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40 years of microvascular reconstruction with latissimus dorsi muscle free flap

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Abstract
Introduction: The first use of the latissimus dorsi as a myocutaneous flap was described as early as the end of the 19th century, in the coverage of an extensive defect following radical mastectomy (Tansini 1895). Subsequently, the surgical procedure was forgotten and later re-introduced as a pedicled flap for breast reconstruction (Olivari 1976). Olivari prompted the microsurgical team from Ljubljana to perform a free muscle transfer (Godina 1978). The first emergency free flap transfer in Ljubljana was performed in 1979.
Patients and Methods: Latissimus dorsi flap can be used as a muscle or musculocutaneous flap, in a pedicle or a free form. The procedure of reconstructing large tibial defects always proceeded as a two-team procedure simultaneously. For the continuity of the axial blood flow of the tibia, M. Godina developed end-to-side anastomosis.
Results: Using latissimus dorsi free flap for reconstruction of tibial defects the first statistics by M. Godina from 134 patients showed a 0.75% flap loss rate and 1.5% infection rate; an average healing time of 6.8 months and a bed rest period estimated at 27 days. In the case of delayed reconstruction, the author reported an infection rate of 17.5%.
Conclusions: Due to clinical experience, good results and a new doctrine of the Ljubljana School of microsurgery played a historical role in the reconstruction of the tibia with a muscular microvascular muscle flap.

Keywords: Microsurgery, tibial soft tissue defect, free muscle transfer

Introduction

The development of microsurgery is historically conditioned [1]. In 1921, the Swedish otologist Nylen used microscope enlargement for the first time in middle ear surgery [2]. This so-called microscopic manipulation then soon spread to other areas of medicine. With microinstruments, suitable sutures, and a surgical microscope, a surgical technique was thus developed that entered the individual disciplines of medicine [3]. Clinical microsurgery initially found a place in hand surgery in partial amputations, revascularizations, later in macro-replantations, and finally finger replantations [4].

With the knowledge of plastic surgery regarding the vascularization of individual tissue units, which were used as axial flaps for reconstructive purposes, the idea of free tissue transfer - axial flap on the vascular pedicle - was born [5, 6]. Thanks to the idea of free soft tissue transfer, microsurgery as a technique found an important place in plastic and reconstructive surgery rather than in vascular surgery [7]. In addition, the microsurgical technique utilizing meticulous, non-traumatic dissection, equipment with finer instruments, and good tissue vascularization mentality, enriched the reconstructive scale and arsenal of knowledge of the plastic surgeon [8]. Hence, free tissue transfers on the already described pedicled axial flaps, such as omental flap, inguinal flap, temporal flap and deltopectoral flap transfer, have been a logical continuation [7]. In the beginning, skin and skin-fascial free flaps were born, and later also muscle and bone-soft tissue flaps [3, 6, 9].

The beginnings of the 'Ljubljana Microsurgery School'

In addition to replantations and experimental microsurgery, the Ljubljana School left a large footprint in the free transfer of muscle flaps for reconstructive purposes [10-12]. This development was conditioned by the use of the latissimus dorsi muscle. Olivari, who used it as a pedicled flap transfer for breast reconstruction, personally prompted M. Godina and the micro-team to perform a free latissimus dorsi transfer [13].

Of course, a lot of experimental work was performed at first, as although the descriptive anatomy was well established in detail, the surgical anatomy of the dissection of the flaps, however, was still in its infancy. Pioneering work in this field was done by M. Godina and E. Eder [14]. The first free latissimus dorsi transfer was performed in 1978, and as an emergency free flap for tibia reconstruction in 1979 [15]. Later, the use of the free flap expanded. In addition to covering, the flap also served as a filling flap for obliteration of dead space, as a gliding flap, and as an innervated flap to restore function [16]. With regard to the use of the free flap, sophisticated and epochal work had been performed to cover soft tissue defects on the tibia [17]. At the same time, the saphenous flap of the thigh was also anatomically defined as a free flap [18]. Later, in 1987, we reported breast reconstruction with free transfer of the body's own tissue taken from the abdomen - TRAM flap [19]. A few years later, we developed a chimeric osteocutaneous free flap for mandibular reconstruction. At the turn of the millennium, an experimental study was made on the free transfer of jejunum into the soft tissue space for the regeneration of lymphatic ducts [20].

