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A cadaveric analysis of the blood supply to rectus Femoris



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KEYWORDS

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Summary Background: Rectus femoris is a versatile muscle frequently used as a pedicled flap in reconstructive surgery. The anatomy and blood supply of rectus femoris needs to be clearly understood in order to safely preserve its reconstructive and functional capabilities. Classical anatomical description states that the proximal pedicle insertion into rectus femoris is 10–15 cm from the anterior superior iliac spine (ASIS). The aim of this study was to dissect and identify the pedicular blood supply to rectus femoris and further map its morphology relative to the ASIS.

Methods: A dissection of 20 embalmed thighs from 10 cadavers was conducted. The distance of arterial insertions into rectus femoris from the ASIS were recorded. The cohort was 60% male of median age 79 with statistical significance defined as $p < 0.05$.

Results: 5%, 50%, and 45% of muscles demonstrated 1, 2, and 3 pedicles respectively. The mean distance from the ASIS to insertion of these pedicles was: proximal 13 cm (SD 2.6), middle 15 cm (SD 2.8), and distal 18 cm (SD 4.1).

When grouped by number of pedicles, there was no difference in the mean height of proximal insertion. However, there was significant difference in mean intramuscular proximal-distal difference. These results were replicated when data were expressed as % of cadaver height.

Conclusions: This study confirms the pedicular supply of rectus femoris but in contrast to classical literature demonstrates a greater range of pedicle insertions heights. We believe these observations should be considered when safely harvesting the pedicled rectus femoris flap.

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Introduction

Rectus Femoris (RF) is one of the muscles of the quadriceps compartment of the anterior thigh. It has important func-

tions in both hip flexion and knee extension. The muscle originates from two tendons, extending from the anterior superior iliac spine (ASIS) and the bony groove of the acetabulum. It inserts into the patella as part of the quadriceps tendon. RF is innervated by the femoral nerve and takes its blood supply from pedicles originating from the lateral femoral circumflex artery, branching from the profunda femoris off the common femoral artery (Figure 1a).¹

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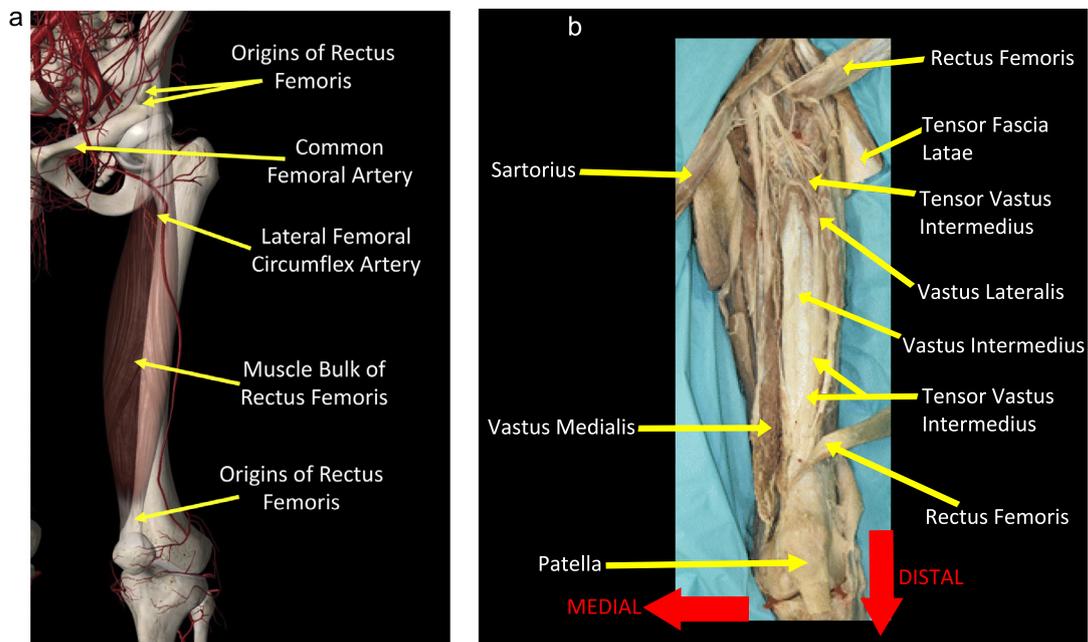


Figure 1 (a) Cartoon illustration of the origin, insertion, and vascular supply of the left rectus femoris muscle. Compared to (b) an example of these structures and their other anatomical relations in vivo when following the dissection methodology applied in this study. Note that for the purposes of fully demonstrating vastus intermedius, in this specimen, rectus femoris has been bisected.

