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Original Article

Feasibility and reliability of supermicrosurgical vasa recta anastomosis for double-pedicled free jejunum transfer ☆

Takuya Iida*, Takafumi Saito, Hidehiko Yoshimatsu, Isao Koshima

Department of Plastic and Reconstructive Surgery, the University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8655, Japan

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ABSTRACT

Background: Although free jejunal transfer is an established and reliable procedure for reconstruction after total pharyngolaryngectomy (TPL), vascular thrombosis remains a surgical challenge. To reduce the risk, a double-pedicled free jejunal flap transfer has been attempted using a root jejunal artery and an arcade artery, although several drawbacks exist. The vasa recta are terminal straight vessels that arborize from an arcade artery without branching. We present a novel double-pedicled free jejunum transfer using vasa recta anastomosis.

Methods: Between 2011 and 2015, we performed 14 double-pedicled free jejunal flap transfers for reconstruction after TPL. Vasa recta were used for second arterial anastomosis in 5 out of 14 patients. Others include a root artery in three patients and an arcade artery in six patients. Indocyanine green (ICG) angiography was performed to confirm the patency and perfusion of the entire flap by the second artery alone.

Results: The flaps survived completely in all cases. The vasa recta (average diameter; 0.8 mm) were anastomosed to the superior thyroid artery and transverse cervical artery in four and one cases, respectively. Supramicrosurgical end-to-side anastomosis was performed in two cases. ICG angiography showed sufficient perfusion of the entire flap with the second artery alone in all cases.

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* Corresponding author.
E-mail address: tiida-tky@umin.ac.jp (T. Iida).

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Conclusion: As vasa recta were confirmed as being capable of perfusing the entire flap up to 25 cm, the double-pedicle method using vasa recta might be an option to reduce the risk of flap necrosis, particularly in high-risk patients.

Introduction

Free jejunal transfer is an established and reliable procedure for reconstruction after total pharyngolaryngectomy (TPL) because of its ample vascularity and high success rate.[1,2] However, when vascular thrombosis develops postoperatively, flap salvage is difficult because of poor ischemic tolerance.[3] To reduce this risk, double-pedicled free jejunal flap transfers have been reported for patients at a high risk for vascular complications such as hypertension, diabetes, and history of cerebral and myocardial infarction. As a second source vessel in the jejunal flap, the use of a root jejunal artery and an arcade artery has been reported.[3,4] However, the use of these vessels has drawbacks, which include limitation in mobility and number of available vessels.

The vasa recta are terminal vessels that arborize from an arcade artery and enter the jejunum (Figure 1). There are multiple pairs of vasa recta along the jejunum, with lengths exceeding 4 cm without branching. Because of their small diameter, usually less than 0.8 mm, one anastomosis of the vasa recta was believed to be incapable of perfusing the entire flap. Here, we present double-pedicled free jejunal flap transfer using vasa recta. The feasibility and reliability of this technique are demonstrated by comparing it with double-pedicled free jejunal transfer using other source vessels such as root and arcade vessels.

Patients and methods

Between 2011 and 2015, we performed 14 double-pedicled free jejunal flap transfers after TPL. All patients were male, whose ages ranged from 46 to 84 years (average 70 years). Their diagnoses included hypopharyngeal cancer in 12 cases, cervical esophageal cancer in 1 case, and laryngeal cancer

