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The Quadriceps Femoris Allograft as an Extension of the Angiosome Concept: A Cadaveric-based Anatomical Feasibility Study

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ABSTRACT

Background: Vascularised composite allo-transplantation (VCA) is emerging as a tailored approach for complex tissue reconstruction. This study focuses on the quadriceps VCA as a potential solution for tissue repair, following trauma, necrotising fasciitis/myositis or tumour ablation.

Methods: Dissections were undertaken in ten adult cadaveric lower limbs to characterise the blood supply to the quadriceps femoris for en bloc muscle allo-transplantation. A mock cadaveric transplantation was performed to (a) define the best neurovascular VCA design and (b) test the feasibility of the procedure. A review of 54 archival radiograph studies from the institution was also performed to further evaluate the muscle vasculature.

Results: In two lower limbs, the quadriceps VCA was harvested designed on the common and superficial femoral vessels and nerve, which revealed a lengthy and bloody dissection, especially of the veins, which could increase clinically with the inability to use a tourniquet for most of the dissection. However, review of our previous archival studies showed that all four quadriceps muscles are supplied within the lateral circumflex femoral angiosome. In a further eight lower limbs, the quadriceps femoris muscle group consistently received its blood supply from the lateral circumflex femoral angiosome, verified by selective lead oxide injections of this artery. The vastus medialis appeared to have a more tenuous blood supply distally based on this angiosome. A successful mock cadaveric transplant was performed based on this data.

Conclusions: We suggest that the best neuromuscular quadriceps VCA should be (a) designed on the lateral circumflex femoral pedicle, (b) should be raised from distal to proximal and (c) should include the descending genicular vessels as a potential supplemental supply to vastus medialis, should all four muscles be required.

INTRODUCTION

Just as the arrival of free flap surgery^{1,2} ushered in a paradigm shift in reconstructive surgery, so too has vascularised composite allo-transplantation (VCA) altered the landscape for reconstructive surgery. With the ever-expanding immunological understanding of the host-allograft environment, the clinical likelihood of more tailored reconstructions incorporating VCA continues to evolve.

Critical structure loss, such as severe facial deformity, hand and upper limb amputation are areas of reconstructive surgery where VCA has provided an elegant “like for like” solution. Just like Volkmann’s contracture³ and other multifaceted reconstructive dilemmas, VCA could provide complete anatomical restoration for tissues lost. Significant lower limb trauma with associated loss of the quadriceps muscle group is uncommon⁴, although presents a significant reconstructive dilemma should the limb be salvageable. Furthermore, soft tissue sarcoma of the lower extremity demands extensive tissue resection for adequate tumour extirpation, with the anterior thigh compartment most frequently affected⁵. The resection can involve a total or sub-total loss of the quadriceps femoris muscle group⁶, potentially alongside critical neuro-vascular structures. The functional consequence of tissue loss to this area can be dramatic, with near complete loss of the extensor mechanism of the knee and associated severe

limitations in mobility^{5,6}. Current limb-salvage approaches for this type of defect, such as the free rectus femoris flap⁷ or latissimus dorsi flap^{8,9} can restore tissue bulk to the thigh and do provide a limited return of extension at the knee joint. However, significant room for improvement remains.

The vascular system to the thigh is well defined and forms a readily-available factory of flap options for complex loco-regional and distant reconstruction, notably the anterolateral thigh flap (ALT)¹⁰ and the descending genicular flap¹¹. Despite well established knowledge concerning the blood supply to discrete tissues within the thigh, blood supply and surgical technique as pertinent to the quadriceps muscle for en bloc harvest and transplantation are not yet defined. Given the potential emerging role for partial organ transplants, such as the elbow VCA¹² and forearm VCA³, there may be a role for vascularised neurotized muscle VCAs where no elegant current option exists. The quadriceps femoris VCA provides a potential solution to those defects where the anterior thigh musculature has been lost, and may become a future viable surgical option, particularly if the barriers of immunological tolerance are lifted.

