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Onco-reconstructive supermicrosurgery

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ABSTRACT

Supermicrosurgery is sophisticated microsurgical technique, which allows dissection and anastomosis of blood/lymphatic vessels and nerves with external diameter of 0.5 mm or smaller. With increasing attention to quality of life of cancer survivors, less invasive and functionally-better oncological reconstruction using supermicrosurgical techniques is warranted. Unlike conventional free flap reconstruction, supermicrosurgical free flaps can be elevated from anywhere using innominate vessels with diameter of 0.1 mm or larger, allowing patient-oriented least invasive reconstruction. Since lymphatic vessels can be anastomosed, lymphatic reconstruction is possible with supermicrosurgery, which plays an important role in management of cancer-related lymphedema. Supermicrosurgeons can harvest vascularized tissues such as skin, fat, fascia, tendon, ligament, bone, muscle, and nerve separately, and reconstruct complicated defects with three-dimensionally-inset multi-component tissue transfer.

Introduction

With advancement of reconstructive microsurgery, various flaps have been applied into reconstruction of defects after oncological resection. First, locoregional flaps such as pectoralis major myocutaneous flap, deltopectoral flap were used without microsurgical anastomosis. Once microsurgical vascular anastomosis became popular, free myocutaneous flaps started to be used for immediate reconstruction of oncologic defects [1–3]. Although myocutaneous free flaps allow immediate reconstruction with better results and handling of flaps compared with locoregional flaps, these flaps are associated with significant donor site morbidities and hardly achieves esthetic reconstruction because of bulk due to the muscle included in a flap. With further advancement of microsurgery, three-dimensional, functional, esthetic, and less morbid reconstruction can be performed with supermicrosurgical techniques [4–7]. Supermicrosurgery, the emerging sophisticated microsurgical technique, is becoming to play an important role in oncologic reconstructive surgery.

Supermicrosurgery

Supermicrosurgery entails microsurgical procedures such as dissection or anastomosis of vessels with external diameter around 0.5 mm [6–13]. Some define supermicrosurgery as microsurgical techniques for vessels of 0.8 mm or smaller in diameter, while others define it for 0.5 mm or smaller vessels [6,7,9,10,12]. The latter definition would be better, because important clinical applications of supermicrosurgery include lymphatic anastomosis; most lymphatic vessels are smaller than 0.5 mm. In this review article, supermicrosurgery is defines as for 0.5 mm or smaller vessels or nerves.

From the technical point of view, microsurgery, in which 1–2 mm vessels are mainly manipulated, entails anastomotic procedures similar to those of macroscopic vascular anastomosis; a needle is inserted into a vessel lumen using the right hand, catching all the layer of the anterior wall and not catching the posterior wall, with the guidance of the left hand's forceps inserting into the vessel lumen. Basically, techniques for microsurgical and macroscopic anastomoses are the same. Unlike microsurgery or macroscopic vascular surgery, 0.5 mm or smaller vessels are anastomosed in supermicrosurgery, where even small micro-forceps cannot be inserted into a vessel lumen to guide suture; a needle has to be inserted into a vessel lumen based only on the right hand's sensation via the needle tip without the left hand's guidance using micro-forceps (Fig. 1). Therefore, techniques for supermicrosurgical anastomosis are different from those for microsurgical or macroscopic vascular anastomoses.

Since supermicrosurgery is technically more demanding than microsurgery, specialized training is required to learn the

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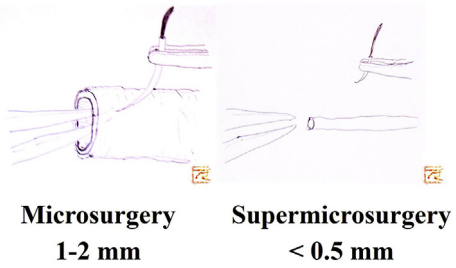

Fig. 1. Differences between microsurgery and supermicrosurgery. Unlike in microsurgery, forceps cannot be inserted into a vessel lumen to guide suturing in supermicrosurgery.

techniques. Several training methods have been reported, and the most common ones are rat training model and chicken training model [6,7,9,10]. Rat epigastric artery or femoral lymphatic vessel are around 0.3 mm in diameter, which is good for supermicrosurgical anastomosis training. Chicken non-vital models use chicken wing or chicken thigh; chicken wing has smaller vessels around 0.3 mm. Being convenient and readily available, chicken model is better for starting supermicrosurgical training. After becoming familiar with manipulations on supermicro-vessels using chicken model, rat model is recommended to simulate vital supermicrosurgical anastomosis; short-term and long-term patency can be evaluated using epigastric artery flap model [7,10].

