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Evaluation of Tissue Blood Flow of the Gastric Tube after Vessel Anastomosis for Esophageal Reconstruction

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ABSTRACT

[Objectives and Methods] Impaired blood flow of the upper end of the gastric tube is one of the major causes of anastomotic leak following esophageal reconstruction after esophagectomy for cancer. We applied an additional microvascular anastomosis procedure-the supercharging technique-to improve blood flow. We investigated blood flow improvement in 15 patients who underwent the supercharging technique after total excision of the thoracic esophagus and gastric tube reconstruction through the posterior mediastinal route from August 2003 to March 2005.

[ResultsTissue] blood flow was measured with laser Doppler flowmetry during surgery and was improved after microvascular anastomosis. Patency and blood flow of anastomosed arteries were evaluated with computed tomography and ultrasonography, respectively. Patency and stable blood flow of anastomosed arteries were confirmed more than 1 month after surgery. Therefore, microvascular anastomosis improved the tissue blood flow of the upper end of the gastric tube. Long-term blood flow improvement was confirmed, which suggests that microvascular anastomosis contributes to reducing the risk of anastomotic leak.

INTRODUCTION

The incidence of anastomotic leak after esophageal reconstruction for cancer is reported to be 0–30%. Cervical anastomoses have higher leak rates (10–25%) [13, 16, 18, 22]. Some studies have shown that leaks occur because of impaired blood flow to the anastomotic site around the upper end of the gastric tube and cervical esophagus [10, 19, 21]. To prevent anastomotic leak through the improvement of blood flow to the anastomotic site, some facilities have applied an additional microvascular anastomosis procedure–the supercharging technique. However, the therapeutic outcome of this procedure has not been sufficiently assessed. In Japan, additional microvascular anastomosis after gastric tube reconstruction following esophagectomy was first reported in 1962. Since then, some reports on the improvement of anastomotic leak had been published. However, vessel anastomosis has not been widely performed because its application is complex and uncertain.

With progress in microsurgery, increasing reports on evaluation of blood flow improvement have recently surfaced [1, 13]. Vessel anastomosis has been carried out in some facilities, although it is not as necessary as reconstruction of the jejunal interposition. However, impaired blood flow of the upper end of the gastric tube clearly poses a crucial risk

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for anastomotic leak after esophageal reconstruction. Thus, improvement of local blood flow is undoubtedly useful for decreasing the risk.

We applied an additional microvascular anastomosis procedure–the supercharging technique–using the left gastroepiploic vessels or the short gastric vessels as donor vessels, and the left cervical transverse artery and the left external jugular vein as recipient vessels. We have carried out vessel anastomosis for all cases from January 1997 to December 2006. From 1980 to 1996, 26 of 107 (24%) patients who had gastric tube reconstruction in our hospital developed anastomotic leak. However, from 1997 to 2004, anastomotic leak was observed in only 3 of 46 (6.5%) patients who underwent gastric tube reconstruction accompanied by arteriovenous anastomosis. These results suggest that additional vascular anastomosis may have contributed to a decrease in the incidence of postoperative anastomotic leak [5]. However, we have not objectively assessed the improvement of blood flow in these patients.

To objectively evaluate the usefulness of microvascular anastomosis, we need to demonstrate the improvement of blood flow at the anastomotic site and the postoperative patency of anastomosed vessels. However, to our knowledge, few reports have demonstrated blood flow improvement during and after surgery.

In our study, to evaluate perioperative improvement of blood flow through an additional microvascular anastomosis procedure–the supercharging technique–we measured the tissue blood flow (TBF) near the anastomotic site during the operation, and the postoperative patency of anastomosed vessels.

MATERIALS ANDMETHODS

Patients and Vessel Anastomosis

From August 2003 to March 2005, 15 consecutive patients with esophageal cancer who underwent esophagectomy at the Division of Gastrointestinal Surgery, Kobe University Graduate School of Medicine, were enrolled in this study. All patients had total excision of the thoracic esophagus and gastric tube reconstruction through the posterior mediastinal route. Patients were aged from 50 to 73 years (average 62.1 years, male/female 13:2; for details, see Table I).