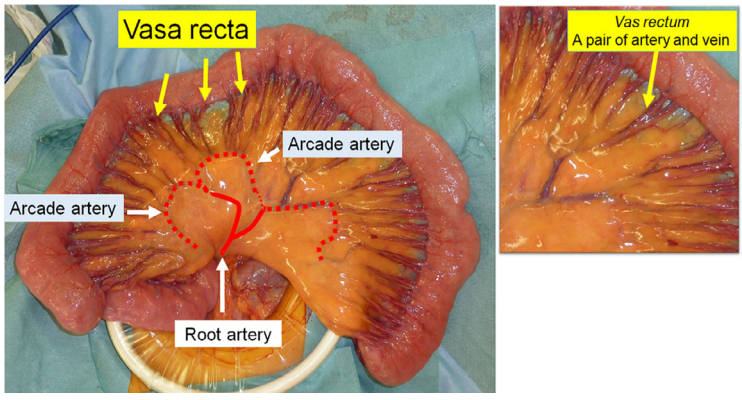

Figure 1. Vascular anatomy of the jejunum; jejunal root artery, arcade artery, and vasa recta and their vena comitans. The vasa recta are terminal vessels that arborize from an arcade artery and enter the jejunum. There are multiple pairs of vasa recta along the jejunum, with lengths exceeding 4 cm without branching (Case 3).

Table 1
Patient characteristics

No.	Age/sex	Diagnosis	Preoperative risks	1st anasto.	Recipient artery	2nd anasto.	Recipient artery	Vein	Total operation time	Complications
1	46M	Hypopharyngeal ca.	Double cancer, staged reconstruction, smoking	Jejunal A	STA	Jejunal A	TCA	IJV	12:59	Abdominal wall hematoma
2[a]	73M	Hypopharyngeal ca.	Cerebral infarction heparinization	Jejunal A	STA	Jejunal A	TCA	IJV	11:56	None
3	67M	Hypopharyngeal ca.	Smoking	Jejunal A	STA	Jejunal A	STA br.	IJV	10:06	None
4	64M	Hypopharyngeal ca.	Af, smoking	Jejunal A	TCA	Arcade	STA	IJV	12:19	None
5[a]	84M	Hypopharyngeal ca.	CAD, arrhythmia, CRF, age	Jejunal A	TCA	Arcade	Lingual A	IJV	13:53	Ileus
6	77M	Hypopharyngeal ca.	HT, smoking, post RT, age	Jejunal A	STA	Arcade	TCA	IJV	10:13	None
7	72M	Cervical esophageal ca.	Smoking, post CRT, Triple cancer (stomach, colon)	Jejunal A	STA	Arcade	TCA	IJV	8:57	Lymphorrhea, hematoma
8	84M	Hypopharyngeal ca.	Post RT/ND, Af, cerebral infarction, anticoagulant, HT, COPD, age	Jejunal A	STA	Arcade	TCA	IJV	7:44	None
9	55M	Hypopharyngeal ca.	Smoking	Jejunal A	STA	Arcade	TCA	IJV	13:25	None
10[a]	79M	Hypopharyngeal ca.	HT, Af, emphysema, age	Jejunal A	TCA	Vasa recta	STA br.	IJV	10:52	None
11	73M	Laryngeal ca.	AV block (pacemaker), CHF (EF20%), HL	Jejunal A	STA	Vasa recta	TCA	IJV	11:42	None
12[a]	70M	Hypopharyngeal ca.	Smoking	Jejunal A	TCA	Vasa recta	STA(e-s)	IJV	11:54	Leakage
13	59M	Hypopharyngeal ca.	Post CRT, HT	Jejunal A	TCA	Vasa recta	STA br	IJV	11:56	None
14	77M	Hypopharyngeal ca.	Smoking, age	Jejunal A	TCA	Vasa recta	STA(e-s)	IJV	10:46	None

Af: atrial fibrillation, CAD: coronary artery disease, CHF: chronic heart failure, CRF: chronic renal failure, CRT: chemoradiotherapy, STA: superior thyroid artery, TCA: transverse cervical artery, IJV: internal jugular vein, e-s: end-to-side anastomosis.

[a] Presented in Case Report.

