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Free Jejunal Flap Transfer Containing Multiple Vascular Pedicles for Pharyngoesophageal Reconstruction in Conjunction with Anterior Mediastinal Tracheostomy

(Running Head: Jejunal Flap Transfer with Anterior Mediastinal Tracheostomy)

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Abstract

Background: When pharyngoesophagectomy is performed in conjunction with anterior mediastinal tracheostomy, reconstructing both the trachea and alimentary tract is extremely difficult. We developed a novel one-stage reconstructive procedure using a single free jejunal flap containing multiple vascular pedicles to decrease postoperative morbidity and mortality. Free jejunal flap transfer with multiple vascular pedicles could offer a viable option for reducing associated life-threatening complications.

Methods: We performed a retrospective review of 34 patients who underwent free jejunal flap transfer with multiple vascular pedicles in anterior mediastinal tracheostomy and pharyngoesophagectomy due to lesions involving both the airway and esophagus. In all cases, one-stage reconstruction of the digestive tract and trachea was performed. Technical details and outcomes were analyzed.

Results: All 34 jejunal flaps (100%) survived. Major morbidity classified as Clavien–Dindo grades III and IV occurred in 10 (29.4%) and 0 (0%) patients, respectively

during hospitalization. With regard to common complications, anastomotic leakage from transferred jejunal flaps and surgical site infections occurred in 0 (0%) and 7 (20.6%) patients, respectively. Five (14.7%) patients experienced tracheal stoma dehiscence. Donor site morbidity was observed in 2 (5.9%) patients. The overall in-hospital mortality rate was 2.9%.

Conclusions: Our one-stage reconstruction procedure achieved low morbidity and low mortality rates following anterior mediastinal tracheostomy and pharyngoesophagectomy. Only one jejunal flap transfer is needed to simultaneously reconstruct the trachea and alimentary tract in a safe and reliable manner with this procedure.

Introduction

Anterior mediastinal tracheostomy is a challenging procedure in which a tracheostomy stoma is constructed with the intrathoracic trachea to establish an airway,[1] and is associated with high mortality rates ranging from 5% to 19%.[2, 3] This procedure is performed to treat extensive cervicothoracic malignancies and recurrence of laryngeal cancer at the stoma site.[1, 2, 4-7] Moreover, patients with extensive involvement of the proximal esophagus also require pharyngoesophagectomy and reconstruction. However, since resection and reconstruction of the trachea and esophagus each presents with a unique set of challenges, the difficulty and risk of combined tracheal and esophageal reconstruction rise exponentially.[8] Not only the complexities of tracheal reconstruction but also difficulties associated with digestive tract reconstruction (e.g., anastomotic leakage from the reconstructed digestive tract) inevitably increase the incidence of mediastinitis and mortality.[9] Ghali et al. reported that the goals of reconstruction for combined tracheal and esophageal defects are (1) to provide a secure airway, (2) to achieve reliable coverage of major blood vessels, and (3) to restore the continuity of the digestive tract. The third goal is sometimes achieved by performing two-stage reconstruction, as combined tracheal and esophageal reconstruction is quite complex.[10] To achieve all three goals in one stage and decrease postoperative morbidity and mortality, we developed a novel reconstructive procedure involving free

jejunal flap transfer. In this procedure, we harvest a long segment of jejunum containing multiple vascular pedicles and voluminous mesentery and transfer it as a free flap. Jejunal flaps with multiple vascular pedicles have high flap survival rates, since two or three pairs of arteries and veins are anastomosed to reduce the incidence of jejunal flap loss. This procedure also reduces postoperative complications such as major vessel rupture and surgical site infections (SSIs), as the redundant mesentery of the flap could be used as a mesenteric flap to protect major vessels and fill in dead space. Here we report on the usefulness of jejunal flaps containing multiple pedicles for pharyngoesophageal reconstruction combined with anterior mediastinal tracheostomy.

