Anatomical Study of Lumbar Artery Perforators in Male Subjects

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Introduction: The lumbar artery perforator (LAP) flap takes an important place in lumbosacral reconstruction and in breast reconstruction. Although studies on the location of lumbar perforators in women are common, no anatomical study has focused solely on male subjects. Our objective is to facilitate the surgical approach to the LAP flap in male subjects by precisely ascertaining the characteristics of the perforators.

Methods: We performed a retrospective review of computed tomographic angiography images of a cohort of 30 patients evaluating the perforator position from the 4 lumbar arteries. In addition, 4 characteristics were studied: the length, the diameter, the path of the lumbar pedicle, and the thickness of tissues available for transfer.

Results: One hundred five lumbar perforating vessels were analyzed on 60 posterior hemi-bodies, of which 86% came from the third and fourth lumbar arteries. The average location was situated 7.4 cm from the midline and in a 6-cm vertical wide area. The position of the lumbar perforator was independent of body mass index, abdominal circumference, and subject size. Our results, compared to previous studies, show no difference in this position between men and women.

Conclusions: The LAP flap is useful for regional reconstructions and as a free flap for both women and men. We provide male-specific tracking values for the dissection of lumbar perforating vessels. Dominant perforators were found to be situated in a wide region of 4 cm × 6 cm in the lumbosacral region at 7.4 cm from the midline.

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INTRODUCTION

In 1988, Kroll and Rosenfield1 described lumbar fasciocutaneous flaps based on musculocutaneous perforating arteries located near the midline. They called them “unnamed perforators.” In 1999, Kato et al2 carried out an anatomo-clinical study describing, for the first time, the vascular territory ensured by the second lumbar artery perforator (LAP). Based on their results, they successfully treated 4 patients with lumbosacral ulcers. Indeed, the LAP flap was initially described as a pedicled flap filling defects of the lumbosacral region (Fig. 1). Subsequently, de Weerd and Weum3 and de Weerd et al4 reported a case in 2002 using the LAP flap bilaterally for the treatment of a large lumbosacral defect, before describing for the first time in 2003 its use as a free method for breast reconstruction. Chronologically, 2 anatomical studies5,6 and an anatomo-clinical publication7 followed in the 2000s: first, Offman et al5 described in 2005 the anatomy of the arteries of the lateral lumbar region by performing a cadaveric dissection subsequent to an arterial injection of lead oxide. A dense subcutaneous vascular network helped to describe well-vascularized and robust lumbar flaps. Computed tomographic angiography (CTA) was used for the first time in 2009 to determine the location of LAPs: in 2 dimensions (2D) in vivo by Kiil et al7 highlighting the efficacy of CTA for locating LAPs of large caliber; in 3 dimensions (3D) postmortem by Lui et al6 which described the anatomy of the lumbar and gluteal arteries. More recently, in 2016, Bissell et al8 accurately described the lumbar arterial anatomy and attested to the interesting profile of the first and fourth LAPs in their use as a perforating flap. In 2007, Sommeling et al9 described the third and fourth LAPs as the dominant perforators with a constant position allowing tracking by Doppler.10

The use of the LAP flap in breast reconstruction had a quiescent period after its first description in 2003 by de Weerd et al.4 The subject was recently revived in 2015 by Peters et al11 who argued that this flap is a very good option in young patients with little available abdominal...
tissue. In 2016, Hamdi et al.12 reviewed all their LAP flaps for breast reconstruction. The location of the LAP, determined preoperatively by CTA, allowed them to locate the dominant perforating artery at 6.95 cm from the midline. Finally, in 2017, Honart et al.13 used the LAP flap as first-line treatment in patients who had no contraindication to the use of a deep inferior epigastric perforator flap, to adapt breast reconstruction to the morphology and the wishes of the patient. A summary table comparing publications illustrates the point that few of the studies have focused on men compared with women (Table 1).

The main disadvantage of the LAP flap is the short length of its vascular pedicle. A graft is indeed often used during free flap reconstructions.11,12 Nevertheless, Honart et al.12 insisted on a thorough and meticulous dissection of the donor site to reduce the use of a graft.

Our project aimed to facilitate the surgical approach to the LAP flap, specifically in male subjects, by accurately determining the location of LAP. Using computed tomography (CT) images, LAP coordinates were indexed and analyzed to establish a fixed skin localization point to facilitate surgical dissection. This is the first in vivo anatomical study of LAP by CTA incorporating only male subjects.