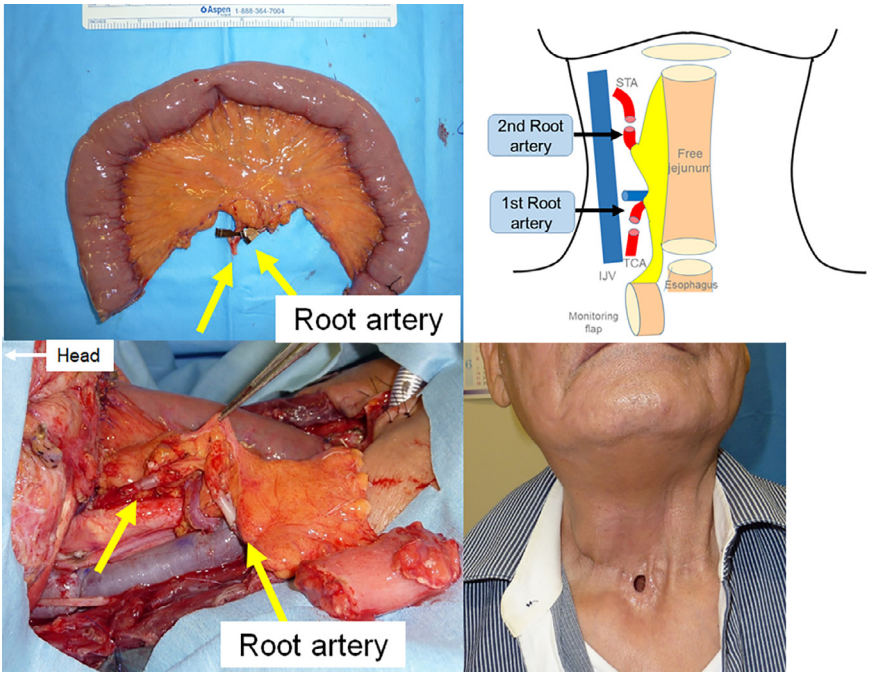

Figure 2. Root artery (Case 1) Double-pedicled free jejunal flap using the jejunal root artery. After the jejunal artery and its vena comitans were anastomosed to the STA and IJV, the second anastomosis was performed between another jejunal root artery and the TCA. Postoperative appearance 15 months after surgery.

in 1 case. Patients' data including vascular risk factors are summarized in Table 1. Regarding the vessels used for the second anastomosis, a root artery was used in three cases, arcade artery was used in six, and vasa recta were used in five. Patients in the vasa recta group were all male (age range, 59–79 years) and had the following risk factors: atrial fibrillation, atrioventricular block with pacemaker, hypertension, diabetes, chronic renal failure, chronic heart failure, smoking, previous irradiation therapy, and coronary artery disease. Follow-up periods ranged from 2 to 65 months (average 21 months).

Operative procedure

A jejunal flap of length approximately 25 cm, whose base was on the second or the third jejunal artery, was harvested by general surgeons. However, pedicle dissection was performed by plastic surgeons. During flap elevation, another set of jejunal root and arcade vessels was marked and ligated depending on their use. The flap was transferred to the defect, and the redundant part of the jejunum was trimmed to fit the defect, while the mesentery was left intact. Both the oral and anal sides of the jejunum were then anastomosed to the remaining mesopharynx and esophagus. After pharyngojejunoesophageal and jejunoesophageal anastomoses, the first arterial anastomosis using the jejunal artery was performed to the recipient artery followed by venous anastomosis between the jejunal vein and the internal jugular vein (IJV).

Then, the second arterial anastomosis was performed using the root artery, arcade artery, or vasa recta (Figure 3).[5] ICG angiography was performed while the first artery was clamped to confirm the patency and perfusion of the entire flap by the second artery alone.

Results

All flaps survived completely in all cases. The second artery was anastomosed to the transverse cervical artery (TCA), superior thyroid artery (STA), and lingual artery in seven, six, and one patient,

