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RECONSTRUCTION OF UPPER LIMB SOFT TISSUE INJURIES, EXCEPT FOR FINGERTIPS LESIONS

RECONSTRUÇÃO DE LESÕES DE PARTES MOLES DO MEMBRO SUPERIOR, EXCETO LESÕES DAS PONTAS DOS DEDOS

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ABSTRACT

Objective: The main purpose of this work was to evaluate the advantages and disadvantages of reconstructive procedures applied in upper limb soft tissue injuries according to their location. Methods: The study involved 94 male and 22 female patients (116 total) operated between April 2001 and November 2017 due to traumatic injuries in a upper limb. Individuals were evaluated considering their age, sex, etiology, reconstruction area , applied methodology and complications. The finger injuries were excluded. Results: The performed reconstruction procedures include 29 skin grafts; six advancement flaps; seven rotation flaps; 33 pedicled fasciocutaneous flaps, 9 free fasciocutaneous flaps; 5 pedicled muscle flaps; 12 free muscle flaps, three pedicled musculocutaneous flaps; one free musculocutaneous flap; 11 neurovascular free flaps. Conclusion: Reconstructive procedures in the upper limbs are diverse, varying from skin grafting to free flaps. The indication of the best option depends on the type of injurie and the surgeon. The final goal is to reach the best functional result combined with the lowest possible morbidity. ***Level of Evidence IV, Case series.***

Keywords: Upper Extremity. Reconstructive Surgical Procedures. Surgical Flaps. Arm Injuries. Shoulder Injuries. Hand Injuries.

RESUMO

Objetivo: O objetivo deste estudo foi analisar as vantagens e desvantagens dos procedimentos reconstrutivos utilizados em lesões de partes moles do membro superior, conforme sua localização. Métodos: Foram analisados 116 pacientes, 94 do sexo masculino e 22 do sexo feminino, operados entre abril de 2001 e novembro de 2017 em consequência de lesões traumáticas no membro superior. As lesões restritas aos dedos foram excluídas. Foram avaliados quanto à idade, sexo, etiologia, área de reconstrução, método empregado e complicações. Resultados: Os procedimentos de reconstrução realizados incluem 29 enxertos de pele; 6 retalhos por avançamento; 7 retalhos por rotação; 33 retalhos fasciocutâneos pediculados, 9 retalhos fasciocutâneos livres; 5 retalhos musculares pediculados; 12 retalhos musculares livres, 3 retalhos musculocutâneos pediculados; 1 retalho musculocutâneo livre; 11 retalhos livres neurovasculares. Conclusão: Os procedimentos reconstrutivos nos membros superiores são muito variados, abrangendo desde a enxertia de pele até retalhos livres. A indicação depende do tipo de lesão e da escolha do cirurgião. O objetivo final é alcançar o melhor resultado funcional com a menor morbidade possível. ***Nível de Evidência IV, Série de casos****.*

Descritores: *Extremidade Superior. Procedimentos Cirúrgicos Reconstrutivos. Retalhos Cirúrgicos. Traumatismos do Braço. Lesões do Ombro. Traumatismos da Mão.*

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INTRODUCTION

The upper limb consists of four segments: shoulder, arm, forearm and hand and it is in constant interaction with the world and, consequently, it is commonly injured. Unlike many other body parts, critical structures of the hand are located just under the skin, which means that the upper limb soft tissue injuries represent a more difficult reconstructive challenge for the surgeon than similar injuries in other body parts.[1]

Upper limb trauma frequently results in serious injuries that compromise multiple structures, including skin, bones, tendons, nerves and blood vessels, which can threaten or impair limb function.[2] Complex injuries usually appear as a result of burns and traffic accidents, as well as workplace and even home related accidents. Mechanisms of injuries include crushing, avulsion, high pressure, firearm firing, fireworks or a combination of two or more.[3]