In this cadaveric study we explore and describe a procurement approach for the quadriceps femoris VCA whilst incorporating details of blood supply to the muscle group using a combination of new anatomical work and archival studies^{13,14}. This study confirms the anatomical feasibility of a tailored neurotised transplant from the anterior thigh compartment based on the lateral circumflex femoral angiosome and highlights its potential clinical application.

MATERIALS AND METHODS

Cadaveric studies were performed using non-embalmed fresh tissue. Ten lower limbs were acquired through our institution's human body donor program. A review was also performed of fifty-four of our archival studies that included forty-two neurovascular examinations^(10, 12). The body habitus between limbs was variable. The study had two components: (A) Exploration of the

angiosomes of the thigh with an emphasis on characterising the blood supply to the quadriceps femoris muscles and determining an efficient procurement technique for potential allo-transplantation. (B) Performing a mock cadaveric transplant of the quadriceps femoris muscles to a defect modelled on a clinical case to demonstrate the anatomical feasibility of this approach and its potential clinical relevance.

The radio-opaque contrast mixture described by Rees and Taylor¹⁵ and modified by Suami, Taylor and Pan¹⁶ was used consisting of powdered lead oxide, gelatin in a 50°C water suspension. The common femoral artery was cannulated in two studies and the lateral femoral circumflex in 8. The mixture (20 ml/kg) was injected in situ into the artery by slow pump infusion. Specimens were cooled at 4°C for a period of twenty-four hours and procured and radiographed. Dissections were performed with patterns of blood supply to relevant muscle, tendon and nerve components recorded with photography and radiography.

Mock Transplant

In conjunction with previous work³, we once again used a two-team approach. One team created the anterior thigh defect, whilst the other team procured the quadriceps allograft, based on the lateral circumflex femoral neurovascular pedicle. Time from vessel disconnection of the allograft to transplantation and re-anastomosis was recorded, relevant for translation to the clinical case.

RESULTS

The quadriceps femoris appeared as a fusiform mass of muscle extending from the pelvis to the knee (Figure 1). Rectus femoris, “the kicking muscle” was

superficial. It attached proximally to the anterior inferior iliac spine (AIIS) and body of the pelvis adjacent to the hip joint and formed a common tendon with the three vasti that insert into the patella sesamoid with fibres continuing to the tibial tuberosity. The three vasti had a fibrous attachment proximally to the intertrochanteric line of the femur adjacent to the hip joint and then a fleshy origin that wrapped around the shaft of the bone, separated posteriorly by only the muscles arising from the linear aspera, and extended to the supra-patella bursa of the knee joint. Proximally the vastus lateralis had a common origin with tensor fascia lata laterally and medially the vastus medialis blended with the origin of the adductors. The deep surface of vastus lateralis and vastus medialis formed aponeuroses that inserted into the patella and capsule of the knee joint.

The quadriceps group was supplied (i) superiorly from the lateral circumflex femoral vessels; (ii) laterally from the four perforators of the profunda; (iii) medially from branches of the superficial femoral and (iv) distally from its descending genicular branch (Figure 2 left). Each muscle spanned three angiosome territories and received blood supply from each, often connected by true anastomoses within the muscle (Figures 2 to 5).

When based only on the lateral circumflex femoral artery (Figure 2 right), all muscles, had a robust blood supply, except for vastus medialis, but remember that this artery was injected in situ in the intact body (see later). From our recent studies the lateral circumflex artery arose from the profunda (deep femoral) in nine cases and from the common femoral in one. It measured in diameter between 0.8 and 1.5cm. The pedicle length to the first branch ranged between 1 and 2.2cm (average 1.4cm) and could be extended by incorporating the profundal artery (Figure 2, left). Combining archival and prospective studies we found that all branches arose from the first 2.5cm of the artery. Radiating like the spokes of a wheel they pass horizontally, obliquely and almost vertically. The horizontal branch, often duplicated, supplies vastus lateralis and tensor fascia lata. The next branch supplies rectus femoris from its under surface. It is long

and connects distally with a branch from the descending genicular artery and supplies the quadriceps tendon and patella.