**METHODS**

**Characteristics of the Study**

Our study was a retrospective analysis of 30 patients who underwent, between 2008 and 2017, abdominal CTA with arterial phase in the context of a vascular pathology of the lower limbs. Patients were included according to 4 criteria: age less than or equal to 75 years; a body mass index (BMI) between 20 and 30; absence of aortic pathology (aortic prosthesis, aneurysm with false lumen); and absence of bone deformity of the pelvis or lumbar spine.

**CTA**

The analysis of CTA images was performed during the arterial phase after injection of 120 cm³ of Iomeron at a flow rate of 4 mL/s. We used Carestream Health.

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**Table 1. Comparison of the Anatomical Publications Describing the Characteristics of the DLA**

| Kato et al.10 | Offman et al.11 | Lui et al.12 | Kiil et al.13 | Bissel et al.14 | Hamdi et al.12 | Sommeling et al.15 |
|--------------|---------------|-------------|--------------|----------------|---------------|------------------|
| No. subjects studied | 11 | 5 | 2 | 22 | 6 | 20 | 24 |
| Sex | In vivo—postmortem | Undetermined | Undetermined | Undetermined | Undetermined | Female | Female |
| Technique | Cadaveric dissection | CTA 3D | CTA 2D | CTA 3D | CTA 2D | In vivo | In vivo |
| Diameter of artery* (mm) | – | 2.1 ± 0.5 | 0.7 ± 0.2 | 2.33 (1.3–4.5) | 0.8 ± 0.2 | 2.6 ± 0.4 | – |
| Pedicle length† (cm) | – | 7.0 ± 3.6 | – | 5.47 (3.9–6.9) | 10.6 ± 2.3 | 6 | – |
| Distance from the midline‡ (cm) | 7.71 (L4) | 5–9 | 10 (DLA) | – | 6.95 ± 0.6 | 8.5 (DLA) | 7–10 |

* Diameter of the perforating artery measured at the exit of the TF.
† The length of the pedicle is measured from the vertebral body to the TF.
‡ The midline passing through the spinous lumbar processes.

DLA, dominant lumbar artery; TF, thoracolumbar fascia.
Incorporation’s “Vue PACS V11” computer program with maximum intensity projection for the analysis of the results. Between 2008 and 2014, the CTA images were acquired with a Siemens Sensation 16 scanner and, as of 2015, with a Siemens Somatom Force scanner. Power settings (kV and mA) were automatically adjusted to the patient’s weight (Fig. 2).

Characteristics of LAPs

The characteristics studied for each LAP were: position, length, path in subcutaneous tissue, diameter at its emergence, and subcutaneous tissue thickness in front of the artery.

The LAP coordinates were determined at the exit point of the thoracolumbar fascia (TF) along the X and Y axes described previously by Hamdi et al.12 The X axis is a horizontal line passing through the upper edges of the iliac crests. The midline or Y axis is a vertical line through the vertebral spinous processes.

The length of the pedicle was measured from the location where the artery moves away from the vertebral body to its appearance at the TF level. In addition, we identified the musculocutaneous or septocutaneous pathway of LAP.

The diameter of the LAP was measured at the point of emergence.

The subcutaneous tissue thickness was measured from the TF to the skin. This characteristic makes it possible to evaluate the thickness of the flap.

A measurement of the abdominal circumference (AC) was performed at the X axis (upper edges of the iliac crests).

From the SPSS computer program, we calculated the Pearson correlation coefficient for the variables (AC–BMI–X and Y coordinate), (height–X and Y coordinate), and (AC–BMI–cutaneous fat thickness).

RESULTS

Thirty male patients aged 16–75 years (mean 54.6 years) with BMI between 20 and 30.5 kg/cm² (mean 25.8 kg/cm²) were studied. Their height varied between 163 and 193 cm (mean 173.8 cm). Also, 22 patients were smokers and 21 had atherosclerosis and/or aortic calcifications.

Out of 60 hemi-bodies, we were able to analyze 6 first lumbar arteries (L1), 11 second lumbar arteries (L2), 38 third lumbar arteries (L3), and 50 fourth lumbar arteries (L4) (Fig. 3). The vessels that were not constantly visualized throughout their length were not included. The dominant LAPs derived from the L3 and L4 in 86% of cases.

The mean left and right X and Y coordinates of the LAPs are summarized in Table 2. The minimum and maximum coordinates of the dominant branches (L3 and L4) were between 6.2 and 10.1 cm from the midline with an average of 7.4 cm. We observed a decrease in this coordinate from L1 to L4, thus mimicking a convergence toward the midline. The average Y coordinate of L4 was 0.2 mm, indicating that this LAP is in a small space around the axis connecting the upper edges of the iliac crests (min −12.4 and max +15.3 mm in our series). On the other hand, the emergence of the third LAP varied significantly between 2.3 and 48.1 mm above this axis.