The order of vascular anastomoses depended on the operative procedure for each patient: arterial anastomosis first in 9 patients (patients 1, 4, 5, 7, 9, 10, 12, 13, and 15), venous anastomosis first in 5 (patients 2, 3, 6, 8, and 11), and venous anastomosis alone in 1 (patient 14).

The gastric tube was created by the curvature of the stomach, which is supplied with blood by the right gastroepiploic vessels and the right gastric vessels.

The left gastroepiploic vessels were used as donor vessels, and they were conserved as long as possible up to the branch of the splenic vessels and resected to be used in additional vascular anastomosis.

The left cervical transverse artery and left external jugular vein or cervical transverse vein were used as recipient vessels.

The gastric tube and cervical esophagus were anastomosed by hand. Then, the vessels were anastomosed with a 9-0, 10-0 nylon line under the microscope. (Figure 1)

Table I. Patient characteristics and vessel anastomosis.

Patient	Gender	Age	Donor vessels		Recipient vessels	
			Artery	Vein	Artery	Vein
1	Male	50	LGEA	LGEV	Cervical transverse artery	External jugular vein
2	Female	56	LGEA	LGEV	Cervical transverse artery	External jugular vein
3	Male	58	LGEA	LGEV	Cervical transverse artery	External jugular vein
4	Male	60	LGEA	LGEV	Cervical transverse artery	External jugular vein
5	Male	73	LGEA	LGEV	Cervical transverse artery	External jugular vein
6	Male	68	LGEA	LGEV	Cervical transverse artery	External jugular vein
7	Male	56	LGEA	LGEV	Cervical transverse artery	Cervical transverse vein
8	Male	61	LGEA	LGEV	Cervical transverse artery	External jugular vein
9	Male	66	LGEA	LGEV	Cervical transverse artery	External jugular vein
10	Male	70	LGEA	LGEV	Cervical transverse artery	External jugular vein
11	Male	63	LGEA	LGEV	Cervical transverse artery	External jugular vein
12	Male	60	LGEA	LGEV	Cervical transverse artery	External jugular vein
13	Male	57	LGEA	LGEV	Cervical transverse artery	External jugular vein
14	Female	72	None	LGEV	None	External jugular vein
15	Male	61	LGEA	LGEV	Cervical transverse artery	External jugular vein

LGEA, left gastroepiploic artery; LGEV, left gastroepiploic vein

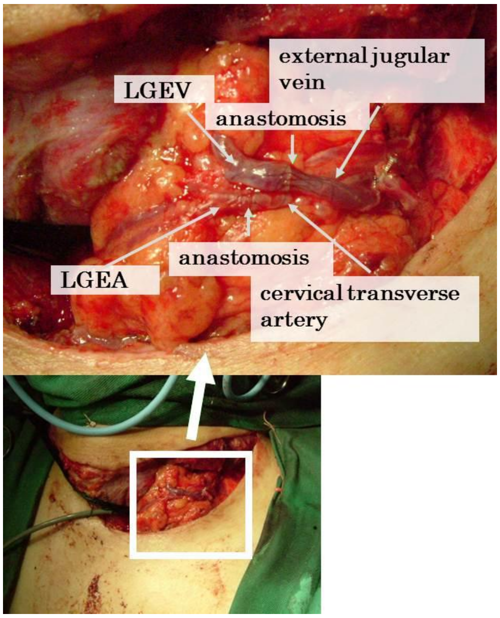

Figure 1. Vessel anastomosis.

Evaluation of Blood Flow

Blood flow was checked using the 3 points below:

A) Tissue blood flow (TBF) at the anastomotic site during vessel anastomosis.
B) Postoperative patency of the anastomosed arteries.
C) Blood flow velocity of the anastomosed arteries.

TBF at the anastomotic site during vessel anastomosis

We measured TBF of the upper end of the gastric tube using a laser Doppler flowmeter(model TBF-LN1; Unique Medical Co., Ltd., Tokyo, Japan) and a contact probe (type C) during vessel anastomosis in patients 1–15 (Figure 2). We used a data collecting system (UAS-108S) for recording.

