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Full title: Anatomic symmetry of anterolateral thigh flap perforators – a computed tomography angiographic study.

Short title: Symmetry of anterolateral thigh flap perforators

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Abstract

Background: The anterolateral thigh (ALT) flap is a workhorse reconstructive flap. Versatility in design is a key strength but perforator anatomy can be variable. Inability to locate perforators prompts consideration of contralateral thigh exploration. However, such exploration would be futile if the absence of perforators proves symmetrical. This study assesses the symmetry of ALT flap vasculature using computed tomography angiography (CTA).

Methods: A retrospective analysis of 20 bilateral thigh CTAs was performed. Each limb was assessed for number, course, location and size of perforators. Only vessels > 0.5mm in size at origin were included. Location was standardised between patients using perforator distance/thigh length ratio (PD/TL). Results were analysed using Wilcoxon Signed-Rank test.

Results: In each thigh, the average number of perforators was 3.58 and average PD/TL was 0.358 ± 0.08. Between both limbs of the same patient, the mean difference in number of perforators was 0.55 ($p=0.002$), and difference in average perforator size was 0.3mm ($p<0.001$). Average perforator location differed by a mean of 3% of thigh length ($p<0.001$) between thighs.

Conclusion: While average vessel size and location appear similar, there does not appear to be symmetry in the number of perforators. Surgical exploration of the contralateral thigh in an absence of perforators should be considered. In patients where abnormal anatomy is expected, mapping with CTA could be considered to reduce morbidity associated with unsuccessful surgical exploration and dissection.

MeSH keywords: perforator flaps, free tissue flaps, microsurgery, reconstructive surgery, computed tomography angiography

Introduction

In 1984, Song et al first described the surgical technique for harvesting the anterolateral, anteromedial and posterior thigh flaps for use in reconstruction of burns contractures[1]. The use of the perforator-based anterolateral thigh (ALT) flap has since seen remarkable growth across a broad range of applications. Offering versatility in design, composition[2] and minimal donor site morbidity[3,4], it has become a workhorse flap with documented usage in head and neck, trunk and extremity reconstruction[2,5–7].

One of the ALT flap's well-known shortcomings, however, is the variability of local vasculature. Without pre-operative imaging or perforator mapping, surgeons can often fall victim to the idiosyncratic vascular anatomy. In its earliest description, it was based on septocutaneous perforators that originated from the descending branch of the lateral circumflex femoral artery (LCFA) and travelled through the intermuscular septum between vastus lateralis and rectus femoris[1]. Since then, studies have demonstrated significant anatomical variance in perforator numbers, origin, course and location[8–11] – all of which can contribute to complexity of flap harvest. The inconsistency in anatomy compounds on the risk of morbidity, especially if surgical exploration fails to yield a viable perforator. The outcome in such cases is an unfruitful incision and dissection. Further morbidity is incurred if exploration of the contralateral thigh is then undertaken and the absence of perforators proves symmetrical. Detailed knowledge of vascular patterns is vital, and an understanding of the

degree of perforator symmetry between paired limbs will guide intra-operative decision-making when initial exploration fails to yield results.

In this study, we aim to assess the symmetry of bilateral lower limb skin perforators using CTA, in order to guide surgical decision-making during ALT flap harvest. More specifically, we endeavour to provide direction on the utility of exploring the contralateral thigh when facing an absence of perforators.

Methods

A single-centre retrospective analysis of 20 bilateral lower limb CTA performed between January 2015 to April 2016 was conducted. All bilateral lower limb CT angiograms performed at our hospital from January 2015 onwards were reviewed in consecutive fashion until a sample size of 20 was achieved. Indications for imaging were predominantly trauma-related, and included assessment for vascular injury as well as recipient vessels prior to free flap reconstruction of lower leg defects. Patients were excluded if there was vascular injury, presence of metallic prostheses, clinically significant pathology existing in the thigh (including infection, tumour, amputation, vascular grafting or stent, aneurysm or abscess)[10] or if the study was deemed uninterpretable due to factors such as insufficient imaging, suboptimal arterial opacification or patient motion artefact.

CTA protocol

CT bilateral lower limb angiogram studies were performed using a 128 slice GE Discovery HD 750 (GE Healthcare, Illinois, USA) CT scanner. CT was performed at 100-120 kVP with

automatic exposure control (AEC). 110 mL Omnipaque 350 (GE Healthcare) was administered intravenously via mechanical power injector. Scans were acquired with patient in the supine position, scan range from coeliac axis or aortic bifurcation to toes[12].