The average lengths of the 4 lumbar pedicles (left and right) were L1 = 89.7 mm (range 79.5–99.5), L2 = 78 mm (range 67–102.9), L3 = 68.7 mm (range 56–80.2), and L4 = 64.4 mm (range 55.5–81.7). It is notable that the length of the pedicle decreased from L1 to L4.

We determined the septocutaneous and musculocutaneous character of the LAP (Fig. 4). The first lumbar artery had an equivalent proportion of septocutaneous and musculocutaneous courses (50%). However, our small sample did not permit interpretation of this result. The second artery was mainly musculocutaneous (72.5%). In this case, an arborization of the muscular branches was visible within the erector muscles of the spine. On the contrary, the third and fourth branches were predominantly septocutaneous (64.5% for L3 and 77.5% for L4).

Imaging techniques limited the sensitivity of our diameter measurements to a minimum of 1.5 mm. It is important to note that 16.7% of LAPs from L1, 41.7% from L2,
and 13.2% from L3 had diameters measuring less than 1.5 mm. The measurement of the diameter of these arteries has, therefore, not been taken into account. In contrast, the L4 branch had a diameter greater than 1.5 mm in 98% of cases. The average diameter of L4 at the output of the thoraco-lumbar fascia (TF) was 2.3 mm. Despite the exclusion of arteries whose caliber was less than 1.5 mm, we observe that the average caliber of LAP increased progressively from L1 to L4.

In our cohort, flap thickness evolved in an increasing manner from L1 to L4. The subcutaneous layer, with regard to the perforator, measured a minimum of 12.2 mm with regard to L1, and a maximum of 81.5 mm with regard to L4. The average AC measured at the level of the iliac crests was 97.4 cm (74.3–113.5 cm). We observed a correlation among BMI, AC, and subcutaneous tissue thickness: subcutaneous tissue thickness increased with BMI \((P = 0.01)\) and elevated AC \((P = 0.01)\). No statistically significant correlation could be found between LAP localization and BMI, AC, or patient size.

The mean results of the LAP characteristics are illustrated in a cross-sectional tomodensitometric image at the level of the fourth lumbar arteries (Fig. 5). Table 3 summarizes the mean values obtained for all lumbar perforating vessels.

Interestingly, the localization of the LAP was not influenced by BMI, AC, or the height of the patient. Demonstrating that the LAP position at the exit of the TF is not, in our sample, influenced by the body type of the patient.

**DISCUSSION**

The localization of LAPs has been discussed several times in the literature, but no study has specifically focused on the male population.\(^9,12\) However, the indications for use of the LAP flap in male subjects are numerous. For example, the LAP flap could be used for lumbosacral reconstructions for pressure sores,\(^2,9,15\) tumor wide excision reconstructions,\(^7,9,15\) radiation ulcers or dermatitis,\(^2\) in trauma situations, or as a free flap for distant reconstructions. Therefore, male-specific data are useful for localizing the lumbar artery in the preoperative setting.

Since 2009, CTA has been the examination of choice for the anatomical study of LAPs. Nevertheless, it has some technical limitations such as the late acquisition of images.

### Table 2. Mean Values of \(X\) and \(Y\) Coordinates of LAPs Studied

|       | L1 (n = 6) | L2 (n = 11) | L3 (n = 38) | L4 (n = 50) |
|-------|------------|-------------|-------------|-------------|
| \(X\) | 83.7 ± 8.3 | 77.1 ± 4.9  | 74.9 ± 7.0  | 73.2 ± 6.6  |
| \(Y\) | 59.5 ± 10.2| 35.1 ± 18.7 | 20.3 ± 10.4 | 0.2 ± 6.4   |

\(X\): Distance from midline; \(Y\): Distance from iliac crest.
in the arterial phase, the presence of artifacts, and insufficient resolution for accurate measurement of small vessels (<1.5 mm). As a result, the small perforators coming from the first and second lumbar arteries cannot be identified with sufficient precision. Cadaveric dissection is probably the best approach for anatomically studying L1 and L2.

It is notable that CT analyses are prone to technical biases and to operator-dependent data. In this study, to avoid these biases, a single operator performed all measurements. In addition, sample size should be increased to reduce these biases.

Our analysis demonstrates a significant dominance of L3 and L4 LAPs, amounting to 86% of our sample, comparable to the 85% of the Sommeling et al. sample. This dominance is due to their size and better visibility on CTA images. In contrast to L1 and L2, they have a larger caliber, are more easily identifiable, and provide a thicker subcutaneous layer. Their intrinsic characteristics make them optimal arteries for the
performance of the LAP flap. Indeed, previous studies identify L4 as the most reliable for a pedicle or a free flap.