The type C probe was fixed on the front of the gastric tube just below the anastomotic site of the cervical esophagus and the gastric tube.

Arterial and venous anastomoses were performed in all patients except patient 14. In patient 14, only venous anastomosis was performed.

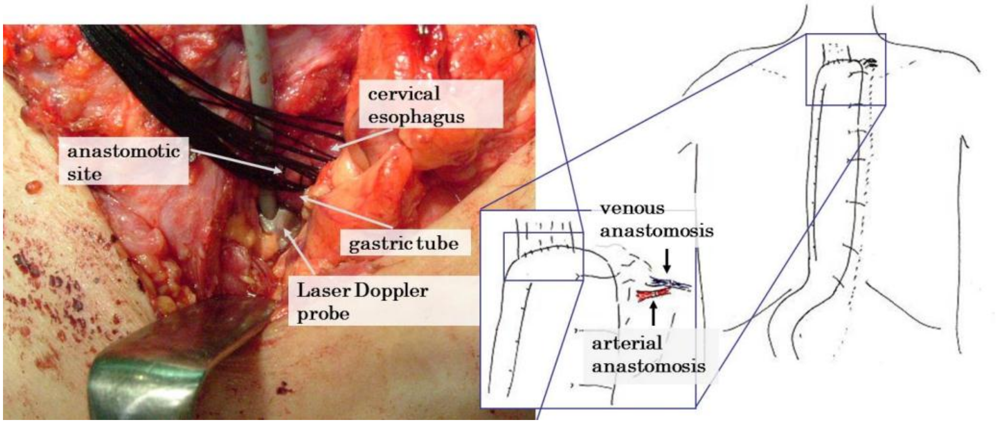

Figure 2. Tissue blood flow measurement.

TBF was checked at 4 points as follows: a) before anastomosis, b) after 1 vessel anastomosis, c) after 2 vessel anastomoses, and d) before skin closure. At each point, TBF was checked continuously for over 10 seconds, then the average was calculated and analyzed.

Postoperative patency of the anastomosed arteries

In patients 1–10, we confirmed the cervical arteries preoperatively and evaluated the postoperative patency of the anastomosed artery 1 month after the operation by computed tomography (CT) for vessel reconfiguration (Figure 3). CT was performed using 1 mm collimation, and reconfigured by 1.25 mm thickness and 1 mm interval.

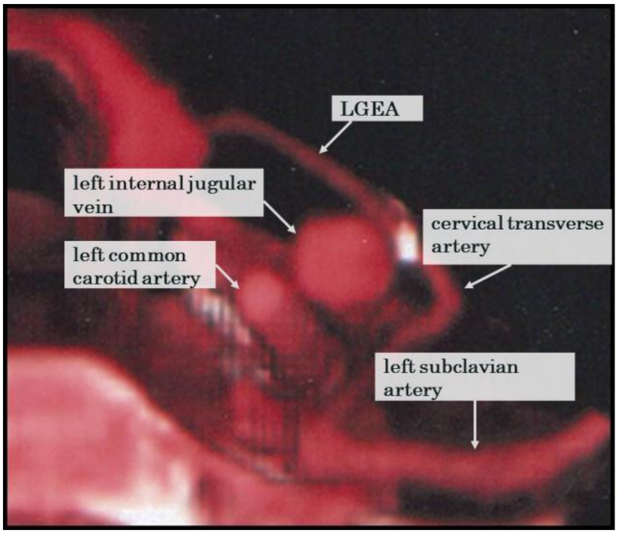

Figure 3. Three-dimensional computed tomography.

Blood flow velocity of the anastomosed arteries

In patients 1–10, 3 days, 1 week, and 1 month after operation, blood flow velocity in the left gastroepiploic artery was measured by ultrasonography (US) with a 6 or 7.5 MHz linear type probe (Figure 4).

