RECONSTRUCTION OF LARGE SKIN DEFECTS OF THE PEDIATRIC UPPER EXTREMITY

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Reconstructive surgery for large tissue repair underwent important changes at the end of the 1970s because of the conjunction of two factors: the application of concepts and techniques of adult reconstructive surgery to children in the early 1970s, and a real separation of surgery for adults and children into the jurisdiction of different departments.

HISTORICAL REVIEW

In a century, reconstructive surgery has had a long maturation. Three axes of development had been the basis for such surgery. The first was a conceptual one, illustrated in 1862 by Wood’s use of a cutaneous axial flap, followed by the description and use of an island flap in 1917 by Esser, and, last, by the realization of the pedicle latissimus dorsi flap by Tansini in 1892.

The second axis of development is the possibility of vascular anastomosis, described by Carrel in the beginning of the 20th century and the use of the operative microscope by Nylen.

Finally, the very fine description of anatomy and vascularization of teguments and skin by Manchot and Salmon is the third axis of development.

After World War II, authors such as Ger, Bakamjian, and Orticochea used muscle flaps almost exclusively, but the crystallization of all these concepts, techniques, and anatomic descriptions in the 1970s led to the rise of reconstructive surgery.

In 1972, Jackson and McGregor described the groin flap, vascularized by the circumflex iliac superficial artery. This flap is practically the same that was described by Wood in 1862. Daniel and Taylor, in 1973, were able to do the first free groin flap revascularized by microanastomosis.

PEDiatric SURGERY

New disciplines, such as pediatric orthopedic surgery, have allowed surgeons to care for children in a very specific way. Harii, in 1975, for the first time related the use of a free groin flap in two 4-year-old children. Ohmori and Harii used the same procedure in a 3-month-old baby a short time later. The smallness of structures no longer was an obstacle for microsurgery. Nonetheless, reconstructive surgery using flaps in children is specific:

The thickness of the adipofascial layer is much more important in children than in a normal adult. Care should be taken in the surgical manipulation of this delicate and poorly vascularized tissue, which is prone to become infected or necrotic. The fat content of the subcutaneous tissue can also be an obstacle to raising a myocutaneous flap.

On the other hand, the suppleness of tissue in children makes the dissection of the pedicles easier. The size difference between children and adults also shortens the time needed to raise a flap.

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In fact, the caliber of the vessels is relatively more important in children than in adults. Evaluation provided by all authors who perform microsurgery in children are converging: 0.8 to 1.5 mm for Parry and 0.8 mm average for Devaraj. The author’s experience is that a caliber more than 0.8 mm is mandatory for reliable anastomosis, and that venospasm in children is frequent and must be prevented. Other factors contributed to the development of this kind of surgery, including advances in pediatric anesthesiology and oncology.

**MATERIAL AND METHOD**

The authors report here the experience of Hospital Trousseau from Paris, in which a team led by Gilbert and Masquelet, between 1977 and 1999, described some important flaps, such as the scapular flap or posterior interosseus flap for coverage of large skin defects of the upper limb. The authors reported 83 flaps done by these surgeons in a period of 22 years.

The trend of the authors’ team is to use free flaps only when a pedicled flap is not available to the defect. In 1980, favorable conditions permitted the authors to develop the surgery of pedicled flaps by numerous anatomic studies. A pedicled flap is used as frequently as possible (Fig. 1). It is a reliable and fast technique that is done in the same traumatized limb. The free flap is used only when no local or regional procedure is available.

**Etiology and Localization**

Causes were largely dominated by sequelae of burns and traumatic injuries. Other causes are specific to children, including sequelae of tissue defects caused by purpura fulminans, congenital malformation, and sequelae of compartment syndrome at the forearm level (Table 1).

The localization of the defect was chiefly the hand and wrist, and the elbow, mainly corresponding to the sequelae of burns (Table 2).