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The study was conducted at the Faculty of Medical Sciences and Health, Pontifícia Universidade Católica de São Paulo.
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No evidence suggests that delayed skin covering may lead to a higher rate of flap failure or wound infection. Negative pressure bandages, after serial operatory debriding are useful tools for temporizing wounds before reconstruction.[1] Inappropriate conduct can lead to amputation or permanent disability, which are major causes of emotional impairment. Covering the injury site with appropriate soft tissues prevents the development of contractures and facilitates tendons and joints mobility, essential for the improvement of motor, sensory and aesthetic functions of the upper extremity.[4]

Optimal coverage is stable, durable and able to withstand heavy work demands. It must also preserve joint mobility and present an aesthetically acceptable appearance – however, always prioritizing function.[5] The simplest technique includes direct primary closure, followed by skin grafting, use of local and regional flaps and, finally, transfer of free or pedicled flaps of vascularized tissue.[1]

The aim of this study was to analyze the advantages and disadvantages of the procedures used to repair 116 traumatic injuries with loss of soft tissue in the upper limb, according to the affected segment.

MATERIALS AND METHODS

The study evaluated and reviewed cases of 116 patients (94 male and 22 female) submitted to surgical treatment of injuries with tissue loss of several different segments of the upper limbs, from April 2011 to November 2017. Patients were evaluated regarding age, sex, injury etiology, reconstituted area, reconstruction methods and complications. The mean age of patients was 25.6 years old (ranging from 18 months to 68 years old). Out of the 116 patients, 82 were over 18 years of age and 34 were less than 18 years old by the time of the surgery. All injuries were result from trauma: 51 work-related injuries; 43 traffic accidents; 7 burns; and 15 from other causes.

Injuries that had been primarily reconstructed and those compromising only the fingers were excluded from our evaluation. X-ray images were taken in appropriate positions to confirm or to discard skeletal injuries. In many cases, serial debridations were required until all the devitalized tissue was completely removed. The use of negative pressure treatment of the wounds allowed a stable temporary wound coverage before definitive reconstruction. All available participants adhered to institutional ethical precepts and the project was evaluated by the Ethics in Research Committee and registered in the *Plataforma Brasil* under the CAAE number 83985818.7.0000.5373.

RESULTS

The events involving upper limb segments, from proximal to distal, were shoulder and armpit (3); arm and elbow (15); forearm (20); fist and hand (78). Reconstruction procedures included 29 skin grafts; six advancement flaps; seven rotation flaps; 33 pedicled fasciocutaneous flaps; 26 groin flap;, four posterior interosseous artery flaps; three radial forearm flaps; nine free fasciocutaneous flaps, four of which were parascapular and 5 lateral arm flaps; 12 neurovascular free flaps; seven dorsal foot flaps; two dorsal foot flaps associated with the first commissure; a dorsal foot flap associated with the second toe transfer; a lateral arm neurovascular flap; a radial forearm neurovascular flap; 13 serratus anterior muscle flaps (10 free and 3 pedicled flaps) ; seven latissimus dorsi muscle flaps– two free flaps (one muscular and one musculocutaneous) and 5 pedicled flaps (2 muscular and 3 musculocutaneous) (Table 1).

Table 1. Distribution of the procedures according the affected segment.

	Shoulder and armpit	Arm and elbow	Forearm	Fist and hand	Total
Skin graft	–	4	7	18	29
Advancement flap	–	–	1	5	6
Rotation flap	–	–	3	4	7
Pedicled fasciocutaneous • Groin • Posterior interosseous artery • Radial Forearm			 4 3	26	33
Free fasciocutaneous • Para-scapular • Lateral arm		 4 5			9
Neurovascular free flap		–	–	12	12
Serratus anterior muscle flap	–	–	–	13	13
Latissimus dorsi muscle flaps	3	2	2	–	7
Total	3	15	20	78	

Table 2 describes the causes of complications . Six patients had partial or complete loss of the flap and reconstruction was achieved with skin grafts.

Table 2. Complications that occurred in patients submitted to free and pedicled flaps.

