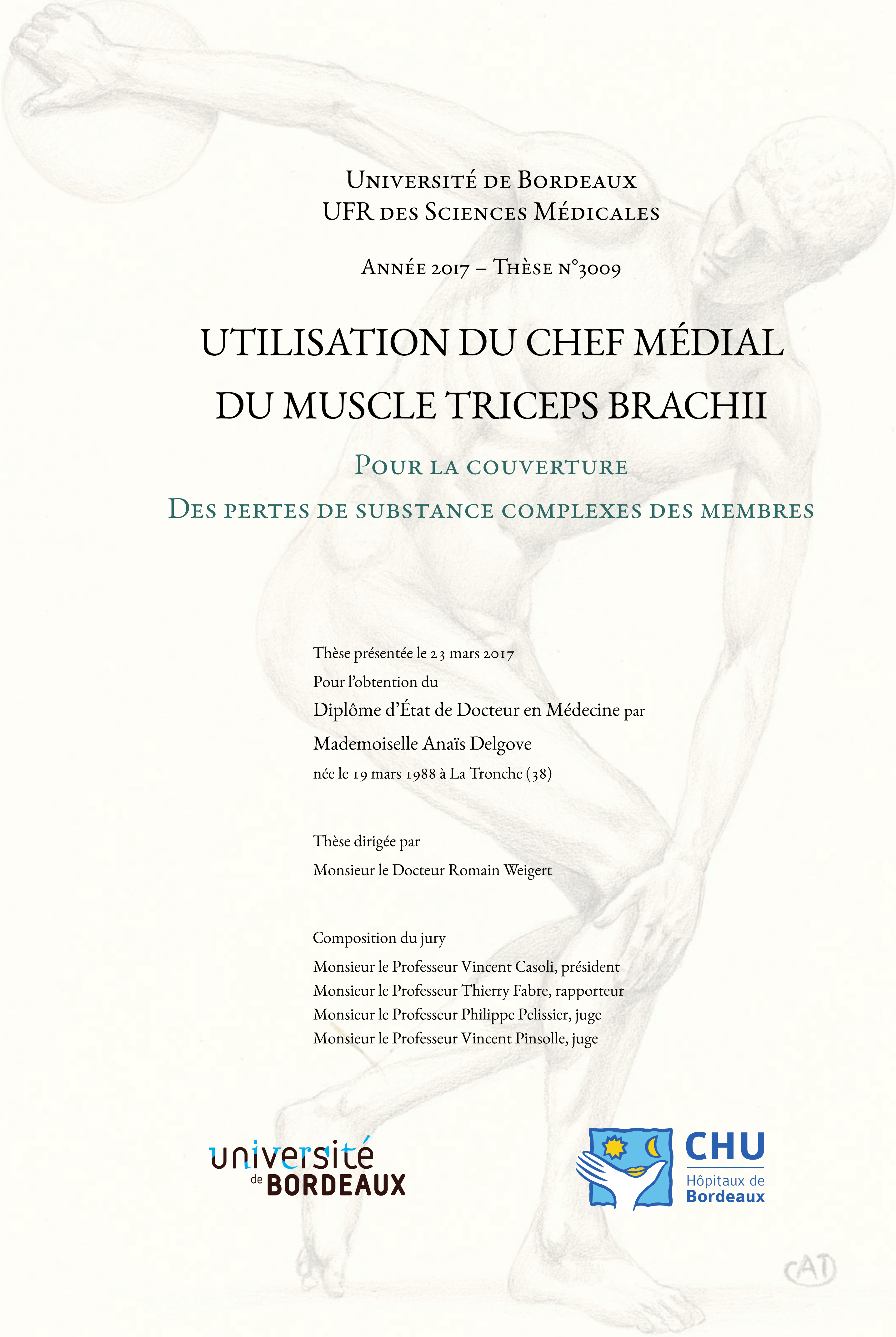
Utilisation du chef médial du muscle triceps brachii pour la couverture des pertes de substance complexes des membres

Anaïs Delgove



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UTILISATION DU CHEF MÉDIAL DU MUSCLE TRICEPS BRACHII

Pour la couverture
Des pertes de substance complexes des membres

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Monsieur le Professeur Philippe Pelissier, juge
Monsieur le Professeur Vincent Pinsolle, juge

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Liste des abréviations

ATA	Artère Tibiale Antérieure	*Anterior Tibial Artery*
BMI	index de masse corporelle	*Body Mass Index*
DBA	artère brachiale profonde	*Deep Brachial Artery*
ITFG	greffe inter-tibio-péronière	*Inter Tibio Fibular Graft*
MCA	artère collatérale moyenne	*Middle Collateral Artery*
MRC		*Medical Research Council*
MTB	chef Médial du muscle Triceps Brachial	*Medial head of the Triceps Brachii muscle*
n		*Number of patients*
NPWT	thérapie à pression négative	*Negative Pressure Wound Therapy*
ORIF	réduction à foyer ouvert - fixation interne	*Open Reduction - Internal Fixation*
POSAS		*Patient and Observer Scar Assessment Scale*
PSCM	Perte de Substance Complexe des Membres	*complex lower limb injury*
PTA	artère tibiale postérieure	*Posterior Tibial Artery*
QuickDASH		*Quick Disabilities of Arm, Shoulder and Hand*
RCA	artère collatérale radiale	*Radial Collateral Artery*

i Introduction

i.1 Problématique des pertes de substance complexes des membres (PSCM)

La reconstruction des pertes de substance complexes des membres est un domaine majeur de la chirurgie plastique et reconstructrice. Les pertes de substance des membres peuvent être d'origine traumatique (fractures ouvertes, écrasements, dégantages), infectieuse (ostéomyélites, ostéo-arthrites), tumorale ou iatrogène (désunions cicatricielles ou nécroses cutanées post-opératoires). Elles peuvent être pluritissulaires (os et/ou muscle et/ou peau et/ou structures vasculo-nerveuses), et associées à une ostéite chronique et/ou une pseudarthrose. La guérison demande la stérilisation des tissus, la consolidation osseuse et la cicatrisation cutanée, ces trois éléments étant largement dépendants les uns des autres. Lorsqu'un ou plusieurs critères ne sont pas acquis et que les solutions de reconstruction sont épuisées, un geste radical non conservateur est proposé : l'amputation.

Les solutions disponibles pour obtenir la cicatrisation cutanée forment un éventail de techniques plus ou moins complexes : cicatrisation dirigée, thérapies à pression négative, greffes de peau, substituts dermiques, lambeaux locaux, régionaux et libres. La cicatrisation dirigée, les thérapies à pression négative, les greffes de peau ou les substituts dermiques ne font pas parties des solutions de première intention en présence d'exposition osseuse ou articulaire ou en présence d'une pseudarthrose. En effet, ces situations nécessitent une couverture par des tissus vascularisés et de bonne trophicité. Dans ces cas d'expositions osseuses ou articulaires, la couverture se fait la plupart du temps par des techniques de lambeaux. Ils sont locorégionaux lorsqu'ils sont prélevés près du site à couvrir ou libres lorsqu'ils sont prélevés à distance et qu'ils nécessitent des anastomoses vasculaires.

i.2 Prise en charge des PSCM

Des parcours de soins identifiés et des équipes pluridisciplinaires et pluriprofessionnelles voient le jour dans les centres hospitaliers universitaires depuis plusieurs années pour prendre en charge les patients nécessitant une reconstruction des PSCM. Ces équipes regroupent des chirurgiens orthopédistes, des chirurgiens plasticiens, des médecins infectiologues, des infirmières spécialisées en cicatrisation, des médecins rééducateurs et des psychologues. Leur domaine d'action s'étend des pertes de substances pluri-tissulaires traumatiques des membres, en passant par les ostéomyélites chroniques fistulisées à la peau, les tumeurs avec résection massive, jusqu'au remodelage des moignons d'amputation ou à la couverture de matériel d'ostéosynthèse exposé [1].

Ces nouvelles filières font l'objet de nombreuses études et semblent diminuer le temps d'hospitalisation, augmenter la rapidité de la prise en charge des patients et diminuer le risque d'ostéite [2–4]. Les dernières décennies ont vu également le développement de raffinement dans les techniques en chirurgie orthopédique (« damage control » orthopédique [5], nouveaux fixateurs externes) et en chirurgie plastique (lambeaux composites) [6], ainsi que des progrès technologiques (substituts dermiques) [7, 8]. Malgré ces progrès, les résultats à long terme des reconstructions n'apparaissent pas meilleurs qu'après amputation et appareillage [9–14]. Les procédures de reconstruction, lorsqu'elles sont mises en oeuvre, font l'objet de complications plus fréquentes, de durées d'hospitalisation plus longues et d'un plus haut taux de ré-intervention.

Le progrès des techniques et des matériaux d'appareillage ainsi que le caractère long et incertain des résultats d'une reconstruction sont les éléments expliquant l'absence de supériorité à long terme de la reconstruction sur l'amputation. Lorsque cette possibilité thérapeutique est expliquée et proposée au patient, elle est en général refusée au premier entretien, vécue comme un échec de la prise en charge, une mutilation définitive et la promesse de grandes séquelles physiques et psychologiques. Un des rôles des équipes pluridisciplinaires et pluriprofessionnelles est d'orienter le patient vers la meilleure solution thérapeutique en terme d'équilibre bénéfices/risques. De nombreux facteurs intrinsèques associés à des mauvais résultats de reconstruction ne peuvent être changés, mais la stratégie globale de prise en charge des PSCM peut être améliorée : réduire les délais de prise en charge, diminuer les taux d'échecs microchirurgicaux, obtenir une adhésion du patient et de sa famille au programme de reconstruction.

Au CHU de Bordeaux, cette équipe pluridisciplinaire a été créée en 2009 et porte le nom "Orthoplast". Une visite hebdomadaire au lit du patient nécessitant un avis de chirurgie plastique a d'abord été instaurée dans tous les services du CHU et plus particulièrement en orthopédie et en infectiologie. Depuis 2014, une réunion de concertation pluridisciplinaire hebdomadaire a complété la filière de prise en charge des PSCM.

i.3 Progrès de la reconstruction

Les avantages de la reconstruction sont la conservation de l'intégrité anatomique, plus ou moins esthétique, et la récupération partielle ou complète des fonctions du membre. Ces avantages sont à opposer aux inconvénients qui sont une plus longue durée de prise en charge médicale, avec de multiples hospitalisations et chirurgies, sans garantie de résultats. Il est nécessaire de continuer à progresser dans le développement de ces techniques de reconstruction afin de réduire les indications d'amputation. Le cahier des charges d'une chirurgie de reconstruction réussie est complexe. Les délais de prise en charge doivent être rapides, l'ostéosynthèse et la couverture tissulaire adaptées.

i.4 Cahier des charges de la prise en charge des PSCM

La couverture des PSCM permet une cicatrisation rapide, une consolidation osseuse et la prévention ou le traitement des ostéites. Elle se fait la plupart du temps par des techniques de lambeaux. Au niveau des membres inférieurs, les particularités des PSCM sont la position immédiatement sous la peau des structures osseuses et articulaires, voire du matériel d'ostéosynthèse et le nombre restreint de sites donneurs de lambeau local, notamment en région distale de jambe ou au niveau du pied. Ceci a plusieurs conséquences : la fréquence accrue d'exposition osseuse lors de traumatismes ou de désunions cicatricielles et le recours plus fréquent à des techniques de lambeaux libres, plus difficiles techniquement et moins fiables [15]. Les lambeaux libres décrits sont nombreux mais aucun n'est idéal : lambeau libre antéro-latéral de cuisse, lambeau de muscle grand dorsal, lambeau brachial externe, lambeau de muscle serratus antérieur, lambeau de muscle gracilis. Le lambeau est choisi en fonction de la taille de la perte de substance, de sa localisation et des structures qu'il doit reconstruire. La morbidité du site donneur, fonctionnelle et esthétique, doit également être prise en compte. Une autre difficulté de la prise en charge des pertes de substance de la partie distale du membre inférieur est la nécessité d'une couverture de taille, d'épaisseur et de stabilité adaptées au chaussage et à la marche.

i.5 Travaux sur la thématique au CHU de Bordeaux

Dans une démarche d'amélioration des pratiques et de recherche appliquée, nous avons développé au CHU de Bordeaux un nouveau lambeau musculaire pur adapté au cahier des charges de la couverture des pertes de substance complexes distales des membres inférieurs : le lambeau de chef médial du triceps brachial (MTB). Deux études cadavériques et une étude préliminaire clinique ont montré la faisabilité et les premiers résultats de cette nouvelle technique [16–18].

i.5.1 Description anatomique du chef médial du triceps brachial

Le triceps brachial est le seul muscle de la loge postérieure du bras. Il est extenseur de l'avant-bras sur le bras. Il est constitué de trois chefs musculaires. Le chef long est inséré sur le tubercule infra-glénoïdien de la scapula. Le chef latéral prend son insertion sur la partie proximale et postérieure de l'humérus au-dessus du sillon du nerf radial. Le chef médial nait de la partie postérieure de l'humérus en dessous du sillon du nerf radial et du septum intermusculaire médial. Les trois chefs musculaires convergent pour se terminer en un tendon unique : le tendon tricipital, s'insérant sur la partie proximale de l'olécrane [19, 20]. L'innervation du triceps provient du nerf radial [21, 22]. Il donne une branche pour chaque chef musculaire. Il existe de rares cas décrits d'innervation partielle par le nerf ulnaire [23]. La vascularisation de ce muscle provient des branches de l'artère brachiale profonde (deep brachial artery, DBA) qui suit le nerf radial dans son sillon le long de l'humérus et se divise en artère collatérale moyenne (middle collateral artery, MCA) et artère collatérale radiale (radial collateral artery, RCA) [24]. Le chef médial du triceps est vascularisé par l'artère collatérale moyenne qui court à la surface du corps musculaire de manière longitudinale (Fig. i.1). Elle rejoint ensuite le cercle anastomotique du coude, en apportant sa vascularisation au muscle anconé [25, 26]. Ces anastomoses avec les artères récurrentes radiales, ulnaires et interosseuses, permettent une utilisation du chef médial en lambeau pédiculé sur sa partie distale.

i.5.2 Technique chirurgicale de prélèvement du chef médial du triceps brachial comme lambeau libre

Le prélèvement s'effectue sous anesthésie générale, en décubitus dorsal, avant-bras reposant sur un appui situé à l'aplomb du thorax. La face postérieure du bras est ainsi exposée. Un champ d'extrémité délimite le site opératoire. Il est possible de positionner un garrot stérile de moyenne largeur à la racine du bras afin de faciliter la dissection. Celui-ci devra toutefois être retiré pour la fin de la dissection.

