—**Original**—

A Comparison of Microsurgical Venous Anastomosis Techniques

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Background: Successful vascular anastomosis is essential for the survival of transferred free tissue. Arterial anastomosis is typically uncomplicated because the lumen is easily maintained and the vessel walls have elasticity. Venous anastomosis, however, is more time consuming because the vessel walls are thin and extensible. This article describes, reviews, and compares 3 currently used venous anastomosis techniques.

Methods: From April 2012 through January 2014, free tissue transfer and supercharging pedicled tissue transfer were performed in 107 and 10 patients, respectively, at our hospital. According to the anastomotic technique used, patients (83 men and 34 women; mean age, 60.6 years) were divided into interrupted suture, continuous suture, and microvascular anastomotic coupling device (MACD) groups. Medical records were reviewed, and postoperative results were analyzed.

Results: The diameter of anastomosed veins did not differ significantly among the groups. However, among the interrupted suture, continuous suture, and MACD groups, there were significant differences in vascular anastomosis time (51, 43.9, and 29.5 minutes, respectively) and transferred tissue ischemic time (151.9, 139.1, and 117.5 minutes, respectively). Surgical site infection occurred in 9 patients, and flap necrosis occurred in 2 patients. However, complication rates did not differ significantly among the 3 groups.

Conclusions: The venous anastomosis technique does not affect the complication rate but does affect anastomosis time and flap ischemia time. On the basis of these results, we believe that the continuous suture and MACD techniques are easier and safer for venous anastomosis than is the traditional interrupted suture technique. (J Nippon Med Sch 2015; 82: 14–20)

Key words: venous anastomosis technique, microvascular anastomotic coupling device, free flap

Introduction

Microvascular anastomosis remains a technically difficult procedure and a critical determinant of the success of free tissue transfer (FTT). Fifty years after Jacobson and Suarez described the first sutured microvascular anastomosis[1], the cumulative efforts of surgeons and researchers have refined FTT to be a reliable modality that often provides excellent cosmetic and functional results. Several researchers have reported FTT success rates of 91% to 99%[2]. Suture techniques that decrease the duration or surgery and vessel wall trauma are valued by microsurgeons[3]. The conventional interrupted suture technique is considered the gold standard for achieving microvascular anastomoses. However, particularly for venous anastomoses, this technique has certain disadvantages, such as increased procedural duration and the risk of considerable intimal and medial damage[4]. Conversely, the microvascular anastomotic coupling device (MACD), an interlocking ring-pin design being increasingly used for FTT, has demonstrated favorable tensile characteristics and healing of coupled vessels in initial animal studies[5]. Favorable results with MACD use have also been reported in subsequent case series[6–11] of reconstructive surgery of the head and neck, breast, and limbs. In this article we describe, review, and compare the following 3 venous anastomosis techniques performed by a single sur-

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Table 1 Patient characteristics

Patient group (n=117)	Interrupted suture (n=44)	Continuous suture (n=25)	MACD (n=48)
Age, years (mean, 60.6)	64.6	61.2	56.6
Sex (men : women) (83 : 34)	35 : 9	18 : 7	30 : 18
Free tissue transfer (n=107)	40	21	46
Supercharging tissue transfer (n=10)	4	4	2
Head and neck reconstruction (n=102)	42	22	38
Breast reconstruction (n=7)	1	0	6
Traumatic injury reconstruction (n=8)	1	3	4

MACD: microvascular anastomotic coupling device; head and neck reconstruction: associated with head and neck cancer resection; traumatic injury reconstruction: includes reconstruction of burns and extensive crush wounds