Patients and Methods

This retrospective study was approved by the Ethics Committees of Osaka University Hospital (approval number 17124-2) and Osaka International Cancer Institute (approval number 1708215155). A total of 34 patients including 29 men and 5 women (mean age, 63.7 ± 5.9 years; age range, 52-77 years) underwent free jejunal flap transfer for pharyngoesophageal reconstruction in conjunction with anterior mediastinal tracheostomy due to lesions involving both the airway and esophagus. Primary diagnoses were made from August 2003 to July 2017 and included esophageal cancer (25 patients) and hypopharyngeal cancer (6) which requires to

divide the high retrosternal trachea, and recurrent laryngeal cancer with cervical esophageal invasion (3). Sixteen patients received preoperative chemotherapy and radiotherapy, 4 patients received preoperative radiotherapy, and one patient received preoperative chemotherapy. In all cases, one-stage reconstruction of the digestive tract and trachea was performed with jejunal transfer and anterior mediastinal tracheostomy after resection of the trachea and pharyngoesophagectomy with (32 patients) or without (2) laryngectomy. Five patients with esophageal cancer involving the cervical and thoracic esophagus also required total esophagectomy with construction of a gastric tube, which was pulled up to the level of the manubrium and anastomosed to the distal side of the transferred jejunal flap at the same time. All patients were examined for postoperative morbidity and mortality during hospitalization using the Clavien–Dindo grading system.[11] Influence of preoperative radiotherapy on the occurrence of major postoperative complications classified as Clavien–Dindo grades III, IV, and V was assessed. Rates of early postoperative complications were also examined, specifically, SSIs, tracheal stoma dehiscence, any salivary leakage from the flap anastomotic site, and donor site morbidity, which are particularly common in pharyngoesophageal reconstruction and tracheostoma creation. In addition, we assessed postoperative enteric stricture and swallowing function.

Surgical Procedure

Free Jejunal Flap with Multiple Vascular Pedicles. The jejunum was exposed through an upper midline abdominal incision. A loop of the bowel roughly 20 cm distal to the ligament of Treitz was selected. A long jejunum segment roughly 80-120 cm in length was harvested with the second, third, and fourth jejunal vessels, and occasionally with the fifth vessel or a branch of the first jejunal vessel (mean number of jejunal vessels per flap, 2.6 ± 0.7; range, 2 - 4) (Figs. 1a and 1b). As the jejunal vessels are typically proximal to each other, flexibility of vessels was achieved by dividing or removing the mesentery between pedicles, while carefully preserving the intactness of the arcade vessel, to ease later vascular anastomoses. The length of proximal and distal pedicles was roughly 20 cm when three pedicles were harvested. This helped vascular pedicles reach either side of the neck and even the chest, thereby providing more options for the choice of recipient vessels when performing multiple anastomoses (Table 1). The exteriorized monitoring flap (i.e., the intestinal segment), originally reported by Katsaros J et al.[12] and Dionyssopoulos A et al.[13], was prefabricated on both pharyngeal and esophageal sides (Fig. 1b); the side to be used as the monitoring flap was subsequently determined based on the position of recipient vessels. The distal side of the jejunum was trimmed, and jejunoesophagostomy was performed in an end-to-end manner, followed by trimming of the proximal side of the jejunum and pharyngojejunostomy in an end-to-end manner. In two patients who

didn't undergo laryngectomy, the proximal side of the jejunum was trimmed and sutured to the pharynx in an end-to-end manner, as in the cases of 32 patients who underwent laryngectomy. In five patients who underwent combined gastric pull-up, the gastric tube was pulled through the posterior mediastinum to the level of the manubrium and anastomosed to the distal side of the transferred jejunum. Multiple pairs of jejunal arteries and veins were anastomosed under the microscope using microvascular anastomotic couplers for end-to-end venous anastomoses. The redundant mesentery was set to fill in dead space, protect major vessels, and cover the intestinal anastomotic area. Special attention was paid to locate the mesentery between the tracheal stump and innominate artery to prevent innominate artery rupture. To close the donor site, abdominal closure and small bowel anastomosis were performed by general surgeons. In uneventful cases, the exteriorized intestinal segment was tied and excised under local anesthesia in the operating room, followed by skin closure.

Anterior Mediastinal Tracheostomy. Anterior mediastinal tracheostomy was performed as previously described.[5, 6, 14] Briefly, the manubrium, the medial third or half of the clavicle, and the adjacent first rib on both sides were resected for proper neostoma construction. Division of the second costal cartilage and sternal division at or below the sternomanubrial junction were performed if it was anticipated that very

distal division of the trachea would be required. The tracheal stump was relocated to the right side of the innominate artery in all but three patients. The innominate vein was divided to create a sufficient space for the mediastinal stoma, if necessary. The tracheal stump was sutured to the native chest skin as an anterior mediastinal tracheostoma.

