



The free innervated latissimus dorsi flap for functional reconstruction following soft tissue sarcoma resection of the posterior compartment of the thigh

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Abstract

Background Soft tissue sarcoma (STS) surgery has evolved significantly over the last half a century. From amputation to limb-salvage and limb-sparing surgery, reconstructive demands have continuously increased in an effort to provide the best function-preserving disease-free outcome. Given STS typically affect the limbs more so than any other region of the body, restoration of function whilst not important oncologically is critical to incorporate in the reconstructive plan of any onco-plastic team. The use of loco-regional flaps as well as free flaps provides the mainstay of reconstructive options. The next advance in the reconstructive journey in this clinical area is the use of innervated flaps to restore function.

Methods Between 2011 and 2016, all patients who underwent sarcoma extirpation from the posterior thigh and reconstruction using a free innervated latissimus dorsi flap were prospectively identified and a case note review was performed.

Results In this series, 7 patients have undergone free flap reconstruction of the thigh posterior compartment achieving MRC (medical research council, UK) grade M5 power restoration in 6/7 patients.

Conclusions The authors believe this technique to be hugely valuable in the surgical armamentarium of the reconstructive plastic surgeon in order to achieve the best functional outcomes in such a cohort of patients.

Level of Evidence: Level IV, therapeutic study.

Keywords Innervated flap · Latissimus dorsi · Hamstring reconstruction · Functional reconstruction · Sarcoma reconstruction

Introduction

According to data from the Australian Sarcoma Study Group (ASSG), this small complex group of heterogeneous non-epithelial cancers poses a greater challenge to clinicians than ever before [1]. Although they comprise 1% of all cancers, their impact is sizeable and disproportionate to their incidence. In Australia, there are just

fewer than 1000 new sarcoma cases per year and this is gradually increasing according to recent data [2]. The impact these cancers have on the community is underestimated and underappreciated with typically more adolescent and young adults affected compared to other cancer types, leading to the loss of approximately 17 life years per patient [3]. As these tumours tend to involve extremities, there is a massive impact on function, quality of life (QoL) and activities of daily living (ADL), aside from the socio-economic burden they pose. Despite numerous public health campaigns, there have been few improvements in overall survival in the last 30 years across sarcoma outcomes worldwide [4].

The postwar era treatment of STS with simple excision resulted in very poor outcomes, with local

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Table 1 The raw data from this cohort who underwent immediate reconstruction following oncological resection for sarcomas in the same setting with latissimus dorsi flaps for various composite defects around the body

Patient	Gender	Age	Comorbidity	Defect size (cm)	Skin defect site	Flap	Complications	Re-operation	Follow-up (months)	Outcome
1	M	46	Ex-smoker	25 × 11	L hamstring	Free LD	–	–	72	M5
2	M	69	IHD, AVR, CABG, OA	22 × 9	L hamstring	Free LD	Haematoma; cef	–	24	M5
3	M	74	HC, BO	22 × 8	R hamstring	Free LD	Recurrence, recon with VRAM	–	72	M5
4	M	78	IHD, HT, CABG	8 × 4	L hamstring	Free LD	CVA 4/12 postop	–	24	M5
5	M	61	IHD, HT	20 × 9	L hamstring	Free LD	Minor flap necrosis	Debrided	3	M0 at 3 months
6	M	87	IHD, CABG, DM	20 × 7	L hamstring	Free LD	–	–	72	M5
7	F	84	PMR, CABG	25 × 10	L hamstring	Free LD	Recurrence pedicled ALT and myocutaneous gastroc flaps performed	–	48	M5
Total										
	Gender	Age	Region	Flap	Outcome					
	6 Males	Mean 73	Lower limb 7	Free 7	Excellent 6					
	1 Female	Range 46–87								