The pedicled RF muscle flap is commonly used in reconstructive surgery of the groin, hip and lower abdomen after tumour resection, treatment for deep infection, and soft tissue defects such as bedsores over the greater trochanter in paraplegic patients,² after infra-inguinal revascularisation,³ and as a composite functional flap in the management of infected hip arthroplasty.⁴

It is a versatile flap with a good arc of rotation and robust pedicle, which allows cover over abdominal, inguinal, and lateral soft tissue defects, with a low donor site morbidity.²⁻⁵

With deep infection it promotes healing due to its size and vascular supply and arguably should be used early in the treatment of sepsis to reduce complications and additional surgery.⁴ In trauma, the RF pedicled flap is useful in the treatment of complex open hip wounds as it is a local, easily harvested and versatile flap.⁶ Its arc of rotation allows its use in abdominal wall reconstruction,⁷ and intra-abdominal surgery.⁸

In surgery, the anatomy of the RF, and its bloody supply, notably the pedicle and its insertion into the muscle, have to be identified and mobilised in order to use the flap. Information such as the number of pedicles which supply RF, their insertion, and the measured distance from anatomical landmarks are key in mobilising the flap without injury during harvesting. From the classical description, the pedicle will be found 10-15 cm distal to the ASIS⁹ and the muscle may be supplied by two pedicles from the deep lateral branch of the lateral circumflex artery.^{9,10} This is important as the gross anatomy may be disturbed, particularly after repeat surgery, infection, and trauma,^{3,4,6} so a fixed point is useful for the surgeon to seek the pedicle and fashion the flap.

The most proximal pedicle, which is normally mobilised and used for the flap is typically found 10-15 cm distal to the

ASIS⁹ or 8 cm distal to the inguinal ligament.¹⁰ Other studies have reported variability in the number of pedicles.^{11,12} These have been classified into Types I, II, and III; describing either a single vascular pedicle, one dominant and one or two minor pedicles, or two dominant pedicles respectively.¹¹

The aim of this study was to describe this variation in pedicle number and the distance of pedicle insertion into the RF from the ASIS. This is intended to clarify what is currently known regarding the blood supply to RF in its use as a pedicled flap.

Materials and methods

This study was conducted using 20 thighs of 10 whole, embalmed, human cadavers obtained from the mortuary at the Medical Sciences Teaching Centre, Department of Physiology, Anatomy, and Genetics, University of Oxford. Specimen height and gender were first recorded. Full consent was in place from all cadaveric donors, according to HTA guidance.

Dissection

Dissection began with a longitudinal midline incision through the skin from the ASIS to the tibial tuberosity. Dissection continued by extending the incision deeper through the subcutaneous fat, superficial fascia, and fascia lata into the anterior compartment of the thigh. Each side of the incision along with all fat and fascia was retracted. Sartorius was bisected and reflected away to fully expose the quadriceps (Figure 1b). RF was isolated with further dissection

Table 1

Pedicle	Incidence (%)	Mean (cm)	SD	CI	Lower normal limit (cm)	Upper normal limit (cm)
Proximal	100	13	2.6	1.1	8	18
Middle	45	15	2.8	1.8	10	21
Distal	95	18	4.1	1.8	10	26

$p = 0.0002^{***}$

Mean, standard deviation (SD), confidence interval (CI) upper and lower limits of the normal range for each proximal, middle, and distal pedicle. ANOVA of means of vessel categories p shown.

posterior to the muscle body, progressing inferior to superior, lateral to medial. Segmental pedicular arterial supply was identified and preserved for measuring.

Measurement

Photographs were taken before both the number of pedicles and the distance of pedicle insertion from the ASIS were recorded. Measurements were taken from the obvious bony prominence of the ASIS to each arterial insertion into the body of RF. Main cohort measurements were repeated in a subpopulation ($n = 8$) by independent blinded investigators to ensure reproducibility of the measurements (no statistical difference, data not shown).