The next two branches are oblique and have a reciprocal size relationship (Figure 2). The most lateral is usually the larger continuing as the main stem of the artery. It approaches vastus lateralis from its medial side entering between the proximal third and middle of the muscle. The medial oblique branch however, may be the larger. It courses on the surface or within vastus intermedius and forms transverse true or choke connections with the blood supply to vastus lateralis and vastus medialis. Both oblique branches supply cutaneous perforators to the overlying skin and their reciprocity may help explain the variable blood supply to the ALT and antero-medial thigh perforator flaps.

Vastus medialis is a three territory muscle (Figure 5). It is supplied in the proximal third to half by longitudinal branches from the lateral circumflex femoral artery. They form choke vessel connections with the blood supply to vastus intermedius and rectus femoris as described above. However, the dominant supply and to the most bulky portion of the muscle, is distally from the superficial femoral and especially its large descending genicular branch with pedicle length ranging between 1 and 2.2cm (average 1.5cm. (Figures 2 to 4).

Paired venae comitantes accompany the arteries that drain into the profunda or femoral vessels with diameters that range from 0.7 to 1.8cm (Figure 3). An unusual variant was noted in three of the prospective studies. Coursing on the surface of vastus intermedius a single large vena communicans was accompanied by two arteries instead of the reverse.

The femoral nerve divides into superficial (mostly sensory) and deep branches (motor) often separated by the lateral circumflex femoral artery. Motor branches to the quadriceps group accompany their blood supply except for vastus medialis. Although a proximal branch enters this muscle the main supply

accompanies the saphenous nerve, entering vastus medialis near the middle of its medial border (Figure 4). An excellent description is provided by J.C. Brash⁽¹⁵⁾.

With the dominant supply to the quadriceps emanating from the lateral circumflex and common femoral arteries, our initial VCA design included both vessels. However, when attempts were made to include the superficial femoral vessels a time consuming and bloody dissection, especially of the veins, took between two and three hours to procure the transplant.

After reviewing archival studies, and with the angiosome concept of the “ability to capture an adjacent anatomical territory on the base artery”^(16,17), focus was drawn to the lateral circumflex pedicle alone. The rectus femoris, vastus lateralis and vastus intermedius receive a dominant blood supply and their vascular pattern matches that of the nerves. Vastus medialis appeared to have a poorer blood supply, in our prospective studies. However, our archival studies, performed with whole body contrast perfusion, revealed more obvious anastomoses between the lateral circumflex and descending genicular pedicles within the vastus medialis (Figure 3). Following this, a mock transplant was performed based on the lateral circumflex femoral pedicle whereby a reduction in procurement time was achieved by more than half with the shortest time being forty-three minutes. The technique is described in the following mock transplant.

Preoperative:

The distance between the anterior superior iliac spine (ASIS) and the tibial tuberosity with the hip and knee extended was measured first. Ideally donor and recipient limbs should be the same length. In our case the recipient limb was 2 cm shorter.

Exposure:

The skin flaps were raised longitudinally in the suprafascial plane from the groin to the tibial tuberosity as shown (Figure 6).

Superior approach – femoral triangle

The Sartorius was identified, detached and reflected from the ASIS to expose the common femoral artery and vein, and the femoral nerve (Figure 7). The proximal attachment of rectus femoris was then defined at the anterior inferior iliac spine (AIIS). Following this, the profunda-superficial femoral bifurcation and the lateral circumflex femoral pedicle as it branched from the profunda femoris artery and associated veins was identified and defined. The superficial and deep divisions of the femoral nerve as they relate to these vessels were then defined. The easily identifiable saphenous nerve from the superficial nerve division was identified since it contains the nerve to vastus medialis. The deep division of the femoral nerve contains the muscular branches to the remaining quadriceps group, and was defined last (Figure 7).

