4 (0–2.1)	0.3 (0–7.7)	0.1 (0–2.1)	0.3 (0–1.0)	0.6 (0–14.2)	0.2 (0–1.1)
La from DFA, Ld from CFA [%] (95% CI)	0.5 (0–1.5)	0.2 (0–0.6)	0.5 (0–2.4)	0.8 (0–9.1)	0.9 (0–4.4)	0.4 (0–1.3)	1.6 (0–18.1)	0.4 (0–1.5)
La from DFA, Ld from SFA [%] (95% CI)	0.4 (0–1.2)	0.2 (0–0.6)	0.5 (0–2.3)	0.5 (0–7.7)	0.1 (0–2.1)	0.3 (0–1.0)	0.8 (0–15.3)	0.3 (0–1.2)
La from DFA, Ld from DFA [%] (95% CI)	0.6 (0–1.9)	0.2 (0–0.6)	0.3 (0–1.8)	3.9 (0–17.0)	0.7 (0–4.0)	0.3 (0–1.1)	7.2 (0–31.8)	0.2 (0–1.1)
La from CFA, Ld from CFA [%] (95% CI)	0.5 (0–1.5)	0.2 (0–0.6)	0.8 (0–3.0)	0.3 (0–7.0)	0.4 (0–3.0)	0.4 (0–1.5)	0.3 (0–12.1)	0.5 (0–1.7)
La from CFA, Ld from DFA [%] (95% CI)	0.3 (0–1.1)	0.2 (0–0.6)	0.3 (0–1.8)	0.3 (0–7.0)	0.6 (0–3.7)	0.3 (0–1.1)	0.3 (0–12.1)	0.2 (0–1.0)
Aplasia [%] (95% CI)	0.3 (0–1.0)	0.2 (0–0.6)	0.3 (0–2.0)	0.3 (0–7.0)	0.1 (0–2.1)	0.3 (0–1.0)	0.3 (0–12.1)	0.2 (0–0.9)
I^2 [%] (95% CI)	91.36 (88.55–93.48)	12.13 (0–86.55)	92.38 (88.56–94.93)	97.96 (96.96–98.63)	91.38 (77.81–96.65)	87.48 (82.38–91.11)	98.70 (97.98–99.17)	92.45 (89.03–94.80)
Cochran's Q, p-value	< 0.001	0.332	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

CI — confidence interval; CFA — common femoral artery; DFA — deep femoral artery; EIA — external iliac artery; La — ascending branch; LCFA — lateral circumflex femoral artery; Ld — descending branch; SFA — superficial femoral artery

Table 3. Prevalence of the various types of CFA origins of the LCFA with subgroups and sensitivity analyses

Population	All	Africa	Asia	Europe	North America	Cadaveric	Imaging
Number of studies (no. of legs)	23 (614)	4 (151)	10 (197)	5 (116)	3 (126)	19 (548)	4 (66)
From CFA (single trunk) [%] (95% CI)	81.8 (64.2–92.0)	80.7 (90.7–100)	78.0 (53.0–98.2)	78.8 (33.1–100)	87.6 (60.7–100)	80.8 (60.0–92.3)	86.2 (59.7–100)
From CFA (with DFA) [%] (95% CI)	10.7 (1.9–23.6)	5.7 (0–53.7)	18.7 (1.6–46.2)	7.9 (0–41.3)	0.9 (0–11.9)	11.2 (1.3–26.3)	8.4 (0–32.4)
From CFA (with MCFA) [%] (95% CI)	3.2 (0–10.4)	9.3 (0–62.5)	1.5 (0–12.3)	2.1 (0–26.0)	6.1 (0–25.3)	3.0 (0–11.2)	3.9 (0–22.7)
From CFA (with DFA and MCFA) [%] (95% CI)	4.3 (0–12.4)	4.4 (0–49.9)	1.8 (0–13.4)	11.2 (0–47.9)	5.4 (0–23.7)	5.0 (0–14.9)	1.6 (0–16.1)
I^2 [%] (95% CI)	94.31 (92.59–95.63)	97.70 (96.08–98.65)	93.10 (89.32–95.53)	95.16 (91.34–97.29)	87.10 (63.26–95.47)	94.95 (93.31–96.19)	86.14 (66.18–94.32)
Cochran's Q, p-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