Statistical analysis

All statistical analysis was conducted in GraphPad Prism 6. Data were assessed for normality using the Shapiro-Wilk test. No data were transformed, instead in the presence of a non-normal distribution non-parametric methods were applied. Statistical significance was defined as $p < 0.05$.

Results

Our cohort was of median height 169 cm (full range 150 - 178 cm) and were 100% White British donors. Specimens were 60% male and of median age 79 (full range 50 - 89).

Definitive dissection was achieved in all 20 thighs apart from one which demonstrated invasive pathology, suggestive of malignancy, where only a single arterial supply could be located (Figure 2a). This specimen was partially retained in statistics shown below as an example of an anatomical variation that may be expected within the population requiring RF flap harvest.

A total of 5%, 50% and 45% of muscles demonstrated 1, 2 and 3 pedicle insertions respectively (Figure 2). The mean distance of proximal, middle, and distal pedicle insertion was 13 cm (SD 2.6, CI 1.1), 15 cm (SD 2.8, CI 1.8), and 18 cm (SD 4.1, CI 1.8) from the ASIS respectively (Table 1). ANOVA revealed significant difference between each of the proximal, middle, and distal pedicle insertion measurements $p = 0.0002^{***}$ (Figure 3).

Specimens were then grouped by the number of pedicles in supply. At this stage the specimen with questionable dissection and one pedicle supply was excluded. Means for the two groups were then recalculated separately. In the

two pedicle group the mean distance of proximal and distal pedicles was 13 cm (SD 3.2, CI 2.0) and 17 cm (SD 4.5, CI 2.7) from the ASIS respectively. An unpaired T test showed that the difference in these means was not significant. In the three pedicle group the mean distance of the proximal, middle, and distal pedicles was 13 cm (SD 2.0, CI 1.3), 15 cm (SD 2.6, CI 1.7), and 19 cm (SD 3.4, CI 2.2) from the ASIS respectively. ANOVA demonstrated a statistically significant difference between these means. When the two and three pedicle groups were compared through an unpaired T test there was no difference between the two groups' proximal and distal means (Table 2).

The difference between the proximal and distal most pedicle insertion was calculated for each specimen in each of the two groups. In the two pedicle group there was a mean difference of 4 cm whereas in the 3 pedicle group there was a mean difference of 6 cm. Upon unpaired T testing this was a statistically significant difference, $p = 0.0194^*$ (Table 2).

All statistical analyses were then repeated with the distances instead expressed as a percentage of the cadaver's height. All statistical analyses were identical except within the two pedicle group where the mean insertion of the proximal and distal arterial insertions became significantly different $p = 0.0292^*$. See comparable data in Tables 3 and 4 with differing statistical result underlined.

Discussion

This study quantified and recorded the variability of the pedicular blood supply to RF. This is of clinical significance in the use of this muscle as a vascularised pedicular graft in reconstructive surgery as there is a variation both in the pedicle number and its distance and insertion from a well-recognised anatomical landmark - the ASIS.

Our study was limited by number, race, and age. It was also limited by height with a range of 150-178 cm. This does not cover the spectrum of heights that could be encountered.¹³ However, the concordance of our results as percentages to the raw values suggest that, whilst raw distances may vary at the extremes of height, expected distances can be easily calculated to be applied to any patient. We cannot give any indication of ethnic variation as our study was limited to White British cadavers.

There were no differences between independent repeated measures, which suggests that these measurements are reproducible. This reproducibility supports its use and measurement from a fixed bony landmark. The ASIS is quick and easy to locate with surface anatomy, is close to the ori-