Image interpretation:

Raw image data was reconstructed in 3mm slice thickness axial, coronal and sagittal images. Images were reviewed on Centricity PACS Workstation system (GE Healthcare). The descending branch of the lateral circumflex femoral artery and perforator branches were identified and the diameter of each vessel was measured at its point of origin. Only perforators >0.5mm were deemed clinically significant and recorded. Perforator distance was measured as a straight line from the anterior superior iliac spine (ASIS) to the origin of the vessel on coronal plane, and thigh length was measured from ASIS to the superolateral pole of the patella, also on coronal plane. Based on its course after branching, each individual perforator was specified as musculocutaneous or septocutaneous.

Statistics

Results were analysed for statistical significance using the Wilcoxon Signed-Rank test, with the threshold for significance taken to be $p < 0.05$. Values are reported as mean ± standard deviation (p-value).

Ethics

Ethics approval was granted by the Alfred Health Office of Ethics and Research Governance (HREC No. 488/16), in accordance with National Health and Medical Research Council

(NHMRC) guidelines. A waiver of the requirement of providing information and obtaining patient consent was approved in accordance with the NHMRC National Statement on Ethical Conduct in Human Research.

Results

Number of perforators

Every limb had at least one perforator, and the mean number of perforators per limb was 3.58.

Of the 20 patients, 11 (55%) had symmetrical number of perforators in both thighs, and 9 (45%) had a difference of either 1 or 2 vessels. The mean inter-limb difference in number of perforators was 0.55 ± 0.69 ($p = 0.002$).

Perforator location

To account for patients of different sizes, the ratio of perforator distance to respective thigh length (PD/TL) was used to represent perforator location. The PD/TL of each perforator was mapped, and the average value calculated for each limb. The dominant perforator in each thigh was identified as the vessel with the largest diameter.

51.7% of perforators were located in the proximal third of the thigh, 47.6% in the middle third and 0.7% in the distal third. The average PD/TL was 0.358 ± 0.08, and mean inter-limb difference for each patient was 0.03 ± 0.03 ($p < 0.001$). Thus, mean perforator location on the left and right thighs differed by 3% of the patient's thigh length.

Of the dominant perforators, 57.5% were located in the proximal third of the thigh and 42.5% were located in the middle third. No dominant perforators were located in the distal third. 11/20 (55%) of patients had dominant perforators in symmetrical thirds in both legs, while 9/20 (45%) had asymmetrical distributions.

Perforator course and size

87.4% of perforators were musculocutaneous and 12.6% were septocutaneous. 7/20 patients (35%) had a symmetrical number of perforators running a symmetrical course in both legs.

The average perforator size was 1.58mm. When comparing both thighs, the mean perforator diameter for each patient differed by an average of 0.30mm ± 0.27mm ($p < 0.001$).

Discussion

The ALT flap has seen a rapid rise in popularity around the world in the reconstruction of head and neck and limb defects. Its advantages lie in a long vascular pedicle, large skin area with potential for sensory reinnervation, minimal donor site morbidity and the opportunity for a two-team combined approach. It was originally described as a fasciocutaneous flap with septocutaneous perforators originating from the descending branch of the LCFA, however anatomical studies have since shown significant variations in perforator anatomy. A systematic review by Lakhiani et al[9] found that the described septocutaneous perforators were present in between 9.5 to 61.5% of cases[4,7,11,13–25], and perforators originated from the descending branch of the LCFA between 57 to 100% of patients[7,8,10,11,13,14,20,22,24–33]. Other perforator origins included the LCFA itself, its anatomical branches (ascending, transverse, oblique), the common femoral artery and profunda femoris artery[7,10,11,20,28]. In 250 anterolateral thigh flaps, Lin et al[34] found that 1.4% had no perforators on either limb after surgical exploration of the contralateral thigh.

In patients where initial exploration proves unfruitful, our results support surgical exploration of the contralateral thigh. We observed a low degree of symmetry between the ALT perforators on each leg, with only 11/20 (55%) patients having the same number of perforators, and an average difference of 0.55 ± 0.69 ($p=0.002$) between thighs. When the course of perforators was included, 7/20 (35%) patients shared symmetry. This relationship also applied to the location of dominant perforators, with only 55% of patients having dominant perforators in symmetrical thirds in each thigh. As such, an absence of perforators on one limb does not reliably indicate a similar absence of perforators on the contralateral

limb. Prior to exploring the contralateral thigh, however, salvage flap options such as the ipsilateral anteromedial thigh (AMT) or tensor fascia lata (TFL) flaps should be considered[35]. Through the initial medial incision made for ALT harvest, the dissection can be continued medially or superiorly to identify any AMT or TFL vessels respectively. These act as useful fallback options in the event of perforator absence or injury to the ALT perforators, but provide less skin coverage than the ALT flap[35].