Distal-to-Proximal approach

It was conceived that this aspect of the dissection could be performed using a sterile tourniquet in a clinical setting. Firstly, the distal end of Sartorius was identified and detached, exposing Hunters Canal with the superficial femoral vessels and saphenous nerve. The patella tendon was divided from the tibial tuberosity (the tibial tuberosity could be included) to expose the infra-patellar space. With a finger in this space, the capsule of the knee was divided to free the patella, and the retinaculæ of the vastus medialis and vastus lateralis. This exposed the suprapatellar space of the knee joint. The dissection then proceeded in a proximal direction. The fleshy origins of the three vasti were separated in the subperiosteal plane. The “lifeboat” descending genicular artery origin from the superficial femoral artery just before it exits Hunter’s Canal at the adductor magnus hiatus was identified and dissected free. Care must be taken not to damage the muscular branches of the descending genicular artery as it courses deep and into vastus medialis. The dissection continued to the mid point of the thigh clipping vessels to the vastus medialis that arose from the superficial femoral and profunda arteries and veins.

Medial approach

Clinically, at this point the tourniquet would be removed and haemostasis confirmed. Having exposed the contents of the femoral triangle and the distal thigh, the two dissections were joined. This sequence enabled easier exposure of this difficult area to define, since the adductor muscles (pectineus adductor longus and brevis) and vastus medialis coalesce at their origins in this area. Finally the motor branch to vastus medialis from the saphenous nerve was separated.

Lateral approach

The anterior border of the fascia lata was identified and incised to expose rectus femoris and vastus lateralis, the latter having a shiny aponeurotic surface more proximally (Figure 1). These two muscles were easily blunt dissected distally from the fascia lata and lower intermuscular septum using the fingers, being attached superficially only by loose areolar tissue, to the fascia lata, until the tensor muscle was reached. The vastus intermedius was thereby exposed beneath rectus femoris. Dissection then proceeded proximally from the knee, whereby the vastus lateralis and intermedius were separated from the femur in the subperiosteal plane. The vastus lateralis attachment to lateral intermuscular septum was detached progressively with a strip of septal fascia, preserved for suture fixation after transplantation. Following further dissection, the vastus intermedius, vastus lateralis and rectus femoris muscles were all detached, releasing the muscles from their respective proximal attachments. The proximal attachment of vastus lateralis was particularly vascular as it was separated from the tensor fascia lata muscle and their common blood supply. Initially we completed the medial dissection first. However with the mobility provide after dissecting these 3 muscles we later found it more practical to raise them before completing the medial dissection of vastus medialis. Finally, the quadriceps VCA was isolated on its neurovascular pedicle. The motor portion of the femoral

nerve was separated up to the inguinal ligament to increase pedicle length (Figure 8 above left). In the clinical setting, at this stage the need to augment the blood supply to vastus medialis would have been apparent. The procurement time was 45 minutes using this technique.

The transplant:

The recipient limb, dissected concurrently, revealed satisfactory recipient vessels and nerves. The flap was detached (Figure 8 above right) and the attachment sequence was as follows: The neurovascular pedicles were aligned proximally. The transplant was attached distally to the tendon stump at the tibial tuberosity. The patella could have been removed, but appeared congruous with the joint surface in our procedure. With knee extended, the transplant was stretched. The tendon of rectus femoris was then shortened by 2 cm to match the transplant to the recipient defect, and attached to the pelvis. The vessel anastomoses were performed, co-apted end to end the donor 1.5 and recipient 1.2cm lateral circumflex femoral arteries. Venous anastomoses were performed. One end-to-end and the other end-to-side to the large recipient vein. The "ischaemic time" was just under 1 hour. Finally, the remaining vasti were attached proximally: the vastus lateralis to the fascia lata and its tensor muscle sheath; vastus medialis to the common tendon with the adductors proximally and to the tendon of adductor magnus distally; and vastus intermedius to the femur near the intertrochanter line (Figure 8 below left). The skin flaps were re-sutured in layers (Figure 8 below right).