CI — confidence interval; CFA — common femoral artery; DFA — deep femoral artery; LCFA — lateral circumflex femoral artery; MCFA — medial circumflex femoral artery

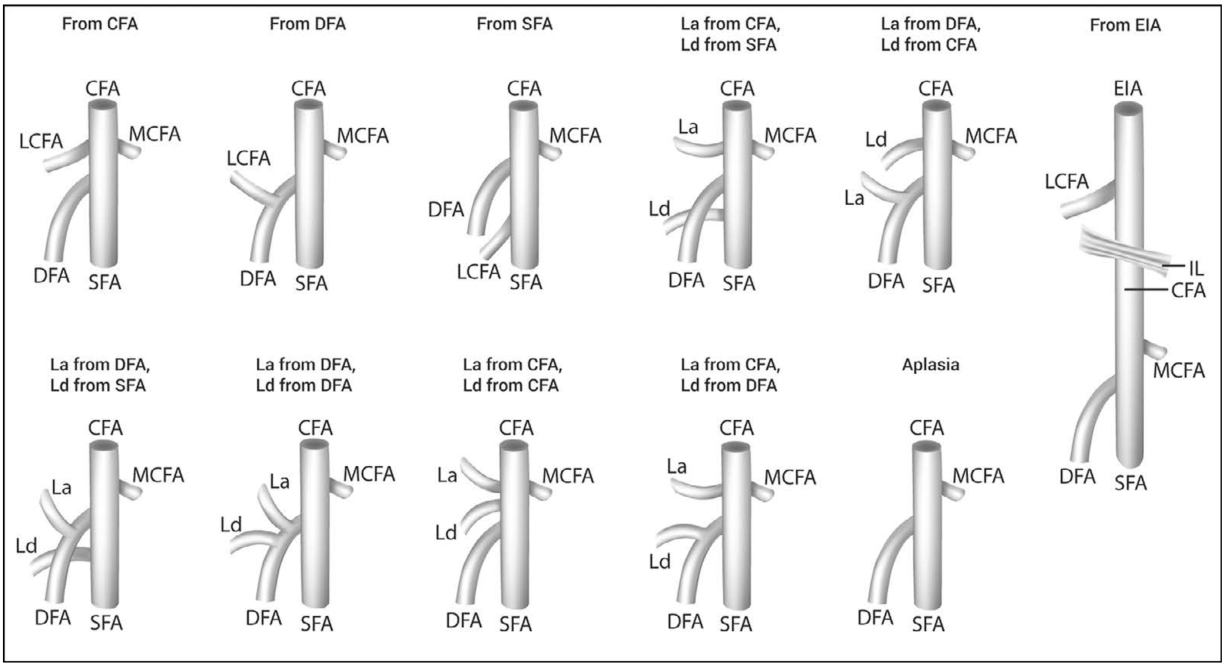

Figure 2. Variants of the origins of the lateral circumflex femoral artery (LCFA); CFA — common femoral artery; DFA — deep femoral artery; EIA — external iliac artery; IL — inguinal ligament; La — ascending branch; Ld — descending branch; MCFA — medial circumflex femoral artery; SFA — superficial femoral artery.