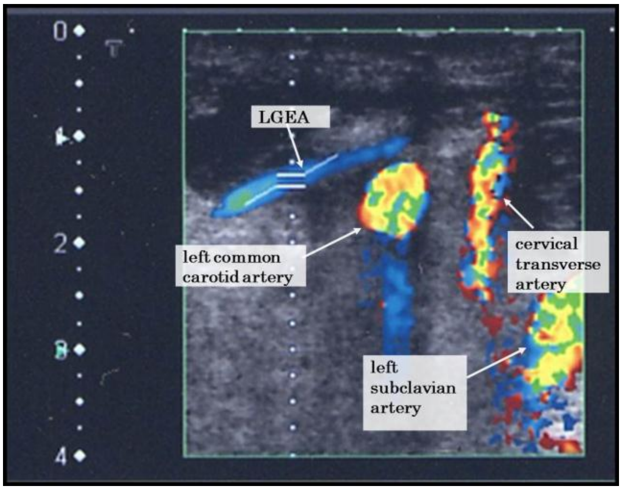

Figure 4. Ultrasonography.

RESULTS

Anastomotic leak throughout the postoperative course

None of the 15 patients developed anastomotic leak during their postoperative courses.

TBF at the Anastomotic Site during Vessel Anastomosis

TBF was measured during vessel anastomosis. Data from patient 1 are shown in Figure 5A. Following arterial and venous anastomoses, TBF reached a plateau after showing 2 peaks.

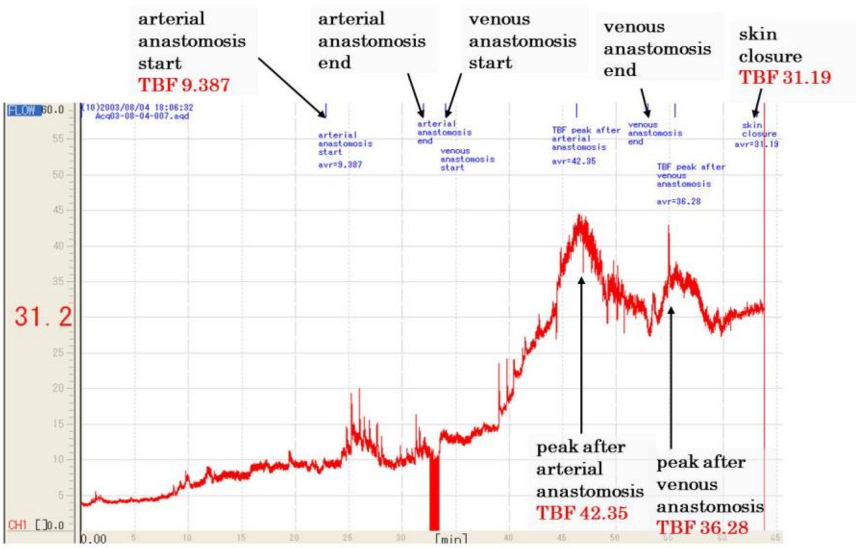

Figure 5A. Tissue blood flow change during operation.

For patients 4, 5, 9, and 11, blood flow change could not be detected; data for other patients are shown in Table II.

TABLE II. Tissue blood flow (mL/min/100 g).

Patient	Before anastomosis	After 1 vessel anastomosis	After 2 vessel anastomoses	Before skin closure
1	9.39	42.35	36.28	31.19
2	5.77	17.27	22.02	18.98
3	3.08	4.10	12.73	10.03
4	N.A.	N.A.	N.A.	N.A.
5	N.A.	N.A.	N.A.	N.A.
6	8.90	12.23	11.31	10.22
7	11.57	16.60	19.12	18.05
8	5.05	5.48	5.90	4.85
9	N.A.	N.A.	N.A.	N.A.
10	22.53	60.85	49.54	41.21
11	N.A.	N.A.	N.A.	N.A.
12	14.44	N.A.	14.32	11.87
13	3.83	3.40	3.32	3.78
14	10.37	17.31	N.A.	13.27
15	8.95	21.24	15.03	12.33

Except for patient 13, all patients whose TBF could be measured before skin closure showed a decrease in TBF between after vascular anastomosis and before skin closure.