IGA inferior gluteal artery, *1 PFA* 1st branch of profunda femoris, *IHD* ischaemic heart disease, *HT* hypertension, *CABG* coronary artery bypass graft, *AVR* aortic valve replacement, *OA* osteoarthritis, *SGA* superior gluteal artery, *TKR* total knee replacement, *HC* hypercholesterolaemia, *BO* Barrett's oesophagus, *VRAM* vertical rectus myocutaneous flap, *2 PFA* 2nd branch of profunda femoris, *4 PFA* 4th branch of profunda femoris, *PMR* polymyalgia rheumatica, *ALT* anterolateral thigh flap

recurrence rates of 75–90% [5]. Evolution of surgical management strategies led to limb amputation with lower rates of local recurrence and better 5-year survival [6]. As a result, limb amputation became the standard of care. A paradigm shift occurred in the mid-1970s where wide local excision combined with adjuvant radiotherapy yielded equivalent recurrence, metastasis and mortality rates to amputation [7]. This led to increasing scope for limb salvage then to limb reconstruction. In the present modern era, functional limb reconstruction is the perceived standard of care. Serletti et al demonstrated the use of non-functional muscle flaps as early as 1998 [8]. The use of free functional flaps as the authors do in this series of 7 patients is a potentially significant upgrade to the published literature. Notably, these landmark events in sarcoma care ran synchronously with the developments in reconstructive techniques with the first free flap, the advent of the surgical microscope, innervated flaps and vascularised composite allotransplantation, respectively, which have contributed to the evolving development of functional reconstruction.

In this series, neo-adjuvant radiotherapy treatment prior to surgical resection was administered. Most centres around the world practice surgical resection

followed by radiotherapy. The sarcoma service feels the oncological outcomes are at least equivalent or better, and functionally, these patients do better overall, hence this approach. The senior author works as part of a multidisciplinary team and has close working relations with the oncological orthopaedic surgeon. Together, they have worked together for the last 10 years providing an immediate onco-plastic approach to sarcoma resection and reconstruction. Working together allows the oncologic surgeon to concentrate on the resection and attaining the best possible margins whilst preserving any useful recipient vessels or nerves for microsurgical transfer. The reconstructive surgeon can concentrate solely on the best reconstruction for the patient without the need to be concerned about oncological clearance. Further, there is one surgical 'hit', i.e. one anaesthetic, one period of rehabilitation and recovery.

The goal of this study is to evaluate the functional outcome of this operative technique and emphasise its utility in sarcoma surgery even after radiation therapy. It is hoped that contributing to the literature in this area will encourage other reconstructive surgeons to consider functional reconstruction where possible in order to provide the best 'like for like' reconstruction for patients.

Table 2 The outcome data for this cohort of patients

Patient	Time to initial re-innervation (months)	Time to strongest re-innervation (months)	Final MRC grade	Inpatient stay (days)	Operative time hours	Active ROM	PROM
1	3	12	5	6	4	0–90	0–100
2	6	18	5	6	4	0–100	0–110
3	4	18	5	6	5	0–100	0–110
4	4	12	5	5	6	0–90	0–100
5	n/a	n/a	0	8	6	n/a	0–120
6	5	18	5	7	6	0–110	0–120
7	6	18	5	7	5	0–90	0–100

Patients and methods

The institutional review board approved the study. All patients underwent neo-adjuvant radiotherapy followed by wide tumour resection by the orthopaedic oncological surgery team and immediate functional reconstruction by the senior author in the same surgical centre in a single stage.

Between 2011 and 2016, 7 patients who underwent sarcoma extirpation from the posterior thigh were prospectively identified and case note review was performed. All patients were operated upon within 6 weeks of their final radiotherapy treatment. With respect to sarcoma aetiology, 4 were pleomorphic sarcomas and 3 were liposarcomas. All patients had received neo-adjuvant radiotherapy with 50–60 Gy.

Preoperative surgical planning took into consideration the potential defect size, need for skin, vascularised tissue and dead space obliteration, need for functional reconstruction, patient positioning and other ergonomic factors.

With the patient marked preoperatively by the resecting and reconstructive surgeons, the patient was

given 5000 units subcutaneous heparin with 2 g of intravenous cephazolin. The patient was placed in a prone position to allow simultaneous tumour resection and flap harvest—this has multiple advantages, namely minimising operative time and thereby the sequelae but also allowing close and regular communication between the two teams especially with respect to preserving local vessels for flap anastomosis and the identification of the sciatic motor nerves supplying the hamstring compartment. A free functioning muscle transfer was planned when a total compartmentectomy was indicated.