Les repères cutanés sont tracés depuis le relief de l'insertion du deltoïde sur l'humérus jusqu'à la fossette olécranienne. L'incision cutanée expose le plan du tendon tricipital. La voie sera ensuite trans-tricipitale sur le bord latéral du tendon. Les fibres du chef médial du triceps sont décollées de la face profonde du tendon. L'espace entre le MTB et le septum intermusculaire latéral est disséqué. Plusieurs branches vasculaires perforantes font, à cet endroit, l'objet d'une hémostase soigneuse. Le pédicule vasculonerveux du MTB est facilement repérable à la surface du corps musculaire, courant de manière longitudinale et centrale jusqu'à la gouttière du nerf radial en proximal et latéral.

La dissection musculaire trouve sa limite distale avant la fossette olécranienne afin de ne pas léser la capsule articulaire du coude et sa limite médiale au niveau du bord médial de l'humérus. Les perforantes à visée osseuse sont coagulées de manière soigneuse lorsque le muscle est détaché de la face postérieure de l'humérus. La dissection proximale intéresse uniquement le pédicule ou le pédicule et les fibres musculaires l'accompagnant. La jonction du pédicule avec la RCA est ligaturée et la DBA est disséquée au contact du nerf radial jusqu'à obtenir une longueur suffisante. Le lambeau est alors sevré et rincé au sérum hépariné.

Les corps musculaires restants sont rapprochés à l'aide de points en croix de fils tressés et le tendon est suturé par un surjet passé. La fermeture cutanée se fait sur drainage aspiratif profond avec un surjet intradermique. Un pansement semi compressif est laissé en place et le bras est surélevé pendant 48 heures. La surveillance postopératoire nécessite un examen sensitivo-moteur du nerf radial et du nerf ulnaire, ainsi que la vérification de l'absence de formation d'hématome. Le drainage est retiré au 3ème jour et le membre supérieur est rapidement mobilisé.

i.5.3 Technique chirurgicale de prélèvement du chef médial du triceps brachial comme lambeau pédiculé

La localisation de ce muscle et sa vascularisation à rétro par le cercle anastomotique du coude ont également permis son utilisation en lambeau pédiculé pour la couverture des pertes de substances de la région du coude. L'installation et la voie d'abord sont similaires. Le chef médial exposé, c'est sa partie proximale qui est exposée en premier afin de ligaturer son pédicule. Il est ensuite séparé de ses attaches osseuses et septales de proximal en distal puis retourné sur la perte de substance à couvrir, en restant attaché par ses insertions distales sur l'humérus. La voie d'abord est refermée sur drainage aspiratif jusqu'à la zone de retournement du lambeau. Celui-ci est greffé en peau fine immédiatement ou dans un second temps.

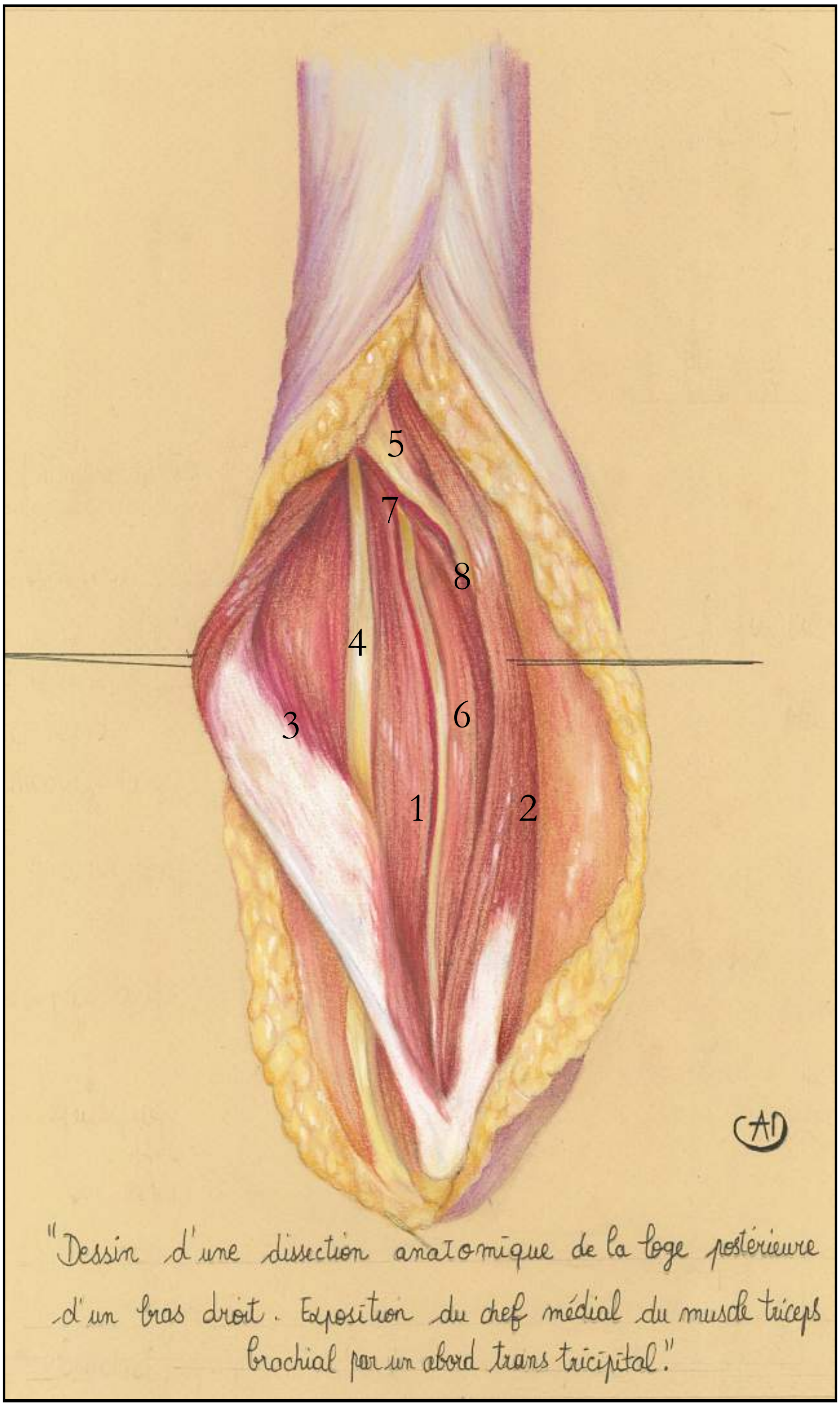

Figure i.1 – Dessin anatomique au pastel. *Anne Delgove.* 1, chef médial du triceps brachii ; 2, chef latéral du triceps brachii ; 3, chef long du triceps brachii ; 4, nerf ulnaire ; 5, nerf radial ; 6, pédicule vasculo-nerveux du chef médial (artère collatérale moyenne et nerf de l'anconé) ; 7, artère brachiale profonde ; 8, artère collatérale radiale.

i.6 Objectifs du travail de thèse

Les objectifs de ce travail étaient :

1. d'évaluer les résultats des reconstructions de pertes de substances complexes du membre inférieur réalisées avec le lambeau libre de chef médial du triceps brachial ;

2. d'évaluer la morbidité du site donneur de ce lambeau ;

3. d'évaluer les résultats des couvertures des pertes de substance du coude avec le chef médial du triceps brachial utilisé en lambeau pédiculé.

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1 Medial triceps brachii free flap in lower limb reconstructive surgery

Background— In lower extremity reconstruction over the last several decades, the plastic surgeon's armamentarium has grown to include free muscle and fasciocutaneous flaps along with perforator and propeller flaps. In this study, we present results of lower limb reconstruction using the medial triceps brachii (MTB) free flap.

Methods— This is a retrospective study of a single surgeon's series of MTB free flaps. Patient characteristics, wound characteristics and procedure details were analyzed. Complications, short and long-term outcomes, secondary procedures, duration of hospital stay and number of surgical procedures needed before wound healing, bone union and walk recovery were assessed.

Results— We identified 24 MTB flaps. The mean follow-up time was 33.9 ±13.6 months. There were 6 distal third leg, 7 ankle, 5 heel and 6 foot wounds. The mean defect size was 20 ±8 cm^2. There were 8 patients in the acute phase of an open fracture (Gustilo III B), 6 patients with secondary cutaneous necrosis after surgical procedure and 10 patients with chronic osteomyelitis. In all cases, bone was exposed. The median duration of the MTB free flap procedure was 5 [4–6.8] hours. There were 3 total flap losses. Two patients developed donor site hematomas. Three patients underwent secondary procedures for re-draping. Twenty MTB free flap procedures led to complete wound healing. In one case, an additional local flap was required, with satisfactory outcomes. Complete wound healing was achieved in 76.5 [42.5–124.5] days after the MTB procedure. Bone union and walk recovery were obtained, respectively, in 3 [3–5.5] and 3 [2–4.5] months after the bone reconstruction procedure for all patients.

Conclusion— This study shows satisfactory results compared to previously-described muscular or fasciocutaneous free flaps. The MTB is an interesting option to cover small- to medium-sized defects of the lower extremity.

Key words— limb reconstruction; free flap; donor site morbidity; medial triceps brachii muscle

1.1 Introduction

Open fractures and chronic defects of the ankle and foot require a well-fitted coverage to allow a normal walk. A new free flap technique has been described using the medial triceps brachii (MTB) [1]. Preliminary single-center results have demonstrated its potential for the coverage of small to medium-sized defects [2]. This free flap represents a serious alternative to gracilis free flap or anterolateral thigh free flap for lower limb reconstruction when local flaps are unavailable. It has several advantages. Its limited size provides a flap appropriate for distal leg, ankle and foot coverage. It is a denervated muscle flap that will atrophy over time, potentially improving contour and cosmetic outcomes without requiring multiple secondary procedures. Its harvest is easy and the procedure can be done using a two-team approach, in order to reduce operative time. Furthermore, direct closure is possible, thus avoiding the additional scar of a skin graft harvest [3]. The aim of this study was to demonstrate the safety and efficacy of the MTB muscle flap as a primary option in reconstructing small- and medium-sized ankle and foot defects.

1.2 Material and methods

1.2.1 Charts and clinical examination

This retrospective clinical study protocol was performed following the local ethical guidelines. Inclusion criteria were: patients of all ages, of both sexes, operated on between March 2011 and July 2015, who underwent MTB free flap procedure to cover defects localized at the distal third tibial shaft, ankle and foot level in our department. A single surgeon performed all surgeries (V.C.). Demographic information, medical comorbidities, mechanism of injury, details of the wound, preoperative imaging, recipient vessel selection, complications, flap survival and associated procedures were recorded. Secondary reconstructive procedures and revision surgeries were also identified. Times to wound healing, bone union and walk recovery were recorded, along with the number of required procedures, and hospitalization lengths of stay. An independent observer examined all patients and charts. A board-certified radiologist or orthopedic surgeon reviewed x-rays or imaging assessing radiographic bony union.

1.2.2 Statistical analysis

All statistical analyses were performed using Matlab (R2014a, The MathWorks®, Inc., Massachusetts, USA). Quantitative data are presented as mean ± standard error (std) for normal distributions and as median [1st – 3rd quartiles] for non-normal distributions. Correlations between quantitative variables were assessed using Pearson or Spearman's correlation coefficient, as appropriate. Inter-group differences were assessed using Student's t-test or Mann Whitney's U-test, as appropriate.

