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Soft tissue reconstruction after pelvic amputation: The efficacy and reliability of free fillet flap reconstruction

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KEYWORDS
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Free flap;
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Sarcoma;
Survival

Summary Background: The majority of hindquarter amputation defects can be reconstructed with local anterior or posterior thigh flaps. Less than 5% of soft tissue defects require free flap reconstruction after tumour resection. Lower extremity fillet flap is described for reconstructing such defects, but the majority of publications are case reports or short single institutional series. There is a lack of data regarding the oncological outcomes of this highly selected patient group.
Methods: Three tertiary sarcoma units treated twelve patients with hindquarter amputation or hip disarticulation for oncological indications with a free flap reconstruction of the soft tissue defect.
Results: The median age of patients was 60 (range 12–76) years. Bone resection was carried out through the SI-joint in six patients and through the sacrum in five patients, with one patient undergoing hip disarticulation. Nine patients had R0 resection margin and three had R1 resection. The median surgical time and flap ischaemia time was 420 (249–650) and 89 (64–210) min, respectively. Median hospital and ICU stay was 18 (10–42) and 3 (1–8) days, respectively. Median

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blood loss was 2400 (950–10000) ml. There were three returns to theatre due to vascular compromise, with one total flap loss due to arterial thrombosis. Overall survival was 58% (95%CI 28–91%) both at 1-year and at 3-years.
Discussion: Carefully selected patients requiring hindquarter amputation with extensive soft tissue defect necessitating free flap reconstruction can be reconstructed with a lower extremity free fillet flap with low rate of local wound complications. Survival of these patients is similar to that in patients requiring less extensive resection.

Introduction

Advances in imaging, chemotherapy and radiotherapy and a greater appreciation of the management of sarcoma has resulted in an increased use of limb salvage surgery for the vast majority of tumour locations. Unfortunately, amputation is still required in some cases of advanced disease where resection with clear margins is not possible due to the size of the tumour or the proximity of nearby vital structures or where resection would result in the formation of a functionless limb due to sacrifice of neurovascular structures[1].

In the majority of cases of hindquarter amputation (HQA), the defect can be reconstructed primarily using local flaps based on the superior gluteal vessels, using a myofasciocutaneous flap comprising the gluteal compartment or the femoral vessels, harvesting a myofasciocutaneous flap from the anterior thigh.[2,3] In select cases where this is not possible, flaps arising from the abdominal wall, either ipsilateral or contralateral ventral rectus abdominus myofasciocutaneous flaps, can be used, but these are limited in the volume of usable tissue and distance of transfer.[4]

In cases where the superior gluteal pedicle and the femoral vessels must be sacrificed to achieve clear tumour margins and where the defect is felt to be too large to use an abdominal flap, an alternative source of tissue to fill the defect and achieve coverage of the wound must be sought. In such cases, a free tissue transfer is required to reconstruct the composite pelvic defect. Numerous free flaps have been described for reconstructing pelvic defects.[5,6] However, a large free flap is often required to reconstruct the defect following HQA which cannot be harvested without donor site morbidity.[7,8] The free fillet flap is harvested from the limb to be sacrificed based on the proximal vessels which can be harvested distal to the extent of the tumour, most commonly on the popliteal vessels. The flap offers a large bulk of tissue to fill the defect following amputation, without the associated donor site morbidity conferred by other free tissue transfers.[9] The fillet flap was first described to reconstruct the defect resulting from a HQA by Workman[10] and Yamamoto.[11] Since its first description, a number of small volume series have been reported,[12-16] and its use has been included in larger volume series relating to pelvic sarcoma surgery.[2,4]

The aim of this study, therefore, was to report on a larger series of patients undergoing HQA or extended hip disarticulation as treatment for a pelvic malignancy, reconstructed using a free tissue transfer from the ipsilateral calf tissue. The primary outcomes of this study were those relating to soft tissue reconstruction, including operating time, blood loss, method of vessel reconstruction and flap survival, whilst the secondary outcomes included oncological outcomes for patients undergoing this treatment, including overall survival (OS), local recurrence free survival (LRFS) and metastasis-free survival (MFS) of this highly selected patient group.