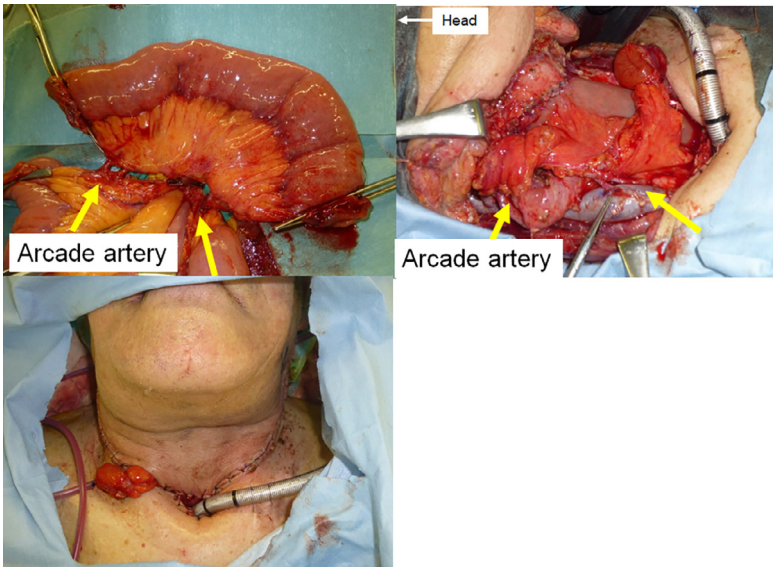

Figure 3. Arcade artery (Case 2) Double-pedicled free jejunal flap transfer using an arcade artery. After the first anastomosis was performed to the TCA and the IJV, the second anastomosis was performed between the arcade artery and the lingual artery.

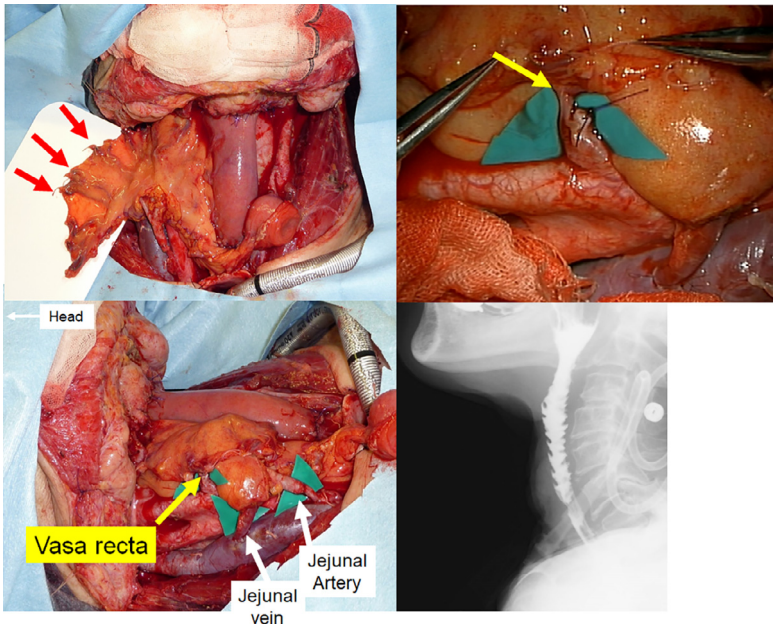

Figure 4. Vasa recta (Case 3) Double-pedicled free jejunal flap using vasa recta. The second anastomosis was performed between vasa recta and a branch of the STA. ICG angiography showed sufficient perfusion of the entire flap only with vasa recta. The flap survived completely without vascular complication.