From the clinical point of view, supermicrosurgery has a significant potential to improve surgical reconstructions. With supermicrosurgical techniques, less invasive and more sophisticated reconstructions are possible. Major clinical applications of supermicrosurgery are; small tissue replantation, true perforator flap transfer, fascicular neuroraphy, and lymphatic anastomosis [7–12].

Small tissue replantation

Since small tissue is nourished by tiny vessels with diameter of 0.5 mm or smaller, secure replantation of such small tissues can be achieved only with supermicrosurgery; digital tip, nasal tip, lip, ear, eyelid, etc. Replantation surgery is required not only in trauma cases, but also in oncological cases, such as in ex-situ excision; distal tissue resected with cancer lesion can be replanted after back-table cancer removal [6,7,13].

True perforator flap transfer

Unlike conventional perforator flaps, true perforator flaps contain only a perforator as a vascular pedicle; no nominate vessels are included. For example, an anterolateral thigh (ALT) perforator flap has the descending branch of the lateral femoral circumflex artery, whereas an ALT true perforator flap includes only a perforator, an innominate vessel perforating the deep fascia to the skin. Since perforators exists anywhere in the human body, surgeons or patients can select favorable donor site, which allows patient-oriented tissue transfer [4,5,14–17].

Fascicular neuroraphy

Nerve gaps are usually treated with nerve transfer or grafting with donor site morbidity. When a nerve gap is relatively short, the gap can be repaired with fascicular turnover flap method. Some parts of fascicles are turned to bridge the gap from the proximal or the distal stump of the nerve. With supermicrosurgical techniques, even a single fascicle can be securely dissected and coaptated. Since the same nerve is used for nerve gap bridging, turnover flap neuroraphy allows less invasive nerve reconstruction [6,9,10].

Lymphatic anastomosis

In oncologic surgery, lymphatic tissue is resected or irradiated with cancer lesion. After lymph node dissection or radiotherapy, lymphatic vessels can be ruptured or obstructed. Rupture of lymphatic vessels results in lymphorrhea or lymphocyst, and obstruction of lymph flows results in lymphedema. In most cases, these lymphatic vessel-related disorders are intractable refractory to conservative treatments. To address these challenging problems, anastomosis of lymphatic vessels, with external diameter around 0.3 mm, is applied into clinical practice with development of supermicrosurgery [6,11,12,18,19].

Head and neck reconstruction

When recipient vessels locate not far from a defect region, true perforator flap can be applied. Superficial circumflex iliac artery perforator (SCIP) flap is becoming a popular true perforator flap in reconstructive supermicrosurgery. Unlike other flaps, no muscle is sacrificed and donor site scar is concealable (Fig. 2). SCIP flap can be used for any part of head and neck regions, such as parietal, frontal, occipital, temporal, facial, oral, and neck defects (Fig. 3) [6,20,21].

Breast reconstruction

Deep inferior epigastric artery perforator (DIEP) flap is the most common flap for autologous breast reconstruction. Other flaps such as profunda femoris artery perforator flap, gluteal artery perforator flap, and lumbar artery perforator flap are used [22–24]. Usually, these perforator flaps require inter- and/or intra-muscular dissection to include a nominate large pedicle vessel, which entails somewhat invasive procedures. When used as true perforator flaps only with innominate perforator not including nominate vessels, these perforator flaps allow less invasive breast reconstruction with the use of perforator-to-perforator anastomosis. SCIP flap can also be used for breast reconstruction (Fig. 4).

Extremity reconstruction

Since there are many perforators in extremities, various true perforator flaps can be transferred with perforator-to-perforator anastomosis, such as SCIP flap, thoracodorsal artery perforator

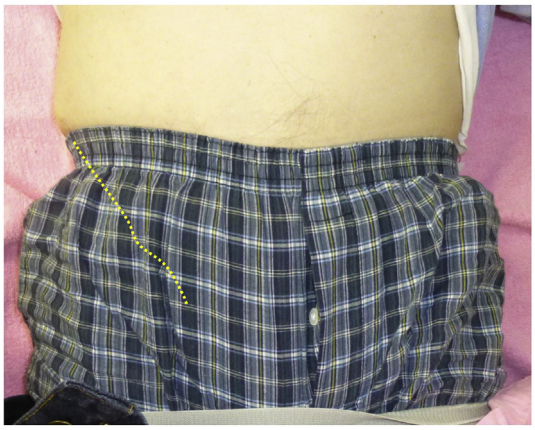

Fig. 2. Donor scar of superficial circumflex iliac artery (SCIA) perforator (SCIP) flap. SCIP donor site scar (dotted line) can be concealed with an underwear.