Materials and methods

Selection criteria

The study comprised a retrospective case review. Having obtained institutional review board approval in each centre, patients undergoing free tissue transfer using a fillet flap following limb sacrifice surgery were identified from prospectively maintained oncology databases at the three contributing tertiary oncology units—Tampere University Hospital, Birmingham Royal Orthopaedic Hospital and Tours University Hospital—between 1st of January 2013 and 31st of December 2018. All patients were reviewed by a sarcoma multidisciplinary team (MDT). The decision to undertake HQA or extended hip disarticulation was based on the underlying diagnosis, the staging of the patient, the volume of the tumour, the projected margin if limb salvage was contemplated, and the acceptance of the patient. A fillet flap was considered for reconstruction where the HQA would require removal of the superior gluteal pedicle and the femoral vessels proximal to the inguinal ligament to achieve resection with a clear margin. All patients underwent vascular assessment comprising CT angiography or percutaneous angiography, including the aorta down to the terminal vessels of the limb from which the flap would be harvested, and compression venography to assess the venous drainage of the limb.

Variables and measurements

Data was compiled following scrutiny of the medical records and database entries from each institution. Collected variables included patient demographics, imaging studies, surgical details, tumour histology and peri-operative complications. Complications relating to the soft tissue reconstruction were collected up until death or the last date of follow-up. All patients were followed up according to nationally agreed-upon standards within a protocol of clinical assessment, local magnetic resonance imaging and chest x-ray surveillance every 3 months until 2 years, every 6 months until 5 years and annually thereafter until 10 years.

Median values and ranges were calculated for continuous variables. All-cause OS was measured from the date of surgery to the date of death or date of last follow-up. LRFS was measured from the date of the surgery to the date of local recurrence, date of death or date of last follow-up. MFS was measured from the date of surgery to the recorded date of the development of metastases, date of death or date of last follow-up. Kaplan-Meier curves were constructed to assess OS, LRFS and MFS. The Mann-Whitney U-test and chi-squared test were used to test the statistical significance for continuous and categorical variables, respectively. A p-value < 0.05 was considered to be statistically significant. All statistical analyses were performed using SPSS Statistics 24.0 (IBM Armonk, NY, USA).

Surgical technique

All procedures were performed by specialist orthopaedic oncologists whilst the soft tissue reconstruction was performed by a team of plastic surgeons with advanced training in sarcoma surgery. The procedure involves two phases. In the first phase, the patient is positioned in a floppy lateral or semi-supine position that allows the limb and torso to be rolled both backward and forward to allow circumferential access to the hemipelvis and lower limb. The patient is draped with the limb exposed down to the ankle, and the abdomen up to the midline. Posteriorly, the drapes are placed to allow exposure of the sacrum across the midline but covering the anal margin. In the majority of cases, the incision for the HQA adopts an extended utilitarian exposure extending posteriorly to the midline sacral structures and extending around the perineum to join the anterior limb of the incision, thereby resecting the hemipelvis with the buttock flap in continuity. In contrast to the conventional HQA or hip disarticulation, the vessels are mobilised proximal to the tumour but not ligated at this stage to minimise the ischaemic time for the flap. Once circumferentially dissected, the osteotomies can be performed at the predesignated level but while maintaining the continuity of the vessels.

The second phase of the procedure comprises the harvest of the fillet flap. In many cases, this can proceed in tandem with the tumour dissection without the use of a tourniquet. The two-team approach requires close co-operation between the orthopaedic team and the reconstructive team to minimise the ischaemia time and to optimise the surgical flow. Banking of the fillet flap is a salvage option in case of need of early ligation of the iliac vessels due to bleeding problem or complicated resection.[14] For the harvest of the flap, the popliteal vessels are exposed together with 1-2 superficial veins. Popliteal vessels should always be dissected above the sural vessels to ensure adequate circulation to gastrocnemii muscles and posterior calf skin. Anteriorly, an incision is made over the proximal tibiofibular joint line, and the tibia is dissected subperiosteally, dividing the intermuscular septum to allow the fibula to be dissected subperiosteally free from the surrounding soft tissues. All three main vessels are kept intact. Distally, the flap is then elevated from the distal tibiofibular joint line at the level of the ankle. Having elevated the flap in its entirety, the popliteal vessels can be divided and flushed locally with heparin solution. Simultaneous intravenous 5000IU heparin is administered prior to iliac vessel ligation. At the same time, the HQA is completed by dividing the iliac vessels proximal to the resection margin. The limb can then be removed in its entirety.