Statistical analysis. Differences between groups were determined by Fisher's exact test. $P < 0.05$ was considered statistically significant. Statistical analysis was performed using Excel 2007 (Microsoft, USA) with Statcel2 (OMS, Saitama, Japan).

Results

All 34 jejunal flaps (100%) survived without any partial necrosis, and no patients had flap congestion/ischemia requiring emergent revision/thrombectomy. The highest-grade complication was reviewed for each patient using the Clavien–Dindo grading system. The overall complication rate was 70.6% (Table 2). Major morbidity classified as Clavien–Dindo grades IIIa, IIIb, and IV occurred in 7 (20.6%), 3 (8.8%), and 0 (0%) patients, respectively. Specifically, grade IIIa complications included pleural effusion (8), pneumothorax (1), mild stenosis of the jejunoesophagostomy site (1), and hematoma in the neck (1) (Table 3). Grade IIIb complications included thoracic empyema (1), intraabdominal abscess (1), hemorrhage from the intercostal

muscle (1), dehiscence of the remnant larynx (1), and partial necrosis of the trachea (1).There was one postoperative death (Clavien–Dindo grade V). In this patient, innominate artery rupture occurred on the 23rd postoperative day and graft replacement of the innominate artery and pectoralis muscle and deltopectoral flap transfer were performed. However, the patient died of an unknown cause (presumably from innominate artery re-rupture) on the 48th postoperative day. The overall in-hospital mortality was 2.9%. Regarding the influence of preoperative radiotherapy, the occurrence of major postoperative complications was significantly higher ($p<0.05$) in irradiated patients (Table 4).

With regard to common complications, salivary leakage from the flap anastomotic site and SSIs occurred in 0 (0%) and 7 (20.6%) patients, respectively. Among the 7 patients with SSIs, 5 (14.7%) required reopening of the incision site for wound drainage, and the remaining 2 (5.9%) were treated with antibiotics. Five (14.7%) patients experienced tracheal stoma dehiscence; 4 were managed conservatively, and the other was managed by re-suturing after debridement under general anesthesia. Donor site morbidity was observed in 2 (5.9%) patients and included intraabdominal abscess and wound dehiscence, without any nutritional absorption disorder.

We assessed postoperative enteric stricture and swallowing function, excluding 4 with inadequate follow-up, in-hospital death or early tumor recurrence. Enteric

stenosis occurred in 7 (23.3%) of 30 patients. Anastomotic stenosis was successfully treated with dilatation therapy in most patients. In the evaluation of swallowing function, twenty nine (96.7%) tolerated an oral diet, whereas one (3.3%) were dependent on an oral diet supplemented by tube feeding.

Representative Case

A 62-year-old man with cervical esophageal cancer with tracheal invasion underwent pharyngoesophagectomy with laryngectomy and bilateral neck dissection (Fig. 2a). Immediate reconstruction was performed using a 120-cm jejunal flap with four vascular pedicles (second, third, and fourth jejunal vessels and a branch of the first jejunal vessel). The jejunum was anastomosed to the pharynx and thoracic esophagus (Fig. 2b). The second jejunal artery was anastomosed to the right superior thyroid artery, and the branch of the first jejunal vein to the right common facial vein. The fourth jejunal artery was anastomosed to the left transverse cervical artery, and the fourth jejunal vein to the left internal mammary vein. The redundant mesentery was used to separate the trachea and innominate artery, fill in dead space, protect major vessels, and cover the intestinal anastomotic area (Fig. 2c). Finally, the remnant trachea was sutured to the native chest skin (Fig. 2d).