	Bruise	Seroma	Suture dehiscence	Problems in the donor area	Venous insufficiency	Arterial insufficiency	Flap loss	Nervous or vascular injury
Radial forearm flap				Donor area skin graft				
Posterior insterosseous artery flap					Flap loss by por venous insufficiency			
Lateral arm flap			Second intention healing		Parcial flap loss (2 cases)			
Scapular flap		Seroma in one case		Injury to the vascular pedicle (1 case)				
Groin flap		Seroma in 2 cases	In 2 cases	Flap disconnection (2 cases)				
Foot dorsal artery flap				Unacceptable scar (10 cases)	Parcial flap loss (2 cases)			
Serratus anterior muscle flap	In one case	Seroma in 5 cases			Flap loss (1 case)			Long thoracic nerve injury (1 case)
Latissimus dorsi muscle flap		Seroma in 4 cases						
Skin graft							Parcial graft loss (2 cases)	
Rotation flap			In one case					
Advancement flap							Parcial flap loss (1 case)	

DISCUSSION

The hands are coated by a special soft tissue consisting of skin, subcutaneous adipose tissue and fibrous septa. Hand skin is quite different in its palmar face and dorsal side. The palmar skin is hard and thick to support its constant usage and to protect deeper structures.[1,2] It presents low mobility, which difficults the rotation of local flaps in palmar skin injuries.[3] Thus, flaps from other places are frequently preferred for reconstruction.[5] Fasciocutaneous flaps are preferred in aesthetically sensitive areas such as hands. Muscle flaps can be designed to adapt to the contour of the lesions and are of great importance in patients with exposed tendons, as they provide a sliding plane for excursion of the tendon.[2,5]

The selection of a flap depends on the receiving area: its size and deepness; injury mechanism; exposed structures; structures that need reconstruction; contamination; color and texture of tissues that surround the lesion; and the need for recovering sensitivity.[6,7] It is also important to consider that, after debriding, the injured area is larger and deeper than before and the microvascular anastomoses must be placed outside of the injury zone. The morbidity of the donating area must be minimized.[4] The variety of available free flaps allows that the donating place can be individually chosen, according to the preference of the surgeon and based on the characteristics of the donating and receiving areas.[6] In the present study, the recovery of 116 upper limbs that suffered trauma (with or without associated bone lesion) was performed.

The radial forearm flap is commonly used as pedicled flap for the ipsilateral hand and it can also be used as free flap for the opposite hand.[5,6] The radial artery must be included in the flap and it is important to perform the Allen test, to ensure appropriate blood flow towards the hand through the ulnar artery, as a part of the pre-operatory planning.[5,7] Advantages of radial forearm free flap include its reliable anatomy, large vessels, long pedicle and wide versatility. It can be used as a composite flap with long palmar tendon, radius segment or lateral cutaneous nerve of the forearm.[6] The main disadvantage is the need of skin graft to coat the donating area, causing an unpleasant appearance specially for women.[7-9] In this study, the radial flap of the forearm was used in four limbs as a pedicled flap: two to coat the first commissure, one for the back of the hand and one as neurovascular flap for the palm. In another case, it was used as a free flap of the amputated hand, to cover a contralateral lesion (Figure 1). No complications occurred in these five cases.

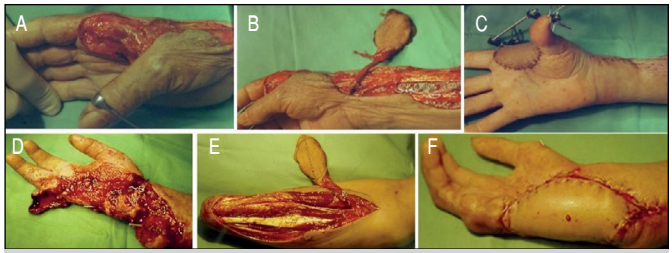

Figure 1 A, B, C. The radial forearm fasciocutanous flap (Chinese flap) to cover tissue losses of the first web space. An external mini fixator was used to maintain the opening of the first web space. **D, E, F.** The radial forearm flap was removed from the limb with amputated left hand and transferred as a free flap to cover tissue loss of the injured right hand.