The harvested flap is now placed over the HQA defect and orientated to give the best coverage. The popliteal vessels of the flap are anastomosed most commonly end-to-end to the stump of the iliac vessels using 7-0 vascular sutures. There is always a mismatch between the iliac and popliteal vessels, but this can be managed by taking a small side wedge out of the larger vessel. Having restored the arterial and venous circulation, the flap can then be inset and sutured over large suction or Penrose drains (Figure 1a-f). The flap is secured with only a minimally compressive dressing to avoid any compression to the pedicle.

All patients recovered in an intensive care unit to allow careful monitoring of blood pressure and fluid balance as well as regular flap observations, being particularly checked for evidence of vascular compromise. The flap was monitored meticulously with hourly clinical exam and with a hand-held doppler by the ICU nursing staff and with two hour interval assessments from the second post-operative day forward. The positioning of the patient and the flap were closely monitored within the first few post-operative days. The patient was placed on an air mattress, and the positions of the patient and the flap were frequently checked. Patients were restricted to bed rest for the first five days to prevent any distension of the large flap.

Results

During the study period, 12 patients (9 males, 3 females), with a median age of 60 (range 12–76) years, underwent pelvic amputation with free fillet flap reconstruction (Table 1). Eleven of the amputations comprised HQAs, whilst the remaining patients underwent extended hip disarticulation. When assessing the tumour involvement to nearby critical structures (sciatic nerve, femoral nerve and iliac/femoral vessels), all patients had at least two of the three critical structures involved. 8 patients underwent amputation as the primary surgical procedure, and 4 were salvage surgeries for the treatment of recurrent disease following a previous internal hemipelvectomy or following an inadvertent, intralesional procedure at another institution. An R0 resection margin was achieved in 9 patients, with the remaining 3 patients having an R1 resection margin.

The median surgical time, flap ischaemia time, blood loss and lengths of ICU and hospital stay are summarised in Table 2. The level of proximal resection was through the sacrum in 6 patients, through the SI-joint in 5 patients and through the hip joint in 1 patient. Comparing those who underwent an extended HQA (amputation through the sacrum) to those who underwent either standard HQA or hip disarticulation revealed no significant difference in terms of resec-

