The use of integrated indocyanine green fluorescence microscope camera for intraoperative lymphography of supermicrosurgery

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Abstract.
INTRODUCTION: Supermicrosurgical lymphaticovenular anastomosis (LVA) toward becoming a treatment alternative for treatment and for surgical management of refractory lymphedema. Effective LVA requires supermicrosurgical systems to detect and Anastomose lymphatic vessels, as they have a small vessel gauge measuring less than 0.5 mm.

METHOD: The antro- and retrograd deep LVAs were performed with the combination of superior-edge-of-the-knee incision method and ventral ankle joint incision method. The direction of lymphatic flow and lymphatic vessels were evaluated intraoperatively with OPMI Pentero Infrared 900 microscope. In postoperative conditions, all 10 patients had undergone intensive Manual Lymphatic Drainage (MLD) and compression therapy.

RESULTS: Total 29 LVAs and 16 skin incisions were performed with intraoperative microscopic ICG lymphography on 10 lower limbs. No lymphatic vessel was detected in one patient at superior-edge-of-the-knee incision. 1 of 29 LVAs showed no patency and 2 of 29 LVAs showed lower patency in intraoperative ICG lymphography. All patients showed reduction in the lymphedema clearly and softer tissues could also be found in postoperative stages.

CONCLUSION: Intraoperative microscope integrated with ICG fluorescence camera can takes shorter time for a lymphatic supermicrosurgeon to discover and dissect deeper lymphatic collector and evaluate anastomosis patency. Manual Lymphatic Drainage and compression therapy should start in early postoperative stages.

1. Introduction

The prevalence of supermicrosurgery has expanded drastically over the previous couple of years. Supermicrosurgery is a technique of microneurovascular anastomosis for vessels of 0.3 to 0.8 mm and single nerve fascicles [1]. Supermicrosurgical lymphaticovenular anastomosis (LVA) toward becoming a treatment alternative for treatment and for surgical management of lymphedema refractory compared to the compression treatments such as bandaging, massage, exercise, pneumatic compression and compression garments [2–5]. The advanced minimally invasive lymphatic supermicrosurgery is also used an effective treatment for longstanding advanced lymphedema and for preventing the developing lymphedema at its high risk [6, 7].

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It is imperative to distinguish and anastomose large functional lymph vessels for preoperative and in lymphatic supermicrosurgery. For the assessment of lymphedema, the fluorescence images through hand-held, near-infrared camera after intradermal injection of ICG help to visualize the function of superficial lymph flows and to determine the severity of the disease [8–10]. In most cases, since the lymphatic vessels are translucent and dispense in the yellow fat tissue, it is hard to discover lymphatic vessels even with preoperative ICG lymphography [5]. Effective LVA requires supermicrosurgical systems, as lymphatic vessels have a small vessel gauge measuring less than 0.5 mm [11]. A near infrared illumination system integrated with operating microscope has been used intraoperatively for supermicrosurgical deeper lymphaticovenular anastomosis (LVA).

2. Patients and methods

Indocyanine green lymphography and intraoperative microscopic ICG lymphography-navigated LVA were performed on 10 patients with secondary lower extremity lymphedema refractory to compression therapy using elastic stockings from January 2018 to April 2018. All selected patients had undergone radical hysterectomy and pelvic lymphadenectomy for the treatment of uterine carcinoma. Age of the patients ranged from 37 to 71 years (average = 55.0 years). Indocyanine Green 100µL with 0.25% concentration was subcutaneously injected at the first web space of the foot the day before surgery for intraoperative lymphography. For the assessment of lymphatic supermicrosurgery, operating microscope integrated with near-infrared illumination system (OPMI Pentero 900; Carl Zeiss, Oberkochen, Germany) was used.

The antro- and retrograd LVAs were performed with the combination of superior-edge-of-the-knee incision method and ventral ankle joint incision method. The direction of lymphatic flow and lymphatic vessels were evaluated intraoperatively with OPMI Pentero Infrared 900 microscope. In postoperative conditions, all 10 patients had undergone intensive Manual Lymphatic Drainage (MLD) and compression therapy.

The study was performed in accordance with the ethical guidelines of Clinical Hemorheology and Microcirculation [12].

3. Result

29 LVAs were performed with intraoperative microscopic ICG lymphography-guidance on 10 lower limbs. Total 16 skin incisions were done and lymphatic vessels were detected by using intraoperative
Fig. 2. Y-shaped LV A (E-E, E-S) with guidance of intraoperative microscopic ICG lymphography. (A) Intraoperative microscopic show good vascularized lymphatic vessel (green arrow) before thoroughly dissected, (B) After completion of LV A, (C) intraoperative microscopic ICG lymphography clearly showed the E-E anastomosis patency (purple arrow); lymph fluid flowed into a venule (blue arrow) and non ICG patency showed the E-S anastomosis.