**Type of Flaps**

Figure 2 allows the reader to ascertain that the authors rapidly abandoned the groin flap in the year 1980. Groin flaps are not easy to perform in children because of the thickness of the subcutaneous tissue and the difficulty in immobilizing strictly the upper extremity in a child. New flaps such as the radial forearm flap and, later, the poste-

**Table 1. CAUSES OF LARGE SKIN DEFECTS IN THE UPPER LIMB**

<table>
<thead>
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<th>Causes</th>
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<tr>
<td>Burns</td>
<td>55</td>
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<tr>
<td>Trauma</td>
<td>18</td>
</tr>
<tr>
<td>Purpura fulminans</td>
<td>2</td>
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<td>Malformations</td>
<td>4</td>
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<td>Volkman</td>
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**Table 2. LOCALIZATION OF FLAPS**

<table>
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<tr>
<th>Shoulder</th>
<th>Axilla</th>
<th>Arm</th>
<th>Elbow</th>
<th>Forearm</th>
<th>Wrist</th>
<th>Hand</th>
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rior interosseous flap, have increasingly improved reconstructive surgery of the upper limb in children and adults.

At the end of 1980, the radial forearm flap (Fig. 3) was progressively abandoned because of its vascular sacrifice. Other flaps need no sacrifice of a main artery, such as the ulnar flap or posterior interosseous flap.

**Indication**

Following are the indications for each flap and a brief summary of indication according the level of injury.

The latissimus dorsi flap is a well-known procedure for coverage of the shoulder girdle and arm. Its arc of rotation allows it to easily cover the
posterior aspect of the elbow because the trunk is relatively longer in children than in adults. Reconstructive surgery of the shoulder girdle after malignant tumor excision requires mobilizing the latissimus dorsi muscle to cover a prosthesis or an allograft of the upper part of the humerus (Fig. 4).

Excision of metastatic lesions of the lungs must be done by thoracic approaches, sparing the latissimus dorsi so it eventually can be used for a soft tissue repair.

The scapular flap was used initially as a free flap to cover skin defects secondary to release of

**Figure 4.** Skin necrosis after a prosthetic reconstruction of the shoulder (osteosarcoma). *A*, Skin defect. *B*, Small latissimus dorsi flap raised (no vascularised distal muscle). *C*, Result 4 years later.
retractile scar in neonatal compartment syndrome or burns. This flap was preferred to the groin flap because the adipofascial layer was thinner and the pedicle longer and more reliable. Repair of the axilla is the elective indication for the pedicled scapular or parascapular flap (Fig. 5). Defects of the axilla secondary to release of a scar should be repaired by a cutaneous flap. A muscle flap ensures a fibrous tissue and recurrence of the limitation of mobility. As far as possible, it is better to use a parascapular flap; rotation of the flap is 90° instead of 180° for the scapular flap, and the donor site is easy to close.

The lateral arm flap, supplied by the posterior

Figure 5. Scar retraction of the axilla in burns. A, Design of the flap. B, Parascapular flap raised. C, Primary closure of the donor site. D, Result with a complete abduction of the shoulder.
branch of the deep brachial artery, has never been used as a free flap in the authors' experience. It has proven to be very useful for coverage of the anterior aspect of the elbow after release of a retractile scar, to provide a supple skin. The flap is distally based, supplied by an adipofascial pedicle nourished by anastomosis with the ascendancy branch of the posterior interosseous artery. Alternative procedures include the pedicled muscle arm flap and the myocutaneous flap of the brachioradialis.

The radial forearm flap, including the radial artery, was introduced rapidly in France by Gilbert and Merle in 1981 and has revolutionized the reconstructive surgery of the upper limb and the conception of the vascular supply of the pedicled flaps.

As stated, after initial intensive use, the authors have practically abandoned it for other procedures requiring fewer sacrifices. Nevertheless, indications for the radial forearm flaps persist; for instance, when the defect involves all the dorsum of the fingers, which cannot be covered by the posterior interosseous flap.

First performed on a child in 1985, the posterior interosseous flap is useful for coverage of the hand and wrist. Its main indication is repair of the first web and coverage of the dorsum of the hand (Fig. 6). Its use requires the integrity of the anastomosis between the anterior and posterior interosseous artery at the distal forearm in the case of electrical burn. Limited skin loss of the posterior aspect of the elbow also can be covered by a proximally based flap raised on the posterior aspect of the distal forearm.