After the tumour had been excised, it was sent for histological confirmation. Haemostasis was thoroughly performed and local anatomy is examined for recipient vessels. Meanwhile, the flap template on the expected resection was raised on its thoracodorsal neurovascular pedicle. The flap was not detached until recipient vessels and nerves were ready for microsurgical anastomosis in order to minimise ischaemia time. As well as the innervated muscle requirement, the templated flap design took into consideration any dead space requirements and skin deficit on inset. For instance, if there was a large dead space component and no skin deficit, then the skin flap will be de-epithelialised and buried. Next, the dichotomy of pedicle length versus vessel calibre was addressed. Once ready for flap detachment, the flap vessels were clipped using surgical ligatures and the thoracodorsal nerve divided. The flap was placed in the defect and then stretched to its original length in order to allow for the final inset and the lengths of the vessels and nerves matched to the recipients. The usual vessel recipient is the first or second perforator off the profunda femoris. The nearest motor nerve, which had been previously tagged during the resection, was utilised for the neuroorrhaphy. Typically, the senior

Table 3 MSTS scores where 5 is the maximum score in each category

MSTS score	5	4	3	2	1	0
Pain	7					
Function	6			1		
Emotion	4	3				
Supports	6			1		
Walking	6		1			
Gait	6			1		



Fig. 1 This series of photographs and videos relates to the only female in the series. This 84-year-old lady is discussed in more detail as one of the complications in the series. The first intraoperative photograph (top left) depicts the initial extent of defect; however, the second photograph (top right) in the series illustrates in addition to the dead space and the volume

component of the required reconstruction which arguably was initially underestimated and unappreciated. The third photograph shows the flap inset having addressed the above issues. The final image is a video of the 12-month postoperative result in the same patient

surgeon would work from deep to superficial having secured the proximal tendon of the flap to prevent avulsion. The vascular pedicles were anastomosed to

whichever proximal recipient vessels off the profunda femoris were available after the tumour resection. The recipient nerves were stimulated intraoperatively before

Fig. 2 This is a series of clinical photographs and videos depicting the postoperative results after 12 and 24 months respectively. These postoperative photographs and videos of the same patient depict range of motion from neutral to full flexion of the knee and therefore full contraction of the hamstring compartment by the innervated muscle



division with a hand-held nerve stimulator in order to confirm the presence of motor axons. Typically, vein, artery and then nerve were anastomosed in this order. The knee was flexed to 60°, and finally, the distal end was tensioned and secured taking care to avoid tension on the surgical anastomosis. The flap was tubularised such that the dead space beneath the flap was filled with the lateral and medial muscle and it is placed deep to the central tensioned fibres. The flap was inset in layers over suction drains using 2/0 Vicryl deep, Inorb staples and 3/0 Monocryl for the intradermal layer and Prineo for dressing. Performing the reconstruction in this systematic and regimented way minimised errors and maximised ergonomics.

Postoperatively, the involved limb was immobilised in a fixed articulated knee flexion splint at 60° for 6 weeks. The patient was confined to bed rest for 6 days and nursed side-to-side or prone. The patients were then mobilised on crutches. During this time, the hip and ankle was allowed to move freely encouraging locomotion in order to prevent stiffness, DVT and other nosocomial postoperative complications. After this 6-week period, patients were allowed to start active and passive range of motion (ROM) under guidance from physiotherapists. Strengthening exercises were commenced after 3–6 months for a minimum period of 12 months. Daily 40 mg subcutaneous Clexane was continued postoperatively for 6 weeks for continued DVT prophylaxis.

The motor re-innervation results were documented by the senior author serially at 3, 6, 12 and 24 months. These results were non-blinded and assessed using the widely accepted MRC grading system. It was done in the prone position and the patient was asked to flex the knee. The senior surgeon has been doing innervated free flaps for more than 10 years and is proficient in assessing motor function. In addition, the Musculoskeletal Tumour Society (MSTS) grading system popularised by Enneking was applied [9].