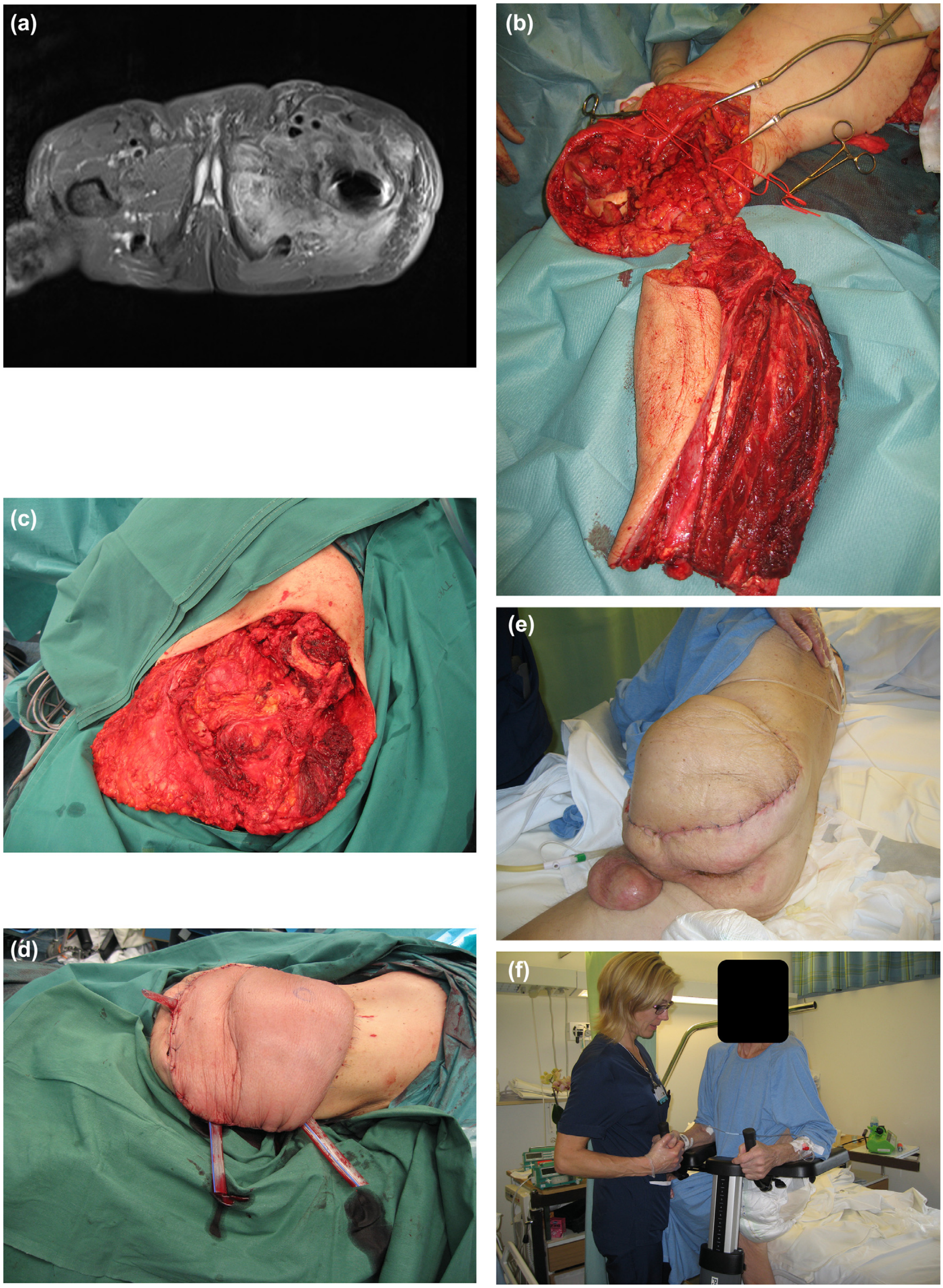

Figure 1 a) Pre-operative MRI image of the pelvic high-grade angiosarcoma showing involvement of all three critical structures. b) Harvested fillet flap. c) Defect after tumour resection. d) Flap inset. e) Post-operative appearance of the flap. f) Patient mobilised 1 week after the tumour resection and microvascular reconstruction.

Table 1 Surgical details of the patients. SIJ = sacroiliacal joint, OR = operating room. NPWT = negative pressure wound therapy