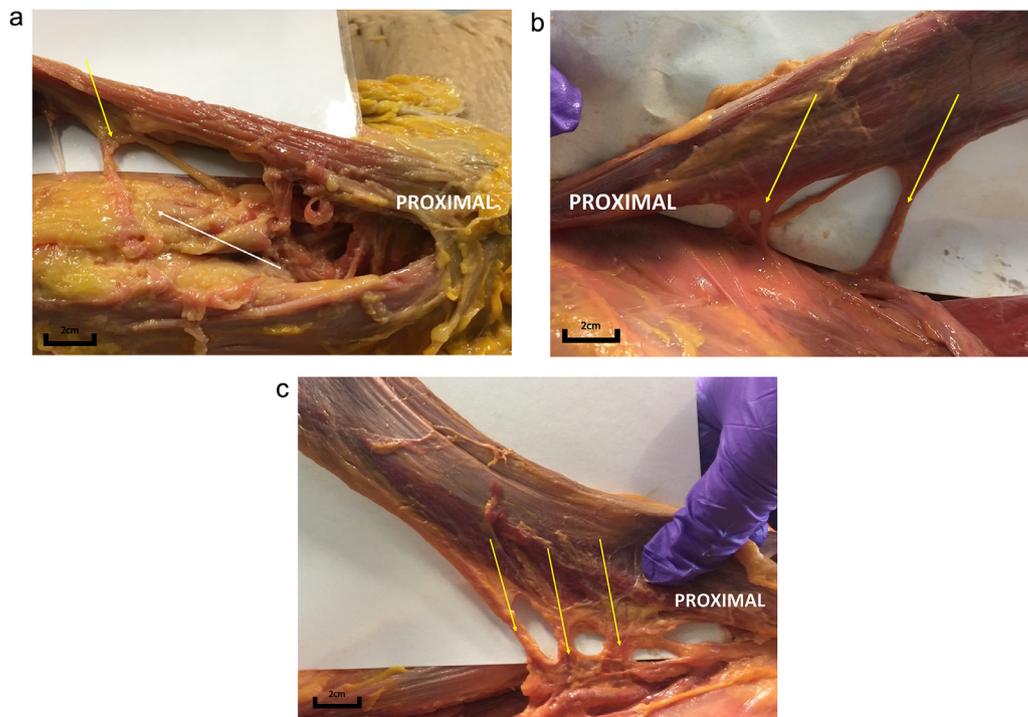


Figure 2 Examples of rectus femoris dissections with 1, 2, and 3 pedicle supplies. Yellow arrows indicate identified vessels. “PROXIMAL” indicates the site of the muscle insertion closest to the anterior superior iliac spine (ASIS). (a) Specimen with one identified pedicle. The white arrow also highlights potential pathology, which may invalidate this specimen. (b) Specimen with two identified pedicles. (c) Specimen with three identified pedicles.

Table 2

Number of pedicles	Proximal mean (cm)	Middle mean (cm)	Distal mean (cm)	mean difference between proximal and distal insertions (cm)	
2	13		17	4	$p = 0.0600$
3	13	15	19	6	$p = 0.0004^{***}$
	$p = 0.847$		$p = 0.170$	$p = 0.0194^*$	

Specimens split by pedicle number with proximal middle (where applicable) and distal means shown. The difference between proximal and distal most supplies is calculated.

Table 3

Pedicle	Incidence (%)	Mean (% of cadaver height)	SD	CI	Lower normal range	Upper normal range
Proximal	100	0.08	0.01	0.006	0.05	0.11
Middle	45	0.09	0.02	0.01	0.06	0.12
Distal	95	0.11	0.02	0.01	0.06	0.15
		$p = 0.0003^{***}$				

Repeat analyses of mean, standard deviation (SD), confidence interval (CI) upper and lower limits of the normal range for each proximal, middle, and distal pedicle expressed as a % of cadaver height. ANOVA of means of pedicle categories p shown.

gin of RF, facilitating sterile exposure of the patient (and therefore can be made sterile without unnecessary exposure of the patient), and is a definitive location.

The classic descriptions of the anatomy of RF and its blood supply predominantly describe a two pedicle supply.^{9,11,12} Of these pedicles, one or both of these may be

dominant and in some cases a third minor pedicle is described.¹¹ In contrast, this study found that only 50% of the RF muscles dissected had two pedicles and 45% had 3 pedicles. Only 5% had one pedicle supplies respectively.

This implies that in almost half of cases where a second pedicle supplying RF is identified, there may be a third

Table 4

Number of pedicles	proximal mean (%)	middle mean (%)	Distal mean (%)	mean difference between proximal and distal insertions (%)	
2	0.08		0.1	0.02	$p = 0.0292^*$
3	0.08	0.09	0.1	0.03	$p = 0.0008^{***}$
	$p = 0.0666$		$p = 0.189$	$p = 0.0395^*$	

Repeat analyses of specimens split by pedicle number with proximal middle (where applicable) and distal means shown expressed as % of donor height. The difference between proximal and distal most supplies is calculated.