This observation is attributed to a change in position, e.g., movement of the anastomotic site to the mediastinal side, and progress in the time course of surgery. The present study was designed to apply vascular anastomosis in order to prevent postoperative anastomotic leak and not to temporarily improve TBF. Therefore, it was considered that TBF reaching a plateau rather than a temporary peak reflected the postoperative state, and the TBF values before skin closure were used.

To stably evaluate the improvement of tissue blood flow by vessel anastomosis, we checked TBF after vessel anastomosis not toward the end of anastomosis but before skin closure. This was done because TBF increased after both vessel anastomoses.

Figure 5B shows that TBF was significantly increased before skin closure compared with before anastomosis ($p < 0.05$).

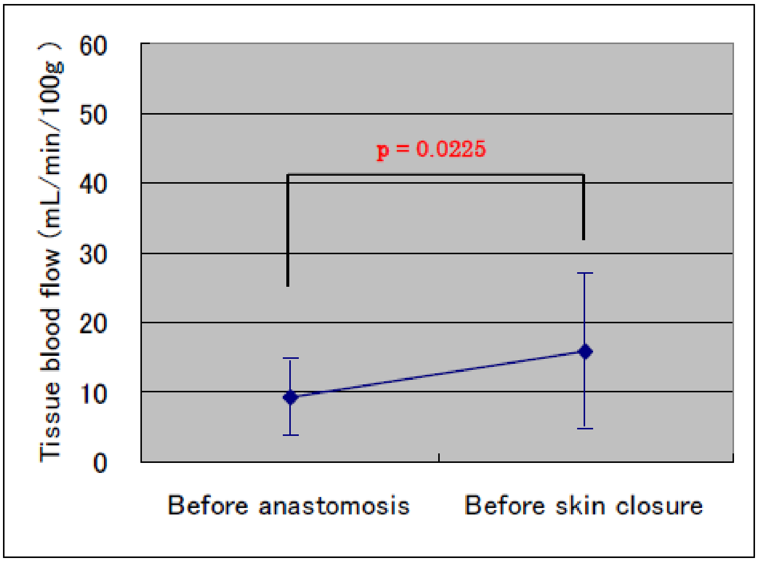

Figure 5B. Improvement of tissue blood flow.

Patency of Postoperative Anastomosed Arteries

In postoperative CT evaluation, anastomosed arteries could not be confirmed in cases 2 and 3 but could be confirmed in the other 8 patients, thus objectively confirming the patency of the anastomosed arteries.

Blood Flow Velocity of Anastomosed Arteries

Because of problems in the methods used, we only show 9 cases in Table III. Figure 6 shows that in 9 patients, 1 month after the operation, stable blood flow was confirmed in the nastomosed arteries.

Table III. Anastomosed arterial blood flow velocities (cm/sec).

	Postoperative		
Patient	Three days	One week	One month
1	66.7	96.6	68.0
2	N.A.	N.A.	N.A.
3	107.5	108.3	114.8
4	46.0	44.5	56.8
5	54.6	55.3	54.4
6	41.1	57.6	64.2
7	66.9	55.4	63.2
8	81.8	70.6	84.2
9	51.8	49.8	70.4
10	35.6	70.0	73.8