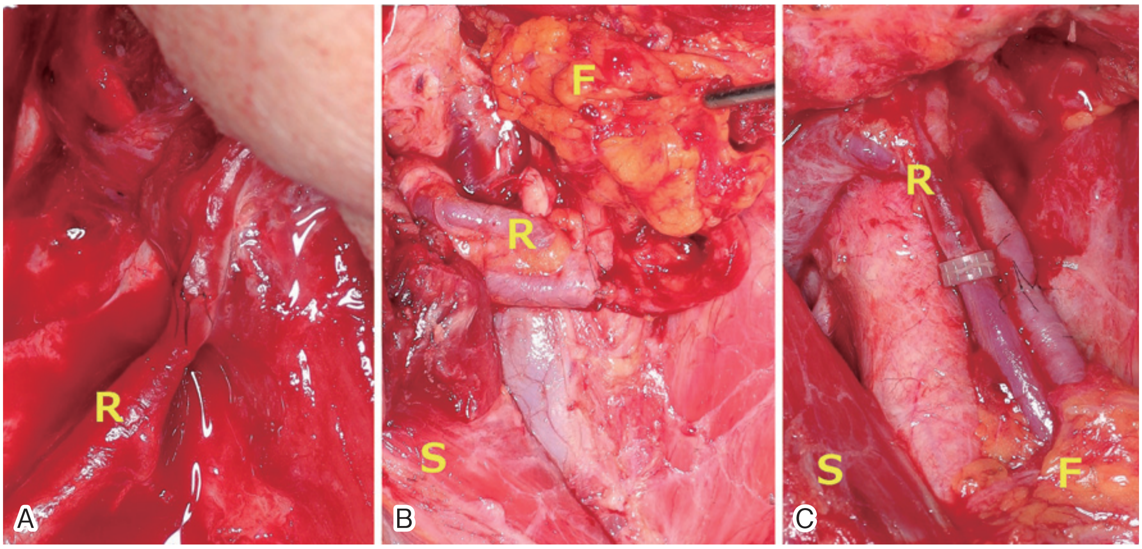

Fig. 1 Three venous anastomosis techniques. (A) Interrupted suture group. The patient was a 59-year-old woman with lingual cancer. After tumor resection, a right anterolateral thigh flap was transferred. The facial artery and external jugular vein were used as recipient vessels. (B) Continuous suture group. The patient was a 77-year-old man with oropharynx cancer. After tumor resection, a right anterolateral thigh flap was transferred. The facial artery and common facial vein were used as recipient vessels. (C) MACD group. The patient was a 63-year-old woman with parotid gland cancer. After tumor resection, a free left rectus abdominis musculocutaneous flap was transferred. The facial artery and common facial vein were used as recipient vessels.
R: recipient vein; S: sternocleidomastoid muscle; F: flap

geon: the interrupted suture, the continuous suture, and the MACD techniques.

Patients and Methods

From April 2012 through January 2014, FTT and supercharging pedicled tissue transfer were performed in 107 and 10 patients, respectively. According to the anastomotic technique used, the patients (83 men and 34 women; mean age, 60.6 years; **Table 1**) were divided into interrupted suture, continuous suture, and MACD groups. Medical records were reviewed, and postoperative results were analyzed. The main outcome measures assessed were vascular anastomosis time, anastomosed venous diameter, anastomotic failure, and surgical complications. In addition, tissue ischemic time of free jejunum (FJ) and free rectus abdominis musculocutaneous (RAMC) flaps transferred for head and neck reconstruction was evaluated. Selection of these 2 surgical protocols permitted this study to compare tissue ischemic time of each surgery impartially. Data were statistically analyzed with the one-way analysis of variance (ANOVA) test and *t*-tests with the software package IBM SPSS Statistics for Windows version 21 (IBM Japan Ltd., Tokyo). A *P*-value of <0.017 (after Bonferroni's correction) was considered statistically significant.