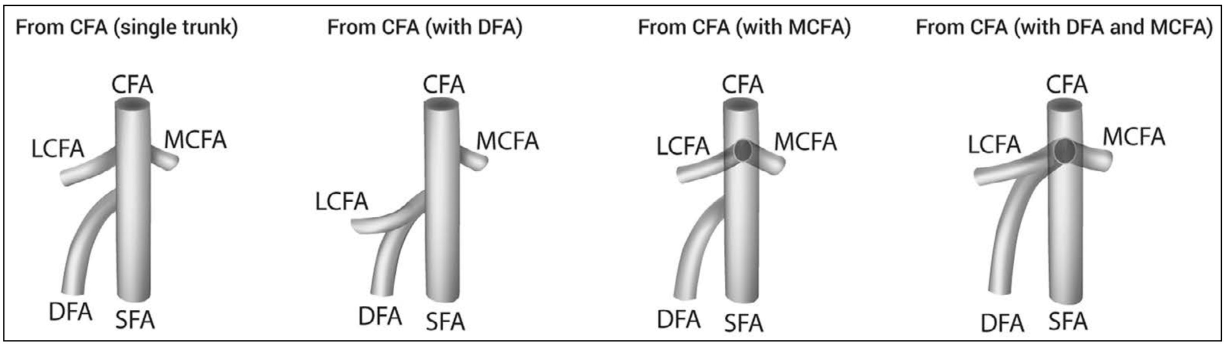

Figure 3. Sub-variants of the lateral circumflex femoral artery (LCFA) originating from the common femoral artery (CFA); DFA — deep femoral artery; MCFA — medial circumflex femoral artery; SFA — superficial femoral artery.

A sensitivity analysis was performed to probe sources of heterogeneity by only including studies with a sample size of 100 or more lower limbs (Table 2); however, no significant differences were noted from the results of our overall analysis. Similarly, subgroup analysis with respect to geography was performed (Table 2), showing no significant differences when compared with the results of the overall analysis.

Origins of the lateral circumflex femoral artery with respect to gender and side

Five studies (n = 695 male lower limbs, 211 female lower limbs) reported data on the prevalence of the various origins of the LCFA with respect to gender and side (Table 4). Our analysis revealed that the LCFA, consistent with our overall analysis, most commonly originated from the DFA. Detailed results on the origins of the LCFA with respect to gender are presented in Tables 4 and 5.

Nine studies (n = 695 lower limbs) reported data on the prevalence of the various origins of the LCFA with respect to side (Table 6). Our results were consistent with the overall analysis, but the prevalence of the LCFA from the DFA was more common on the left side (77.6%) vs. the right side (73.9%), although these results were not statistically significant. In contrast to LCFA from the DFA, the LCFA originating from the CFA was more com-

Table 4. Prevalence of the various origins of the LCFA with respect to gender

	Male			Female		
	Total	Right	Left	Total	Right	Left
Number of studies (no. of legs)	5 (695)	3 (259)	3 (260)	5 (211)	3 (82)	3 (83)
From CFA [%] (95% CI)	21.9 (15.1–29.8)	23.7 (15.1–33.9)	17.9 (10.5–27.1)	23.3 (15.5–31.3)	25.1 (12.4–41.8)	19.1 (11.8–29.4)
From DFA [%] (95% CI)	75.5 (68.1–83.1)	71.4 (61.4–81.2)	78.7 (70.0–87.5)	73.0 (66.3–82.7)	69.5 (55.2–85.5)	73.5 (66.6–85.3)
From SFA [%] (95% CI)	0.6 (0–2.3)	0.8 (0–3.4)	0.8 (0–3.3)	1.5 (0–4.2)	2.7 (0–9.7)	1.6 (0–5.1)
La from CFA, Ld from SFA [%] (95% CI)	0.3 (0–1.6)	0.4 (0–2.3)	0.4 (0–2.3)	0.6 (0–2.5)	0.9 (0–5.5)	0.8 (0–3.5)
La from CFA, Ld from CFA [%] (95% CI)	0.5 (0–2.1)	1.2 (0–4.3)	–	1.0 (0–3.3)	–	2.1 (0–5.9)
La from DFA, Ld from CFA [%] (95% CI)	1.0 (0–3.1)	2.1 (0–6.7)	1.9 (0–5.3)	1.0 (0–3.3)	0.9 (0–5.5)	2.1 (0–5.9)
La from DFA, Ld from SFA [%] (95% CI)	0.3 (0–1.6)	0.4 (0–2.3)	0.4 (0–2.3)	0.6 (0–2.5)	0.9 (0–5.5)	0.8 (0–3.5)
I^2 [%] (95% CI)	74.69 (37.44–89.76)	49.65 (0–85.40)	47.63 (0–94.68)	42.46 (0–78.84)	54.24 (0–86.91)	3.95 (0–90.01)
Cochran's Q, p-value	0.003	0.137	0.148	0.138	0.112	0.353