Apart from an absence of perforators, iatrogenic injury to the vessels is also a relative indication to consider abandonment of flap harvest on a particular side. If the vascular injury cannot be repaired and the remaining ipsilateral perforators are of insufficient calibre to sustain the flap, then the contralateral thigh may be the most suitable alternative donor for reconstructive options. When comparing perforator locations on both limbs of each patient, the average point of emergence was shown to differ by 3% of the patient's thigh length, suggesting a high degree of symmetry in perforator location. By condensing the field of exploration in the contralateral limb based on the corresponding perforator location in the initial thigh, the search for suitable vessels can be quickened.

With increasing availability of imaging facilities, pre-operative identification of suitable perforators through colour Doppler ultrasound and CTA has received increasing support in the literature [11,18,36–38]. The benefits of colour Doppler include its non-invasive nature, absence of radiation and high positive predictive value[39]. However, the procedure is time-consuming (30-40 mins) and is operator-dependent. A high degree of operative knowledge is required to perform a relevant assessment and identification of the vessels. CTA has come to the fore as

a superior, non-invasive and operator-independent modality that has a strong impact on surgical planning[36,38]. It identifies not just the subcutaneous location of each perforator, but also provides anatomical information on the course and health of the vessel from origin to emergence. This is especially helpful when more complex reconstruction using multi-perforator or chimeric flaps is required. With the comprehensive mapping of ALT vasculature, limb and perforator selection can be made pre-operatively, thus reducing operative time and risk[11]. However, CTA comes at the significant cost of radiation and contrast exposure, drawbacks that have to be considered in young or pregnant patients and patients with kidney disease respectively. In our practice, we do not routinely perform pre-operative imaging on patients prior to ALT flap harvest, unless abnormal anatomy due to injury or disease is anticipated.

The study is currently limited by the small patient sampling group, which restricts the distribution of anatomical variations that can be studied. In particular, given all patients had at least one perforator in each leg, we were unable to comment on the vascular symmetry if there was a complete absence of perforators in one or both thighs. Correlation of the anatomical symmetry on CT with intraoperative findings or cadaveric dissections would also increase the significance of these findings.

Conclusion

The ALT flap is a workhorse flap that is used widely in reconstructive surgery. However, its variable perforator anatomy can complicate flap harvest. In patients where no viable vessels are identified on initial exploration, exploration of the contralateral thigh should be

considered due to the low degree of perforator symmetry between paired thighs. Should pre-operative perforator mapping be required, CTA is a superior imaging modality to colour Doppler ultrasound due to reduced inter-operator variability and greater consistency. In situations where abnormal anatomy is anticipated due to disease or trauma, CTA is recommended to further delineate surgical anatomy and reduce risk of perforator injury. Design of complex reconstructive options such as multi-perforator or chimeric flaps would also be greatly aided by CTA.

Disclosure statement

The authors declare that there is no conflict of interest regarding the publication of this article.

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anterolateral thigh flap cutaneous perforators by colour Doppler flowmetry. 2003;56(1):21-25.

Figure legends

Figure 1: Anatomical distribution of all perforators

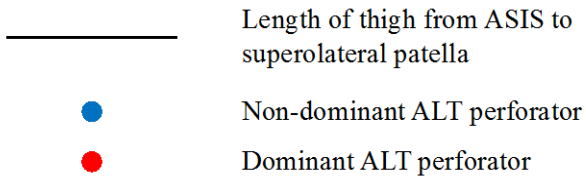

Figure 2: Anatomical distribution of dominant perforators

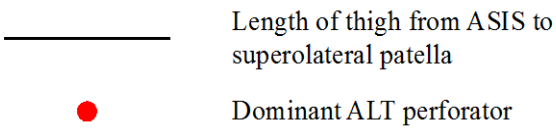

Table 1. Results

	Right					Left				
Patient	No. of perforators	No. of musculo-cutaneous perforators	No. of septo-cutaneous perforators	Average diameter at origin (mm)	Average perforator distance/thigh length (PD/TL)	No. of perforators	No. of musculo-cutaneous perforators	No. of septo-cutaneous perforators	Average diameter at origin (mm)	Average perforator distance/thigh length (PD/TL)
1	5	4	1	1.46	0.448	5	3	2	1.62	0.420
2	3	3	0	1.73	0.333	3	3	0	1.63	0.312
3	3	1	2	1.57	0.336	3	2	1	1.17	0.355
4	4	4	0	1.33	0.315	4	4	0	1.25	0.321
5	4	3	1	1.35	0.435	4	4	0	1.43	0.327
6	4	4	0	1.70	0.419	3	2	1	1.57	0.447