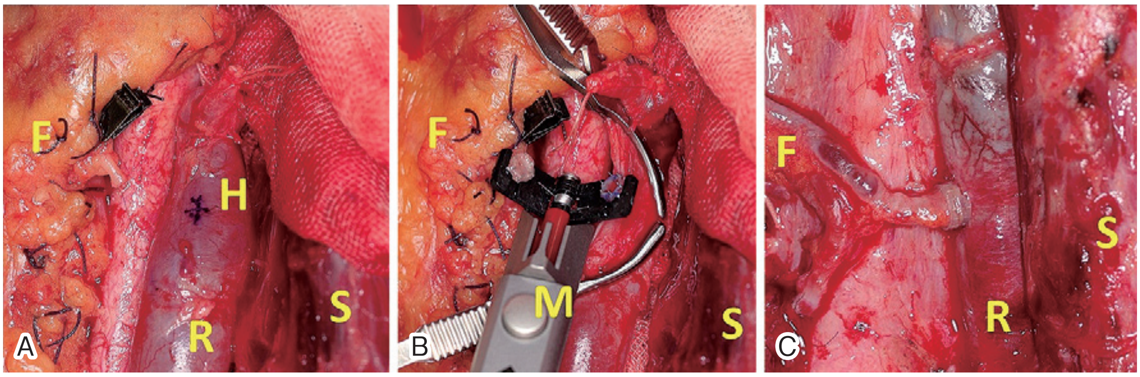

Fig. 2 MACD technique for end-to-side anastomosis. (A) A small incision was then made in the internal jugular vein (IJV). (B) The vessel ends were mounted on the coupler rings, and the walls of each vessel were everted. (C) The coupling device was closed, and the pins on the rings interlocked with each other to create a secure vascular anastomosis.
R: internal jugular vein for recipient vessel; S: sternocleidomastoid muscle; F: flap; H: design of crucial incision; M: MACD

Table 2 Surgical factors 1 (Transferred flap)

Patient group (N=117)	Interrupted suture (n=44)	Continuous suture (n=25)	MACD (n=48)
Free jejunum (n=34)	18	5	11
Free rectus abdominis musculocutaneous flap (n=28)	7	10	11
Free anterolateral thigh flap flap (n=24)	9	2	13
Free deep inferior epigastric perforator flap (n=7)	1	0	6
Free osteocutaneous fibula flap (n=4)	1	2	1
Free forearm flap (n=2)	0	0	2
Free latissimus dorsi musculocutaneous flap (n =7)	3	2	2
Free osteocutaneous scapula flap (n=1)	1	0	0
Supercharging ileocolic transfer (n=7)	4	2	1
Other supercharging flap transfer (n=3)	0	2	1

MACD: microvascular anastomotic coupling device

Surgical Techniques

Vascular Anastomosis

Vessel spasms were neutralized with the application of 1.2% papaverine hydrochloride. Single microvascular clamps were placed proximally and distally on the vessel. All arterial anastomoses were achieved with 9-0 nylon (120-μm diameter, 4.0-mm length, and 3/8 circle needle) using interrupted sutures under a microscope.

Venous anastomoses were achieved with the techniques described below.

Conventional Interrupted Suture Technique

The 180° halving technique was performed with 9-0 nylon. The needle was inserted at a right angle to the wall at a distance from the margin that was slightly greater than the vessel wall thickness. For a 2.5-mm vessel, 10 to 12 sutures were usually necessary (**Fig. 1A**).

Continuous Suture Technique

Sutures were placed with 9-0 nylon from the far corner to the opposite corner. The front side was then sutured and secured with a knot. Subsequently, the clamp and vessel were inverted, and the second suture was placed up to the opposite corner, where it was secured with a knot (**Fig. 1B**).

MACD Technique for End-to-end Suture

A vessel-measuring gauge was used to determine the correct coupler size, ensuring that the true vessel diameter was slightly larger than the marked diameter on the measuring device. Once the appropriately sized coupler was selected, the donor vein, followed by the recipient vein, was attached to the individual coupling components. The ends of the vessels to be anastomosed were pulled through the opposing rings and everted onto the device pins. Vessels were irrigated with heparinized saline, and the instrument knob was then rotated to mate the vessel ends (**Fig. 1C**).