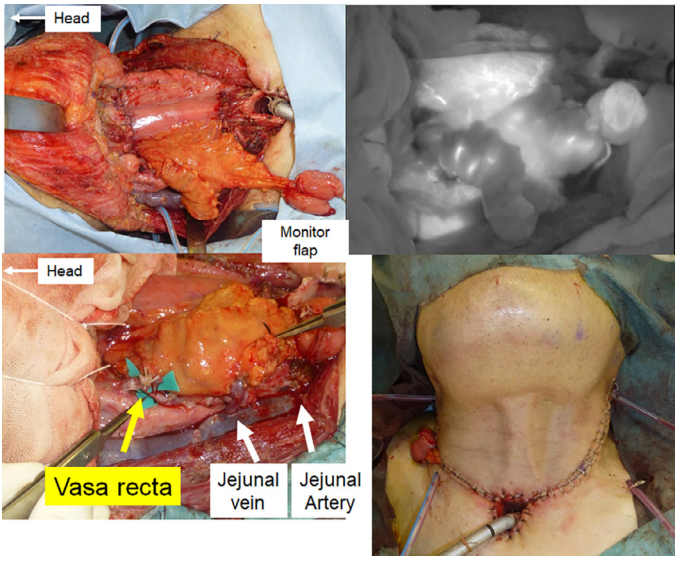

Figure 5. Vasa recta (Case 4) Double-pedicled free jejunal flap using vasa recta. The second anastomosis was performed between vasa recta and the STA in an end-to-side fashion. ICG angiography showed sufficient perfusion of the entire flap only with vasa recta. The flap survived completely without vascular complication.

respectively. In the vasa recta group, the vasa recta were anastomosed to the STA in four cases and TCA in one case. Mean diameters of the second artery were 3.5, 2.2, and 0.8 mm, respectively (root, arcade, and vasa recta). End-to-side arterial anastomosis was performed to address the size discrepancy between the vasa recta and the recipient artery in two cases. The jejunal vein was anastomosed to the IJV in an end-to-side fashion in all cases. ICG angiography showed sufficient perfusion of the entire flap with the second artery alone in all cases (Movie 1). On the other hand, the vena comitans of the arcade vessels and vasa recta were insufficient for venous drainage of the whole flap. Ischemia time of the flap ranged from 2 h 12 min to 3 h 28 min (average 2 h 20 min), and total operating time ranged from 7 h 44 min to 13 h 53 min (average 11 h 20 min). There was no case of skin grafting or use of another flap to cover the jejunal flap. Complications included abdominal wall hematoma in two cases, lymphorrhea in the neck in one, and anastomotic leakage at pharyngojejunostomy in one.

Case 1. Root artery (Patient 2, Figure 2)

A 73-year-old man with hypopharyngeal carcinoma underwent TPL and free jejunal flap transfer. He had a history of cerebral infarction; hence, heparinization was performed during the perioperative period. After pharyngojejunoesophageal and jejunoesophageal anastomoses, the jejunal artery and its vena comitans were anastomosed to the STA and IJV, respectively. The second arterial anastomosis was then performed between another jejunal root artery and the TCA. ICG angiography showed sufficient perfusion of the entire flap with one of the other jejunal root arteries after temporarily clamping the first jejunal artery. The postoperative course was uneventful, and the flap survived completely.

Case 2. Arcade artery (Patient 5, Figure 3)

An 84-year-old man with hypopharyngeal carcinoma underwent TPL and free jejunal flap transfer. He had a history of coronary artery disease, chronic renal failure, and cardiac arrhythmia. During flap elevation, arcade vessels were identified and marked. After the first anastomosis was performed to the TCA and the IJV, the second anastomosis was performed between the arcade artery and the lingual

artery. The arcade vein was also anastomosed to a branch of the common facial vein. ICG angiography showed sufficient perfusion of the entire flap only with the arcade artery, whereas the flap could not be sufficiently drained by the arcade vein alone. The flap survived completely without vascular complications.

Case 3. Vasa recta (Patient 10, Figures 1 and 4, Movie 1)

A 79-year-old man with hypopharyngeal carcinoma underwent TPL and free jejunal flap transfer. He had hypertension, atrial fibrillation, and emphysema. After the first anastomosis, the second anastomosis was performed between vasa recta and a branch of the STA. ICG angiography showed sufficient perfusion of the entire flap only with the vasa recta, while temporarily clamping the jejunal artery (Movie 1). The flap survived completely without vascular complications.

Case 4. Vasa recta (Patient 12, Figure 5, Movie 1)

A 70-year-old man with hypopharyngeal carcinoma underwent TPL and free jejunal flap transfer. After the first anastomosis between the jejunal artery and the TCA, the second anastomosis was performed between vasa recta and the STA in a side-to-end fashion. ICG angiography showed sufficient perfusion of the entire flap only with the vasa recta, as the jejunal artery was temporarily clamped (Movie 1). The flap survived completely without vascular complication.