Some other flaps were used rarely in the authors' series. The distal ulnar flap supplied by a skin branch issued from the ulnar artery is actually a rotation flap. The indications are precise but limited. It is suitable for defects of the ulnar side of the hand (Fig. 7) or the dorsum of the wrist.

The brachioradialis muscle flap, already mentioned, is indicated for the lateral or anterior aspect of the elbow joint.

Figure 6. Posterior interosseous flap for coverage of a skin defect after subcutaneous chemotherapy injection. A, Excision of the scar and dissection of the posterior interosseous flap. B, Coverage of the skin defect and ransom of the donor site, which have been grafted.
The following is a summary of pedicled flaps according to site.

Shoulder girdle and arm: latissimus dorsi
Axilla: scapular or parascapular flap
Elbow joint:
  Anterior aspect: lateral arm flap and brachioradialis muscle flap
  Posterior aspect: latissimus dorsi and posterior interosseous flap, radial forearm flap
Hand and wrist
  Radial forearm flap, posterior interosseous flap (dorsum of the metacarpophalangeal (MP) joint included), distal ulnar flap, groin flap

The indication for free flaps at the upper limb results from huge defects caused by traumatic injuries or electrical burns. In fact, the indication for a free flap in children at the upper limb is rare. Electrical burns represent a specific and chal-
lenging problem because of the vascular lesion, which can be located far from the initial site of injury. In many cases, pedicled flaps are not available. A free flap should be employed with skin grafts so that anastomosis can be performed in a healthy area.

COMPLICATIONS OF FLAP SURGERY IN CHILDREN

In the authors’ series of flaps at the upper limb and lower limb, no general complications were found. Expertise in flap surgery and anesthesiology allows complex procedures, including, at the same time, excision of tumor, possible replacement of bone through reconstruction, and soft tissue repair by a flap. No child has needed blood transfusion in direct relationship with flap surgery.

Local complications in the postoperative course in the total series, including lower and upper limb (289), are very rare. The main complication is ischemic necrosis. It averages 10% whatever the type of flap. For a free flap, necrosis is total. For a pedicled flap, necrosis is partial and involves an extremity of the flap. Special care should be taken regarding the distally based pedicled flaps, where the venous return can be impaired by a kinking or twist of the pedicle.

EVOLUTION OF THE FLAP WITH GROWTH

At the beginning of the authors’ experience, one of the main questions was the effect of growth on the flaps. Following some patients for 20 years allows the authors to draw the following conclusion: In very mobile areas like the joints, it is preferable to use fasciocutaneous flaps because skin flaps are subject to growth. On the contrary, the use of a muscle flap leads to fibrous tissue, with a late recurrence of the retraction.

Paradoxically, a skin flap acquires a large volume several years, later at adolescence. This evolution to a bulky aspect is probably attributable to the blood supply, which plays a role in growth. This notion implies long-term follow-up to prevent the bulkiness of the flap by using compressive garments and excision of subcutaneous tissue.

Muscle flaps can be employed only in nonfunctional areas such as the middle segments of the limbs.

EVOLUTION OF THE DONOR SITE

When raising a flap, it is always preferable to close primarily the donor site. For that reason, the authors prefer to employ muscle flaps instead of musculocutaneous flaps except in some conditions in which a skin paddle is absolutely necessary. The muscle flap is then covered with a split-thickness skin graft. Donor sites of fasciocutaneous flaps usually are covered with a skin graft. Tight closure must be avoided in children to prevent compartment syndrome.

In nonfunctional areas, thick skin grafts do not retract as a result of growth. Scars can be improved at adolescence by skin expansion and excision.

Finally, no growth disturbance of the shoulder girdle or spine has been noted secondary to raising the latissimus dorsi muscle.

SUMMARY

Reconstructive surgery of the locomotion apparatus in children has been built from several surgical advances. It is a specific activity that cannot be detached from all other orthopedic pediatric surgery. The care of problems in a child must be provided with a holistic point of view: It cannot be the addition of different techniques done by different surgeons. Bone morphology has a close relationship with the soft tissues; an injury of the envelope has consequences for growth harmony.

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