MACD Technique for End-to-side Suture

A small crucial incision was then made in the internal jugular vein, and the hole was dilated to the diameter of

Table 3 Recipient vessels

Artery	Interrupted suture (n=44)	Continuous suture (n=25)	MACD (n=48)
Suprathyroid artery (n=52)	23	13	16
Transverse cervical artery (n=23)	11	7	5
Facial and lingual artery (n=22)	6	4	12
Other artery (n=20)	4	1	15
Vein			
Internal jugular vein (n=62)	37	14	11
External jugular vein (n=18)	3	7	8
Common facial vein (n=17)	1	4	12
Middle thyroid vein (n=3)	0	0	3
Another vein (n=17)	3	0	14

MACD: microvascular anastomotic coupling device

Table 4 Surgical results

Anastomotic group (n=117)	Interrupted suture (n=44)	Continuous suture (n=25)	MACD (n=48)
Vascular anastomosis time (average minutes±SD)	51.0±11.1	43.9±5.3	29.5±7.0
Anastomosed venous diameter (mm)	2.21	2.45	2.59
Surgical complication (n=14)	7	2	5
Anastomotic failure (n=2)	1	0	1
Surgical site infection (n=11)	4	2	5
Fistula and leakage (n=5)	1	2	2
Flap necrosis (n=2)	1	0	1
Tissue ischemic time (FJ and RAMC) (average minutes±SD)	151.9±24.0	139.1±26.2	117.5±32.9

MACD: anastomotic coupling device group, FJ: free jejunum, RAMC: rectus abdominis musculocutaneous flap, SD: standard deviation
Flap ischemic time includes the tissue ischemic time associated with FJ transfer for head and neck reconstruction and free RAMC transfer for intraoral reconstruction.

the donor vein (**Fig. 2A**). The vein was irrigated with heparinized saline. The vessel ends were mounted on the coupler rings, everting the wall of each vessel, and thus permitting complete visualization of the 2 lumens (**Fig. 2B**). The coupling device was closed, and the pins on the rings interlocked with each other to create a secure vascular anastomosis (**Fig. 2C**).

No antithrombotic agents were used after surgery.

Results

There were no significant differences in the general characteristics of each group. Head and neck reconstruction was the most commonly performed surgery (**Table 1**). A total of 34 patients underwent FJ transfer for head and neck reconstruction (**Table 2**). Free RAMC flap transfer was performed in 24 patients with intraoral cancer and 4 with parotid gland cancer. The most commonly performed supercharging tissue transfer was the ileocolic transfer (n=7). The suprathyroid artery and the internal jugular vein were most frequently used as recipient vessels (**Table 3**). The end-to-side technique was typically selected for patients in whom the internal jugular vein was the recipient vein. There were no significant differences in the venous diameter of anastomosed vessels in the 3 groups. The mean vascular anastomosis times with the MACD technique (29.5 minutes) was significantly shorter than that with interrupted suture techniques (51 minutes; P=0.001) and that with continuous suture (43.9 minutes; P=0.003), which was also significantly shorter than that with interrupted suture techniques (P=0.002) (**Table 4**). Tissue ischemic times for FJ transfer during pharyngeal reconstruction and RAMC transfer during intraoral reconstruction with the MACD technique (117.5 minutes) was significantly shorter than that with interrupted suture techniques (151.9 minutes; P=0.0003), but neither differed significantly from that with continuous suture techniques (139.1 minutes; *P*=0.192 and *P*=0.107, respectively; **Table 4**).

The incidence of complications was similar in all groups. Surgical site infection was the most frequent complication (9 cases). Fistulae and leakage occurred after oral cavity reconstruction in 5 patients. Anastomotic failure occurred in 2 patients. Arterial thrombosis occurred in the interrupted suture group, and venous thrombosis occurred in only MACD group. Additional surgical treatment was necessary in these 2 MACD group patients because the tissue had become completely necrotic. All other complications were successfully treated with conservative management.