Discussion

Recent advances in microsurgical techniques have reduced the rate of flap failure to <5%.[6] Perez-Smith et al. reported 368 cases of free jejunum transfer and flap failure occurred in 11 cases (2.98%).[7] In our experience, 80 cases of free jejunum transfer were performed in recent 5 years and flap necrosis occurred in 2 cases (2.5%). One case is due to arterial thrombosis on postoperative day 3, and the other case was due to venous thrombosis on postoperative day 7. Both cases were successfully managed by second free jejunal flap transfer. However, in free jejunal transfer after TPL, flap necrosis may be devastating and result in irreparable damage to adjacent vital organs including the carotid artery. Moradi et al. reported in their 43 free jejunum transfers that one patient developed pharyngocutaneous fistula and died as a result of carotid blowout.[8]

To reduce the risk of flap necrosis, several methods including double vascular anastomosis of a jejunal flap have been reported.[3,4,9,10] Numajiri et al. reported a double arterialized free jejunal flap transfer using another jejunal root artery for safer flap transfer when conditions are unfavorable.[9] Okazaki et al. reported the use of the arcade artery in double-pedicled free jejunum transfer for less donor site morbidity.[3] However, the use of these methods has two drawbacks. First, the root artery method is too invasive because it sacrifices a longer segment of the jejunum, hindering future operations or increasing the risk of short-bowel syndrome, resulting in increased donor site morbidity. In addition, harvesting another root takes longer time and is a tedious procedure. Second, the arcade artery has numerous branches that render microvascular anastomosis difficult; vessel preparation is also tedious and takes longer operation time.[3,4] In addition, the availability of only two sites for anastomosis, i.e., both ends of the mesentery, limits the feasibility of the anastomosis. As the success rate exceeds 95%, costs required for the second arterial anastomosis should not surpass its benefits; the double pedicle method should be “cost-effective.” Numajiri et al. reported that indication of a supercharged free jejunum should be limited to high-risk cases.[10] We also think that indication of this method should be limited to cases with unfavorable conditions. Our indication of second anastomosis was determined by both preoperative and intraoperative assessments; preoperative assessments included past medical history of ischemic heart disease, hypertension, diabetes, arrhythmia, and previous irradiation and radiological imaging such as contrast-enhanced CT. Intraoperative assessments included vessel condition such as atherosclerosis, flow speed, intraoperative thrombosis, and scarring due to previous radiation or surgery.

To make it more cost-effective, we developed the vasa recta method to make it as less invasive as possible. The vasa recta are straight, terminal branches that arborize from the arcade artery and

enter the jejunum, and the length exceeds 4 cm. As their diameter is often <0.8 mm, it has been considered to be technically difficult for anastomosis and insufficient for the perfusion of the entire flap. However, recent advances in supermicrosurgery have made their anastomosis possible, and ICG real-time intraoperative angiography can show the perfusion area of the flap. Our observation using ICG angiography clearly showed that single vasa recta can sufficiently perfuse the entire jejunal flap up to a length of 25 cm. To the best of our knowledge, this is the first report that demonstrated that a single vasa recta artery can perfuse the entire flap. We assume that this is because free jejunum is a highly perfused flap. Takanari et al. reported that the jejunal flap has the lowest vascular resistance and highest blood flow among seven types of commonly used free flaps, including anterolateral thigh, rectus abdominis, radial forearm, and latissimus dorsi flaps.[11]

Although flap survival by single vasa recta is not proved directly, our observation is based on not only physical examinations such as flap color, bleeding, and peristalsis but also ICG real-time angiography, which provides more objective observation. Correlation between ICG perfusion area and flap survival has been established.[12,13] As ICG showed good perfusion of the entire flap by a single vasa recta artery, as shown in the movie of Cases 3 and 4, this could be evidence for flap survival with vasa recta artery alone.