Discussion

Anterior mediastinal tracheostomy following resection of extensive cervicothoracic tumors is a challenging procedure associated with high morbidity and mortality. This procedure was introduced by Waddell et al.[15] in 1959 and Sisson et al.[7] in 1962, with reported mortality rates of 33-50%.[16] Although only a few reports have described the postoperative course after anterior mediastinal tracheostomy since 1980,[1-3, 5, 6, 14, 17-22] advances in operative techniques and patient care have dramatically reduced mortality rates to 5-19%.[2, 3] Innominate artery rupture is the main cause of mortality and is associated with pressure necrosis of the innominate artery caused by tension on the tracheostoma resulting from a short remnant trachea. Therefore, well-vascularized tissue is interposed between the remnant trachea and innominate artery (e.g., pectoralis major flap,[1, 3, 5, 16, 19, 20] omental flap,[17, 22, 23] and latissimus dorsi flap).[5, 10]

Following pharyngoesophagectomy, alimentary tract reconstruction is performed using visceral (e.g., stomach, jejunum, and colon), musculocutaneous, or fasciocutaneous flaps in order to restore the continuity of the digestive tract.[6, 24] In particular, the use of free jejunal flaps has been considered reliable due to low complication rates and low donor site morbidity,[25, 26] with high overall success rates of 92-97%.[24, 25, 27-31] We aimed to achieve restoration of digestive tract continuity in conjunction with anterior mediastinal tracheostomy using a novel one-stage technique to reconstruct both the trachea and alimentary tract, although two-stage

reconstruction is sometimes used given the complexity of combined tracheal and esophageal reconstruction[10]. This technique uses a long segment of jejunum containing multiple pedicles as a free flap. This flap is much longer than ordinary jejunal flaps (Figs. 1b and 1c) and contains a redundant mesentery after trimming the unnecessary intestinal portion. The redundant mesentery can be used as a mesenteric flap to separate the remnant trachea and innominate artery during anterior mediastinal tracheostomy. Furthermore, this redundant mesentery has additional advantages; it can protect other major vessels such as the innominate vein, subclavicular and carotid arteries, and the internal jugular vein, fill in dead space, and cover the intestinal anastomotic area, thereby decreasing postoperative complications such as major vessel rupture, SSIs, and pharyngoesophageal fistula formation, which are also linked to innominate artery rupture.[5] Generally, SSIs occur in head and neck cancer surgery with flap reconstruction at a rate of 8.1 to 40.6%.[32-34] In this report, the rate of SSIs was 20.6%, and only 8.8% required re-opening of the incision for pus drainage. These rates are not so high considering the invasiveness of surgery. With respect to fistula formation, Pazza et al.[35] reported an occurrence rate of 12% among 1014 cases using jejunal flaps in ordinary pharyngoesophageal reconstruction. Although the number of cases was limited, no intestinal anastomotic leakage was observed in our patients. These findings suggest that jejunal flap transfer with multiple vascular pedicles is a safe and reliable procedure. Yamamoto et al. used the

mesenteric part of a jejunal flap to protect the innominate artery in combination with omental and pectoralis major flaps in three cases.[36] Our method differs largely in that we harvested a long (80-120 cm) segment of jejunum containing multiple vascular pedicles with a redundant mesentery, as compared to a 30-cm segment with one vascular pedicle in the previously reported cases. Moreover, our jejunal flaps have voluminous mesenteries which do not require transfer of the second flap, and one flap transfer is sufficient even for such complex reconstruction.

To prevent arterial rupture, tissue is interposed between the trachea and innominate artery, commonly with a pectoralis major flap,[1, 3, 5, 16, 19, 20] omental flap,[17, 22, 23] or latissimus dorsi flap[5, 10]. In particular, pectoralis major flaps are used most frequently for their feasibility (i.e., easy to elevate) and close location in the operative field. However, muscle flaps are known to atrophy over the postoperative course due to denervation.[37, 38] Yamaguchi et al. reported that muscle volume decreased to 50% in 12 months,[38] and therefore, muscle flaps possibly lose the thickness required to prevent pressure necrosis of the innominate artery. On the other hand, fat volume is resistant to postoperative atrophy as long as patients remain disease-free, and may even exhibit a propensity to increase postoperatively in some patients.[38] In fact, one of our patients showed maintained fat volume on CT 11 months postoperatively (Fig. 3). Therefore, our procedure may be superior to the method that uses a pectorals major muscle flap, although a long-term follow-up study will be necessary given the

relatively poor prognosis of anterior mediastinal tracheostomy and pharyngoesophagectomy.