1.3 Results

1.3.1 Population

Twenty-four patients were identified with lower extremity injury and had a MTB free flap procedure during the study period, representing 30% of all free flaps in our department. All patients were included. There were 9 women and 15 men, mean age 46.2 ±13.3 years old at the time of surgery. Twenty-two patients ambulated independently before their injury. One patient had paraplegia due to spina bifida and another had peripheral immunologic neuropathy. Comorbidities were frequent, including tobacco use in 12 patients and diabetes in one patient. The 24 patients were addressed to our department at different stage of the care process and for different indications: 8 patients in the acute phase of an open fracture (Gustilo III B) (Group 1), 6 patients with secondary cutaneous necrosis after surgical procedure (Group 2) and 10 patients with chronic osteomyelitis (Group 3) (Table 1.1). Over time, no trend to a specific indication was observed (Fig. 1.1).
Etiology of the defect was mostly traumatic (75%). The most common mechanisms of injury were motorcycle accidents (33%) and falls (28%). In traumatic etiologies, 8 wounds were directly due to open fracture, 3 related to septic pseudarthrosis, and 7 were due to secondary disunion of open reduction and internal fixation of a closed fracture. Other etiologies of the defect were diabetes/neurologic in 3 cases, and iatrogenic in 3 cases. There were 6 distal third leg, 7 ankle, 5 heel, and 6 foot defects treated with free tissue transfer. The mean defect size was 20 ±8 cm2. At the time of admission, local infections were observed for 15 patients.

1.3.2 Surgical procedure

Concerning preoperative imaging, all patients with a traumatic injury history, tobacco use or no palpated peripheral pulse underwent angiography to evaluate lower extremity vessels. Wounds were managed with negative pressure wound therapy (NPWT) up to the flap procedure date. The arterial anastomosis was end-to-side on the anterior tibial artery (10 patients), end-to-end on the anterior tibia artery (7 patients), end-to-side on the posterior tibial artery (6 patients) and end-to-end on the posterior tibial artery (1 patient). Two venous anastomoses were performed if possible (41.7%). In all cases, the anastomoses were done outside of the injured zone.

Duration of surgery was not significantly increased when two venous anastomosis were performed (p=0.14). The median duration of the MTB free flap procedure was 5 [4–6.8] hours. Procedure du-

	Group 1 (n=8) Open fracture	Group 2 (n=6) Secondary cutaneous necrosis after surgical procedure	Group 3 (n=10) Chronic osteomyelitis	Total (n=24)
Trauma mechanism, n				
MCA	2	1	4	7
GSW	1	0	1	2
Crush injury	2	0	0	2
Fall	3	3	1	7
Non trauma*, n	0	2	1	6
Work accident, n	3	2	1	6
Location of soft tissue defect, n				
Distal third leg	2	1	3	6
Ankle	3	2	2	7
Heel	0	0	5	5
Foot	3	3	0	6
Mean defect size , ±std, cm²	27 ±3	19 ±5	14 ±2	20 ±8
Admission, n				
Primary	6	4	0	10
Secondary	2	2	10	14
Local infection at admission, n	0	5	10	15

Table 1.1 – Mechanism and wound characteristics in the three groups of patient.
MCA : motorcycle accident ; GSW : gun shot wound; * diabetes/neurologic or postsurgical chronic wound.

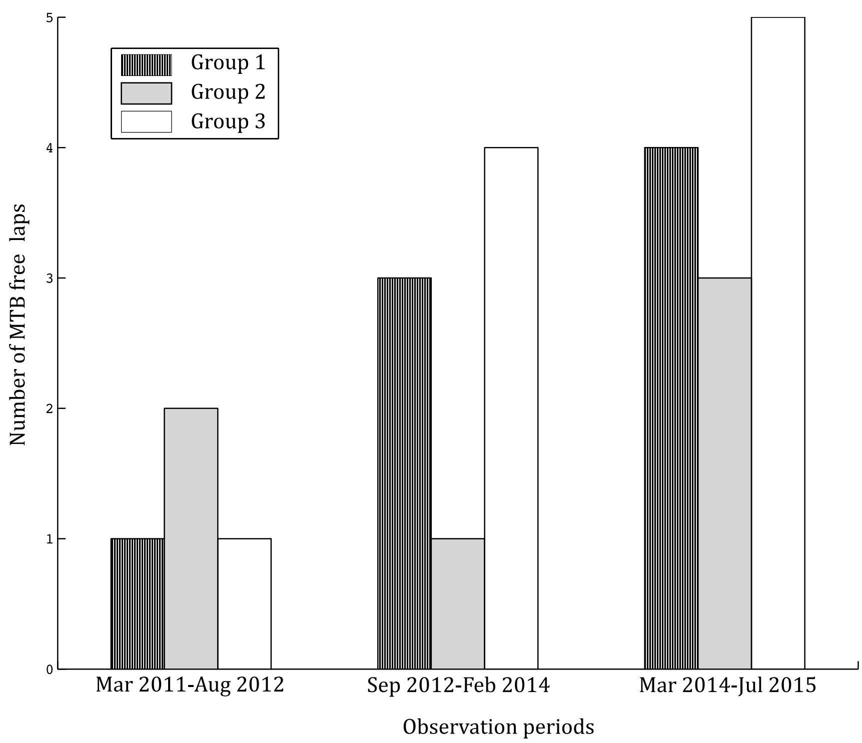

Figure 1.1 – Number of MTB free flap in each group on the observation period.

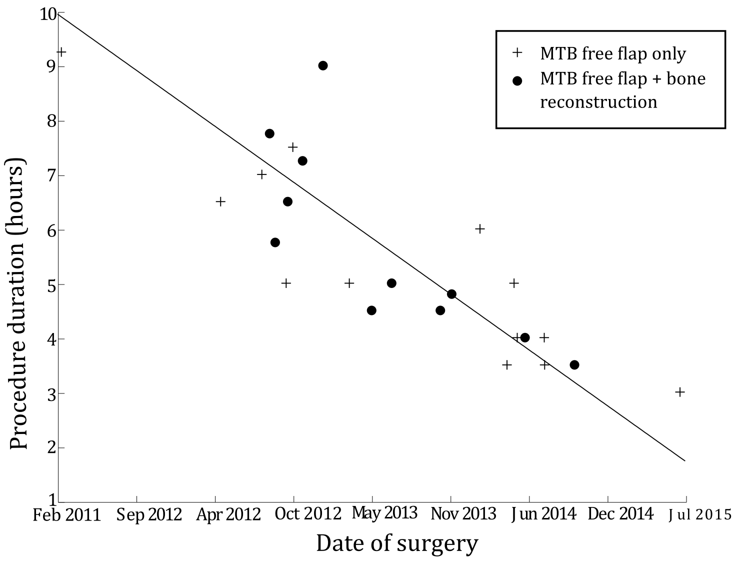

Figure 1.2 – Learning curve of the MTB free flap procedure.

ration decreased significantly with the surgeon experience (rho = -0.89, $p < 0.01$) (Fig. 1.2). There was no statistical difference in terms of duration between a MTB free flap procedure with (5 [4.4–7.1] hours) or without (5 [3.9–6.6] hours; p=0.62) an associated bone reconstruction procedure. To avoid tension during skin closure, a dermal substitute was placed on anastomoses and grafted 3 weeks later if necessary (58.3%) (Fig. 1.3).

When an infection occurred on orthopedic hardware, it was systematically removed (4 patients). In the case of chronic osteomyelitis without fracture, curettage was done (7 patients). Multiple bone samples were taken at each procedure and bacteriological analysis carried out. Patients were placed on an intravenous antibiotics regimen following guidelines from our local expert bacteriological department (probabilistic association of piperacillin-tazobactam and vancomycin). When bacteriological results were obtained, targeted double therapy was continued for 6 to 8 weeks. Reconstruction of bone substance loss was carried-out using an iliac bone graft in 4 cases, the technique of induced membranes [4] in 5 cases and with an inter-tibio-fibular graft (ITFG) in 2 cases. Delay between the two procedures in the induced membrane technique was in average 4 [2.8–6.3] months.

Median size of harvested MTB was 40 [27–52] cm^2. There were 2 harvest complications: 2 hematomas, 1 requiring revision for hemostasis.

1.3.3 Short and long-term results, complications

The series presented 3 total necrosis of MTB free flap (12.5%). There was no significant difference between these 3 patients and the 21 that healed regarding number of venous anastomoses, type of arterial anastomosis, delay before surgery (Table 1.2). In these patients, wound healing was obtained with another procedure (one dermal substitute and two local flaps). Twenty MTB free flap procedures led to wound healing. In one case, an additional local flap was required, with satisfactory outcomes.

No patient required flap debulking surgery but three underwent flap re-draping after an average of 18 ±11.5 months. In these 3 cases, the flap was localized on the calcaneus. One of these remodeling procedures led to a complete necrosis of the flap, requiring a secondary amputation, 2 years after the initial cover procedure.

The mean follow-up time was 33.9 ±13.6 months (Table 1.3). Median time from reconstruction decision to soft tissue cover was 41 [28–55] days. Complete wound healing was achieved in 76.5 [42.5–124.5] days after the MTB procedure. Bone union and walk recovery were obtained in 3 [3–5.5] and 3 [2–4.5] months after the bone reconstruction procedure, respectively. Results regarding bone reconstruction

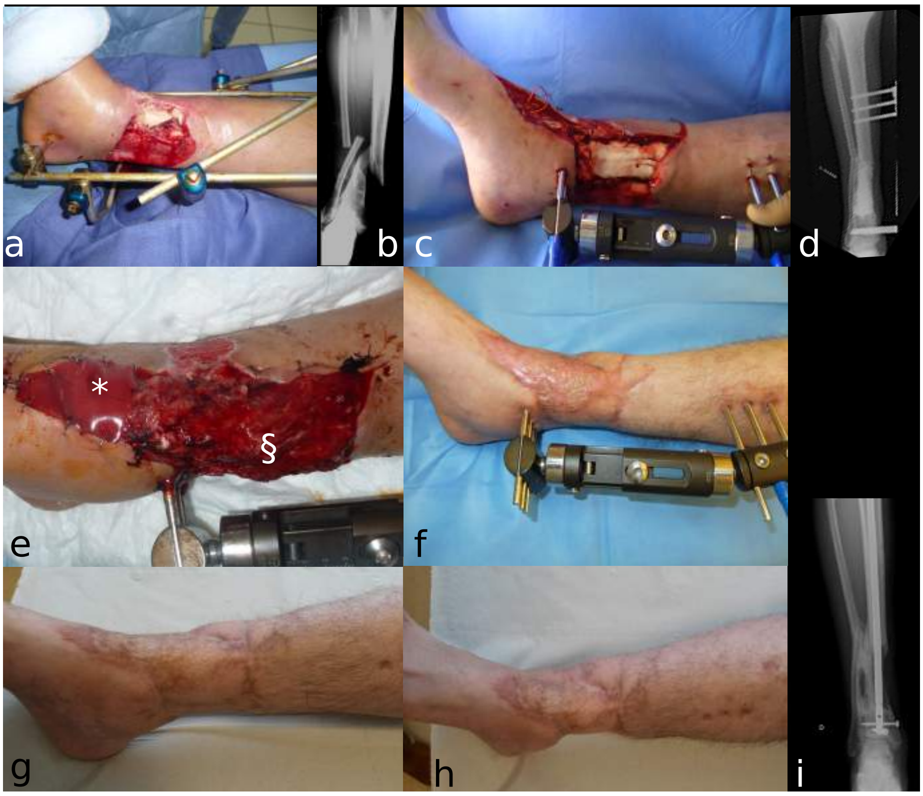

Figure 1.3 – 42 years-old patient, who fell from a high point. (A,B) Distal third of tibial shaft and fracture were exposed. (C,D) Soft tissue and bone debridment was done and antibiotic cement was placed to fill the bony loss of substance. (E) Dermal substitute (*) was placed on the vascular pedicle of the MTB flap (§) to avoid tension during skin closure. (F) Wound healing at 1 month. (G,H,I) Wound and bone healing at 33 months.

	Patient a	Patient b	Patient c
Age (y) / gender	55/M	42/M	55/M
Tobacco	0	0	1
Wound Location	Tibial pilon	Foot	Distal 1/3 tibia
Group	1	2	3
Delay to wound coverage (d)	39	75	Several years
Anastomosis type and location	End-to-end on ATA	End-to-end on ATA	End-to-side on PTA
Number of veins	2	1	1
Duration of surgery (h)	7.25	4	3.5
Delay thrombosis (d)	1	13	3
Time to re-exploration (h)	2	NA	NA

Table 1.2 – Characteristics for flap failure.
Abbreviations: y, years; d, days; h, hours; ATA, anterior tibial artery; PTA, posterior tibial artery; NA, not applicable

	Group 1 (n=8)	Group 2 (n=6)	Group 3 (n=10)
Follow-up, mean ±std, months	34.6 ±15.6	26.7 ±9.1	37.6 ±13.7
MTB free flap as a first cover attempt, %	100	83.3	40
Delay between, median [1st–3rd quartiles]			
Reconstruction team advice and MTB flap procedure, days	33.5 [28–43]	33 [19–49]	48 [35–81]
MTB flap procedure and complete wound healing, days	80.5 [41–93]	50 [35–123.3]	75 [48.5–212]
Injury and bone union, months	7.5 [3.5–14]	8.5 [6–10]	20 [19–21]
Bone reconstruction procedure and bone union, months	3 [3–4]	3 [2–7]	5 [4.3–6.5]
Injury and walk recovery, months	6.5 [3.5–12]	5.5 [3–8]	29.5 [22–43.5]
Bone reconstruction procedure and walk recovery, months	3 [3–4]	3 [2–3.8]	4 [1.5–8]
Long-term complications			
Secondary amputation, n	0	0	1
Wound recurrence, n	0	0	1
Partial pseudarthrosis, n	0	0	1
Return to work, %	60	20	50

Table 1.3 – Care delays, time to wound healing, bone union, walk recovery and complications in each group

type are exposed in Table 1.4. All of the 24 patients were able to walk at the time of the last follow-up. Long-term complications were partial pseudarthrosis in 1 patient and wound recurrence in the diabetic patient. Of 16 patients who were working before the injury, 7 returned to work. The patient with secondary amputation underwent prosthetic rehabilitation and returned to work.