CI — confidence interval; CFA — common femoral artery; DFA — deep femoral artery; LCFA — lateral circumflex femoral artery; SFA — superficial femoral artery

Table 5. Prevalence of the various types of CFA origins of the LCFA according to gender

	Male			Female		
	Total	Right	Left	Total	Right	Left
Number of studies (no. of legs)	4 (139)	3 (59)	3 (44)	2 (19)	3 (21)	3 (16)
From CFA (single trunk) [%] (95% CI)	87.6 (61.6–100)	80.4 (35.9–100)	83.0 (46.0–100)	64.4 (22.5–100)	76.7 (40.5–100)	63.1 (21.5–100)
From CFA (with DFA) [%] (95% CI)	7.2 (0–26.1)	11.3 (0–48.3)	12.5 (0–54.0)	30.9 (0–77.5)	13.3 (0–50.4)	24.4 (0–68.4)
From CFA (with MCFA) [%] (95% CI)	3.2 (0–17.9)	3.9 (0–31.7)	2.2 (0–28.7)	2.3 (0–25.0)	6.6 (0–37.1)	8.4 (0–42.2)
From CFA (with DFA and MCFA) [%] (95% CI)	1.9 (0–14.5)	4.4 (0–33.2)	2.2 (0–28.7)	2.3 (0–25.0)	3.3 (0–28.3)	4.0 (0–31.4)
I^2 [%] (95% CI)	89.99 (77.28–95.59)	86.94 (62.70–95.43)	84.65 (54.39–94.83)	69.85 (0–93.22)	71.77 (4.42–91.67)	67.61 (0–90.63)
Cochran's Q, p-value	< 0.001	< 0.001	0.001	0.069	0.029	0.046

CI — confidence interval; CFA — common femoral artery; DFA — deep femoral artery; LCFA — lateral circumflex femoral artery; MCFA — medial circumflex femoral artery; SFA — superficial femoral artery

mon on the right side (22.1%) vs. the left side (19.1%); however, these differences were also not statistically significant. When the LCFA originated from the CFA, it most commonly arose as a single trunk, thus consistent with the results of our overall analysis (Table 7).

Morphometrics of the lateral circumflex femoral artery

Two studies (n = 29 lower limbs for LCFA originating from CFA, 117 lower limbs for LCFA originating from DFA) reported data on the pooled mean distance of the various origins of the LCFA to the MIP (Table 8). The pooled mean distance of the LCFA originating from the CFA to the MIP was 38.79 mm (95% confidence interval 28.10–49.48) and the pooled mean distance of the LCFA originating from the DFA to the MIP was 51.06 mm (95% confidence interval 44.61–57.51).