Results

The average length of the surgery was approximately 5 h and average length of stay was 11 days. Within this data set, there were no intra-operative complications, and overall, there was one re-operation performed due to a minor skin flap necrosis which was treated with dressings. Patient demographics and complications can be seen tabulated in Table 1. Skin defect size ranged

from 8 × 4 cm to 25 × 11 cm with the majority of cases having very large defects.

In our institution, there is no funding for detailed electromyographic and nerve conduction studies in this setting, and therefore, functional results were assessed using the MRC muscle grading system and the MSTS.

As expected, initial postoperative strengths in all cases began at M0 postexcision. Initial motor re-innervation returned between 3 and 6 months and M5 strength returned on average after 12 months (mean taken from 6 cases as no long-term follow-up for case no. 5). Results are summarised in Table 2. In this cohort, there were no flexion contractures and active range of motion and passive range of motion results were good. Some reported a return to swimming and running, which were activities used as qualitative measures of the outcomes.

The MSTS grading system for function of the lower limb revealed excellent results which supported the MRC grading system (see Table 3). The best score is 5 in each category and the best total score is 30. Encouragingly, 4 patients scored a maximum of 30 points and 2 patients scored 29. The one patient who only had a follow-up of 3 months and had no re-innervation yet obviously scored less at 18. No patients experienced long-term pain and 6 patients received a full score of 5 in all functional aspects. As expected, the emotional results were more mixed with 4 patients giving a score of 5 meaning they were enthused and would recommend it to other patients, whereas 3 patients were very satisfied and would do it again.

Two patients required subsequent further operations from synchronous recurrences. One such patient had a total of 5 recurrences (2 of which was after the LD flap) and underwent a pedicled ALT flap combined with a myocutaneous gastrocnemius as the recurrence arose within the free innervated LD flap which was located outside the radiotherapy field. After her second reconstruction, she had further recurrences for which she was considered for possible above knee or hindquarter amputation. We would accept that this patient may not be deemed a good candidate for a functional reconstruction due to tumour biology. However, of note is that not only did the flap re-innervate to an M5 power but also the patient had significant disability in gait prior to the muscle re-innervating. She gained 4 years of functional outcome and was exceedingly pleased to be free of walking aids during this time (Figs. 1 and 2). The second patient suffered a recurrence at the flap site, which required a pedicled VRAM flap to superior aspect of the hamstring after re-excision. Both these patients had high-grade aggressive tumours.

Discussion

Oncological resection of STS can be debilitating anywhere in the body, but perhaps even more so in this region. Resection of the hamstrings and posterior compartment affects locomotion and ADL considerably, in turn affecting the patient's QoL [10]. Furthermore, combined with the need for radiotherapy and its sequelae, journeys to hospital, getting in and out of MRI and CT scanners, hospital beds and vehicles, these events can lead to a miserable existence for the patient who may be left with postoperative morbidity and partial or total loss of function following surgery. This also has a massive impact on their autonomy and self-esteem, aside from their reduced ability to remain independent [11].

Motor re-innervation can provide the dual functions of active contraction and soft tissue coverage, and therefore seem to be ideal for reconstructions after oncological resections or for secondary reconstruction following trauma or infection. Furthermore, the use of soft tissue flap reconstruction promotes primary wound healing, introduces vascularised tissue promoting angiogenesis and fills dead space, as well as providing better contour and aesthetics, all of which are critical for rehabilitation and return to society. Once the wound has healed and the myocytes re-innervated, the muscle can be conditioned and trained as in anywhere else in the body gradually to function as a new hamstring, leading to a functional reconstruction [12].

Although the authors have no experience working with postoperative radiotherapy, there is mixed evidence that the adjuvant therapies may affect nerve regeneration both positively and negatively [13, 14]. The oncological outcomes achieved by the local sarcoma service are analogous to the postoperative radiotherapy figures and the authors support the recommendations of the multidisciplinary team. From the senior author's experience, his microsurgical outcomes operating in a radiotherapy field versus in virginal tissues are the same; therefore, this does not play a role in his reconstructive decision-making. In centres where radiotherapy is performed postoperatively, the reconstructive surgeons often favour muscle or musculocutaneous flaps due to their ability to withstand the effects of radiotherapy better both in the short and longer terms, with respect to wound healing, contour and aesthetics. Theoretically, better nerve regeneration would be expected in non-irradiated tissues; however, this has been poorly studied and is not supported by the literature. Further, there is a paucity of data supporting the use of nerve transfers or innervated free flaps in irradiated fields [5, 8].