Median number of procedures to complete wound and bone healing from the MTB procedure was 3.5 [2–5] (Table 5). MTB free flap procedure was follow by a skin graft within 10 days, with a median total length of stay for this cover procedure of 15.5 [13–21] days. Median duration of hospital stay from

	Induced membrane technique	Iliac bone graft	Inter-tibio-fibular graft
Time to bone union, median [1st–3rd quartiles], months	3 [2.5–3.5]	3 [2.5–7]	5 [3–7]
Time to walk recovery, median [1st–3rd quartiles], months	3 [2.8–5.3]	3 [2.5–3.5]	6 [5–7]

Table 1.4 – Time to bone union and walk recovery regarding reconstruction bone type

	Group 1 (n=8)	Group 2 (n=6)	Group 3 (n=10)
Number of surgical procedure needed to			
complete wound and bone healing from MTB free flap procedure	2 [2–3]	2.5 [2–4]	3 [2–4]
Duration of hospital stay, median [1st–3rd quartiles], days			
for MTB procedure	14.5 [13–18]	14.5 [11–17]	20.5 [16–23]
from MTB procedure to complete recovery	26 [18–33.5]	22.5 [14–31]	36.5 [25–54]

Table 1.5 – Number of surgical procedure and duration of hospital stay for each group

MTB procedure to complete wound and bone healing was 30 [19.5–38.5] days.

1.4 Discussion

This study represents an institutional review of lower extremity reconstruction using an MTB free muscle flap over a 4-year period. In our practice, we preferentially choose the MTB muscle flap for small- and medium-sized defects of the lower tibia, ankle and foot. The harvesting technique has been thoroughly described [2]. The donor site morbidity is very low with a very good patient satisfaction and no impairment of the elbow function (Delgove A, Weigert R, Casoli V. Evaluation of donor site morbidity after medial triceps brachii free flap for lower limb reconstruction, submitted for publication). Its vascular pedicle is 2.9 cm long and if necessary the deep brachial vessels can also be dissected up to their origin from the brachial vessels and harvested with the medial collateral vessels, providing an 8–12 cm long "extended" pedicle [1]. In this series, the MTB free flap allows to cover defects with median size of 40 cm^2. In the reconstructive microsurgeon's armamentarium, this flap can cover defects of sizes smaller than the serratus free flap or the gracilis free flap [5, 6]. Learning curve was significant (9.3 hours for the first flap versus 3 hours for the last flap of the series). This result is in line with published reports of free flap procedures in lower extremity reconstruction [7, 8]. When an infection occurred on orthopedic hardware, it was systematically removed (4 patients) in agreement with local multidisciplinary recommendations and literature [9].

We performed two venous anastomoses each time it was possible, and this did not impact surgical time. It was always possible to find two veins in the vascular pedicle of the flap but sometimes the recipient vessels were not adequate to perform two venous anastomoses. Heidekrueger *et al.* have done a complete review of literature about this debated subject [7, 10–13]. Some authors recommend one venous anastomosis arguing that venous thrombosis results from low blood velocity and more than one anastomosis would reduce the venous flow and thus increase the risk of forming venous thrombosis. On the other hand, to enhance venous drainage and especially to provide a rescue venous drainage if one of the venous anastomoses occludes, other authors postulate the use of two or more venous anastomoses. Actually, we performed two venous anastomoses if these conditions were met: two veins are present on the pedicle, two recipient veins are available and suitable.

Our flap loss rate of 12.5% and overall lower extremity salvage rate of 95.8% is in line with published reports of free flap survival in lower extremity reconstruction. We did not identify any significant predictive factor of flap loss.

The first patient was 55 years old and admitted after a motorcycle accident with an open tibial pilon fracture Gustilo IIIa. He had no comorbidity. Skin necrosis occurred after open reduction-internal fixation (ORIF) and coverage was performed 39 days after bone exposure. End-to-end arterial anastomosis on the anterior tibial artery and two venous anastomoses were performed. Venous congestion occurred at day 1 and day 3 and flap failure occurred notwithstanding 2 procedures to redo the venous anastomosis within 2 hours of clinical congestion. Wound healing was obtained using a dermal substitute. The patient had a bone graft three months after wound healing, through another surgical approach and had a delayed bone union (11 months).

The second patient was 42 years old and had secondary skin necrosis after tibiotalar arthrodesis procedure. He had no comorbidity. Flap procedure was done 75 days after bone exposure associated with hardware removal. End-to-end arterial anastomosis on the anterior tibial artery and one venous anastomosis were done. Venous congestion and flap necrosis occurred 13 days after surgery, and no attempt for anastomosis refection was done. A distally based sural flap was performed one month later, leading to wound healing in 19 days. Arthrodesis union was obtained in 6 months, allowing non-painful walk.

The third patient was 55 years old and a heavy smoker (40 pack-years) with peripheral arterial disease. He had chronic tibial exposure for several years, next to a 30-year old open fracture. Pre operative imaging showed a developed collateral circulation in the entire lower limb but a good flow in a non-stenotic posterior tibial artery. He sustained two successive free flap failures with an anterolateral thigh free flap (arterial thrombosis at day 1 and unsuccessful refection of anastomoses) and an MTB free flap. End-to-side arterial anastomosis on the posterior tibial artery and 1 venous anastomosis were done. Arterial thrombosis occurred at day 2. Beyond this third arterial thrombosis, no attempt for re exploration was done. In the end, delayed wound healing was obtained 10 months after the surgery, using a local fasciocutaneous flap associated with dermal substitute and medical wound care.
Two risk factors described in the literature were found: long operative time (7.25 hours) for the first patient and tobacco use in the month preceding the microsurgery for the third patient [14].
In the literature, the highest failure rates concern the reconstruction of lower limbs. Sakurai *et al.* has shown that the arteriovenous pressure gradient for a lower-limb free flap is significantly lower than that for a free flap located elsewhere [15]. This elevated venous pressure accounts for the poor perfusion of lower limb flaps.
Our time to reexploration for the first patient was as reduced as possible, in accordance with literature, but did not avoid flap failure [16].

In our series, 3 patients required flap re-draping to allow normal walk recovery. Their flaps were placed on heel and were shearing on the bone, leading to difficulties for footwear and normal walk. The calcaneus has a particular curved shape and when the free flap is initially placed on it, it should not be positioned too tight in order to avoid vascular tension. After flap healing, tissues are more elastic and tension is reduced, and the flap is then shearing on the calcaneus. This problem is well identified for muscular and fasciocutaneous flaps in weight-baring areas of the heel [17, 18]. Debulking of free flap on the ankle and foot is frequently required but there is little data on the need of re-draping [19, 20]. A complete necrosis of one of this re-draped flap occurred, probably due to an invasive mobilization of the flap 18 months after the initial procedure. Different studies suggest a neovascularization of muscle flap from the bed wound that can provide blood supply and survival in cases of main pedicle lesions [21–23]. When the flap is detached from the base, this supply may be cut off and lead to flap necrosis. In the acute trauma group, our median delay to cover was 41 days. 95.8% of patients with acute lower extremity wounds requiring microsurgical reconstruction did not receive soft tissue coverage within 7 days due to primary trauma, physiologic instability, patient comorbidities, or orthopedic and plastic surgery operative backlog.

Consequences of delayed coverage are still open to debate, but early studies concerning open lower limb fractures suggest that soft tissue coverage should be carried out as soon as possible, and that delays to flap surgery above seven days lead to higher infection rates [24]. More recent studies do not significantly report higher infection or flap loss rate in case of delayed coverage [25]. However, others recent studies demonstrate the other way [26, 27].

Delay from injury to bone union was 7.5 to 8.5 months in Group 1 and 2 patients, widely depending on delay from injury to bone reconstruction procedure. Indeed, once the bone reconstruction procedure was done, 96% of our patients obtained bone union at 3 to 5 months, in accordance to the literature [28].
This study has limitations inherent to a retrospective review. There is no control group leaving conclusions to be drawn from comparisons to the current literature on the topic. A direct comparison between two flap types in lower extremity reconstruction remains challenging due to the extreme heterogeneity of patient comorbidities, mechanisms of injury, wound defects, and reconstructive options as well as the sample size needed to detect a meaningful difference between two reconstructive options.

Strengths of this study are the original series report of this new technique and the long follow-up. It confirms the safety and efficacy of the MTB free flap as a primary option in reconstructing ankle and foot defects.

1.5 Conclusion

Wound healing, osteomyelitis treatment, bone union and walk recovery are obtained in adequate delay with an MTB free flap procedure. The harvest is simple and there is a reliable neurovascular pedicle. Furthermore, the donor site morbidity is low. These different points make the MTB a very attractive option to cover small- to medium-sized defects of the lower extremity.

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2

Evaluation of donor site morbidity after medial triceps brachii free flap for lower limb reconstruction

Background— The medial head of the triceps brachii muscle (MTB) free flap is an attractive solution to cover small to medium defects of the lower limb. This muscular head has no well-identified function, suggesting minimal impact of its removal on elbow mobility. The aim of this study was to evaluate the safety and reliability of the harvest procedure and the functional and cosmetic morbidity of this donor site.

Methods— All consecutive MTB free flaps were performed for reconstructive surgery of the lower limb between 2011 and 2015. Patients and their records were retrospectively examined. Functional results were evaluated by assessing elbow extension strength using a dynamometer and with a Quick-DASH questionnaire. Elbow extension strength of our patients was compared to the strength of a healthy cohort. Cosmetic results were assessed using the POSAS observer and patient scales.

Results— 24 patients were followed up postoperatively for an average of 33.9 months. In all cases, the MTB was harvested on the non-dominant arm. No major complication (in particular, no ulnar nor radial nerve injury) occurred during harvest. No patient complained of elbow pain or reduction in strength. Elbow extension was complete in all patients and the median strength was calculated at 92.3% of the contralateral arm, similar to a healthy control population (89.9% [85.5–98.6], p=0.71). The POSAS scale scored an average 8.6 ±3.3 for the observer and 10 ±4.3 for the patient. Cosmetic results using the POSAS scale were satisfactory in all patients.

Conclusion— Objective evaluation of patients who underwent a MTB free flap for limb reconstruction shows no impact of the harvesting procedure on elbow extension. Patient satisfaction with the donor site was high. It appears that this surgery is safe, aesthetically acceptable, and preserves elbow function.

Key words— limb reconstruction; free flap; donor site morbidity; medial triceps brachii muscle

2.1 Introduction

Open fractures and chronic defects of the ankle and foot require adapted coverage to allow for normal walk. A new free flap technique has recently been described using the medial triceps brachii (MTB) [1]. This muscle is vascularized by the deep brachial artery and the middle collateral artery. Preliminary single-center results have demonstrated its potential for the coverage of small to medium-size defects [2]. There have been significant advancements in lower extremity reconstruction over the last several decades, and the plastic surgeon's armamentarium has grown to include free muscle and fasciocutaneous flaps along with local perforator and propeller flaps. Lower limb reconstruction is often a long process entailing several hospitalizations and surgical procedures, which is why patients have to be fully involved in the reconstruction process. Flap choice depends on patient and wound characteristics, but must also take into consideration donor site morbidity. To obtain complete patient adherence to the proposed strategy, benefits and drawbacks of the chosen flap have to be thoroughly explained [3]. Triceps brachii is one of the longest muscles of the upper limb. It acts as the main extensor of the forearm across the elbow joint [4]. The medial head of this muscle however, has no well-identified function described in the literature. Nevertheless, morbidity of MTB free flap harvesting has to be evaluated. The aim of this study was to evaluate the safety and reliability of the harvest procedure and post-operative donor site functional and cosmetic morbidity.

2.2 Methods

2.2.1 Study design

This was a singe-center retrospective study. After receiving approval of the institutional ethics committee, all consecutive patients who underwent a MTB free flap between 2011 and 2015 in our institution were included. Functional and cosmetic outcomes were evaluated at the date of retrospective analysis. All patients provided written informed consent.

2.2.2 Health record analysis

Data concerning patient characteristics at the moment of surgery, wound size, surgical technique and complications were retrospectively retrieved from our institution's electronic medical record system.