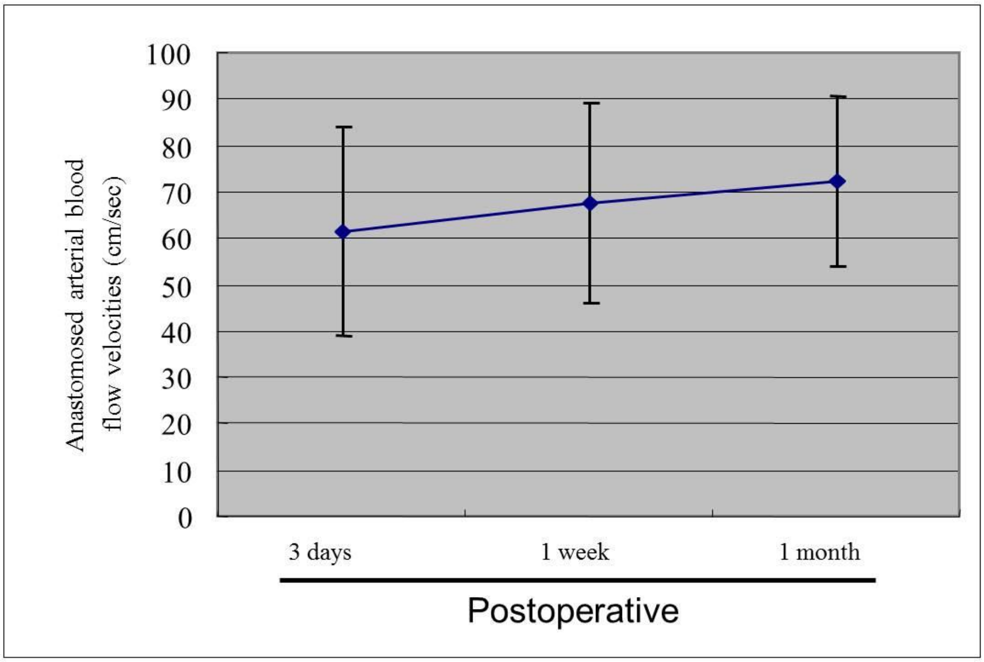

Figure 6. Anastomosed arterial blood flow velocities.

DISCUSSION

Anastomotic leak in esophageal reconstruction for cancer has been reported to occur more frequently than in other gastrointestinal tract anastomosis; this is because of the lack of blood flow near the anastomotic site [19, 21].

To improve blood flow, the technique of microvascular anastomosis in reconstruction following esophagectomy, first described by Longmire in 1947, is proposed. He reported a method of anastomosing one of the primary vessels in the mesentery of the mobilized loop to the internal mammary vessels [9]. In Japan in 1962, Dr. Nakayama et al. reported the first vessel anastomosis performed for esophageal reconstruction to improve the blood flow near the anastomotic site of the gastric tube. They reported vessel anastomosis of the splenic artery and branching of the subclavian artery. In 1968, Dr Ishigami et al. reported another technique involving not only arterial anastomosis between the splenic and subscapular arteries but also venous anastomosis between the splenic vein and the internal or external jugular veins [6]. In 1971, Dr. Nakamura et al. reported that anastomosis of the splenic and subclavian arteries, and anastomosis of the splenic and internal jugular veins at the same time, decreased the frequency of anastomotic leak by one-third [14]. Some patients did not undergo splenectomy for the purpose of using the splenic vessels as donor. In 1993, Kanamaru et al. reported using the short gastric artery, and in 1996, Nagawa et al. reported using the left gastroepiploic artery, as the donor artery [13].

In our hospital, to avoid anastomotic leak in esophageal reconstruction, we have been using vessel anastomosis to improve blood flow near the anastomotic site. We use the left gastroepiploic or short gastric vessels as donor vessels, and the left transverse cervical artery, left thyroid artery, left external jugular vein, or left transverse cervical vein as recipient vessels, and carry out vessel anastomosis in collaboration with a plastic surgeon. We believe that anastomosing both artery and vein will make the blood flow of the gastric tube similar to physiological conditions. Thus, we carry out both arterial and venous anastomoses whenever possible [2]. This retrospective study indicates that the introduction of additional vascular anastomosis in our hospital since 1997 may have contributed to the observed decrease in the incidence of postoperative anastomotic leak in patients undergoing gastric tube reconstruction. We have not previously assessed the effect of vessel anastomosis; thus, we investigated the following 2 points: a) if the blood flow was improved after vessel anastomosis; b) if the anastomosed vessels are still patent and if blood flow can be confirmed after the operation.