New classification system for origin of the lateral circumflex femoral artery

After a thorough assessment of the results of the analysis, a new classification system for the origin of

Table 6. Prevalence of the various origins of the LCFA according to side

	Right	Left
Number of studies (no. of legs)	9 (695)	9 (695)
From CFA [%] (95% CI)	22.1 (18.1–27.0)	19.1 (15.8–23.3)
From DFA [%] (95% CI)	73.9 (70.1–79.5)	77.6 (74.8–82.5)
From SFA [%] (95% CI)	0.8 (0.1–2.2)	0.7 (0.1–1.8)
From EIA [%] (95% CI)	0.5 (0–1.4)	0.3 (0–1.0)
La from CFA, Ld from SFA [%] (95% CI)	0.4 (0–1.1)	0.3 (0–1.0)
La from CFA, Ld from CFA [%] (95% CI)	0.5 (0–1.6)	0.4 (0–1.2)
La from DFA, Ld from CFA [%] (95% CI)	1.1 (0.2–2.6)	0.9 (0.2–2.1)
La from DFA, Ld from SFA [%] (95% CI)	0.4 (0–1.1)	0.3 (0–1.0)
Aplasia [%] (95% CI)	0.5 (0–1.4)	0.3 (0–1.0)
I^2 [%] (95% CI)	43.22 (0–73.79)	28.64 (0–66.86)
Cochran's Q, p-value	0.079	0.190

CI — confidence interval; CFA — common femoral artery; DFA — deep femoral artery; EIA — external iliac artery; LCFA — lateral circumflex femoral artery; Ld — descending branch; SFA — superficial femoral artery

Table 7. Prevalence of the various types of CFA origins of the LCFA according to side

	Right	Left
Number of studies (number of legs)	9 (154)	9 (131)
From CFA (single trunk) [%] (95% CI)	78.0 (47.2–98.4)	76.8 (50.2–98.8)
From CFA (with DFA) [%] (95% CI)	15.6 (0–44.9)	18.3 (0.8–48.2)
From CFA (with MCFA) [%] (95% CI)	3.7 (0–19.7)	2.6 (0–16.8)
From CFA (with DFA and MCFA) [%] (95% CI)	2.7 (0–17.2)	2.2 (0–15.6)
I^2 [%] (95% CI)	92.13 (87.29–95.13)	90.42 (84.08–94.24)
Cochran's Q, p-value	< 0.001	< 0.001

CI — confidence interval; CFA — common femoral artery; DFA — deep femoral artery; LCFA — lateral circumflex femoral artery; MCFA — medial circumflex femoral artery

Table 8. Pooled mean distance of the various origins of the LCFA to the MIP

	LCFA originating from CFA	LCFA originating from DFA
Number of studies (no. of legs)	2 (29)	2 (117)
Pooled mean distance [mm] [%] (95% CI)	38.79 (28.10–49.48)	51.06 (44.61–57.51)
I^2 [%]	0.0	0.0

CI — confidence interval; CFA — common femoral artery; DFA — deep femoral artery; LCFA — lateral circumflex femoral artery; MIP — mid-inguinal point

the LCFA was established and presented in Figure 4. Five different types of origin variations that met the a priori thresholds were included in the classification: Type 1 (normal) — LCFA branching from the DFA; Type 2 — LCFA branching from the CFA as a single trunk; Type 3 — LCFA branching from the CFA with the DFA; Type 4 — LCFA branching from the SFA; and Type 5 — direct branching patterns (from CFA, DFA, and SFA), where the La and Ld branches of the LCFA originate directly from one of the main femoral vessels without a common branch. While none of the individual direct branching patterns alone reached a threshold of ≥ 1%, due to the several different reported patterns in combination reaching a value well above the threshold, a single category (Type 5) was made to incorporate all La and Ld direct branch-