Fig. 3. LV A (E-S) with guidance of intraoperative microscopic ICG lymphography. (A) Intraoperative microscopic show good vascularized lymphatic vessel (green arrow) before thoroughly dissected, (B) After completion of LV A, (C) intraoperative microscopic ICG lymphography clearly showed the E-E anastomosis patency (purple arrow); lymph fluid flowed into a venule (blue arrow).

microscopic ICG lymphography. After additional injection of 200 μL ICG, no lymphatic vessel was detected in one patient at superior-edge-of-the-knee incision. One of 29 LVAs showed no patency (Fig. 2) and another one showed lower patency in intraoperative ICG lymphography (Fig. 4). After three days of postoperative intensive MLD and compression therapy, all patients showed reduction in the lymphedema clearly and softer tissues could also be found (Figs. 5 and 6).

4. Discussion

There are several operation options for lymphedema treatment such as vascularized lymph node transplantation, lymph collector transplantation, lymphovenous anastomosis and multiple lymphovenous anastomosis [13–17]. Sub-clinical lymphedema can be detected by preoperative ICG lymphography and further the area of incision sites could also be minimalized [18–20]. As lymph vessels which can be detected by ICG lymphography are mostly superficial, more lymphovenous anastomosis are needed for effective surgery. Some case reports described about the deeper lymphovenous anastomosis which cannot be detected by preoperative lymphography [21, 22]. According to Seki Y. et al., single LVA could be done for early-stage lower extremity lymphedema [23, 24].

In this study, LVA was performed from epifascial lymphatic collector to superficial venular. Deeper lymph collectors are larger than lymph vessels and transportation of lymph fluid is much more efficient.
Fig. 4. π (pi) shaped LVA (2 × E-S) with guidance of intraoperative microscopic ICG lymphography. (A) Intraoperative microscopic show good vascularized lymphatic vessel (green arrow) before thoroughly dissected, after completion of LVA, (B) intraoperative microscopic ICG lymphography clearly showed the E-S anastomosis patency (purple arrow); lymph fluid flowed into a venule (blue arrow) ones low ICG flowed into a venule.

Fig. 5. The patient is an 60-year-old woman who had suffered left LEL after hysterectomy and pelvic lymphadenectomy. Preoperative ICG lymphography showed stardust patterns (green arrow) at the lower leg and thigh region and diffuse pattern (blue arrow) at left ankle. The superior-edge-of-the-knee incision method (red arrow) combined with ventral ankle joint incision method (yellow arrow) were performed and intraoperative microscopic ICG lymphography clearly showed the anastomosis patency.

Fig. 6. The patient is a 74-year-old woman who had suffered left LEL after hysterectomy and pelvic lymphadenectomy. Preoperative ICG lymphography showed stardust patterns at the lower leg and thigh region and splash pattern at left ankle.
Furthermore, Hasselhof et al. described about the autonomous peristaltic contractility of lymphatic collectors and the pace maker cells, Cajal-like cells (ICLCs) in the media lymph collectors [25].

Neurosurgeons commonly use a near infrared illumination system-integrated microscope in intracranial aneurysm operation and oncology neurosurgery [26–28].

Supermicrosurgery takes further beyond the limits of human vision by using the operating microscope. Indocyanine green (ICG) lymphography could be performed in order to detect lymphatic vessels appropriate to LVA. Moreover, ICG images also provide lymphatic microsurgeons about the information where the skin should be exactly dissected. Supermicrosurgery improves the severity and reduces the complications of lymphedema with possible complications including infection, lymph leak, and rarely worsening of lymphoedema. It is additionally helpful for the patency assessment and lymphodynamics after anastomosis [5].

In any case, the utilization of LVA for lymphedema treatment remains questionable because of different outcomes of previous supermicrosurgery studies and high technical skill level requirement. Although numerous studies presented the encouraging results for LVA utilization treatment and also reported that intraoperative microscopic ICG lymphography are minimally invasive and effective to detect lymphatic vessels suitable for LVA, some studies showed less good results [4, 5, 7]. Moreover, supermicrosurgical methods require high magnification, specialized equipment and specialist technical expertise and training for eye–microscope–hand coordination, ingenious ability to handle tissues, and more refined motor skills [29].

Recent development in imaging systems have enabled surgeons to all the more likely assess the patency and function of lymphatic vessel and to allow more reliable planning, enhanced long-term patency of anastomosis [30]. The presentation of additional advanced methods and refinement of the technique will probably keep on improving results later on.

Intensive Manual Lymphatic Drainage and compression therapy should start in intraoperative conditions to reduce the possibility of occlusion [31, 32].

5. Conclusion

Intraoperative microscopic ICG lymphography visualized lymphatic vessels simultaneously during microscopic procedures, which results in shorter time for a lymphatic supermicrosurgeon to find and dissect lymphatic vessels. Intraoperative microscopic ICG lymphography visualized lymphatic vessels simultaneously during microscopic procedures, which results in shorter time for a lymphatic supermicrosurgeon to find and dissect lymphatic vessels. Intraoperative microscope integrated with ICG fluorescence camera can detect lymphatic vessels simultaneously during supermicrosurgery procedure and it takes shorter time for a lymphatic supermicrosurgeon to discover and dissect deeper lymphatic collector, evaluate anastomosis patency. Further we recommend the performance of Manual Lymphatic Drainage and compression therapy in intraoperative stages.

References