In the literature, the position of the LAPs varies from 5 to 10 cm from the midline. Kato et al were the first to determine the average location of the 4 LAPs at 7.22 cm from the midline. More recently, Hamdi et al reviewed this measurement at 6.95 cm, followed by Sommeling et al with 8.5 cm. However, their values were based primarily on the dominant perforating arteries represented by the L3 and L4 branches. Under the same conditions, we characterized the dominant branch at a mean distance of 7.41 cm from the midline. In our series of male subjects, the level of emergence of the LAP was located in a space of 6 cm in width around the iliac crests (−1.2 to +4.8 cm around the X axis). These values are comparable to the results published by Sommeling et al (from −2 to 5.7 cm around the same axis). The fourth lumbar artery has the distinction of being located, on average, on the line connecting the upper edges of the iliac crests.

In practice, the location of the dominant LAP can be defined to a specific area (Fig. 6). Depending on the results of our study, we can deduce that 95% of the perforating arteries required for the completion of the LAP flap are included in a 4 cm × 6 cm wide region, centered on a reference point located 7.25 cm from the spinous process and 2 cm from the top edge of the iliac ridge. We also define a more limited area of 1.5 cm × 3.5 cm, centered on the average localization from the midline of the dominant perforator (7.4 cm).

The major disadvantage of LAPs is the short length of the pedicle. Our results confirmed that the lower the LAP on the abdomen, the shorter the vascular pedicle, achieving a mean length of 6.5 cm for dominant perforators in our series. In this context, the use of a graft may be necessary. In the Hamdi et al series, 57% of the flaps required the interposition of a graft from the lower epigastric vessels, versus 77% of the flaps from Peters et al. The only series without graft interposition came from Honart et al and only concerned 3 patients but the results seemed encouraging.

The diameters measured in our study were comparable to the values obtained in the literature. Mathur et al conducted a study of 250 female patients who underwent preoperative CT angiography for breast reconstruction. Of the 500 hemi-bodies analyzed, they described perforating diameters greater than 1.5 mm in 78% of cases for L3 and 86.6% of cases for L4. By performing a comparable analysis, we obtained values of 86.8% for L3 and 98% for L4. This leads us to conclude that the caliber of the lumbar arteries seems larger in male population than in the female population. Nevertheless, further analysis should be conducted to confirm our results. On the other hand, the localization of the lumbar artery, in our study, is significantly similar to that of the previous anatomical research conducted in female subjects.

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**Table 3. Mean Values of Studied Characteristics of the Lumbar Arteries**

|                | L1 (n = 6) | L2 (n = 11) | L3 (n = 38) | L4 (n = 50) | L1 (n = 6) | L2 (n = 11) | L3 (n = 38) | L4 (n = 50) |
|----------------|------------|-------------|-------------|-------------|------------|-------------|-------------|-------------|
| Pedicle length (mm) | 88.9       | 74.9        | 68.6        | 64.3        | 90.5       | 81.1        | 68.9        | 64.5        |
| Diameter (mm) | –          | –           | –           | 2.2         | –          | –           | –           | 2.3         |
| Distance from midline (mm) | 84.9   | 76.1        | 75.3        | 73.2        | 82.5       | 78          | 74.5        | 73.2        |
| Distance from iliac crests (mm) | 57     | 31.7        | 16.8        | −0.9        | 62.1       | 38.6        | 23.4        | 1.2         |
| Subcutaneous tissue thickness (mm) | 25.9  | 38.3        | 48.9        | 54.2        | 27.5       | 43.2        | 48.3        | 53.8        |

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**Fig. 6.** Diagram locating the dominant perforating artery along 2 axes, X and Y. Blue area of 4 cm × 6 cm centered on a reference point located 2 cm from the top edge of the iliac ridge and 7.25 cm from the spinous process. Green area of 1.5 cm × 3.5 cm centered on a reference point located 1.25 cm from the upper edge of the iliac crest and 7.4 cm from the spinous process.
CONCLUSIONS

The LAP flap provides an interesting tool in the arsenal of a plastic surgeon either for lumbosacral reconstructions or for free flaps transfer. This study presents male-specific spotting values to provide assistance in locating the LAPs. The dominant vessels arise mainly from the third and fourth lumbar arteries and are predominantly septocutaneous. They have a sufficient caliber and a relatively constant position allowing their clinical use for reconstruction. The dominant artery perforator is situated, on average, 7.4 cm from the midline in a specific area of 4 cm × 6 cm in the lumbar region. Their mean diameter and pedicles are 2.3 mm and 6.7 cm, respectively. In clinical practice, preoperative markings should include these references without taking into account BMI, AC, or patient size.

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