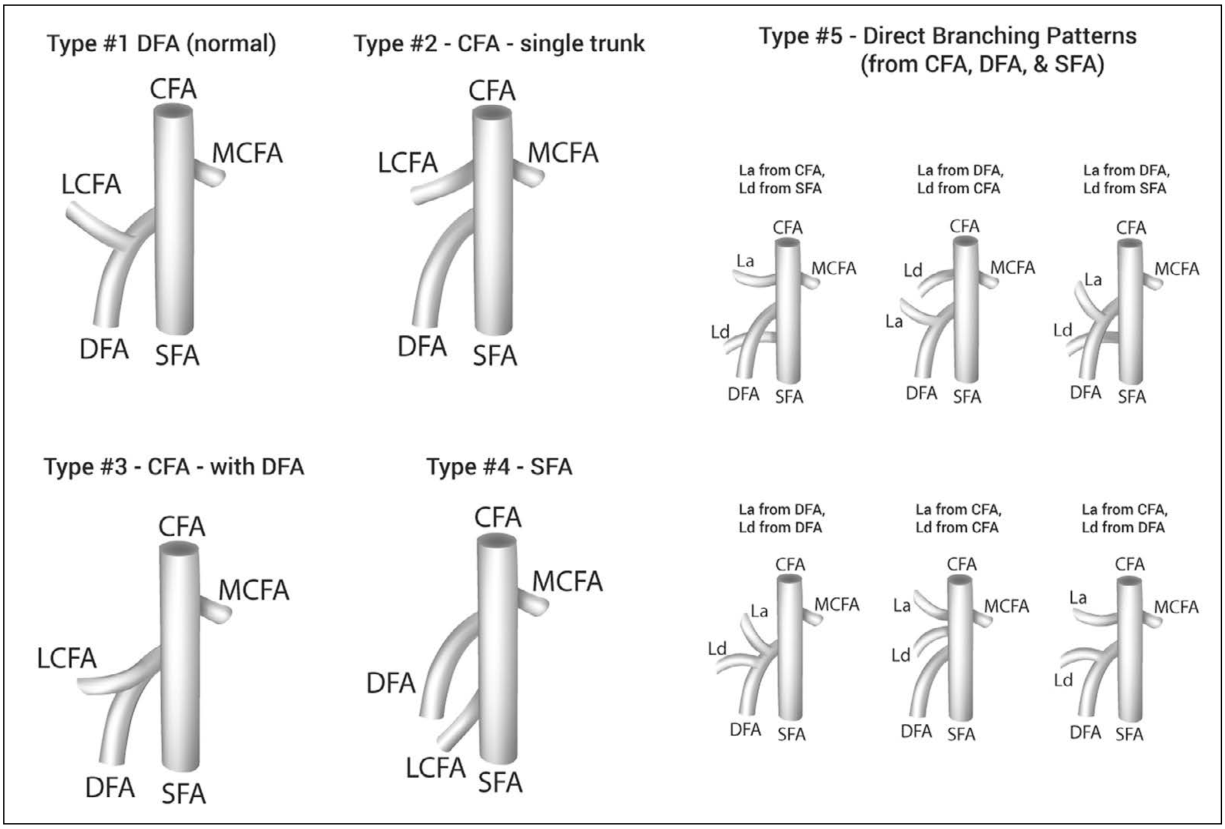

Figure 4. New classification system of the origin of the lateral circumflex femoral artery (LCFA); CFA — common femoral artery; DFA — deep femoral artery; La — ascending branch; Ld — descending branch; MCFA — medial circumflex femoral artery; SFA — superficial femoral artery.

ing patterns. All other variants of the LCFA origin not included in the classification system should be considered rare anomalies (Supplement S3. Raw data — see journal website, supplementary file).

DISCUSSION

The LCFA has been shown to supply the head and neck of the femur, the greater trochanter, the vastus lateralis muscle, and the knee [32]. The overall aim of our study was to gather and analyse all available data from a comprehensive literature search on LCFA, with a focus on its branching and morphometric variations, to provide a detailed analysis of the artery, and its clinically important characteristics.

Detailed anatomical knowledge about the LCFA is useful in a number of clinical procedures, including aortopopliteal bypass [10, 29], anterolateral thigh flaps [33], and coronary artery bypass grafting [8], thus giving its normal and variant anatomy a high degree of clinical significance. Furthermore, its branches may also be used in various procedures. The ascending branch of the LCFA can be used for vascularised iliac transplant, and its descending branch may be employed as a collateral for an obstructed SFA, and can also be used in coronary artery bypass grafting [12, 32].