Discussion

Although there was no significant difference in the incidence of complications among the 3 groups, anastomosis and tissue ischemic times were significantly shorter in the MACD group than in the interrupted and continuous suture groups.

Speed in achieving anastomoses decreases the levels of tissue anoxia, vessel wall trauma, and tissue desiccation[12]. The present study found significant differences in vascular anastomosis times among the 3 techniques. Similarly, Radad et al. have reported that anastomosis time is much shorter with continuous suturing than with simple interrupted suturing[13]. Moscona and Owen[14] and Chen et al.[15] have also reported that in patients requiring arterial end-to-end anastomosis the simple continuous suture technique decreases the microvascular anastomosis time by 50% compared with the simple interrupted suture technique.

The interrupted suture technique facilitates the checking of the inner membrane of the vessel and the fine-tuning of vessel position. However, because microsurgical ligation is infrequent, continuous suture anastomosis time is shorter than interrupted suture time. Nevertheless, excessive traction of microsurgical sutures may cause stenosis; therefore, continuous sutures are not recommended for extremely narrow vessels. In our experience, a continuous suture pattern can be applied without difficulty if the venous diameter is less than 1.5 mm.

The potential advantages of using the MACD technique include shorter anastomosis time and, consequently, shorter ischemic time. Compared with other venous anastomosis techniques in this study, the MACD technique significantly decreased the anastomosis time. Yap et al. have reported that 10 to 55 minutes is required for venous anastomosis with sutures compared with 2 to 36 minutes with MACD[16]. Specific technical aspects of the coupled anastomotic procedure contribute to speed and accuracy and can allow for anastomoses with moderate discrepancies in vessel diameter. Furthermore, MACD facilitates inspection of the everted vessel ends and correction of errors before ring approximation and closure. Recently, end-to-side venous anastomosis with MACD was reported, and the flap survival rate was 99%[9].

In contrast, with hand-sutured anastomoses, technical errors and tissue debris may not be visible[16]. However, MACD anastomosis may pose a risk of vessel twisting during placement on the ring and trauma to the intima and endothelium during application. The inner diameter of relaxed and fully dilated smaller-caliber vessels should be approximately 10% larger than that of the ring[10].

With regard to transferred tissue ischemic time associated with FJ transfer for pharyngeal reconstruction and RAMC transfer for intraoral reconstruction, there were significant differences among the techniques. The tissue ischemic time was influenced by microvascular anastomosis time. The surgical procedure, such as flap cutaneous suturing or jejunal-esophageal suturing, has a significant effect on tissue ischemic time. In the present study, the statistical difference in tissue ischemic time was affected by anastomosis time and re-anastomosis time. In head and neck reconstruction, the diameter of the venous anastomosis depends on the diameter of the transferred venous tissue because the neck of the recipient vein is thick. If the diameter of the recipient vein is thin, the diameter of the venous anastomosis depends on the recipient vein. In the selection of the recipient vessels, there was no significant difference among the 3 anastomotic techniques used in this study (**Table 3**). Our findings suggest that MACD and continuous suturing decrease venous anastomotic and tissue ischemic time. However, venous diameter can affect the selection of the anastomotic technique.

Previously reported success rates of FTT range from 91% to 99%[2]. Jandali et al. have reported a series of 1,000 consecutive cases of FTT breast reconstruction with MACD anastomoses in which they observed only 6 cases of venous thrombosis (0.6%) and no cases of flap failure[10]. This group has also reported a series of 569 consecutive cases of free RAMC flap transfer in which all anastomoses were performed with 9-0 nylon; complications included 1 case of total flap loss (0.2%), 16 cases of venous thrombosis (2.8%), and 19 cases of arterial thrombosis (3.3%)[17]. In the present study, the flap survival rate was 98.2% for all techniques (115 of 117 cases), 97.7% (43 of