The posterior interosseous artery flap provides a very fine quality skin to cover skin lesions on the hand. It is a reverse flow flap based on the distal communication between the anterior and posterior interosseous vessels (artery and vein).[10] After complete dissection of the pedicle, it can be rotated distally to reach the wrist and hand – but not the fingers.[10,11] If the pedicle is rotated proximally, it is possible to cover forearm and elbow lesions. The pedicle flap consists of the posterior interosseous artery and vein located between the extensor *carpi ulnaris* and extensor *digitorum* muscles.[10] The vessels that compose the pedicle flap are not frequently chosen as free flaps, once they have very thin caliber that difficulties anastomosis. The use of this flap is not recommended for patients with previous or current injuries in the distal wrist or forearm that could have compromised the communication between vessels.[10,11] They are recommended only in small injuries, once primary closure of the donor area is possible, which makes skin grafting unnecessary. The use of the fascia flap alone provides a thin flap allowing the primary closure of the skin.[1,11] Through such flap. it is exceptionally possible to incorporate a radium bone segment. In this study, flaps of the posterior interosseous artery were performed: two to coat the back of the hand (Figure 2); and one for the first commissure. In these three cases, primary closure was possible , without skin graft. In the fourth case, a fascia flap was performed, however, the flap was lost due venous insufficiency and the resulting area was coated with skin graft.

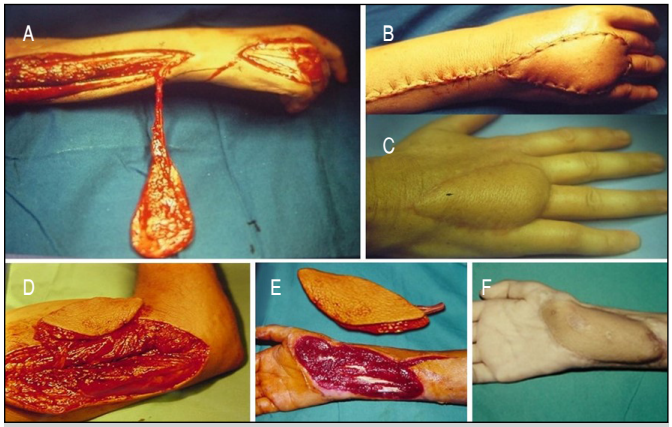

Figure 2 A, B, C. Posterior interosseous fasciocutanous flap to cover tissue loss of the dorsal aspect of the hand. **D, E, F**. The lateral arm flap has the advantage that it can be used as a free flap on the same side of the traumatized hand, so that dissection in both the donor and recipient area is restricted to the injured extremity.

The lateral arm flap receives vascular supply from the posterior radial collateral artery, which is the most calibrated branch of the deep brachial artery. It is located in the septum between the triceps and brachioradial muscles, it branches into the fascia, goes towards the skin of the lateral of the arm and ends up anastomosing with the interosseous recurrent artery, at the level of the lateral epicondyle of the humerus.[12] The flap can be lifted simply as a facia flap, decreasing the morbidity of the donor area. During the lifting of the flap, the radial nerve that lays at the side of the pedicle must be protected from lesions. The posterior cutaneous nerve of the arm – which is a sensitive branch of the radial nerve – goes along the vascular pedicle and sends sensitive fasciculus to the skin of the lateral of the arm, allowing it to be used as a neurovascular flap.[1,6] It can also be a composite flap, incorporating a segment of the humerus or triceps. It has the advantage of presenting a long pedicle with calibrated vessels that allow its use as a free flap at the same side of the traumatized hand, in such way that the dissection – both in the donor and receptor areas – is restricted to the injured extremity.[13,14] When such flap is wider than 7 cm, direct closure of its edges is not possible and skin grafting is required, which causes an unpleasant aesthetic aspect.[2,5,14] In this study, the latera flap of the arm was used as a free flap in five limbs: one of

them as a neurovascular flap to coat the palm of the hand (Figure 3). In two cases a partial loss of the flap occurred due to venous insufficiency; they were solved with skin grafting. In another case a suture dehiscence occurred that healed by second intention.