Of all of the thigh sarcomas, only approximately 20% arise in the posterior compartment [1–3, 11]. Nevertheless, the sciatic nerve runs within this compartment and therefore any excision and/or reconstruction of this region must be addressed. Compared to the other regions, posterior thigh sarcomas are often easily accessible and therefore resectable. It is rare to see sciatic nerve involvement as the sarcoma pseudocapsule often displaces it to the side. Historically, hemipelvectomy was the treatment for tumours in this region. However, more recent convention is for partial or total muscle groups to be included in the resection only, in order to maximise oncological margins but also to preserve function.

Preservation of the posterior compartment of the thigh is underrated in terms of reconstruction. Being bi-articular, hamstring weakness or deficit leads to inability to perform the gross actions of hip extension and knee flexion which significantly impacts locomotion, stair ascent and descent, as well as any physical activity which involves running. Further analysing the muscle fibres, it is known that approximately 70% of the muscle fibres are fast twitch fibres, meaning that they contribute to explosive, high force and high velocity activities. The hamstrings function eccentrically and/or isometrically to control and decelerate knee flexion and can provide an effective co-contraction with the quadriceps, working to reduce anterior shear force, knee valgus and rotation of the tibia.

In this modest case series of 7 patients, it has been shown that functional reconstruction following sarcoma resection is not only possible, but actually preferable in view of the excellent results which can be achieved even amongst a relatively elderly cohort (mean age 73 years). Six out of seven patients achieved MRC grade 5 strength with normal function. This was further supported by the MST scores in which those 6 patients had a score of 29 or 30 out of a maximum of 30. The last patient did not have sufficient follow-up to enable a proper assessment of functional rehabilitation.

In the opinion of the senior author, there is not much difference between raising an innervated free flap as opposed to a non-innervated free flap especially as in the case of the latissimus dorsi flap, the nerve lies adjacent the pedicle. Although dissecting out recipient nerve(s) and appropriately securing the musculotendinous components as well as tensioning the flap are critical in achieving a good outcome, this is not hugely time-consuming. The main limitation of this study is the small number of patients and the short-term

follow-up. The authors accept that use of a non-blinded assessor is an obvious limitation, together with lack of objective measures of function. No force transduction resources were available to aid confirmation; however, with all patients returning to walking at a minimum of 3 months, walking unaided within 6 months, running, cycling and swimming at 12 months, we accept the performance of these activities as adequate objective evidence supporting M5 grade power.

Muscle strength, active and passive contractility and the ability to condition the muscle over time are all keys to restoration of limb function. Being a free flap, the innervated latissimus dorsi flap has many qualities to its advantage for use in this context. These include freedom of flap design to subsequent site of coaptation, contouring ease and reliable myocutaneous flap perfusion, all in addition to its overall size. Disadvantages of the use of this flap choice, although previously cited in the literature in regard to donor site morbidity, flap bulk, sacrifice of the core stabilising and upper girdle muscle as well as shoulder stiffness were not noted to be issues in this patient group [15]. Further, larger studies are necessary to compare this reconstruction with non-innervated muscle flaps [16–18].

Conclusion

Although limb-sparing surgery with adjuvant radiation and chemotherapy has become the preferred treatment for upper extremity sarcomas, adequate tumour resection can compromise crucial limb function. Functional reconstructive surgery, with its intuitive benefits in restoring limb utility, should be offered to patients as one of many reconstructive options following sarcoma resection. Despite positive outcomes with functional reconstruction, the adoption of this strategy has not been universally accepted. Although functional muscle is not a prerequisite for limb salvage, it is not technically onerous for the microsurgeon. It may be more time-consuming both preop and intra-operatively as well as being more expensive than soft tissue-only reconstruction but there are clear benefits for the patient as shown by the authors in various studies to date.