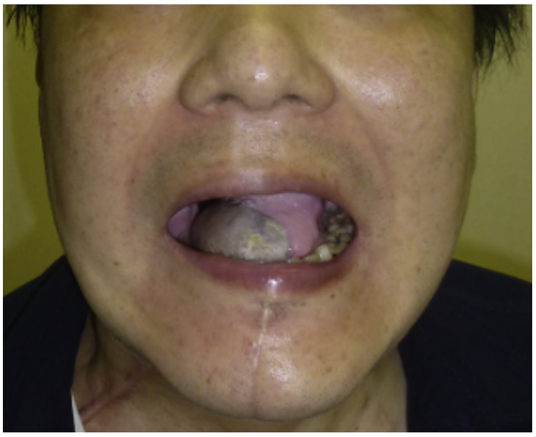

Fig. 3. SCIP flap for head and neck reconstruction. A SCIP flap is used to reconstruct the tongue after hemiglossectomy.

flap, paraumbilical perforator flap, peroneal artery perforator flap, and anterolateral thigh true perforator flap [6,14,20,25,26]. Among them, SCIP flap is useful for concomitant lymphatic reconstruction as described precisely below in "Lymphatic Reconstruction" and leaves esthetically pleasing donor site scar. Functional muscle, bone, nerve, tendon/fascia can be simultaneously reconstructed with chimeric flaps [6,15,17,31].

For reconstruction of the hand, the fingers, and the thumb, short pedicle toe flaps and super-thin true perforator flaps are used to achieve functionally- and esthetically-pleasing results. Although toe flaps are not frequently used for simultaneous reconstruction of the digit, donor site of toe flap can be less-invasively reconstructed with domino SCIP flap [13,20,28].

Trunk and perineal reconstruction

Although a conventional flap is considered reliable to reconstruct a large defect necessitating reconstruction of hard tissue such as chest/abdominal wall and pelvic floor, true perforator flaps and chimeric perforator flaps can be used [3,6,22,29]. With the use of chimeric SCIP flap including vascularized deep fascia based on the deep branch of the superficial circumflex iliac artery is useful to reconstruct the abdominal wall or the pelvic floor without anastomosis [20,30]. Unlike pedicled tensor fascia lata flap which is the most popular flap for the reconstruction of lower part of the abdominal wall below the umbilicus level, chimeric SCIP deep fascia flap allows upper part of the abdominal wall beyond the umbilicus (Fig. 5) [6,21,27,30].

Nerve reconstruction

Vascularized nerve true perforator flap is a useful option to treat sensory deficit or motor nerve injury. Compared to a nerve graft without vascular pedicle which is the most common method for nerve reconstruction, vascularized nerve flap allows more rapid nerve regeneration after neuroraphy; rapid nerve regeneration is especially important for motor nerve reconstruction such as facial reanimation surgery. When a nerve defect is relatively short, fascicular turnover flap can be used as previously described [8–10].

Lymphatic reconstruction

There are two types of lymphatic problems; lymphocyst/lymphorrhea due to lymphatic vessel rupture, and lymphedema due to lymph flow obstruction. Both disorders can be caused by oncological resection especially with lymph node dissection or irradiation [6,11,18,19,32–36]. For the treatment of lymphocyst/lymphorrhea, conservative treatments such as aspiration, drainage, and compression are applied first, and surgical treatment is considered when refractory to conservative treatments. Massive or macroscopic ligation is performed, but sometimes insufficient to stop the leakage. For secure treatment of lymphocyst/lymphorrhea, ruptured lymphatic vessel should be anastomosed to a nearby lymphatic vessel or vein; lymph flow is reconstructed physiologically [18].

Lymphatic anastomosis is applied also for lymphedema treatment. Although lymphaticolymphatic anastomosis (LLA) can be a possible therapeutic option, a long lymphatic vessel graft is required to bridge from an obstructed lymphatic vessel to an intact lymphatic vessel over an obstruction site, which makes LLA impractical due to invasiveness. In most cases, lymphaticovenous anastomosis (LVA) is applied into lymphedema treatment refractory to conservative treatments (Fig. 6) [6,11,12,15,19,37,38].