Figure 3 A, B, C. The scapular flap was designed to cover this deep lesion on the back of the wrist and hand. With this dimension, it is possible to directly close the donor zone. **D, E, F, G**. The pedicled fasciocutaneous groin flap repaired a tissue loss on the back of the hand. The Superficial iliac circumflex artery supplies the flap.

The scapular flap is projected transversely along the spine of the scapula and the para-scapular flap is located obliquely along the lateral edge of the scapula; they are based on transverse and descending branches of the subscapular artery, respectively. It is a fasciocutaneous flap that receives blood supply through the cutaneous branches of the circumflex scapular artery, which originates from the subscapular artery.[14-16] It has a long and reliable pedicle, with low morbidity of the donor area, which can usually be closured primarily.[14] A segment from the scapula can also be included in the flap.[2,6,14] Their disadvantages include the need of a intraoperative lateral positioning and the absence of a defined skin innervation in this region, so it cannot be used as a neurovascular flap.[6,14] In order to obtain larger amount of tissue in extensive reconstructions, it can be associated to muscle flaps from the latissimus dorsi and serratus anterior, in a single common subscapular pedicle.[2,6] Its use has been declined lately due to the advent of the anterolateral thigh flap.[13,17] In the present study, such flap was used in four limbs with extensive injuries involving hand and distal forearm and no complications were observed (Figure 4). In one case, seroma formation seroma occurred, but it was spontaneously solved. In another limb, the vascular pedicle was damaged during dissection and the procedure was aborted and the flap was placed back in its original position.

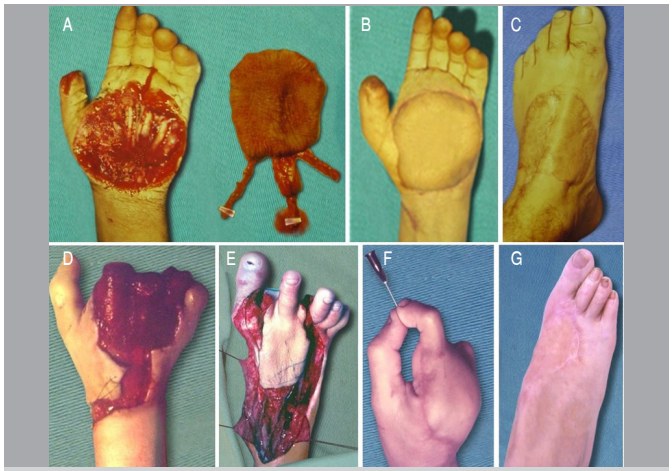

Figure 4 A, B, C. Neurovascular dorsalis pedis fasciocutaneous free flap to cover the palmar aspect of the hand. **D, E, F, G**. Dorsal neurovascular free flap of the foot, associated with the transfer of the second toe.

The groin flap is indicated in the recovery of extensive skin lesions involving the distal third of the forearm, fist and hand,[3,18] once it offers good quality skin for coating. It is an axial flap, thus it has a well-defined, constant and reliable blood circulation. The groin flap has as axis the surface of circumflex iliac artery, originated in the femoral artery–c.a. 2 cm distally from the inguinal ligament. The main advantage of groin flaps is that its use can be planned accordingly to the size of the injury in the upper extremity.[1,13,14] The main disadvantage is the need of a second surgery after three weeks of immobilization, revascularization and flap removal. Once it has a short pedicle, its use as a free flap is not recommended. It can be used as pedicled osteocutaneous flap, in which case the deep iliac circumflex artery must be incorporated into the flap, once it is the main responsible for the vascularization of the attached osseous segment.[1,14,18] Here, the pedicled groin flap was the preferential method for 26 patients with hand and fist injuries. In two cases an osseous segment from the iliac crest was incorporated into the flap to repair osseous tissue loss (Figure 5). In two non-collaborative patients, the flap was removed and placed back in donor area; in another two, the occurrence of seroma was observed, but it was spontaneously solved.