Patient	Age	Gender	Comorbidities	Preoperative radiotherapy	Primary or salvage operation	Histology	Tumour grade	Tumour dimensions (WxHxD in cm)	Iliac vessels involved	Femoral nerve involved	Ischial nerve involved	Closest margin (mm)	Bone resection	Flap ischemia (min)	Flap anastamosis	Surgical Time (hh:min)	Hemmorhage (ml)	Hospital Stay (days)	ICU days	Re-operations	Complications	Post operative mobility	Local recurrence	Metastasis	Alive	Follow-up time (months)
1	62	Male	1) Coronary artery disease (angioplasty twice)	No	Primary	Spindle cell sarcoma	High grade	8.7x10.7x11.6	Y	N	Y	Fascia	Sacrum	210	Popliteal a&v => common iliacal a&v (vein end-to-side)	08:08	3500	16	1	1) Vein re-anastomosis 2) Secundary closure	1) Venous congestion (thrombosis)	N/A	No	No	Yes	27
2	76	Male	1) Prostate cancer 2) Coronary artery disease (by-pass)	No	Salvage	Angiosarcoma	High grade	13x13xN/A	Y	Y	Y	0	SIJ	N/A	Popliteal a&v => common iliacal a&v	04:09	1500	19	3	1) Vein re-anastamosis 2) Seroma drainage in OR	1) Venous congestion (kinking of pedicle vein) 2) Infected seroma	Wheelchair	No	Lymph node (at the time of surgery)	No	6
3	76	Male	1) Chronic obstructive pulmonary disease	No	Primary	Chondrosarcoma	High grade	12x13x13	N	Y	Y	4	Sacrum	77	Popliteal a&v => common iliacal a&v	09:04	950	14	1	None	None	Crutches (short distance) and wheelchari (long distance)	No	Pulmonary (at 3 months)	No	9
4	47	Female	1) Deep vein thrombosis	No	Primary	Chondrosarcoma	Intermediate	26X19X17	Y	Y	N	8	Sacrum	N/A	Popliteal a&v => common iliacal a&v	06:53	2500	20	2	None	None	Crutches	No	No	Yes	13
5	63	Male	1) Total hip replacement 2) Depression	No	Salvage	Osteosarcoma	High grade	49X27X30	N	Y	Y	0	SIJ	N/A	Popliteal a&v => common iliacal a&v	04:30	NA	32	2	None	None	Crutches (short distance) and wheelchair (long distance)	9 months	Pulmonary (at the time of amputation)	No	12
6	12	Female	None	Yes	Primary	Osteosarcoma	High grade	20x19x16	Y	Y	Y	0	Sacrum	64	Popliteal a&v => common iliacal vessels	06:02	NA	42	8	1) Exploration, flap removal and application of NPWT 2) Local perforator flap reconstruction and aplication of NPWT 3) Multiple NPWT changes and washouts	Total flap loss	Crutches	No	No	Yes	22
7	73	Male	1) Hypertension 2) Atrial fibrillation 3) Temporal arteritis	No	Primary	Leiomyosarcoma	High grade	18x8.5x7	Y	Y	Y	1.5	Sacrum	N/A	Popliteal a&v => common iliacal vessels	NA	NA	10	NA	None	Death at 10 POD	N/A	No	No	No	0
9	58	Male	1) P1 resection for chondrosarcoma (2 years prior)	No	Salvage	Chondrosarcoma	High grade	Multinodular	Y	Y	Y	N/A	SIJ	N/A	Popliteal a&v => common iliacal vessels	10:50	10000	28	8	1) Fibula trimming	Fibula compressing skin	N/A	No	No	Yes	37
10	16	Female	None	No	Primary	Osteosarcoma	High grade	28.5x11.5x8	Y	Y	N	2	SIJ	N/A	Popliteal a&v => external iliacal vessels	07:17	2800	10	3	None	None	Crutches	No	No	Yes	51
13	35	Male	None	No	Primary	Osteosarcoma	High grade	33x21x20	Y	Y	N	100	Hip	180	Popliteal artery => femoral artery & Long sapheneus v => femoral v	09:00	NA	14	4	None	None	N/A	No	No	Yes	18
11	74	Male	1) Polycystic kidney disease 2) Left nephrectomy 1996 (same side as tumor) with retroperitoneal approach 3) Renal transplant	No	Primary	Dedifferentiated liposarcoma	Intermediate	25x25x20	N	Y	Y	4	SIJ	77	Popliteal a&v => common iliacal a&v	07:00	1300	29	4	None	1) Sepsis from pyelonephritis at day 10 2) Frontal bilateral hydroma that did not requiere surgical intervention	Crutches (short distance) and wheelchari (long distance)	No	No	Yes	1
12	35	Male	1) Lower limb enchondromatosis 2) P1 resection for chondrosarcoma (12 years prior)	No	Salvage	Chondrosarcoma	Intermediate	27x18x14	Y	Y	Y	3	Sacrum	100	Popliteal a&v => common iliacal a&v	07:00	2300	16	2	None	None	Crutches (short distance) and wheelchari (long distance)	No	No	Yes	5

Table 2 Surgical time, bleeding, flap ischaemia and length of stay of the patients. ICU = intensive care unit.