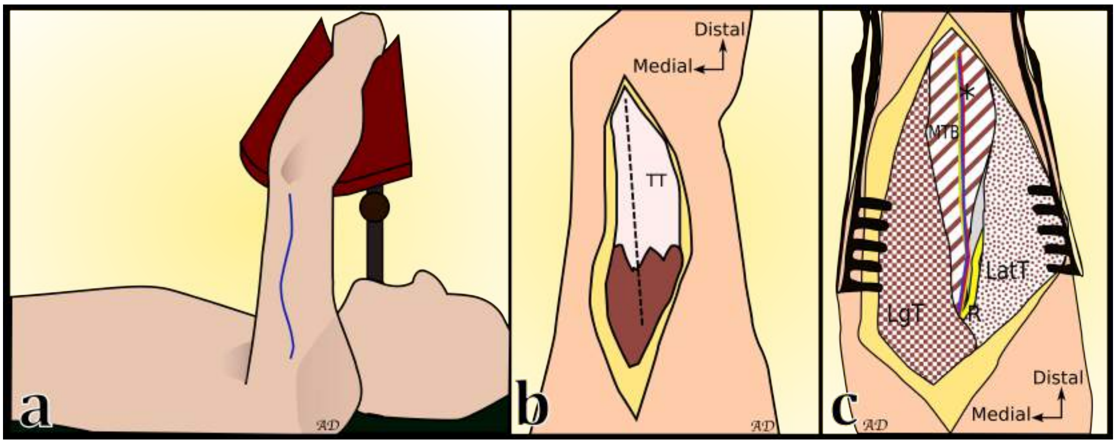

Figure 2.1 – a: Surgical setup b: Trans tricipital approach. c: MTB individualization. TT, tricipital tendon; LgT, long head of the triceps brachii muscle; LatM, lateral head of the triceps brachii muscle; R, radial nerve; *, vasculonervous pedicle of the flap (middle collateral artery and anconeus nerve).

2.2.3 Surgical technique

The harvesting procedure has previously been described [2]. Briefly, patients were in dorsal position, shoulder and elbow at 90° of abduction and flexion, on an armrest (Fig. 2.1 a). Skin was incised from the depression between the lateral and long head of the triceps (posterior to the deltoid tuberosity) to the olecranon fossa. The tendinous part of the triceps muscle was directly exposed and incised longitudinally, separating the long and lateral heads (Fig. 2.1 b). A cleavage plane was found, superficially separating the lateral and long heads from the medial head.. Distal to the radial groove, the medial head was separated from the lateral border of the humerus, following the lateral intermuscular septum (Fig.2.1 c). The flap was then dissected from the long head and the posterior aspect of the humerus. This dissection was limited to the medial border of the humerus; the ulnar nerve was not visualized during the dissection. Proximally, the MC pedicle was dissected and separated from the radial nerve and its sensitive branches, following it to its origin at the deep brachii artery (DBA). The flap isolated on its pedicle was then harvested. Interrupted, absorbable sutures, followed by an overlapping continuous suture were placed between the lateral and long bellies to restore triceps muscle and tendon continuity. Primary skin closure of the cutaneous incision was done with intra-dermic absorbable suture. Early mobilization of the shoulder and elbow was done on the third post-operative day.

2.2.4 Patient questionnaires

Risk factors for poor wound healing (smoking, diabetes, Body Mass Index over 30) were collected. The functional morbidity was evaluated using a quick DASH (Disabilities of the Arm, Shoulder and Hand. Annexe a) questionnaire [5]. Cosmetic results at the time of examination were assessed directly by the patients using the PSAS score (Patient Scar Assessment Scale from the global POSAS "Patient and Observer Scar Assessment Scale" Annexe a) [6–8]. Influence of patient gender on PSAS score

0	No movement observed
1	Trace or flicker of movement or fasciculation observed in the muscle
2	Muscle move if the resistance of gravity is removed
3	Further reduced muscle strength, joint can be moved only against gravity with the examiner's resistance completely removed
4	Reduced muscle strength and muscle contraction against resistance
5	Normal muscle contraction against full resistance

Table 2.1 – Medical Research Council scale

and correlation between time since surgery and cosmetic results was evaluated. Similar to Klinkenberg *et al.*, global satisfaction was assessed by asking the patient: "Would you have preferred another donor site for your reconstruction?" [9].

2.2.5 Clinical examination

Arm (humeral head to olecranon fossa) and scar sizes were measured. The cosmetic results were judged using the OSAS score (Observer Scar Assessment Scale from the global POSAS "Patient and Observer Scar Assessment Scale" Annexe a). Correlation between scar length and PSAS was assessed. Arm extension strength was assessed using the Medical Research Council (MRC) scale (Table 2.1) for muscle strength.

In patients for whom the MRC scale was 5, a complementary strength measurement was obtained using a numeric dynamometer (CH 50K50, Kern & Sohn, Balingen, Germany). The arm was placed in a standardized position for all measurements. Each patient was standing with the elbow flexed at 90°, and the forearm in a neutral position. The shoulder was positioned at 0° abduction to minimize the contribution of the long and lateral heads to elbow extension [10]. The patient was asked to grip the handle of the dynamometer and pull down to extend the elbow. The non-operated side was evaluated in the same way and was used as control. As the non-dominant arm was expected to be weaker than the dominant arm, a healthy population of 10 adults was tested with the same technique to determine the average difference between dominant and non-dominant arm.

2.2.6 Statistical analysis

All analyses were performed using Matlab (R2014a, The MathWorks®, Inc., Massachusetts, USA). Quantitative data are presented as mean ± standard error (std) for normal distributions and as median [1st – 3rd quartiles] for non-normal distributions. Correlations between quantitative variables were assessed using Pearson or Spearman's correlation coefficient, as appropriate. Inter-group differences were assessed using Student's t-test or Mann Whitney's U-test, as appropriate.

Patient characteristics	n=24
Follow-up, mean ±std, m	33.9 ±13.6
Age at last follow-up, mean ±std, y	46.2 ±13.3
Gender, n (%)	
Male	15 (62.5)
Female	9 (37.5)
Job before injury, n (%)	
Manual worker	14 (58.3)
Office worker	3 (12.5)
Unemployed/Housewife/Pensioner	7 (29.2)
Risks factors for poor wound healing, n (%)	10 (42)
BMI > 30	1 (4.2)
Smoker	9 (37.5)
Diabetes	1 (4.2)
BMI, mean ±std	26.5 ±2.9

Table 2.2 – Patient characteristics. m, months; y, years.

2.3 Results

2.3.1 Population

An MTB free flap was harvested in 24 patients to cover a distal lower limb defect. All patients were examined at the mean follow-up of 33.9 ±13.6 months (Table 2.2). There were 9 women and 15 men; mean age was 46.2 ±13.3 years old. In all cases, the MTB was harvested on the non-dominant arm. Ten patients had identified risk factors for poor wound healing. No major surgical complication (radial or ulnar nerve injury) occurred. There were two postoperative hematomas at the donor site, with one requiring surgical drainage. All donor sites healed within 15 days. Concerning the recipient site, mean wound area was 20 ±8 cm^2.

2.3.2 Functional results

All patients exhibited normal extension strength (MRC = 5/5) except one patient with multiple trauma and a severe distal fracture of the humerus (MRC = 4/5) (Table 2.3). Median extension strength was estimated at 93.8% [81.1–100] of the opposite arm strength. This result was not statistically different from the control population (89.9% [85.5–98.6]) (p=0.71). In our study, women exhibited a higher ratio of operated arm extension strength to healthy arm extension strength than men (100% [93.4–100] versus 83% [75–94.1]) ($p<0.01$). The median Quick DASH was 0 [0–2.3] (normal (=0) in 71% of cases, subnormal (0–10) in 25% of cases and poor (>10) in the patient with the humerus fracture). Extension strength was not correlated to the Quick DASH score (r=−0.13, p=0.55).

Functional results	
Elbow extension strength	
5/5 MRC, %	95.8
Dynamometer strength, median [1st–3rd quartiles]	93.8 [81.1–100]
> 90 % of the contralateral side, %	52
80-90 % of the contralateral side, %	29
< 80 % of the contralateral side, %	19
QuickDASH, median [1st–3rd quartiles]	0 [0–2.3]
0/100, n (%)	17 (71)
1/100 - 10/100, n (%)	6 (25)
> 10/100, n (%)	1 (4)

Table 2.3 – Functional results

2.3.3 Cosmetic results

Scars were 18.1 ±1.7 cm long for men and 16.9 ±1.8 cm long for women, representing 63% of the total arm length in both cases (Table 2.4). Average global POSAS score was 18.6 ±7, with 14 being "normal skin" and 140 the "worst scar imaginable". Average PSAS was 10 ±4.3. Average PSAS' score was better in men (8.7 ±2.3) than in women (11.7 ±5.9) but the difference did not reach statistical significance (p=0.1). Average OSAS score was 8.6 ±3.3 and was only moderately correlated to PSAS (r=0.7, p=0.01) (Fig. 2.2). Most of scars were well integrated (Fig. 2.3). There was no correlation between PSAS score and scar length (r=0.02, p=0.9) and between POSAS global scale and follow up duration (r=−0.16, p=0.42).

2.3.4 Global satisfaction

Global satisfaction was excellent. To the question: "Would you have preferred another donor site for your reconstruction?", all patients answered, "No, I would not".

2.4 Discussion

The aim of this study was to evaluate the safety and reliability of the harvest procedure and the functional and cosmetic morbidity of the donor site. The MTB free flap has several advantages: its limited size provides a non-bulky flap, appropriate for distal leg, ankle and foot coverage. It is a denervated muscle flap that will atrophy over time, potentially improving contour and cosmetic outcomes without requiring multiple secondary procedures. Its harvest is easy and the procedure can be done using a two-team approach, in order to reduce operative time. Furthermore, direct closure is possible, thus avoiding the additional scar of a skin graft harvest. In our series, the surgical procedure was reliable. No anatomical variation was encountered during dissection. Different anatomical variation have neverthe-

Cosmetic results	
Scar length, mean ±std, % of the arm length	62.7 ±6.6
Scar length in male patients, mean ±std, cm	18.1 ±1.7
Scar length in female patients, mean ±std, cm	16.9 ±1.8
POSAS	
Global scale, mean ±std	17.5 ±5.1
<28, %	95
28-49, %	5
>49, %	0
PSAS, mean ±std	9 ±2.4
<28, %	100
28-49, %	0
>49, %	0
OSAS, mean ±std	8.5 ±4
<28, %	100
28-49, %	0
>49, %	0

Table 2.4 – Cosmetic results

less been described in the literature and could disturb harvesting [11, 12], such as ectopic ulnar nerve branches traveling above the elbow, or four-headed triceps muscles. MTB free flap surgery involves dissection of the vascular pedicle along the radial nerve. The ulnar nerve is not seen during this surgery. The medial limit of our dissection is the medial edge of the humerus in order to stay at a distance from the nerve (Fig. 2.4). An ongoing imaging study aims to confirm the safety of this approach.

In our cohort, two patients presented postoperative hematomas due to insufficient hemostasis, one requiring surgical drainage. In comparison to others flaps, the MTB free flap leads to very few donor site-related complications. A systematic review and pooled analysis of donor site complications following free tissue harvest from the thigh (anterolateral thigh, vastus lateralis, anteromedial thigh, transverse upper gracilis, tensor fascia latae, gracilis and rectus femoris flaps) found paresthesia (0–36.4%), wound dehiscence (0.9–8.3%), contour deformity (0–5.2%), pain (0–6.3%), and seromas (0.4–2.0%). Pooled-analysis of dynamometric studies demonstrated a significant reduction in strength after rectus femoris flap (21%).[13] Klinkenberg et al. analyzed donor site morbidity of three different fasciocutaneous flaps in 60 patients [9]. He found that sensory disorders were present in 100% of cases following lateral arm free flap, 90% of cases following anterolateral thigh free flap, and 45% of cases following parascapular free flaps. Postoperative complications were seromas (parascapular, n=2), hematomas (parascapular, n=1; lateral arm, n=2), and dehiscence (n=4 for each flap). In the thigh, Purnell et al. found more donor site wound complications, including a skin paddle, in comparison with pure muscular donor sites [14].