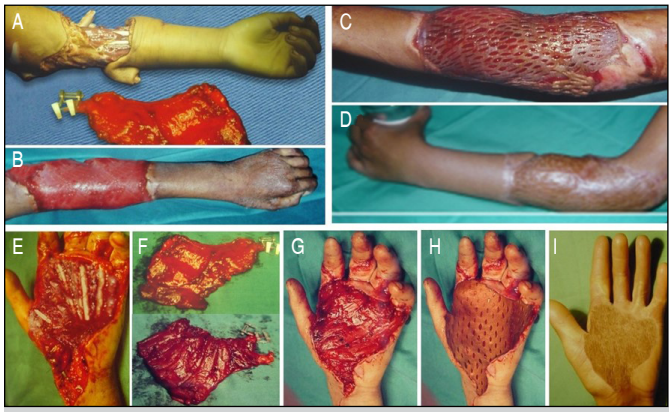

Figure 5 A, B, C. The anterior serratus muscle flap can be used as a free flap, as in this case, in which crushing with open fractures and loss of soft tissues occurred. **D, E, F, G, H, I**. The superficial portion of the serratus muscle was used to cover a lesion of the palm with exposure of the flexor tendons. The portion covered by the fascia is placed in contact with the flexor tendons to prevent their adherence to the musculature, with the bloody muscular area facing the surface, which is grafted with partial skin.

Dorsal foot flap has good quality and its tissue structure is similar to the hand.[19,20] Its main advantage is the good quality restoration of the hand palm surface and fingers sensitivity , besides being a fine flap that generates few volume when placed on the palm surface. It has a relatively long pedicle, reliable vascular anatomy and the potential to include specific vascularized structures, such as tendons. The inclusion of the fibular nerve surface in the flap allows it to be used as a neurovascular flap, while the inclusion of the deep fibular nerve makes it a neurovascular flap of first commissure.[2,20] However, the morbidity in the donor area may be a disadvantage in the use of such flap. Samson et al.[21] recommended that this flap should only be used when there are no other options available. To avoid more serious sequels, the flap should not be extensive and the distal edge must be at least 2 cm proximal to the digital mommissures.[21] In this study, foot dorsal neurovascular flap was used in ten upper limbs: 7 dorsal foot flaps, 2 dorsal foot flaps associated to the first commissure, 1 dorsal foot flap associated to the second toe transfer (Figures 6 and 7) (Table 1).

Partial flap loss was observed by venous insufficiency and in one case required skin graft. The morbidity of the donor area was unacceptable in all limbs.

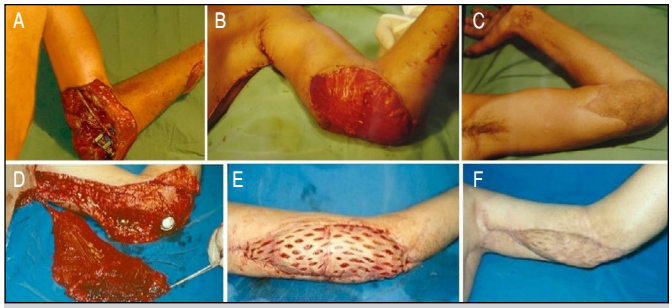

Figure 6 A, B, C. The anterior serratus muscle flap can be used, without the need for microvascular anastomoses, as in this case, in which an extensive injury occurred on the medial surface of the elbow, with associated ulnar nerve damage. **D, E, F**. Transposition of the vascular pedicle flap of the latissimus dorsalis muscle to cover a prosthesis of the elbow joint.