The advantages of using vasa recta as additional vascular pedicles are as follows: (1) multiple pairs of vasa recta exist along the jejunum; (2) the vasa recta do not branch until entering the jejunum, which makes anastomosis easier and faster; (3) long pedicles measuring more than 4 cm are available, which enable the flap to be anastomosed to two different arterial sources (the carotid artery and subclavian artery system); and (4) no additional sacrifice of gut and/or vessels is necessary, resulting in lower donor site morbidity.

Another possible benefit of the second arterial anastomosis is reduction in anastomotic leakage and jejunal stenosis. Numajiri et al. reported that in the double-anastomosed free jejunum, pO_2 was better than that in single-artery anastomosed flap by blood-gas analysis.[14] Compared with cutaneous tissues that usually have more veins than arteries (vein-predominant), jejunum has commonly more arteries than veins (artery-predominant), which can account for its abundant blood flow. Therefore, arterial-supercharged free jejunum flap has a physiological circulatory environment that is more similar to intra-abdominal condition. Richer vascular supply may have a better influence on enteric anastomosis and better wound healing, resulting in the reduction of leakage.[9,14] In animal studies, hyperbaric oxygenation therapy can reduce intestinal membrane destruction.[15]

The disadvantage of this method is that vasa recta generally have smaller diameters than the jejunal arteries (<0.8 mm vs. 3–5 mm). However, supermicrosurgical techniques, which have been applied in head and neck surgery, can solve this problem.[5,16–18] Recently, supermicrosurgical techniques have become widely used.[5,16,17] Several training methods can help to acquire the technique quickly and effectively.[19] We believe that these techniques can broaden the application of the double-pedicled free jejunum flap using vasa recta. Another disadvantage is that additional anastomosis results in longer operating time, which may lead to higher morbidity in high-risk patients. Preparation for the second vasa recta anastomosis usually takes approximately 15 min, and supermicrosurgical anastomosis takes approximately another 15 min. However, total operation time of this surgery usually exceeds 8 h. Considering that flap loss may result in a devastating condition such as carotid artery rupture, we believe that this additional 30 min for the additional anastomosis seems to be acceptable to reduce the risk in this extensive surgery.

Venous thrombosis is also a concern, although jejunal vein is naturally large in diameter and has a thick wall. We first anastomosed vasa recta veins and then arteries. However, it turned out that the vein was insufficient for complete drainage of the flap. Therefore, we switched the method to anastomosing only the artery, aiming for reduction in arterial thrombosis. Walker et al. reported that in 104 cases of free jejunal flap transfer, arterial occlusion occurred in 11 out of 104 cases, whereas venous occlusion occurred in the same number.[20] Thus, arterial thrombosis constitutes a substantial portion of the flap failure causes, and we think that reduction in arterial thrombosis alone is meaningful for preventing flap failure. In addition, it is also suggested that venous thrombosis might be reduced because double arterial anastomosis can also increase venous flow.[9,21]

Acceptable ischemia time of a free jejunum flap has commonly been believed to be less than 2 h. The microvascular anastomoses were, therefore, routinely performed before the intestinal anastomoses

to shorten the ischemia time. However, from our clinical experience, we noticed that this flap was capable of tolerating longer ischemia times, and we, therefore, changed the procedure sequence to the following: (1) cephalic anastomosis, (2) caudal anastomosis, and (3) microsurgery. No apparent adverse effects have been observed.

A limitation of this study is that it is difficult to confirm the validity of this method because of the small number of cases and low thrombosis rate. Further experience and accumulation of patients and data will hopefully confirm its validity in the future.

We believe that this method can be an option for free jejunum transfer after TPL to reduce the risk of total necrosis in patients with high vascular risks.

Conclusions

Double-pedicled free jejunal flap transfer using three types of arteries for reconstruction after TPL was performed in 14 patients, including 5 cases in which vasa recta were used. The flaps survived completely in all cases. Vasa recta were confirmed as being able to perfuse the entire flap up to a length of 25 cm, and reduction in the risk of flap failure is suggested. The double-pedicle method using vasa recta might be an option for reconstruction after TPL, particularly in high-risk patients.

Conflicts of interest

None.

Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jpra.2019.01.004.

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