Global patient satisfaction was excellent. No patient complained of elbow pain or instability or re-

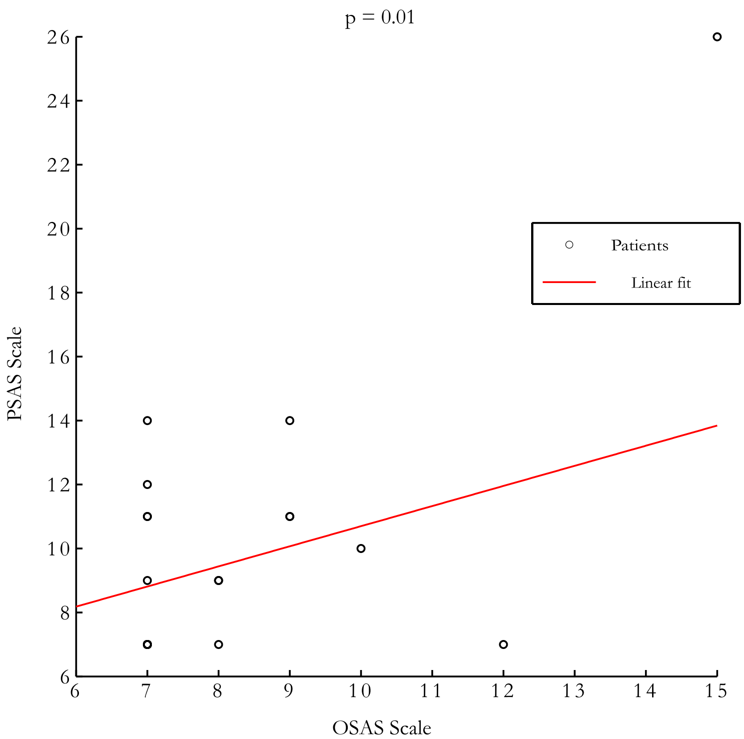

Figure 2.2 – Correlation between OSAS and PSAS scales

duction in strength. Elbow extension was complete in all patients and median extension strength was 93.8% of the contralateral dominant arm. This positive functional result is probably explained by the straight trans tricipital approach that was chosen to dissect the flap. As stated in the literature, this approach provides access to the entire medial head and its pedicle without weakening the tricipital tendon [15].

Cosmetic results were satisfactory. Patients do not see the scar because of its dorsal localization on the arm. This contributes to its acceptance, contrary for instance to the lateral arm flap that gives scar on the lateral aspect of the distal arm [16]. Moreover, the dorsal skin of the arm generally gives good quality scars. They were in average 16.9 cm long for women and 18.1 cm long for men, which represent 63% of total arm length in both cases. The length of the skin incision can be reduced at its distal part if the loss of substance which has to be covered is close to the recipient vessel. In this case, it is not necessary to harvest the muscle through the olecranon fossa. However, the incision has to go through the distal part of the deltoid in order to dissect the flap pedicle. Except for burn graft donor sites, there are very few studies on donor site morbidity using the POSAS scale despite good intra- and inter-observer reproducibility [6, 8]. Xu *et al.* analyzed their fibula donor site morbidity for mandibular reconstruction and found similar results (OSAS = 12.10 and PSAS = 10.57) [17]. Yang *et al.* found an OSAS score of 12.10 and a mean PSAS score of 11.07 at 6 months post costal cartilage harvest for mastoid

Figure 2.3 – Scars on the posterior aspect of the arm

obliteration [18].

There are limitations to our study. Sample size was small, and the studied population was heterogeneous. Concerning elbow function evaluation, pre-operative values for extension strength in the operated arm were not measured. Nevertheless, the comparison between the dominant and the non-dominant arm in the control group shows the same ratio than in our patients.

The medial head of the triceps brachii muscle has no well-defined role in the literature. Bertelli et al. have evaluated elbow extension strength after nerve transfer from the triceps medial head to the deltoid following axillary nerve palsy [19]. One month after nerve transfer, there were no reports of weakness and elbow extension strength averaged 13 ±3.0 kg, which was not statistically different from the normal side (11.1 ±2.3 kg).

This study focusing on donor site morbidity completes the evaluation of the MTB free flap for reconstructive surgery. The MTB has a reliable anatomy and can be harvested with a low complication rate. Moreover, our extensive follow-up using validated questionnaires and scores has demonstrated excellent functional and cosmetic outcomes at the donor site. These different points make the MTB a very attractive option for ankle and foot defect coverage. For this task, it is our opinion that donor site morbidity is indeed a key element in the choice of the strategy and hence requires discussion between

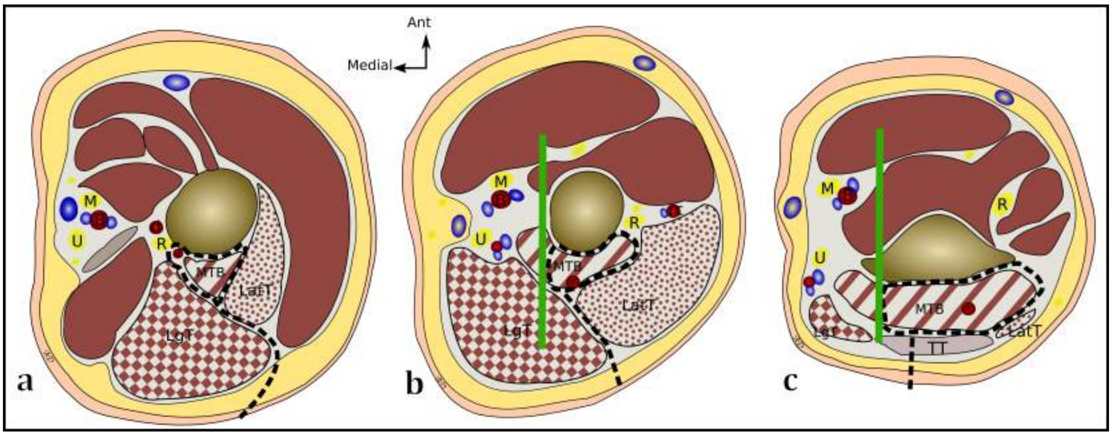

Figure 2.4 – Surgical approach and anatomical landmarks (transverse sections). a: Proximal third b: middle third c: distal third of the arm. Ant, anterior; LgT, long head of the triceps brachii muscle; LatM, lateral head of the triceps brachii muscle; M, median nerve; U, ulnar nerve; R, radial nerve; B, brachial artery; d, deep brachial artery; rc, radial collateral artery; *, middle collateral artery; dotted line, surgical approach; green line, medial limit of the dissection.

the medical team and the informed patient [20].

2.5 Conclusion

Objective and subjective evaluations of elbow function in patients who underwent MTB free flap for limb reconstruction showed no sequelae. Esthetic and overall patient satisfaction with the donor site was high. MTB harvesting is safe and minimal impact on elbow function, making it an attractive solution for small- to medium-sized wound coverage.

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3 A new local muscle flap for elbow coverage: the medial triceps brachii flap. Anatomy, surgical technique and preliminary outcomes

Background— The medial triceps brachii (MTB) is vascularized by the middle collateral artery and the arterial circle of the elbow. This vascularization allows a distal pedicled utilization to cover soft tissue defect of the elbow. We report our experience using this flap to cover traumatic or post surgical wounds.

Methods— Patients who underwent a pedicled MTB free flap between 2008 and 2015 were included. Data concerning patient characteristics, wound size, surgical technique and complications were retrospectively reviewed. An independent observer examined patients and accessed outcome of the coverage procedure: wound healing, scar length, range of motion of the elbow and patient satisfaction.

Results— 8 patients were included (70.6 ±17.7 years old at the time of surgery). All patients had serious comorbidities and risk factors of poor wound healing. Etiologies of the defect were post-operative scar complications (five patients), skin necrosis secondary to an underlying olecranon fracture (one patient) and two direct open fractures. Soft tissue defects had a median surface of 17 [14–22] cm^2. The olecranon was exposed in seven cases and the medial humeral epicondyle in one case. Mean procedure duration was 83 ±14 minutes. There was no intra operative or post-operative complication. All patients healed properly at 3-weeks follow-up. No wound recurrence or surgery related complication was reported after a median follow-up of 40.5 [21.5–69.5] months.

Conclusion— Favorable outcomes in all of our 8 patients make this flap an interesting option to cover small to medium defect of the posterior aspect of the elbow.

Key words— limb reconstruction; locoregional flap; medial triceps brachii muscle

3.1 Introduction

The elbow joint is covered by a thin, elastic and soft tissue envelope, which can withstand and allow for repetitive flexion and extension. This envelope can be compromised after infected elbow prosthesis or open fracture. A number of soft tissue procedures to cover the elbow region have been described [1–3]. These procedures consists of fasciocutaneous flaps [4, 5], pedicled muscle flaps, perforator flaps [6] and free tissue transfers [7]. Described pedicled flap techniques use different muscles, including the anconeus [8, 9], the brachioradialis [10], the flexor carpi ulnaris [11–13], the extensor carpi radialis longus, or the latissimus dorsi. In patients with heavy comorbidities or multiple traumas, the coverage technique has to be safe, quick and reliable. The medial triceps brachii (MTB) is one of the three heads of the triceps brachii muscle. It extends from the posterior aspect of the humerus to the tricipital tendon. Its vascularization mainly comes from the middle collateral artery (a branch of the deep brachial artery) but also from the arterial circle of the elbow [9, 14, 15]. This vascularization allows a distal pedicled utilization of the medial triceps brachii as a local flap to cover soft tissue defect of the elbow. It can provide coverage for small to medium-sized defects about the elbow without requiring any microvascular anastomosis. It has previously been shown to have acceptable donor site morbidity when it is harvest as a free transfer [16]. The aim of this study is to report our experience using this flap to cover soft tissue defects of the elbow. We analyze our indications and long-term results.

3.2 Materials and methods

3.2.1 Study design

This was a singe-center retrospective study. After receiving approval of the institutional ethics committee, all consecutive patients who underwent a pedicled MTB flap between 2008 and 2015 in our institution were included. All patients provided written informed consent. Data concerning patient characteristics at the moment of surgery, wound size, surgical technique and complications were retrospectively retrieved from our institution's electronic medical record system. An independent observer examined patients and accessed outcome of the coverage procedure: wound healing, scar length, range of motion of the elbow and patient satisfaction.

3.2.2 Statistical analysis

All analyses were performed using Matlab (R2014a, The MathWorks®, Inc., Massachusetts, USA). Quantitative data are presented as mean ± standard error (std) for normal distributions and as median

[1st-3rd quartiles] for non-normal distributions.

3.3 Results

3.3.1 Population

The procedure was carried out on 8 patients (3 women, 5 men). Subjects were 70.6 ±17.7 years old at the time of surgery. All patients had serious comorbidities and risk factors of poor wound healing (Table 3.1). Etiologies of the defect were post-operative scar complications (4 patients for traumatic surgery and 1 patient for a chronic olecranon bursitis), skin necrosis secondary to an underlying olecranon fracture (one patient) and two direct open fractures. Soft tissue defects had a median surface of 17 [14–22] cm^2. The olecranon was exposed in seven cases and the medial humeral epicondyle in one case. Median delay between wound and soft tissue coverage was 24.5 [12–39.5] days.

3.3.2 Surgical technique

All patients underwent a similar procedure. Patients were in dorsal position, shoulder at 90° of abduction, elbow at a right angle, on an armrest (Fig. 3.1). Skin incision is vertical on the posterior aspect of the arm, from the depression between the lateral and long head of the triceps (posterior to the deltoid tuberosity) to the olecranon fossa. The tendinous part of the triceps muscle was directly exposed and longitudinally incised, separating the long and lateral heads. A cleavage plane was found, superficially separating the lateral and long heads from the medial head. Using retractors placed on the lateral and the long heads, the medial head was exposed. Its pedicle was easily located proximally in the radial groove, then on the muscle surface. It was ligated at its proximal part, immediately distal to the radial groove. The flap was then dissected from proximal to distal. It was separated from the long head and

Patient	Gender/Age	Comorbidities	Defect etiology Associated injuries	Wound size (cm^2)
1	M/60	Tobacco, diabetes	Polytrauma, distal humerus open fracture Gustilo 2, secondary skin necrosis after ORIF	13
2	M/80		Polytrauma, open elbow dislocation	18
3	M/40	Tobacco, alcohol abuse	Polytrauma, distal humerus fracture, secondary skin necrosis after ORIF	20
4	F/78	Tobacco, aortic prosthesis, cardiac insufficiency, rhabdomyolysis	Closed olecranon fracture with skin necrosis	24
5	M/53		Open distal humerus fracture multioperated, infection of a TEA	15
6	F/92	Tobacco, diabetes, arrhythmia, hypertension, coronary heart disease, osteoporosis	Close humerus fracture treated with TEA, post operative infection	12
7	F/78	Diabetes, severe Parkinson disease	Open olecranon fracture	16
8	M/84	Tobacco, diabetes, atrial fibrillation	Osteomyelitis after surgery for a hygroma	24

Table 3.1 – Patient characteristics. ORIF, open reduction-internal fixation; TEA, total elbow arthroplasty

Figure 3.1 – (A) Patient 1 who had an open fracture of the left distal humerus in a road traffic accident. He had a chronic wound with olecranon exposure after internal fixation of the fracture. (B) Installation for surgery. (C) Wound debridement. (D) Dissection of the medial head of the triceps under the long and lateral heads and the tricipital tendon. (E) The flap is flipped over to cover the wound. (F) Primary skin closure of the surgical approach. (G) Thin skin graft on the muscular flap. (H) Result at 3.5 years.

the posterior aspect of the humerus and separated from the lateral border of the humerus, following the lateral intermuscular septum, leaving the posterior radial collateral vessels in place laterally. Medially, it was separated from the long head of the triceps. The dissection stopped once the olecranon fossa was reached and the flap was rotated 180° to cover the elbow. It was placed on the defect without any tension at 90° of elbow flexion. The distal vascularization is not seen during the harvest. Interrupted, absorbable sutures, followed by an overlapping continuous suture were placed between the lateral and long bellies to restore triceps muscle and tendon continuity. Primary skin closure of the cutaneous incision and a thin skin graft on the muscular flap were done.