The flap was first used as a pedicled flap in 1895 for reconstruction of defect following an extensive, radical mastectomy [21]. Subsequently, it was forgotten and re-introduced by Olivari in 1976. The first free flap transfers followed: Godina 1978, Maxwell 1978, Watson 1979. The first emergency flap transfer in the University Medical Center Ljubljana was used in 1979 in the surgical treatment of an extremity trauma of a miner, caused by a mining cart [15].

Patients and methods

Latissimus dorsi muscle flap

The flap is a quadrangular flat back muscle. It is used as a muscle or musculoskeletal flap. As previously mentioned, it can be used in a pedicled or free form. With regard to the vascular anatomy, the flap is classified as type 5, which means that the muscle has a dominant vascular pedicle and a few smaller segmental parietal pedicles [8]. As anastomosis occurs between both vascular systems in the tissue, partial death of the transferred flap can be sometimes observed in the case of poor connection [6]. The muscle is innervated by the thoracodorsal motor nerve. The muscle itself can form the basis for a larger skin island, which can measure 40 x 20 cm, and such shape is called a tailored flap. The flap is distinguished by a long vascular pedicle measuring 10-12 cm, vascular diameter is 2-3 mm, and the artery is accompanied by a parallel vein [22]. Numerous variations of pedicles have been described, which we must be prepared for when elevating the flap [6]. The flap can be combined with the serratus anterior muscle as a mega flap, or with the scapular flap as a chimeric flap. Another option is a chondro-muscular flap, as some muscle is inserted to four lower ribs [16]. If taken with a nerve, a functional flap can be created that can be either pedicled or free. Further surgical forms include the thoracodorsal perforator flap, the gliding flap if the back wall fascia itself is taken, and the axillary flap on the cutaneous arteries of the armpit [3]. As a prefabricated free flap, it did not have major value.

Ideas and innovations

From the beginning, the reconstruction of the tibia was performed on the basis of a collaborative team approach, in the case of fractures together with traumatologists, and in the case of tumour resections with oncologists and orthopedists. The surgery was also carried out by two teams simultaneously. Therefore, the lateral positioning of the patient with the raised arm has been developed to allow optimal access to the armpit and the entire back region. The operated leg with Esmarch tourniquet is positioned beneath. This allows two teams to operate simultaneously and the patient does not need to be turned. This position is also appropriate for access to the dorsal tibia [7].

The selection of the receiving artery is very important [23]. This should be as far away from the injury zone as possible, the lumen ratio should be appropriate, and there should be as little fibrous tissue as possible in the vicinity. Prior to surgery, angiography of the tibial arteries is performed to rule out any vascular pathology and to assess patency. Most commonly we opt for *a. tibialis posterior*, which is far from the injury zone, protected by the bone and lying deeper compared to *a. tibialis anterior*. Perioperatively, the latter showed greater spasticity [17]. For the continuity of the axial blood flow of the tibia, M. Godina developed both experimental as well as surgical end-to-side anastomosis [24]. Good hemodynamic properties have been demonstrated, flow is adequate, and the risk of re-thrombosis is lower. The receiving veins are deep comitant veins, and the superficial venous system is generally avoided. Vein anastomoses are end-to-end. Postoperatively, free flap monitoring is performed on the ward in the form of "q1h" (hourly) observation protocol.

Results

Immediate reconstruction of tibial defects

By definition, immediate, emergency free soft-tissue transfer, if the patient's general condition is appropriate, requires team surgery, consisting of necrectomy, internal or external osteosynthesis, restoration of circulation if necessary, and immediate closure with an appropriate flap within the first 24 hours after injury [25, 26]. Primary reconstruction does not require the exclusive use of a free latissimus dorsi flap. For these purposes, flaps such as *m. serratus*, *m. gracilis* or *m. rectus abdominis* can also be used, depending on the size of the defect after necrectomy. From the very beginning, we have been advocating the doctrine of the emergency free flap use [17]. Already the first statistics by M. Godina from 134 patients showed a 0.75% flap loss rate and 1.5% infection rate; an average healing time of 6.8 months and a bed rest period estimated at 27 days. In the case of delayed reconstruction, the author reported an infection rate of 17.5% [7], which is significantly higher than in the case of immediate reconstruction. An important emphasis is on soft tissue necrectomy, which ultimately results in a clean anatomical wound. At the same time, we also perform a fasciotomy of all four tibial compartments, if necessary. In the case of amputation, consensus is required between the traumatologist, plastic surgeon and the patient.