Lymph node transfer (LNT) is performed for progressed lymphedema cases refractory to LVA due to severe lymphosclerosis [15,27,39–44]. As in other true perforator flaps, LNT can be performed using true perforator lymph node flaps with perforator-to-perforator anastomosis. Various kinds of lymph node true

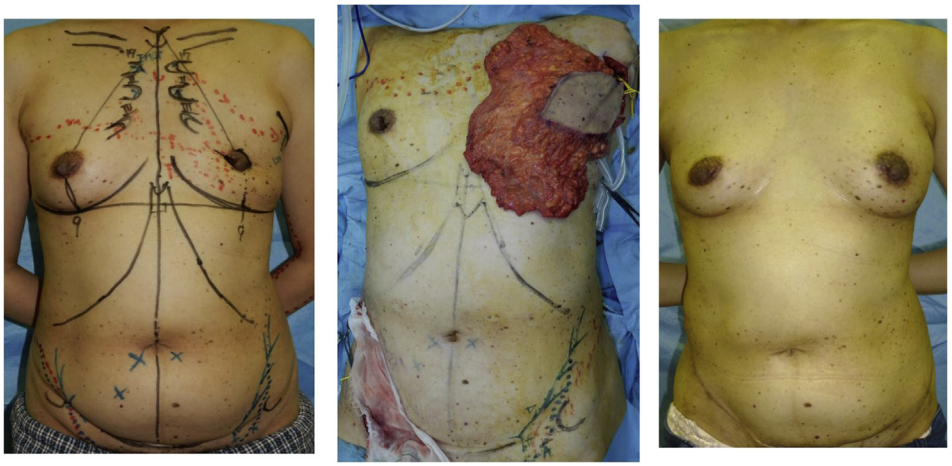

Fig. 4. SCIP flap for breast reconstruction. An extended SCIP flap based on the deep and the superficial branches of the SCIA is transferred.

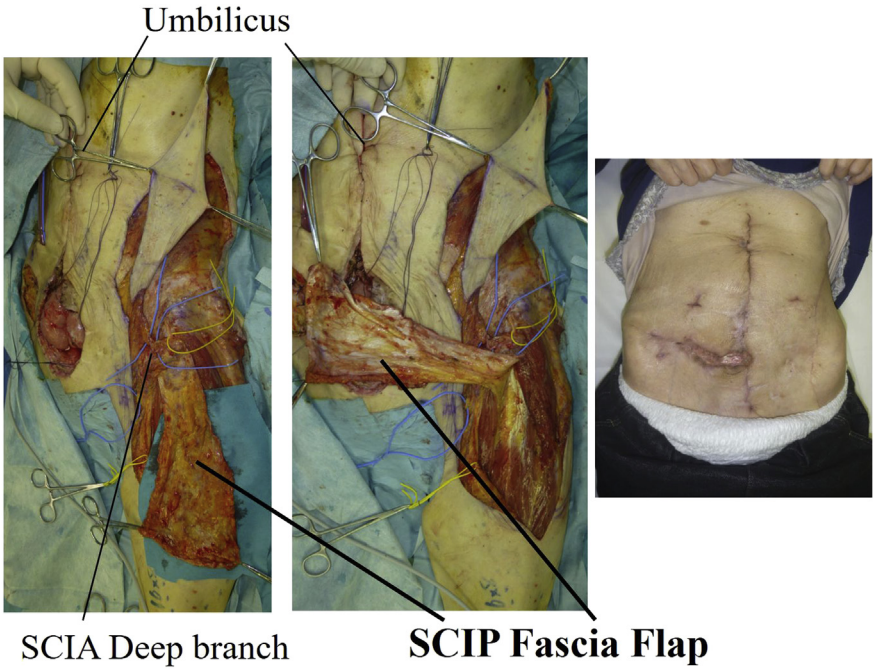

Fig. 5. SCIA deep branch-based SCIP fascia flap for abdominal wall reconstruction.

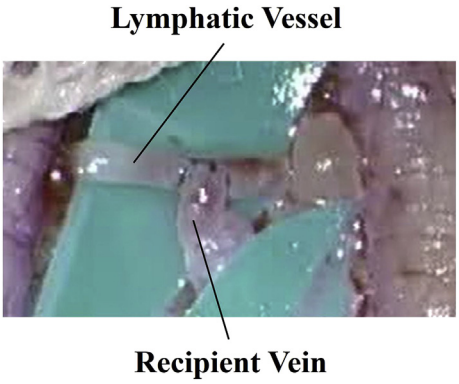

Fig. 6. Supermicrosurgical lymphaticovenular anastomosis (LVA). Side-to-end LVA is performed by anastomosing a 0.50-mm recipient vein to side-wall of a 0.45-mm lymphatic vessel via lymphotomy.