Compliance with ethical standards

Patient consent All of the patients have given consent.

Conflict of interest Damien Grinsell and Zeeshan Ahmad declare that they have no conflict of interest.

Ethical approval Gained from the Local Quality Assurance Subcommittee of the Human Research and Ethics Committee (Reference: QA 057/16).

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References

1. Australian Institute of Health and Welfare; Australasian Association of Cancer Registries (2001) Cancer in Australia 1998: Incidence and mortality data for 1998. Cancer series no. 17. AIHW cat. no. CAN 12. [cited 2008 Dec 12]. Available from: www.aihw.gov.au/publications/can/ca98/
2. Begg S, Vos T, Barker B, Stevenson C, Stanley L, Lopez AD (2007) The burden of disease and injury in Australia 2003. Canberra: Australian Institute of Health and Welfare. [cited 2007 Nov 14]. Available from: <http://www.aihw.gov.au/publications/hwe/bodaiia03/bodaiia03-c00.pdf>
3. Australian Institute of Health and Welfare (2005) Health and Welfare Expenditure Series Number 22: Health system expenditures on cancer and other neoplasms in Australia, 2000–01. Canberra: Australian Institute of Health and Welfare. [cited 2007 Nov 14]. Available from: <http://www.aihw.gov.au/publications/hwe/hsecna00-01/hsecna00-01.pdf>
4. Bleyer A, Montello M, Budd T, Saxman S (2005) National survival trends of young adults with sarcoma: lack of progress is associated with lack of clinical trial participation. *Cancer* 103:1891–1897
5. Siegel R, Ward E, Brawley O, Jemal A (2011) Cancer statistics, 2011: the impact of eliminating socioeconomic and racial disparities on premature cancer deaths. *CA Cancer J Clin* 61(4):212–236
6. Suit HD, Russell WO, Martin RG (1973) Management of patients with sarcoma of soft tissue in an extremity. *Cancer* 31(5):1247–1255
7. Emrich LJ, Ruka W, Driscoll DL, Karakousis CP (1989) The effect of local recurrence on survival time in adult high-grade soft tissue sarcomas. *J Clin Epidemiol* 42(2):105–110
8. Serletti JM, Carras AJ, O'Keefe RJ, Rosier RN (1998) Functional outcome after soft-tissue reconstruction for limb salvage after sarcoma surgery. *Plast Reconstr Surg* 102(5): 1576–1583
9. Enneking WF, Spanier SS, Goodman MA (1980) A system for the surgical staging of musculoskeletal sarcoma. *Clin Orthop Relat Res* (153):153–154
10. Gundle KR, Cizik AM, Jones RL, Davidson DJ (2015) Quality of life measures in soft tissue sarcoma. *Expert Rev Anticancer Ther* 15(1):95–100
11. Quinn GP, Gonçalves V, Sehovic I, Bowman ML, Reed DR (2015) Quality of life in adolescent and young adult cancer patients: a systematic review of the literature. *Patient Relat Outcome Meas* 6: 19–51
12. Grinsell D, Di Bella C, Choong P, Functional reconstruction of sarcoma defects utilising innervated free flaps, *Sarcoma*, 2012, 315190, 26
13. Tung TH (2015) Clinical strategies to enhance nerve regeneration. *Neural Regen Res* 10(1):22–24
14. Hsu S-T (2017) Effects of taxol on regeneration in a rat sciatic nerve transection model. *Sci Rep* 7:422

15. Stubblefield MD, Burstein HJ, Burton AW (2009) NCCN task force report: management of neuropathy in cancer. *J Natl Compr Cancer Netw* 7:S1–S26
16. Clark RL Jr, Martin RG, White EC (1959) A critical review of the management of soft-tissue sarcomas. *J Lancet* 79(7):327–331
17. Yasko A, Patel R, Pollack A, Pollack RE (eds) (2001) *Sarcomas of soft tissue and bone*. Atlanta: American Cancer Society
18. Lee KT, Mun GH (2014) A systematic review of functional donor-site morbidity after latissimus dorsi muscle transfer. *Plast Reconstr Surg* 134(2):303–314