	Median	Range
Surgical time (minutes)	420	249-650
Bleeding (ml)	2400	950-10,000
Flap ischaemia (minutes) (n = 6)	88.5	64-210
ICU stay (days)	3	1-8
Hospital stay (days)	17.5	10-42

tion margin, surgical time, length of stay, ICU stay or blood loss.

OS for all patients was 58% (95% CI 26-92) after 1 year and 3 years. LRFS was 86% (95% CI 33-98) after 1 year and 3 years. MFS was 88% (95% CI 39-98) at 1-year and 3-year (Figure 2A-C). All local recurrences and metastases occurred within 12 months of the amputation.

In one patient, a vascularised fibula was also included to fillet flap and used to bridge the defect between the resected hemisacrum and the contralateral pubis which was secured with intraosseous bone suture anchors in an attempt to give better sitting balance. Reconstruction in the remaining patients was performed with a musculocutaneous flap alone. The popliteal artery was anastomosed to the iliac or femoral artery from end to end for all patients. The popliteal vein was anastomosed to the iliac or femoral vein for 11 patients. The anastomosis was end-to-end in 10 patients and end-to-side due to size discrepancy between vessels in 1 patient. In 1 patient, due to the development of a deep vein thrombosis whilst receiving chemotherapy for an osteosarcoma, the long saphenous vein was anastomosed to the femoral vein by an end-to-end anastomosis.

Following initial recovery from the procedure, three patients were able to ambulate with crutches. Four patients were able to ambulate short distances with crutches but were largely reliant on a wheelchair. In one patient, they were completely reliant on a wheelchair for mobility. Ambulation data was missing for 2 patients, and 1 patient had only recently undergone the procedure so no meaningful information regarding ambulation could be used. No patients remained permanently confined to bed.

All complications are presented in Table 1. Four patients required a return to theatre. In 3 patients, this was due to vascular compromise which comprised 1 venous anastomosis thrombosis, 1 venous kink and 1 extensive arterial thrombosis. All vascular complications occurred during the first 24 hours after the operation. The fourth patient required a return to theatre to trim the transplanted vascularised fibula as it had resulted in pressure necrosis on the overlying skin. All patients who required a return to theatre to address a vascular compromise required further theatre visits—two for secondary wound closure and one for drainage of an infected seroma. Eleven of the 12 fillet flaps survived completely whilst 1 patient suffered a total flap loss due to extensive arterial thrombosis that could not be resolved. This patient underwent flap debridement, negative pressure wound therapy (NPWT) and eventual wound closure with a local flap and secondary healing. There was one unexpected post-operative death at tenth post-operative day due to a massive cardiac event.