DISCUSSION

Sub-total or total loss of the quadriceps muscle group secondary to trauma, infection or tumour extirpation has significant consequences for gait function and ambulation, dramatically limiting extension at the knee and leaving a poor functional outcome for the patient. A variety of free flap reconstructive

procedures have been described. The latissimus dorsi free flap is the most popular option for this type of defect. Advantages include the necessary fibre length for the range of contraction required for adequate knee extension, sufficient soft tissue bulk and a single nerve for muscle re-innervation¹⁷. The rectus femoris free flap has also been described⁷ and carries advantages that include a single dominant pedicle, a bipennate muscle configuration with a relatively short and powerful fibre length, and primary donor site closure⁷. Despite the attributes of these two approaches, complete functional replacement of the quadriceps muscle group remains a significant challenge. In particular, extensor lag with less than ideal limitations on mobility appears to be an ongoing issue for autologous approaches^{7,8}.

The anatomical feasibility of harvesting the quadriceps femoris VCA is demonstrated in this study. From an angiosome perspective, not only do the rectus femoris, vastus lateralis and vastus intermedius receive a dominant blood supply from the lateral circumflex femoral artery but also the muscular innervation pattern conveniently follows the same pattern. The vastus medialis on the other hand may have a more tenuous blood supply from the lateral circumflex femoral artery. Our injection study was into the lateral circumflex femoral artery in the intact body, not into the isolated transplant. It would have underestimated the flow from anastomotic vessels connecting to those of the adjacent muscles due to the “overflow phenomenon”¹⁹. Indeed, our archival work did show that true anastomoses were common within the muscle (Figure 3). If the autologous vastus medialis cannot be preserved, we make two suggestions. In the allograft, first dissect from distal to proximal to give time for the viability of the muscle to declare. Secondly, include the “lifeboat” descending genicular vessels at their origin with a cuff or segment of the superficial femoral vessels where this can be done under tourniquet. If in doubt therefore, although this latter approach requires two sets of arterial anastomosis to be performed, it assures allograft vascularity, especially if the patella and patellar tendon beyond

are included in the transplant. Given the flap is buried, another useful concept is the addition of a skin island to help monitor the muscle VCA during the postoperative period but also in the setting of response to immunosuppressive therapy¹².

It must be recognised that the role of immunosuppressive therapy in transplant surgery remains a current and evolving issue that limits more generalised application of VCA techniques. Similar to our previous anatomical study³, the use of a muscle-only VCA with associated nerve and tendon components as described in this paper, could provide an additional immunological advantage given that muscle triggers a lower allograft-based immune response compared to skin¹⁸. Because of the potential of recurrence to malignancy, to date most VCA transfers have been for traumatic defects or for a patient already on immunosuppressive therapy. Meanwhile, until issues of immune tolerance are resolved and the opportunity for a quadriceps VCA presents, this anatomical data provides the basis for such a transplant.

For in the sage words of Alexander Graham Bell “*before anything else, preparation is the key to success*”.

CONCLUSION

We suggest that the best neuromuscular quadriceps VCA should be (a) designed on the lateral circumflex femoral pedicle, (b) should be dissected from distal to proximal and (c) should include the descending genicular vessels. The latter ensures a potential supplemental supply to vastus medialis should all four muscles be required and if vastus medialis becomes ischaemic following isolation of the VCA on the lateral circumflex femoral pedicle.