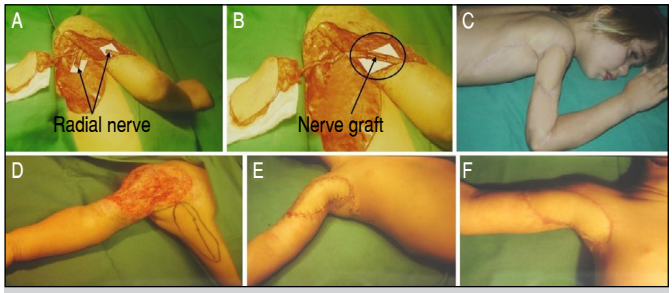

Figure 7 A, B, C. Injury with loss of soft tissue in the axillary region, covered with latissimus dorsalis musculocutaneous flap. **D, E, F**. Injury with loss of soft tissue and lesion of the radial nerve. The sural nerve was grafted and covered with latissimus dorsalis musculocutaneous flap.

The anterior serratus muscle flap is generally used to cover lesions that are not so extensive, it has a long and reliable pedicle, so it is a fine flap that fits well to the back and palm surfaces of the hand and forearm. The serratus muscle begins in the nine first ribs and inserts itself in the medial edge of the scapula, with the function of keeping it in position, avoiding its upper or posterior displacement. It has been of significant importance in reparations of upper limbs lesions.[22,23] No more than the last four attachments can be safely removed. It is innervated by the long thoracic nerve that originates from the roots C5, C6 and C7 of the brachial plexus. The inferior part, with more extensive attachments, receives blood supply through the artery of the anterior serratus muscle, which originates from the thoracodorsal artery, one of the terminal branches of the subscapular artery.[24] The anterior serratus muscle flap can be used as a free flap for extensive lesions of hands and forearms. For the coating of armpit, arms and elbow, only displacement of the flap can be used, without microvascular anastomoses, as its pedicle can reach up to 15 cm, if dissected until its emergence in the axillary artery. It can also be used as a musculoskeletal flap, by inserting its last digits in the costal arches.[25] The flap with the fascia of the serratus muscle cover can also be used. However, it is preferable to associate a muscular portion of at least one centimeter thick with the fascia, to facilitate the venous return. The damage in the donor area is minimal, just a linear scar in the middle axillary line, which is covered by the arm. In this study, the serratus muscle flap was used in 13 limbs: in two as a pediculate flap to coat arm and elbow areas (Figure 6); three free flaps in forearm; and eight free flaps for hands–three for palm and five for the back hand and fist web space (Figure 5). Only one case used the serratus fascia flap, in which total loss of the flap occurred due to venous insufficiency. In four cases presented seroma formation. In another case, injury of the long thoracic nerve was observed.

The *latissimus dorsi* muscle flap, supplied by the thoracodorsal artery is very reliable; it is the largest isolated muscle used to cover large defects in the extremities.[2] As the serratus muscle (scapular or para-scapular), its vascular supply comes from the same pedicle (subscapular artery) and it can be associated to more than one flap with a single pedicle.[14,24] The loss of muscle function at the donor site is compensated by the action of the teres major and pectoralis major muscle, non-athlete patients do not report significant disability due to the removal of the latissimus dorsi muscle, which should be removed from the non-dominant side.[2] The dissection is easy and it presents a long pedicle (8-11 cm) with large caliber vessels. It can be bused as a pedicled flap to repair injuries in shoulders and armpits, simply by flap transposition without vascular anastomoses[26,27] (Figure 7). The occurrence of seroma in donor area is frequent, if draining is not carefully performed. The thoracodorsal artery flap is based on perforating branches of the thoracodorsal artery and it can be used with minimal morbidity at the donor area.[14] Only one segment of the dorsal can be used.[28] In the present study, such flap was used in seven limbs, three as pedicled skin muscle to coat the deltoid area and armpit; two as pedicled flap for arm and elbow; and two for forearm–one musculocutaneous and one muscular. Seroma formation occurred in three cases.

CONCLUSION

The reconstructive procedures on the upper limbs are varied, from skin grafting to free flaps. The indication depends on the type of injury and the choice of the surgeon. The ultimate goal is to achieve the best functional result with the lowest possible morbidity.

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