To investigate whether blood flow was improved after vessel anastomosis, tissue blood flow (TBF) measurements by laser Doppler flowmetry [4, 11, 13, 15] and hydrogen gas clearance [3], tissue oxygen partial pressure [3], tissue oxygen saturation [15], and pH [15] determinations were performed. In this study, we used the tissue blood flowmeter on laser method from Unique Medical Co., Ltd., to measure the TBF change TBF during vessel anastomosis. This method does not require puncturing the measurement site, and can measure and record TBF less invasively and continuously during the operation. Our results show that TBF changed during the operation and significantly improved after the operation, compared with before vessel anastomosis ($p = 0.0225$) (Figure 5B). In summary, TBF was variable during the operation and significantly increased after vessel anastomosis. Thus, vessel anastomosis improved the tissue blood flow at the upper end of the gastric tube. Our TBF data were severely affected by the location of the probe and the time of measurement; thus, to accurately evaluate TBF, we need to firmly fix the probe and continuously measure the blood flow. In our laboratory, we did our best to perform both vein anastomosis and artery anastomosis. However, which of these 2 procedures is more important is still controversial. To demonstrate the importance of artery anastomosis, Nagawa et al. [13] performed the procedure and used laser Doppler flowmetry to check TBF. After artery anastomosis, TBF was increased and anastomotic leak was not observed. Thus, they concluded that in the artery anastomosis cases, vein anastomosis is not absolutely needed. Moreover, Hanagaki et al. [2] reported that artery anastomosis without venous anastomosis did not cause congestion because a mechanism similar to oscillating veins, in which blood flows bidirectionally between adjacent veins, exists in the vessels of the stomach wall and greater omentum, which contributes in reducing congestion. To demonstrate the importance of vein anastomosis, Ishigami et al. reported that the addition of this procedure decreases the venous pressure and promotes arterial blood flow; artery anastomosis alone may increase the venous pressure and cause congestion at the end of the gastric tube [6]. On the other hand, Endo et al. performed vein anastomosis without artery anastomosis if the venous pressure was more than 30 cm H_2O, and performed both artery and vein anastomoses if the venous pressure was less than 30 cm H_2O [1]. They believe that vein anastomosis is important to reduce congestion at the end of the gastric tube, whereas artery anastomosis should be done when there is no congestion. Murakami et al. reported that venous anastomosis alone increases the arterial input flow by preventing venous stagnation after esophagogastrostomy [12]. Sekido et al. performed arterial or venous anastomosis alone, and both arterial and venous anastomoses for the gastric tube, pedicle jejunum, or colon reconstruction after esophagectomy, and obtained good results [17]. They concluded that 1 artery and 1 vein should be anastomosed to recipient vessels. Ueda et al. suggested that anastomosing both artery and vein supercharged their experimental flap in rats [20]. Thus, they concluded that performing both artery anastomosis and vein anastomosis is the safer choice and should be applied whenever possible. In our study, we did our best to do both vein anastomosis and artery anastomosis.

To investigate if the anastomosed vessels are still patent and if blood flow could be confirmed after operation, we considered a noninvasive method to estimate the patency and blood flow of the anastomosed vessels 1 month after the operation. We performed 3-dimensional CT and ultrasound (US) examinations. Three-dimensional CT is used to evaluate graft patency after a bypass operation in patients with chronic limb ischemia [7]. Both CT and ultrasound examinations are used to evaluate stenotic lesions in carotid arteries [8]. In detail, we used CT for vessel reconfiguration for objectivity, and US for blood flow evaluation in 10 patients. Our CT examination was able to identify the anastomosed vessel in 8 cases. On the other hand, US was able to measure arterial blood flow in 9 cases. In case 2, for which both CT and US failed to detect the patency or blood flow of anastomosed vessel, obstruction of vessels were expected but anastomotic leak was not found. Through US, arterial blood flow velocity was measured 1 week and 1 month after the operation, and stable arterial blood flow was confirmed in 9 cases 1 month after the operation.

In summary, we can conclude that vessel anastomosis could improve tissue blood flow in the anastomotic area of reconstruction after esophagectomy. More than 1 month after operation, stable blood flow could still be detected in the anastomosed arteries. Thus, microvascular anastomosis improved the tissue blood flow of the upper end of the gastric tube. Moreover, long-term blood flow improvement was ensured, which can contribute in reducing the risk of anastomotic leak.

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