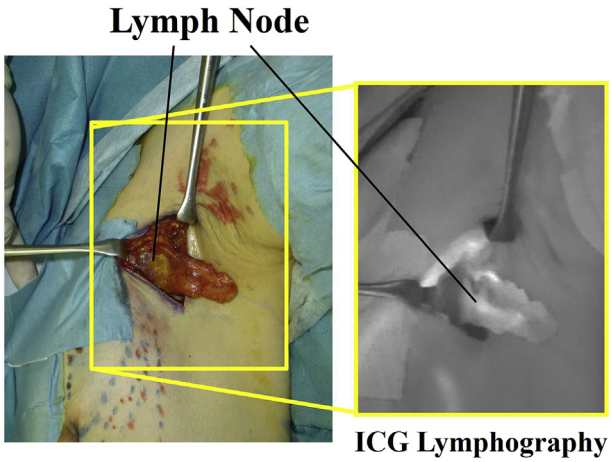

Fig. 7. Supermicrosurgical lymph node true perforator flap.

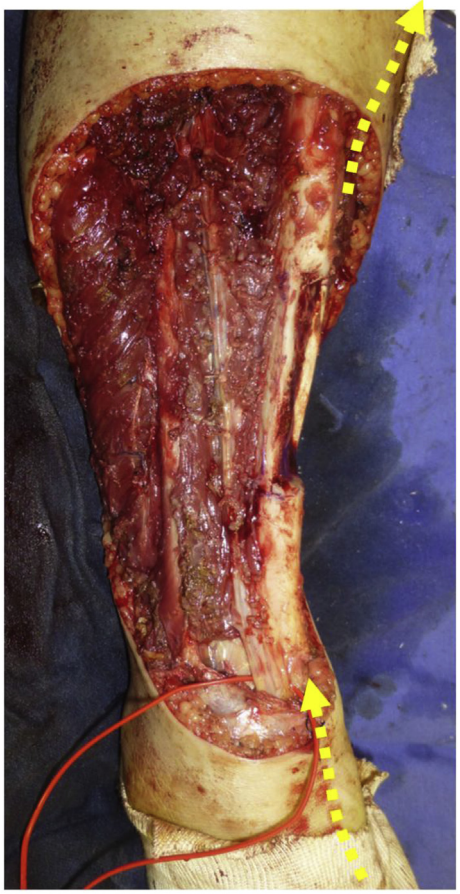

Fig. 8. Main lower leg lymphatic vessel (dotted lines) are removed with tumor resection.

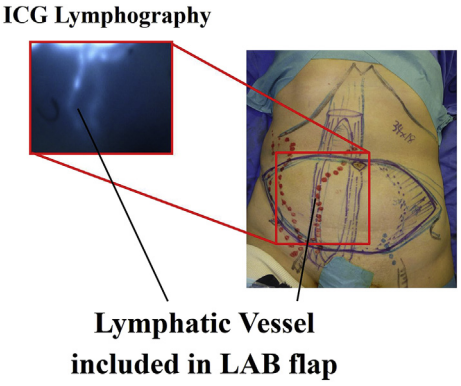

Fig. 9. Lymph-axiality-based (LAB) flap for primary lymphatic reconstruction. Lower abdominal lymphatic vessels are included in the LAB flap.

perforator flaps are available, such as axillary lymph node flaps based on thoracodorsal artery perforator, lateral thoracic artery perforator, and intercostal artery perforator, and inguinal lymph node flaps based on superficial inferior epigastric artery perforator and superficial circumflex iliac artery perforator (Fig. 7) [6,15,39,40,45].

In extremity reconstruction after tumor extirpation such as sarcoma, main lymphatic pathways can also be removed with tumor (Fig. 8), which leads to life-long lasting progressive lymphedema distal to the resection site. Simultaneous lymph flow restoration is possible in cancer resection surgery including main lymphatic pathways. Based on precise lymphatic anatomy shown on indocyanine green lymphography in both a recipient site (defect lesion) and a donor site of a flap, lymph flows can be reconstructed with a lymph-axiality-based (LAB) flap transfer (Fig. 9) [19,32–36,46]. By approximating lymphatic vessel stumps between recipient sites and a LAB flap, the transected lymphatic vessels.

LAB flap can be elevated from any body parts and allows lymph flow reconstruction without lymph node or lymphatic anastomosis.

Conclusions

Supermicrosurgery allows less invasive and more sophisticated reconstructions in any body parts. Supermicrosurgical lymphatic reconstructions play important roles in management of long-lasting progressive lymphatic disorders.

Disclaimers and disclosure of conflicts of interest

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