Our results demonstrated that the LCFA most commonly originated from the DFA with a pooled prevalence of 76.1%. Thus, we consider a DFA origin to be the normal type of LCFA origin (Type 1). This trend held true across all subgroups including side, gender, and geographical regions.

The second most common origin of the LCFA was found to be from the CFA, with a pooled prevalence of 19.6%. A CFA-derived LCFA was also most commonly found to branch as a single trunk, with a pooled prevalence of 81.8%. These findings were consistent when acknowledging gender, side and geographical location. Though not statistically significant, it is interesting to note that the LCFA originated from the CFA on the right limb more frequently than the left in both men and women. Other variations of the origin of the LCFA, such as the SFA [8], external iliac artery [5] and instances where the anterior and descending limbs of the LCFA branch directly from the main femoral vessels without a common trunk [8], have been reported (Table 2).

The highly variable branching pattern of a CFA--derived LCFA was found to branch alongside the DFA, the MCFA, or with the DFA and MCFA concurrently (Fig. 3). Accurate anatomical details concerning the LCFA origin can help physicians make informed decisions during interventional procedures and operations in the femoral region. Moreover, knowledge on the existence of these rarer LCFA origin variations is crucial for surgeons to avoid iatrogenic injuries.

In order to supply some organisation to the multitude of reported origin patterns of the LCFA, we formulated a simple classification system based on the results of our comprehensive meta-analysis (Fig. 4). Previous classifications [35] often attempted to encompass the origins and anatomy of multiple arteries versus a simple classification system for LCFA origin. Difficulty in adhering to such systems can be seen in the lack of consistency in the reporting of LCFA origin between studies in the literate, and thus indicating the need for a new, simple classification system. Our system is inclusive of all the most common variants with a population prevalence ≥ 1.0%, and organised as most common — Type 1 (DFA origin) to least common — Type 4 (SFA origin). Additionally, we formulated a Type 5 for direct branching patterns, inclusive of all variants where the La and Ld branch directly from one of the main femoral vessels without a common branch. The proposed classification system should be further assessed and evaluated in future original anatomical studies.

The distance from LCFA origin to the MIP was also analysed, with a pooled mean of 51.06 mm when originating from the DFA, the most common origin of the artery (Table 8). When the LCFA originated from the CFA, it was found to do so with a pooled mean distance from the MIP of 38.79 mm, substantially shorter than that of a DFA origin. The differences in distance, however, were not found to be statistically significant. Due to the lack of studies on this parameter [2], as well as the overall lack of other substantial morphometric studies on the LCFA, further research is needed to determine the precise vessel measurements throughout populations, as this data may be of value to interventional radiologists and orthopaedic surgeons. Additionally, future studies should examine the spatial arrangement of the LCFA, to better understand the exact location of its origin.

Our study was limited by the lack of a quality assessment tool and risk of bias assessment method for anatomical studies, as well as lack of a proper measure for publication bias in multi-categorical pooled prevalence meta-analysis. Furthermore, our meta-analysis was also limited by the high heterogeneity among the included studies, which persisted despite extensive subgroup analysis. We there attribute the high heterogeneity to be most likely due to the highly variable nature of the vessel itself.

CONCLUSIONS

In conclusion, the most common origin of the LCFA is from the DFA, branching at an average distance of 51.06 mm from the MIP. However, the origin of the LCFA is variable throughout the general population and thus a new simple anatomical classification system was proposed. Accurate knowledge of the anatomical properties of the LCFA may convey important information to surgeons, especially during aortopopliteal bypass surgery and anterolateral thigh flap procedures. The high degree of variability within this artery requires physicians to proceed with caution in order to decrease the risk of iatrogenic injuries. Thus, we highly recommended radiographic assessment of the vessel anatomy prior to surgical procedures in the femoral region.

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