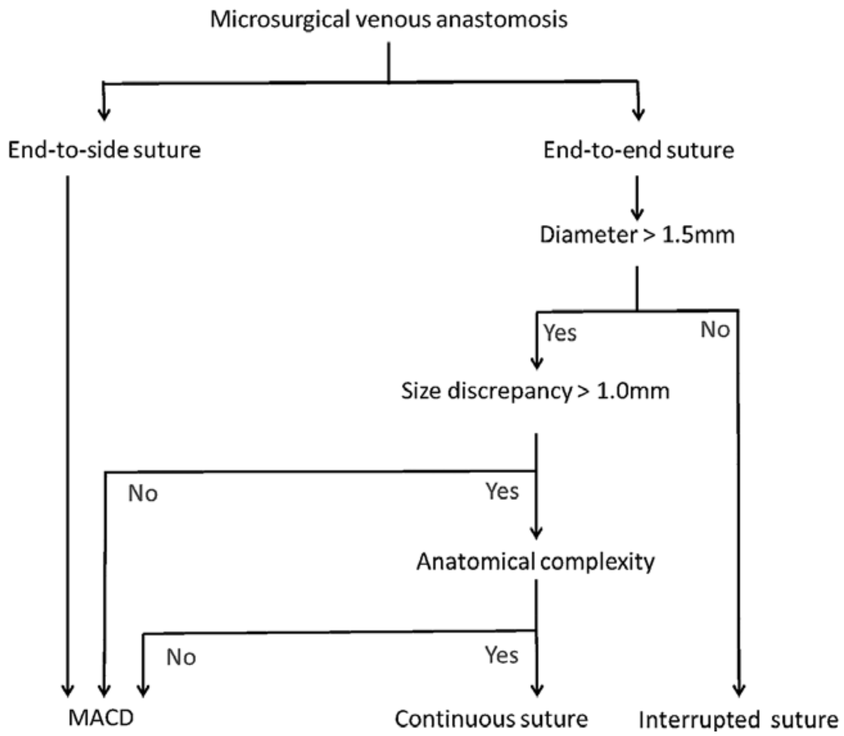

Fig. 3 Decision procedure for the venous anastomosis technique
MACD: microvascular anastomotic coupling device

44 cases) with the interrupted suture technique, 100% with the continuous suture technique (25 of 25 cases), and 97.9% (47 of 48 cases) with MACD. Our results are similar to previous results. Arterial thrombosis occurred in 1 patient in the interrupted suture group because of a technical problem involving anastomotic vessel placement, and venous thrombosis occurred in 1 in the MACD group because of excessive twisting. Therefore, continuous sutures should be selected when there are concerns about anatomical complexity, such as compression of anastomosis vein by coupler and a twisted vascular pedicle. In addition, size discrepancies greater than 1 mm typically require the smaller vessel to be beveled and the anastomosis to be sewn by hand[11]. Our rates of venous and arterial thrombosis were comparable to the best results achieved with sutured anastomoses reported by experienced surgeons. Considering these discussions which include venous diameter, anastomosis times and suture techniques, we recommend a decision procedure for the microsurgical venous anastomosis technique (**Fig. 3**).

Nonthrombotic complications occurred in 12 of our patients (10.3%) and were conservatively treated; the complication rate in the present study was comparable with previously reported rates of 13% to 36%[17–19]. The most frequent complication was surgical site infection (9 patients, 7.7%), and there were no significant differences among groups with regard to complications. All nonthrombotic complications, such as cervical abscesses, hematomas, and fistulae, developed occurred in patients undergoing head and neck reconstruction. The surgical and venous anastomosis techniques did not affect the nonthrombotic complication rate in the present study.

Conclusions

Although the venous anastomosis technique did not affect the complication rate in this study, it did affect both anastomosis time and flap ischemic time. On the basis of our experience, we believe that the use of an MACD makes venous anastomosis easier and safer than with traditional interrupted suturing, and continuous suturing can be used when MACD cannot.

Conflict of Interest: None of the authors has any financial interest in any of the products, devices, or drugs mentioned in this article.

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