Discussion

In literature, the classification of immediate soft tissue defects is very heterogeneous. In the initial years, the Clinical Department of Plastic, Reconstructive, Aesthetic Surgery and Burns of the University Medical Center Ljubljana, together with traumatologists, developed a classification of acute post-traumatic defects of a more descriptive nature; burns, muscle compartment, soft tissue defect not involving a bone defect (laceration, lacero-contusion, contusion, avulsion), open fracture, segmental defects of the tibia, lower-limb amputation [7]. With regard to the classification of open fractures (Figure 1 and 2) resulting in severe soft tissue injury, however, the classification according to Allgöwer (1971) was used first, and then according to Tscherne (1983), which was more precise. Less commonly, we used the Byrd (1985) classification, which takes into account the degree of soft tissue loss. Ultimately, we used the Gustilo classification (1984).

Coverage of a chronic tibial wound

Experience with treating soft tissue defects of the tibia soon led to the realization that the treatment of a chronic defect is significantly more difficult compared to the acute form. Fibrous tissue, infection, inflammation, swelling, discharge – all of these are additional defects that make reconstruction all the more difficult [25]. This has been shown in chronic osteomyelitis of the tibia (Figure 3) [27]. In the first decades of coverage with the microvascular latissimus dorsi flap in Ljubljana, methods of treatment such as soft tissue and bone necrectomy, the use of garamycin impregnated spacers, osteosynthesis if necessary, and coverage with muscle, were developed [27]. After many years of experience, antibiotic action of the flap lobe was demonstrated with appropriate clinical signs such as reduction of inflammation, reduction of infection, swelling and scarring. A quality flap also ensured further reconstructive interventions on the bone. The fact is that muscle is much better vascularized than the fascia or skin and has bactericidal action [6]. Further research also showed that by establishing a vascular network, we increased the flow of antibiotics and other tissue and immune mediators, including complement and immunoglobulins, as well as oxygen content. Leukocyte activity was increased in terms of phagocytosis and bactericidal activity [25]. The muscle itself had an advantage, not only providing coverage but also filling the dead space. Necrectomy is very important in surgical treatment, which has always been emphasized by the Ljubljana School. In subsequent years, a flap selection algorithm was then developed for chronic osteitis of the tibia [28]. Thus, as a rule, we now use a gastrocnemius pedicled flap for the upper third of the tibia, and less often, a free latissimus dorsi muscle flap. For the middle third of the tibia, we usually use the latissimus dorsi muscle flap, in larger defects in combination with the serratus muscle. For the distal third, we use the serratus anterior or gracilis muscle, and the latissimus dorsi muscle (Figure 4) in case of extensive defects. Throughout, treatment was conducted in conjunction with the traumatologist responsible for bone necrectomy and further bone reconstruction. In recent times, the number of patients has declined, due to better antibiotic therapy, better surgical osteosynthesis, and a decrease in the number of war injuries [15].

Figures are taken from an archive of Clinical department of plastic, reconstructive, aesthetic surgery and burns, University medical centre of Ljubljana.

Fig 1: Comminuted tibial fracture with soft tissue defect.

Fig 2: Osteosynthesis with external fixator and coverage with free latissimus dorsi muscle flap.

Fig 3: Chronic osteomyelitis of the tibia

Fig 4: Condition after reconstruction with free latissimus dorsi muscle flap.

Conclusion

Muscle flaps, microvascular surgery and bone transport are milestones that have dramatically contributed to surgical treatment of severe tibial injuries. The aforementioned surgical procedures and techniques alone dictate an interdisciplinary approach, team management of the patient and a highly qualified medical institution. All these conditions were met. Nevertheless, the tireless pioneering and experimental work of M. Godina and his colleagues should be highlighted. Clinical experience, good results and a new doctrine emphasize the historical role of the Ljubljana School in the reconstruction of the tibia with a muscular microvascular muscle flap. After the epochal work 40 years ago, work at the University Medical Centre then continued further.

Despite the current use of VAC drainage, hyperbaric oxygen therapy ventricles, and dermal xenografts, free muscle flap reconstruction remains an indispensable, solid element in the reconstruction of tibial defects. The combination of the listed methods and perhaps even new ones, brings even better results and patient satisfaction.

Conflict of interest

The authors report no conflict of interest.

Statement of all funding sources

There were no funding sources involved.

Data availability statement

The authors confirm that the data supporting the findings of this study are available within the article and its supplementary materials.

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