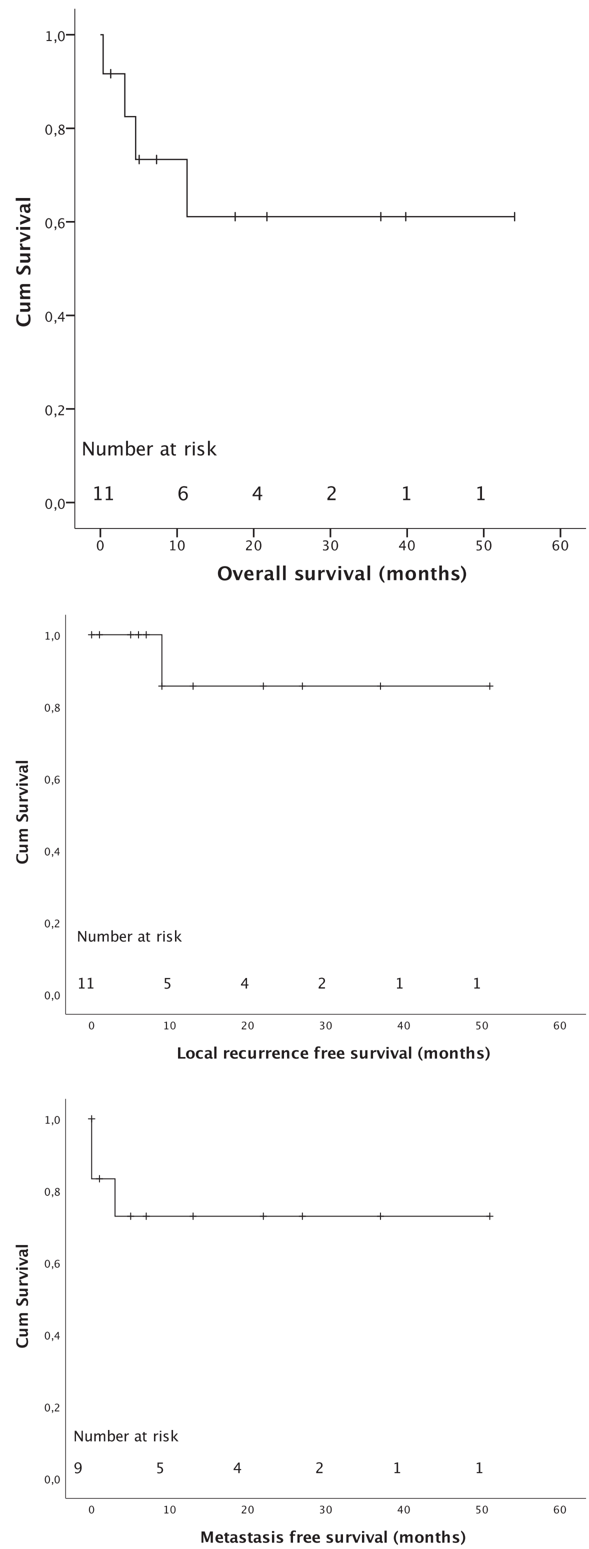

Figure 2 a) OS of patients undergoing pelvic amputation and free flap reconstruction. b) LRFS of patients undergoing pelvic amputation and free flap reconstruction. c) MFS of patients undergoing pelvic amputation and free flap reconstruction.

Discussion

In this retrospective multicentre study, we have reported the outcomes of surgery and oncological reconstruction for large pelvic amputation defects in 12 patients treated with a free fillet flap. In all cases, the fillet flap was harvested from the amputated limb and therefore saved the patient unnecessary donor site morbidity. We have shown this to be a reliable method of reconstruction in select patients. Eleven of the 12 free flaps survived completely, with only one total flap failure. No partial flap losses were noted in this series.

The majority of patients undergoing pelvic amputation could undergo reconstruction with local flaps, most commonly with posterior or anterior flaps.[2-4,17] Free flap reconstruction is indicated when local or regional tissues are not available due to tumour involvement or vascular compromise due to the tumour or tumour resection. Multiple free flaps have been used for covering large pelvic amputation defects including latissimus dorsi, anterolateral thigh and tensor fascia lata flaps.[5,6] The fillet flap, harvested from the amputated extremity, provides robust tissue without additional donor site morbidity. All survived flaps in our series resulted in stable wound coverage, without the development of significant hernias requiring surgical intervention or the development of major wound complications, other than the case of an infected seroma which developed after discharge of the patient. This is an improvement on the reported outcomes of conventional flap coverage where wound complications are reported to occur in up to 39% of cases.[2,17,18] This demonstrates an attractive alternative to the conventional local flap options and should be considered where there is doubt of the viability of the conventional gluteal or thigh flap technique. Free flap reconstruction after major amputation is associated with a lower incidence of complications when compared to local flap reconstruction options in massive oncological defects.[6] In this series, we had a total of four flap-related complications. One flap was lost due to extensive thrombosis. This was salvaged with NPWT and a random local flap. Contralateral vertical rectus abdominal myocutaneous flap is an alternative salvage flap for reconstructing a complicated HQA wound.[4] The majority of the vascular complications were successfully corrected in the emergency reoperation. The vascular complications were considered to be mostly caused by mechanical problems in this study. It is doubtful whether using double venous anastomosis would have prevented this. All venous complications were successfully recovered by re-operation suggesting that the single venous outflow vessel is sufficient with the fillet flap. The number of returns to theatre for vascular complications highlights the need for a multidisciplinary approach, not only in planning and executing this kind of major surgery, but also during the recovery period. In this series, the median flap ischaemia time was 88 minutes. The ischaemia time could be reduced if the majority of the flap dissection is done prior to tumour resection and proximal vessel ligation.[16] However, the one flap loss seen in this series did not have an ischaemia time in excess of the median for the series.