A recent study reported the use of microsurgical free flaps as a clinically safe reconstructive procedure in the head and neck region, with success rates exceeding 95%.[39] However, once total flap loss occurs due to anastomosed vessel thrombosis, it is apparently life-threatening given the nature and invasiveness of this type of surgery. Moreover, occlusion of anastomosed vessels and subsequent total flap loss are unavoidable even for skilled surgeons. Therefore, we developed a procedure for multiple anastomoses with the aim of reducing the incidence of total jejunal flap loss, since anastomosing multiple pairs of arteries and veins ensures flap survival. We harvested a long jejunum segment preserving the intactness of the arcade vessel so that one pair of vascular anastomosis is sufficient to perfuse the entire flap. That is, even if one vessel is thrombosed, another vessel can supply blood to the whole jejunal flap through the arcade vessel in the mesentery, thereby achieving a nearly 0% total flap loss rate. We started off with flaps containing two vascular pedicles and then switched to those containing more pedicles over time. Currently, our standard procedure requires flaps with three pedicles. Furthermore, vascular pedicles used in our procedure are longer than ordinary jejunal flaps, and can reach either side of the neck and chest. This feature increases options for the choice of recipient vessels (Table 1) and likely contributes to increased flap success rates. Numajiri et al.

previously reported 5 cases of doubly vascularized jejunal flap transfer,[40] which is similar to our procedure using two jejunal root vessels. The major difference is that we harvest a long (80-120 cm) jejunum segment with a redundant mesentery, as compared to 30 cm in their cases. Therefore, our jejunal flaps have voluminous mesenteries covering major blood vessels, with fewer life-threatening complications such as innominate rupture despite SSIs.

Our postoperative stricture rate was 23.3%, as compared to previously reported rates of 0-30%.[29,30,35,41-44] Our patients also demonstrated good swallowing function, with 96.7% tolerating an oral diet with no need for tube feeding, compared to 65-83% in previous reports, [29,45] although our sample size was rather small.

Although it is more time-consuming to harvest a long jejunum segment and dissect multiple vascular pedicles compared to ordinary jejunal harvest, a two-team approach is possible during tumor excision. With this approach, flap harvesting itself would not consume any additional operating time other than the time required for anastomosing additional vessels. Anastomoses of vessels reportedly require 22 min (arterial anastomosis) or 25 min (venous anastomosis) by manual suture, and can be reduced to 5 minutes using an anastomotic venous coupling device.[46-48] That is, this procedure requires an additional 47 minutes with manual suture, or 27 minutes with a coupling device to complete the anastomosis of an additional artery and vein. In fact, at our institution, anastomosis of an additional artery and vein required an average of

42 minutes in 15 recent cases. However, we consider that the extra time is acceptable, given that a 0% flap failure rate can be achieved.

Conclusion

Our one-stage reconstruction procedure achieved low morbidity and low mortality rates following anterior mediastinal tracheostomy and pharyngoesophagectomy. Only one flap transfer is made to simultaneously reconstruct the trachea and alimentary tract in this procedure. Moreover, with multiple vascular pedicle anastomoses, the rate of flap loss is reduced. Therefore, our procedure can be performed safely and reliably following anterior mediastinal tracheostomy and pharyngoesophagectomy.

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Figure Legends

Figure 1. (a) A long segment of jejunum is harvested based on the second, third, and fourth jejunal vessels. (b) After removal of excess intestinal portions. Black arrows show the short segment of jejunum used as an exteriorized monitoring flap. (c) An ordinary jejunal flap with one vascular pedicle.

Figure 2. Intraoperative view. (a) The defect after total pharyngolaryngoesophagectomy and bilateral neck dissection, and relocation of the trachea (white arrow) below the innominate artery (white arrowhead). (The top of each photograph in Figure 2 corresponds to the cephalic direction, and the bottom corresponds to the caudal direction.) (b) The jejunum (black arrow) was anastomosed to the pharynx and esophagus. (c) The redundant mesentery was used to separate the trachea (white arrow) and innominate artery (white arrowhead), fill in dead space, and cover the intestinal anastomotic area. Black arrow indicates the jejunum. (d) Skin closure was performed. White arrow shows a short segment of the jejunum externalized to monitor perfusion.

Figure 3. Postoperative CT scan shows non-atrophied mesenteric fat (black arrowhead) separating the innominate artery (white arrowhead) and trachea (white arrow) 11 months postoperatively.

Table Legends

Table 1. Recipient vessels used for anastomoses.

Table 2. Overall complications.

Table 3. Major compilations classified as Clavien–Dindo grades IIIa, IIIb, and V.