3.3.3 Flap procedure and wound healing

Mean procedure duration (including soft tissue coverage and bone debridement, orthopedic hardware removal in two cases) was 83 ±14 minutes (Table 3.2). There was no intra operative or post-operative complication. All the flaps survived and there was no partial necrosis. A skin graft was performed after a mean time of 5.2 ±1.9 days. All patients healed properly with no further intervention needed for soft tissue coverage at 3-weeks follow-up. Elbows were immobilized using a shoulder scarf until

Patient	Proc. length	HW exposure	HW salvage	Follow-up (m)	Extension	Flexion	Pronation	Supination
1	90'	1	0	46	-30°	100°	70°	85°
2	72'	0	NA	97	-20°	120°	70°	10°
3	90'	1	1	50	-20°	120°	85°	80°
4	105'	0	NA	15	-40°	110°	30°	30°
5	78'	1	0	35	0°	120°	0°	85°
6	75'	1	1	25	-10°	120°	70°	70°
7	90'	0	NA	18	-10°	120°	70°	70°
8	60'	0	NA	89	-10°	120°	85°	85°

Table 3.2 – Surgical procedure characteristics. Proc, procedure; HW, hardware; m, months; ', minutes; NA, not applicable.

complete wound healing was obtained, at which point the patients were authorized to move with no restriction and included in an adequate rehabilitation protocol. No wound recurrence or surgery related complication was reported after a median follow-up of 40.5 [21.5–69.5] months. Soft tissue coverage allows hardware salvage in 2 cases without infection recurrence. Clinical examination showed median extension of -15 [-25 – -10] °, median flexion of 120 [115–120] °, median pronation of 70 [50–77.5] °, median supination of 75 [50–85] ° (Fig. 3.2).

3.4 Discussion

The aim of this study was to report our experience using the MTB as a locoregional flap to cover soft tissue defects of the elbow. The elbow region is prone to wound healing complications. Reported wound complication rates after total elbow arthroplasty is about 6% [17]. Reported complication rates after surgical fixation of distal humerus fractures are higher [18]. In a study of parallel plate fixation of complex distal humerus fractures, 12% of patients had postoperative wound complications. Other studies demonstrated a 4-6% wound complication rate after open reduction internal fixation of a distal humerus fracture. Post-surgical or post-traumatic wounds are frequent and due to the thickness of soft tissues, bone and orthopedic hardware are often exposed. In elderly or weak patients, the goals of reconstruction should be to tailor coverage to the defect size, to minimize donor site morbidity, to limit surgical time and to allow early motion. Muscle flaps for elbow coverage are preferred when infection is present or significant defects needs to be filled. They can provide more bulk than fasciocutaneous flaps to obliterate dead space. Moreover, perforator flaps should be avoided in patients with arterial diseases. Our patients had severe comorbidities or multiple traumas. They had a low-demand function but required a quick and reliable procedure to cover small to medium size defect. Our experience demonstrates that the MTB flap will have an average length of 10.7 cm when it is harvested up to the olecranon fossa [19]. It can therefore cover the olecranon, the medial epicondyle, but also the lateral epicondyle. The flap was effective in covering defects of different sizes; with a median wound size of 17 cm2.

Figure 3.2 – (A) Patient 8 (B) Surgical approach and debridement (C) medial head 180° reversed on the defect (D) direct skin closure at the level of the arm (E) scar at 90 months follow-up in extension (F) scar in flexion (G) functional result in flexion (H) functional result in extension

The MTB flap can be compared to the anconeus muscle which can cover defects which include the lateral radiocapitellar joint, the distal triceps tendon at its insertion, and the olecranon [9]. However, the anconeus can only be expected to reliably cover a 5 to 7 cm² wound and has a very small rotation arch.

In this study, no flap complications were reported and all wounds were fully healed 3 weeks after the surgery. In Choudry's work, 99 flaps were reviewed [20]. Pedicled flaps accounted for 65% of the coverage procedures. The most common of these was the radial forearm flap, followed by latissimus dorsi. The overall complication rate was 31%. There were 30 minor complications that did not require additional reconstructive procedures, and 10 flap losses (9.9%) that did require additional coverage procedures. The highest complication rate (55%) was seen in the latissimus dorsi rotational flaps when used to cover defects distal to the olecranon tip.

When a flap reconstruction technique is chosen, it is essential for the surgeon to carefully evaluate the presence and integrity of the main flap pedicle, especially when damage by previous fracture or surgery is suspected. Choudry et al. highlighted the contraindications of the anconeus flap when the muscle is involved in the zone of injury. Elhassan et al. reported routine wound healing in all 20 patients with chronic elbow wounds. All patients healed within 3 weeks of surgery, but almost all patients had not

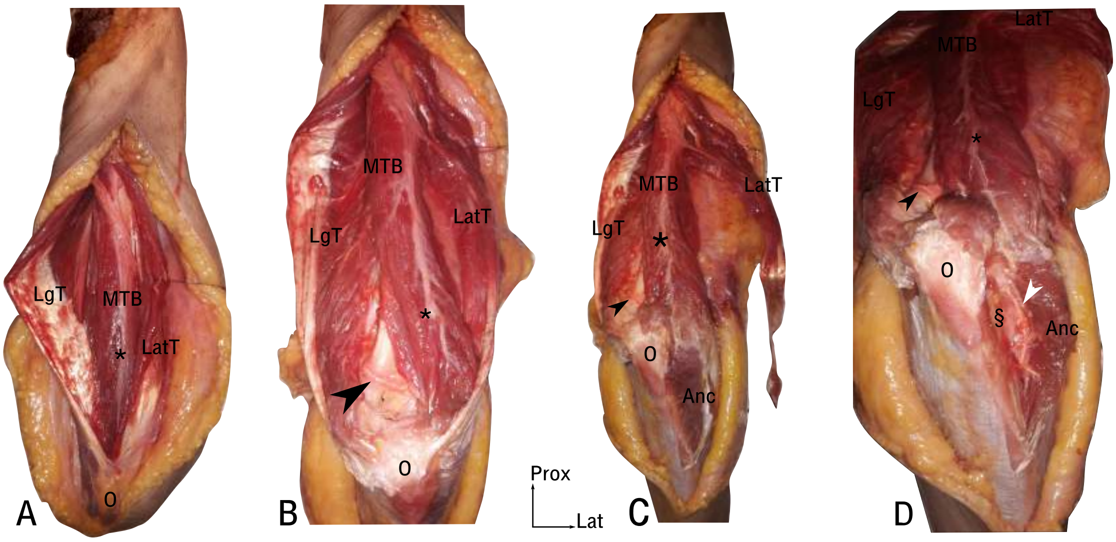

Figure 3.3 – Anatomical dissection on a right arm from a latex-injected fresh cadaver, posterior view (A) MTB visualization after splitting lateral (LatT) and long head (LgT) of the triceps brachii (B) Tricipital tendon is disconnected from the olecranon. Inferior ulnar collateral artery (black arrow) participates to the vascular anastomotic circle of the elbow (C) Posterior aspect of the proximal forearm, anconeus muscle (Anc) visualization (D) The anconeus muscle is disconnected from the olecranon. The interosseous recurrent artery (white arrow) vascularized the anconeus muscle and reaches the main pedicle of the MTB, the middle collateral artery (*). O: olecranon, §: interosseous membrane. Prox: proximal. Lat: lateral.

had previous elbow surgeries, so the pedicle was more often intact than expected in cases of previous trauma or surgery [21]. In our study, seven of our patients underwent this procedure to cover chronic open wounds after elbow fracture and/or surgical approach, and all of them healed. This good result is probably due to the rich vascular network of this area (Fig. 3.3), well described by Casoli et al. in their 69-arms dissection [14]. They have always found the MCA directly anastomosed in a transverse pattern with the inferior ulnar collateral artery, just above the olecranon fossa. Distally from this arcade, the posterior ulnar recurrent artery ran downwards. The MCA was also anastomosed longitudinally with the interosseous recurrent artery.

In comparison with other possible options for medium size defect coverage, MTB flap is a reliable procedure because of its constant anatomy. Sharpe et al. show good results in eight patients using the flexor carpi ulnaris (FCU) [13]. The FCU can cover larger defect but its dominant pedicle has no constant anatomy and it is a dominant flexor and ulnar deviator of the wrist and a potential stabilisator of the elbow and reduction of the wrist strength. Donor site morbidity could be further limited by the use of only the ulnar origin of the FCU for rotational coverage as demonstrated by case reports and anatomic studies [22, 23]. Another flap have been described by Morrison et al. The reverse-flow lateral arm flap has been use to cover 3 complex traumatic elbow injuries with good results but this flap required a delay of 15 to 21 days between flap elevation and re-inset and local transfer [5].

There are limitations to our study. Pre-operative ranges of elbow motion were not measured. Nevertheless, functional outcomes are often more related to the underlying lesions rather than the specific coverage procedure. These clinical outcomes are our beginning experience so the sample size is small. Further studies are necessary to specify indications and expected results, in particular in youngest patients with functional high-demand.

The strength of this study is the long-term follow up, providing information on the stability and durability of the coverage in this elbow area that is constantly solicited in motion.

3.5 Conclusion

This study describes the use of the MTB as a pedicled flap to cover medium size elbow wounds. The MTB has a reliable anatomy and can be harvested quickly without complication. Early wound healing allows early mobilization and rehabilitation of the elbow. Favorable outcomes in all of our 8 patients make this flap an interesting option in this indication. Additional studies with a higher number of patients are necessary to confirm these results.

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Conclusion

L'objectif de notre travail était d'analyser les résultats des reconstructions des membres avec le lambeau de chef médial du muscle triceps brachial. Son utilisation en lambeau libre pour la reconstruction de la partie distale de la jambe, de la cheville et du pied permet de couvrir des pertes de substances de 20 à 40 cm² et d'apporter un tissu bien vascularisé permettant la guérison des ostéomyélites et des pseudarthroses septiques dans des délais similaires aux autres lambeaux. Sa taille est adaptée à la partie distale du membre inférieur, autorisant le chaussage et la marche. Malgré la courbe d'apprentissage, son prélèvement est rapide, simple et fiable, grâce à une anatomie constante. Les complications majeures à type de nécrose complète du lambeau sont de fréquence identique aux autres lambeaux. Son utilisation autour du calcanéum, comme la plupart des autres lambeaux, est fiable mais nécessite pour la moitié des cas dans notre série un redrappage secondaire du lambeau, compte tenu de l'effet de savonnage sur le talon [1].

La morbidité du site donneur est minime [2]. Aucune complication nerveuse n'a été observée dans notre série, toutefois le prélèvement du lambeau nécessite une attention particulière vis à vis du nerf radial qui doit être disséqué pour libérer le pédicule vasculaire du MTB et du nerf ulnaire surtout à la partie distale du bras, lorsqu'il devient postérieur et se rapproche du chef médial du triceps. Nous avons toujours pris comme limite médiale le bord médial de l'humérus afin de rester à distance du nerf ulnaire. Cette limite peut être franchie si une largeur de lambeau supérieure à 4 cm est nécessaire mais dans ce cas, il est nécessaire de repérer le nerf ulnaire et de le protéger pendant toute la dissection. La force d'extension du coude, évaluée à long terme, n'est pas affectée par la voie d'abord trans tricipitale et le prélèvement du chef musculaire médial, comme le démontre les évaluations objectives de force et subjectives de capacité réalisées dans notre étude. L'évaluation esthétique subjective du patient et de l'examinateur montre des résultats corrélés et satisfaisants. La cicatrice est linéaire, à la face postérieure du bras, cachée de la vue du patient. Nous n'avons pas retrouvé dans notre série de douleurs ou d'anesthésie en regard de la zone de prélèvement, comme décrit pour d'autres zones donneuses de lambeaux [3].

La vascularisation du MTB a été initialement décrite comme un type I de la classification de Mathes et Nahai avec un pédicule unique ou de type II avec un pédicule dominant et des pédicules accessoires

[4–6]. Les travaux de dissection ont permis de montrer l'importance de sa vascularisation distale par le cercle anastomotique du coude, suggérant plutôt un lambeau musculaire de type V, avec un pédicule vasculaire dominant et des pédicules accessoires compétents [7]. Cette vascularisation distale importante permet son utilisation pédiculée pour la couverture de la face postérieure du coude, dans les cas de nécrose cutanée post-traumatique ou post-chirurgicale avec exposition olécranienne ou des épicondyles huméraux, pour des pertes de substance de 17 cm^2 en moyenne. Le prélèvement s'effectue par la même voie d'abord que dans la technique de lambeau libre mais la dissection se déroule de proximal (ligature première du pédicule dominant) en distal jusqu'à la fossette olécranienne qui ne doit pas être dépassée pour préserver les pédicules accessoires. Notre travail préliminaire sur les huit premiers cas montrait une technique de prélèvement simple, fiable et rapide avec des résultats fonctionnels et esthétiques satisfaisants à long terme, malgré les terrains fragiles des patients opérés. En effet, il étaient soit âgés avec de sérieuses comorbidités soit polytraumatisés. Le lambeau pédiculé de MTB offre ces avantages par rapport aux lambeaux décrits dans la littérature [8]. D'autres études devront déterminer si il est possible de proposer son utilisation pour la couverture du coude chez des patients à haute demande fonctionnelle.