REFERENCES

1. Taylor GI, Daniel RK. The free flap: composite tissue transfer by vascular anastomosis. *Aust N Z J Surg*. 1973 Jul;43(1):1–3.
2. Daniel RK, Taylor GI. Distant transfer of an island flap by microvascular anastomoses. A clinical technique. *Plastic and Reconstructive Surgery*. 1973 Aug;52(2):111–7.
3. Taylor GI, Sparks DS, Gascoigne AC, Corlett RJ, Ashton MW. Angiosome-Based Allografts: Vascularized Composite Allotransplantation for Tailored Subunit Reconstruction with Volkmann Ischemic Contracture as a Case in Point. *Plast Reconstr Surg*. *Plastic and Reconstructive Surgery*; 2017 Jun;139(6):1291e–1304e.
4. Rtshiladze MA, Andersen SP, Nguyen DQA, Grabs A, Ho K. The 2009 Sydney shark attacks: case series and literature review. *ANZ J Surg*. Wiley/Blackwell (10.1111); 2011 May;81(5):345–51.
5. Pisters PW, Leung DH, Woodruff J, Shi W, Brennan MF. Analysis of prognostic factors in 1,041 patients with localized soft tissue sarcomas of the extremities. *Journal of Clinical Oncology*. 1996 May;14(5):1679–89.
6. Walley KC, Taylor EM, Anderson M, Lozano-Calderon S, Iorio ML. Reconstruction of quadriceps function with composite free tissue transfers following sarcoma resection. *J Surg Oncol*. Wiley-Blackwell; 2017 Jun;115(7):878–82.
7. Wechselberger G, Ninkovic M, Püzl P, Schoeller T. Free functional rectus femoris muscle transfer for restoration of knee extension and defect coverage after trauma. *J Plast Reconstr Aesthet Surg*. 2006;59(9):994–8.
8. Innocenti M, Abed YY, Beltrami G, Delcroix L, Balatri A, Capanna R. Quadriceps muscle reconstruction with free functioning latissimus dorsi muscle flap after oncological resection. *Microsurgery*. Wiley-Blackwell; 2009;29(3):189–98.
9. Muramatsu K, Ihara K, Miyoshi T, Yoshida K, Hashimoto T, Taguchi T. Transfer of latissimus dorsi muscle for the functional reconstruction of quadriceps femoris muscle following oncological resection of sarcoma in the thigh. *J Plast Reconstr Aesthet Surg*. 2011 Aug;64(8):1068–74.
10. Song YG, Chen GZ, Song YL. The free thigh flap: a new free flap concept based on the septocutaneous artery. *Br J Plast Surg*. 1984 Apr;37(2):149–59.
11. Acland RD, Schusterman M, Godina M, Eder E, Taylor GI, Carlisle I. The

- saphenous neurovascular free flap. *Plastic and Reconstructive Surgery*. 1981 Jun;67(6):763–74.
12. Steinberger Z, Xu H, Kazmers NH, Thibaudeau S, Huffman RG, Levin LS. Elbow vascularized composite allotransplantation-surgical anatomy and technique. *J Shoulder Elbow Surg*. 2017 Aug;26(8):1325–34.
 13. Pan W-R, Taylor GI. The angiosomes of the thigh and buttock. *Plast Reconstr Surg*. 2009 Jan;123(1):236–49.
 14. Suami H, Taylor GI, Pan W-R. Angiosome territories of the nerves of the lower limbs. *Plastic and Reconstructive Surgery*. 2003 Dec;112(7):1790–8.
 15. Rees MJ, Taylor GI. A simplified lead oxide cadaver injection technique. *Plastic and Reconstructive Surgery*. 1986 Jan;77(1):141–5.
 16. Suami H, Taylor GI, Pan W-R. A new radiographic cadaver injection technique for investigating the lymphatic system. *Plast Reconstr Surg*. 2005 Jun;115(7):2007–13.
 17. Hallock GG. Restoration of quadriceps femoris function with a dynamic microsurgical free latissimus dorsi muscle transfer. 2004 Jan;52(1):89–92.
 18. Lee WP, Yaremchuk MJ, Pan YC, Randolph MA, Tan CM, Weiland AJ. Relative antigenicity of components of a vascularized limb allograft. *Plastic and Reconstructive Surgery*. 1991 Mar;87(3):401–11.
 19. Taylor GI, Pan WR. *The Angiosome Concept and Tissue Transfer*, Volume 1, 55-56. Published by CRC Press, ISBN 9781576261613, Nov 2013.

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