The OS for the included patients in this series was 58% after 1 and 3 years. In the literature, there are no studies that report the oncological outcome of patients with large central pelvic tumours, requiring extensive resections where a free flap is required to fill the amputation defect. When compared to series reporting the OS for patients undergoing HQA, the OS reported here compares favourably to the 27–45% 5-year survival reported elsewhere, though it should be noted that the requirement for fillet flap reconstruction reflects the large size of tumours, which is itself a poor prognostic indicator.[17-21] Therefore, our study indicates that OS with large pelvic tumour necessitating amputation and free flap reconstruction is similar to patients who can be managed with regional pedicled flaps at least during a short follow-up.[18,20,21] We acknowledge the limitation of a small number of patients surviving more than three years; however, an important finding from our results is that HQA accompanied with fillet flap reconstruction preserves adequate survival. It is known that larger tumour volume is associated with a worse MFS and OS; however, surgical margin has been shown to be predictive of LR in pelvic sarcoma as well as for OS.[21,22] Therefore, the principal aim in managing pelvic sarcoma must be to achieve clear surgical margins in an attempt to improve LRFS and OS. Using free flap reconstruction, large pelvic defects can be closed reliably, which therefore negates the perceived compromise of achieving soft tissue coverage with a more aggressive resection. This study demonstrated favourable local control for the underlying histological subtype, with LRFS of 86% at 3-years, with only one local recurrence in a patient with an R1 resection margin, which is comparable to other reported results following pelvic sarcoma.[17,21,23]

In this series, 7 of the 12 patients were able to ambulate with crutches across at least short distances. One patient was only able to mobilise with a wheelchair. No patients were confined to bed following rehabilitation. The mechanism and return to mobility of our cohort is similar to that previously reported.[18] We did not specifically study the stability of the remaining pelvis nor the incidence of pain related to instability. Bony reconstruction of the pelvic ring may be considered to provide an improved load transference between the spine and the remaining pelvis in both sitting and standing positions. In the literature, the use of vascularized bone, including the femur,[11,15] vascularized tibia and vascularised fibula, have been described for pelvic ring reconstruction.[24,25] The OS of these patients was somewhat better than we anticipated, and a majority of the patients were able to ambulate at least short distances. Therefore, the pelvic ring reconstruction with the use of a vascularized bone transfer from the amputated limb could be considered for pelvic stabilization with a possible improvement in patient ambulation. However, we would not advocate the use of a vascularised fibula to restore the pelvic ring in an attempt to improve sitting posture, as it is our experience that in the one patient on whom it was used, it was associated with soft tissue failure due to prominence of the fibula, which subsequently had to be removed.

The retrospective nature of this study is an inevitable limitation. However, the current study is the largest series to demonstrate the reliability of the free fillet flap reconstruction technique following extensive limb sacrifice surgery. The patient data, oncology data and follow-up ares prospectively recorded in the included oncology database of each institution. We acknowledge that making meaningful inferences on survival with such a small number of patients is not possible but highlight the rarity of this procedure.

Conclusion

HQA patients with extensive soft tissue defects requiring free flap reconstruction can safely undergo reconstruction with lower extremity free fillet flap following careful patient selection and MDT management. Special care needs to be addressed for reconstructing the venous outflow. Oncological outcomes in this patient group appears to be similar to those who undergo HQA with lesser soft tissue resection and local flap reconstruction, with a relatively low wound complication rate.

Ethical Approval

ETL-code R18603

Declaration of Competing Interest

None

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