L'ensemble de notre travail confirme que le lambeau de chef médial de triceps brachial est une option fiable et efficace dans la couverture des pertes de substance des membres. Il doit néanmoins faire l'objet d'études comparatives avec les lambeaux perforants locorégionaux et libres [9, 10]. En effet, ces derniers sont, depuis quelques années, des lambeaux appréciés pour la faible morbidité du site donneur avec préservation du muscle sous-jacent, fermeture directe souvent possible, leur pédicule habituellement long et la possibilité de réinnervation sensitive [11, 12].

Les avancées réalisées dans le domaine de la reconstruction des membres, que ce soit dans la reconstruction osseuse ou dans les techniques de couverture, visent à réduire les délais de cicatrisation, de consolidation et de récupération de la marche, les durées d'hospitalisation, le nombre de procédures chirurgicales, les complications majeures et les indications d'amputation.

Pourtant pour l'instant, de grandes études prospectives ne montrent pas de différence en terme de qualité de vie ou de résultats fonctionnels à long terme entre les patients amputés et les patients ayant bénéficié d'une reconstruction complexe orthoplastique [13]. Ils restent encore de nombreux progrès à réaliser.

Il est également licite de réfléchir à l'avenir lointain de la chirurgie orthoplastique dans le sauvetage des membres lorsque la technologie prothétique et les interfaces homme-machine pourront surclasser d'un point de vue fonctionnel et économique les reconstructions allogéniques.

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a Annexes

1

Quick DASH

Veuillez évaluer vos possibilités d'effectuer les activités suivantes au cours des 7 derniers jours en entourant le chiffre placé sous la réponse appropriée

		Aucune difficulté	**Difficulté légère**	**Difficulté moyenne**	**Difficulté importante**	**Impossible**
1.	Dévisser un couvercle serré ou neuf	1	2	3	**4**	5
2.	Effectuer des tâches ménagères lourdes (nettoyage des sols ou des murs)	1	2	3	**4**	5
3.	Porter des sacs de provisions ou une mallette	1	2	3	**4**	5
4.	Se laver le dos	1	2	3	**4**	5
5.	Couper la nourriture avec un couteau	1	2	3	**4**	5
6.	Activités de loisir nécessitant une certaine force ou avec des chocs au niveau de l'épaule du bras ou de la main. (bricolage, tennis, golf, etc..)	1	2	3	**4**	5

		Pas du tout	Légèrement	Moyennement	Beaucoup	Extrêmement
7.	**Pendant les 7 derniers jours**, à quel point votre épaule, votre bras ou votre main vous a-t-elle gêné dans vos relations avec votre famille, vos amis ou vos voisins ? (entourez une seule réponse)	1	2	3	**4**	5

		Pas du tout limité	Légèrement limité	Moyennement limité	Très limité	Incapable
8.	**A**vez-vous été limité dans votre travail ou une de vos activités quotidiennes habituelles en raison de problèmes à votre épaule, votre bras ou votre main?	1	2	3	**4**	5

	Veuillez évaluer la sévérité des symptômes suivants **durant les 7 derniers jours.** (entourez une réponse sur chacune des lignes)	**Aucune**	**Légère**	**Moyenne**	**Importante**	**Extrême**
9.	Douleur de l'épaule, du bras ou de la main	1	2	3	**4**	5
10.	Picotements ou fourmillements douloureux de l'épaule, du bras ou de la main	1	2	3	**4**	5

		Pas du tout perturbé	Un peu perturbé	Moyennement perturbé	Très perturbé	**Tellement perturbé que je ne peux pas dormir**
11.	**Pendant les 7 derniers jours**, votre sommeil a-t-il été perturbé par une douleur de votre épaule, de votre bras ou de votre main ? (entourez une seule réponse)	1	2	3	**4**	5

Le score *Quick*DASH n'est pas valable s'il y a plus d'une réponse manquante.

Calcul du score du ***Quick*DASH** = **([somme des n réponses] - 1) X 25, où n est égal au nombre de réponses.**

1 *Questionnaire DASH*

Figure a.1 – QuickDASH. Part 1.

1

Quick DASH

Veuillez évaluer vos possibilités d'effectuer les activités suivantes au cours des 7 derniers jours en entourant le chiffre placé sous la réponse appropriée

		Aucune difficulté	Difficulté légère	Difficulté moyenne	Difficulté importante	Impossible
1.	Dévisser un couvercle serré ou neuf	1	2	3	4	5
2.	Effectuer des tâches ménagères lourdes (nettoyage des sols ou des murs)	1	2	3	4	5
3.	Porter des sacs de provisions ou une mallette	1	2	3	4	5
4.	Se laver le dos	1	2	3	4	5
5.	Couper la nourriture avec un couteau	1	2	3	4	5
6.	Activités de loisir nécessitant une certaine force ou avec des chocs au niveau de l'épaule du bras ou de la main. (bricolage, tennis, golf, etc..)	1	2	3	4	5

		Pas du tout	Légèrement	Moyennement	Beaucoup	Extrêmement
7.	**Pendant les 7 derniers jours**, à quel point votre épaule, votre bras ou votre main vous a-t-elle gêné dans vos relations avec votre famille, vos amis ou vos voisins ? (entourez une seule réponse)	1	2	3	4	5

		Pas du tout limité	Légèrement limité	Moyennement limité	Très limité	Incapable
8.	Avez-vous été limité dans votre travail ou une de vos activités quotidiennes habituelles en raison de problèmes à votre épaule, votre bras ou votre main?	1	2	3	4	5

	Veuillez évaluer la sévérité des symptômes suivants **durant les 7 derniers jours.** (entourez une réponse sur chacune des lignes)	**Aucune**	**Légère**	**Moyenne**	**Importante**	**Extrême**
9.	Douleur de l'épaule, du bras ou de la main	1	2	3	4	5
10.	Picotements ou fourmillements douloureux de l'épaule, du bras ou de la main	1	2	3	4	5

		Pas du tout perturbé	Un peu perturbé	Moyennement perturbé	Très perturbé	**Tellement perturbé que je ne peux pas dormir**
11.	**Pendant les 7 derniers jours**, votre sommeil a-t-il été perturbé par une douleur de votre épaule, de votre bras ou de votre main ? (entourez une seule réponse)	1	2	3	4	5

Le score *Quick*DASH n'est pas valable s'il y a plus d'une réponse manquante.

Calcul du score du ***Quick*DASH = ([<u>somme des n réponses</u>] - 1) X 25, où n est égal au nombre de réponses.**

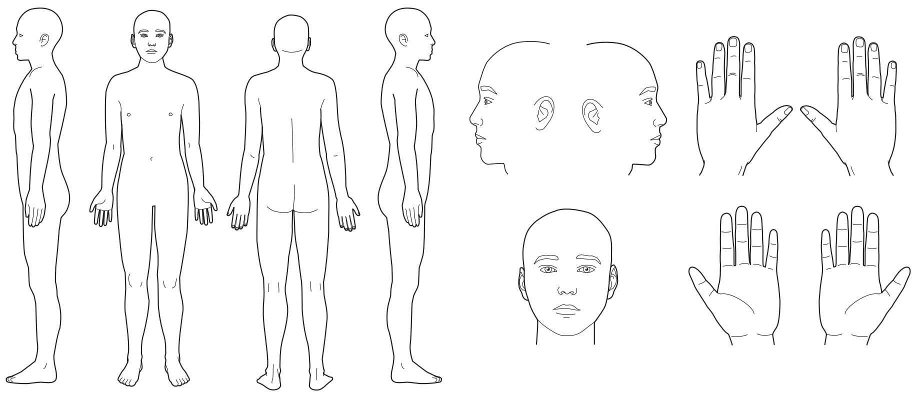
1 *Questionnaire DASH*

Figure a.2 – QuickDASH. Part 2.

POSAS Observer scale

The Patient and Observer Scar Assessment Scale v2.0 / EN

Date of examination:	**Name of patient:**
Observer:	
Location:	**Date of birth:**
Research / study:	**Identification number:**



1 = normal skin — worst scar imaginable = 10

PARAMETER	1	2	3	4	5	6	7	8	9	10	CATEGORY
VASCULARITY	○	○	○	○	○	○	○	○	○	○	PALE | PINK | RED | PURPLE | MIX
PIGMENTATION	○	○	○	○	○	○	○	○	○	○	HYPO | HYPER | MIX
THICKNESS	○	○	○	○	○	○	○	○	○	○	THICKER | THINNER
RELIEF	○	○	○	○	○	○	○	○	○	○	MORE | LESS | MIX
PLIABILITY	○	○	○	○	○	○	○	○	○	○	SUPPLE | STIFF | MIX
SURFACE AREA	○	○	○	○	○	○	○	○	○	○	EXPANSION | CONTRACTION | MIX
OVERALL OPINION	○	○	○	○	○	○	○	○	○	○	

Explanation

The observer scale of the POSAS consists of six items (vascularity, pigmentation, thickness, relief, pliability and surface area).
All items are scored on a scale ranging from 1 ('like normal skin') to 10 ('worst scar imaginable').
The sum of the six items results in a total score of the POSAS observer scale. Categories boxes are added for each item. Furthermore, an overall opinion is scored on a scale ranging from 1 to 10.
All parameters should preferably be compared to normal skin on a comparable anatomic location.

Explanatory notes on the items:

- **VASCULARITY** Presence of vessels in scar tissue assessed by the amount of redness, tested by the amount of blood return after blanching with a piece of Plexiglas
- **PIGMENTATION** Brownish coloration of the scar by pigment (melanin); apply Plexiglas to the skin with moderate pressure to eliminate the effect of vascularity
- **THICKNESS** Average distance between the subcutical-dermal border and the epidermal surface of the scar
- **RELIEF** The extent to which surface irregularities are present (preferably compared with adjacent normal skin)
- **PLIABILITY** Suppleness of the scar tested by wrinkling the scar between the thumb and index finger
- **SURFACE AREA** Surface area of the scar in relation to the original wound area

Figure a.3 – POSAS Observer Scale

POSAS Patient scale

The Patient and Observer Scar Assessment Scale v2.0 / EN

Date of examination:

Observer:

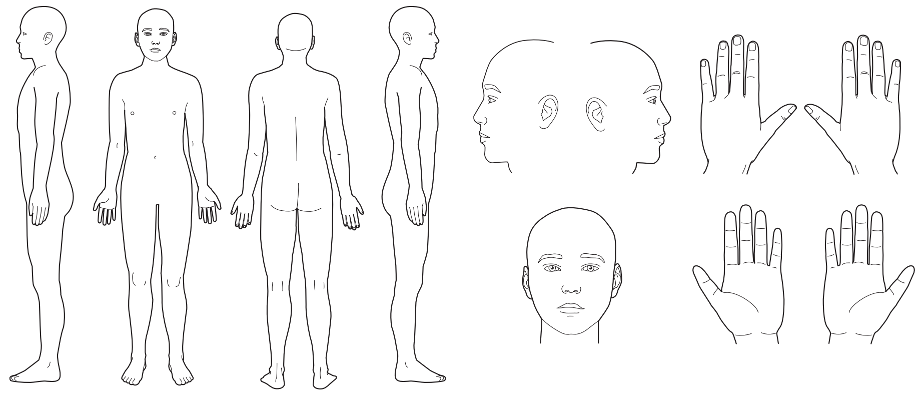
Location:

Research / study:

Name of patient:

Date of birth:

Identification number:



1 = no, not at all … yes, very much = 10	1	2	3	4	5	6	7	8	9	10
HAS THE SCAR BEEN PAINFUL THE PAST FEW WEEKS?	○	○	○	○	○	○	○	○	○	○
HAS THE SCAR BEEN ITCHING THE PAST FEW WEEKS?	○	○	○	○	○	○	○	○	○	○

1 = no, as normal skin … yes, very different = 10	1	2	3	4	5	6	7	8	9	10
IS THE SCAR COLOR DIFFERENT FROM THE COLOR OF YOUR NORMAL SKIN AT PRESENT?	○	○	○	○	○	○	○	○	○	○
IS THE STIFFNESS OF THE SCAR DIFFERENT FROM YOUR NORMAL SKIN AT PRESENT?	○	○	○	○	○	○	○	○	○	○
IS THE THICKNESS OF THE SCAR DIFFERENT FROM YOUR NORMAL SKIN AT PRESENT?	○	○	○	○	○	○	○	○	○	○
IS THE SCAR MORE IRREGULAR THAN YOUR NORMAL SKIN AT PRESENT?	○	○	○	○	○	○	○	○	○	○

1 = as normal skin … very different = 10	1	2	3	4	5	6	7	8	9	10
WHAT IS YOUR OVERALL OPINION OF THE SCAR COMPARED TO NORMAL SKIN?	○	○	○	○	○	○	○	○	○	○

Figure a.4 – POSAS Patient Scale