7	1	1	0	3.00	0.337	1	1	0	4.00	0.291
8	6	5	1	1.37	0.380	5	4	1	1.20	0.422
9	4	3	1	1.58	0.341	4	3	1	1.75	0.326
10	3	3	0	1.50	0.348	4	3	1	1.53	0.299
11	2	1	1	1.70	0.375	3	2	1	1.60	0.355
12	4	4	0	2.20	0.309	4	4	0	1.35	0.357
13	3	3	0	1.70	0.310	4	3	1	1.13	0.357
14	4	4	0	1.38	0.312	2	2	0	1.15	0.315
15	3	3	0	1.40	0.392	3	3	0	1.17	0.364
16	3	2	1	1.33	0.291	3	3	0	0.97	0.300
17	4	4	0	0.98	0.336	5	5	0	1.06	0.422
18	4	4	0	1.85	0.318	4	4	0	1.33	0.309
19	4	4	0	2.00	0.330	2	2	0	2.25	0.324

20	5	4	1	1.30	0.431	4	4	0	1.70	0.359

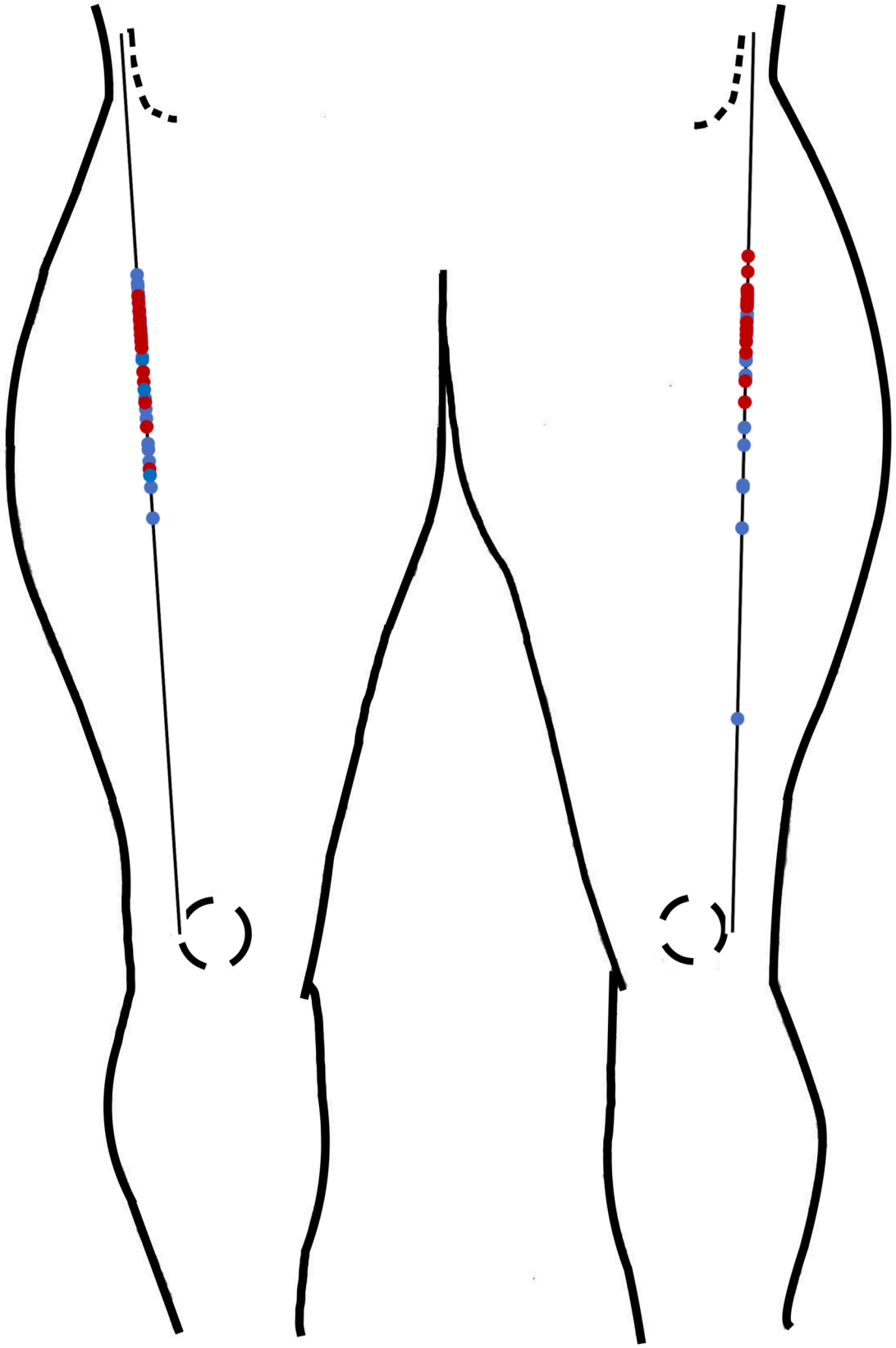

FIG 1_ALT all perfs.tiff

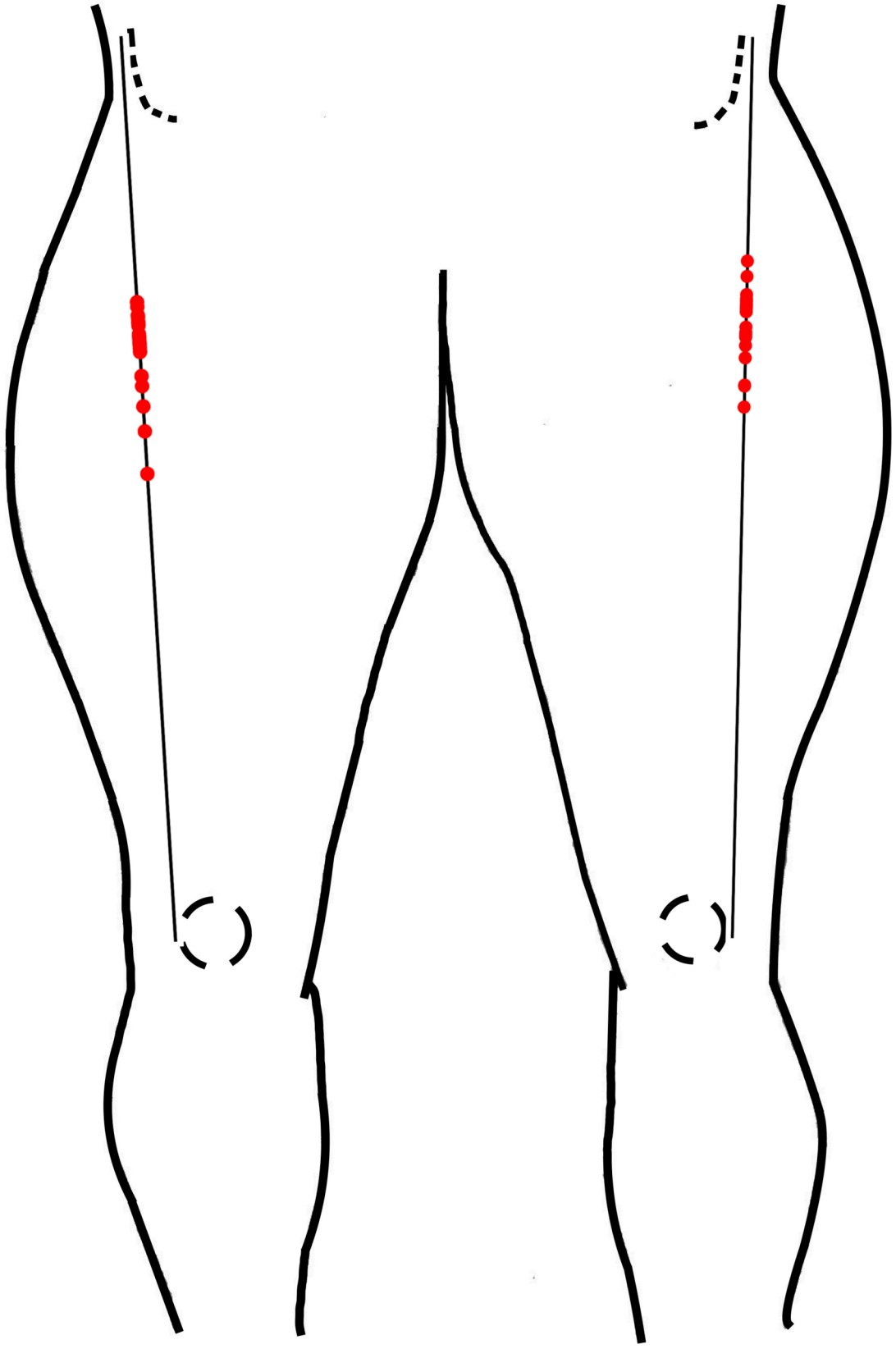

FIG 2_ALT dom perfs.tiff