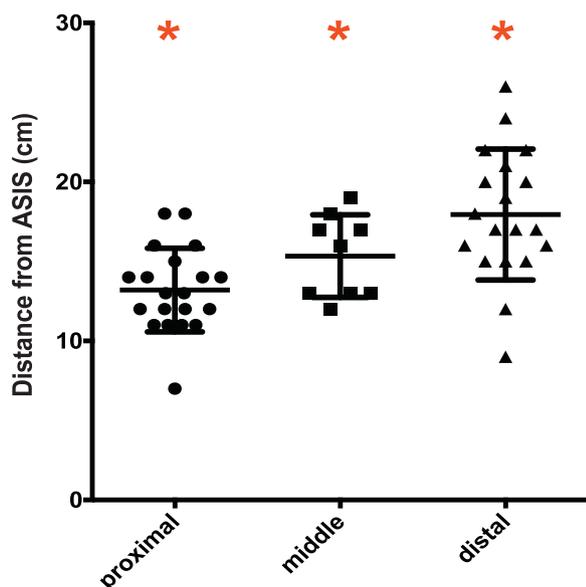


Figure 3 Graph to demonstrate the mean and standard deviations of proximal, middle, and distal pedicle distances from the anterior superior iliac spine (ASIS). ANOVA revealed significant difference (*) between each of the proximal, middle, and distal pedicle insertion measurements ($p = 0.0002^{***}$).

pedicle more proximal and inferior to the ASIS. In this case, the muscle can therefore be mobilised on its more proximal pedicle closer to its origin from the ASIS, so giving a greater arc of rotation for coverage of lateral hip, abdominal, or groin defects.

For the clinician, if one pedicle is identified, there is a significant chance there will be a more proximal pedicle as the majority in cadaveric dissection have two or more pedicles that supply the muscle.

In keeping with classical descriptions of the pedicular supply to the RF,^{10,11} we found the mean insertion of the proximal vascular pedicle was 13 cm (95%CI 11.9–14.1 cm). There was no significant difference between proximal-ASIS distances for 2 or 3 vessel patterns. These results suggest that there is little need for angiography in determining the blood supply of the muscle before its use in surgical reconstruction. However when a normal range is calculated, the pedicles can be expected to be found anywhere between 8 and 26 cm, which is a much wider range than is previously described.^{9,10}

In addition, our normal range in cadavers for the most proximal pedicle was 8 to 18 cm. There were four instances where the most proximal pedicle was greater than 15 cm from the ASIS. Two of these had only two pedicles supplying the whole muscle.

These findings suggest that the surgeon cannot assume that the pedicle is always within 10 to 15 cm of the ASIS as previously stated. The safest dissection is that when a single pedicle is identified, a more proximal one should be sought before mobilising and sectioning the least dominant pedicle. An important finding in this study is that any more proximal pedicle will normally be found within 5 cm of the pedicle distal to it. This implies that, whenever a pedicle is identified, if the surgeon is unable to identify an additional pedicle within 5 cm proximal to this, then they should regard it as the most proximal pedicle and so preserve it maintaining blood supply to the flap.

Conclusions

In this study a 2 or 3 pedicled muscle was found in 95% of cases. Only 5% had a single pedicle supply. 95% of pedicles were found between 8 and 26 cm from the ASIS. The most proximal pedicle was found between 8 and 18 cm (mean distance: 13.0 cm, 95% 11.9–14.1 cm) from the ASIS. This contrasts with previous anatomical descriptions, which describe the proximal-most pedicle between only 10 and 15 cm from the ASIS. Mean middle pedicle insertion was 15.0 ± 1.8 cm and distal insertion was 18.0 ± 1.8 cm. RF muscles demonstrating 2 or 3 pedicles had no difference between their mean proximal and distal insertion. However, the proximal and distal pedicles were closer together in the 2 pedicle group. These findings were replicated when distances were instead expressed as a percentage of total cadaver (body) height.

This study confirms that, contrary to classical literature, there is a greater range of variability in the number of pedicles and their insertion distance from their ASIS. These are important considerations in the safe and successful harvesting of pedicled RF flaps in reconstructive surgery.

Conflict of interest

N/A.

Financial disclosure statement

Nothing to declare.

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