Table 4. Influence of preoperative radiotherapy on the occurrence of major complications classified as Clavien–Dindo grades IIIa, IIIb, and V.

Note

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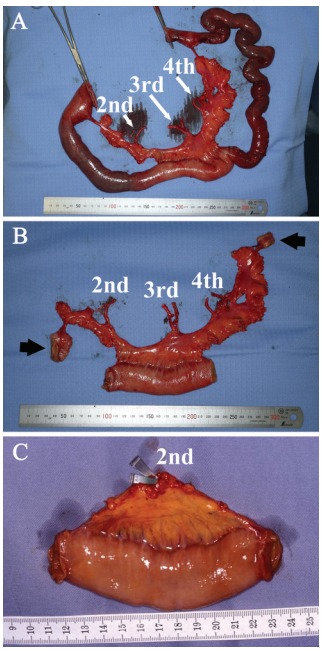
Conflict of Interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.



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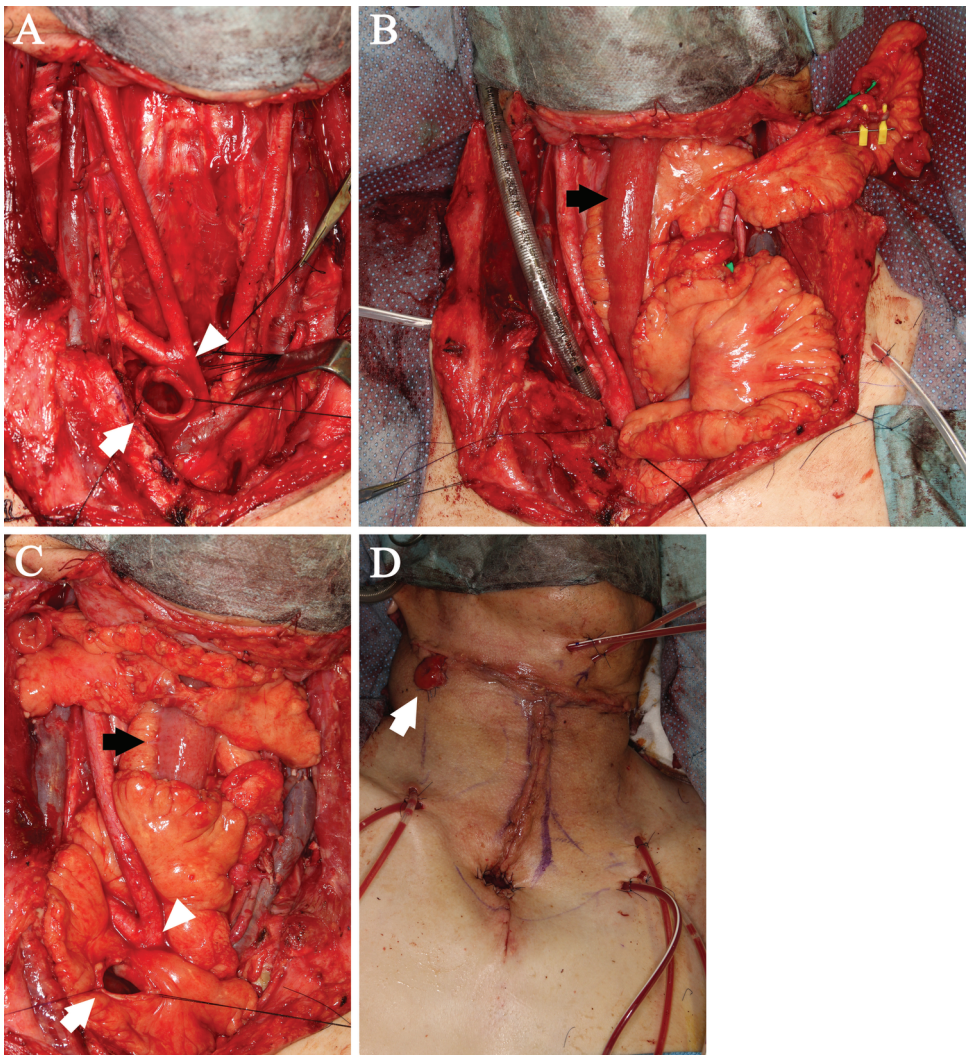

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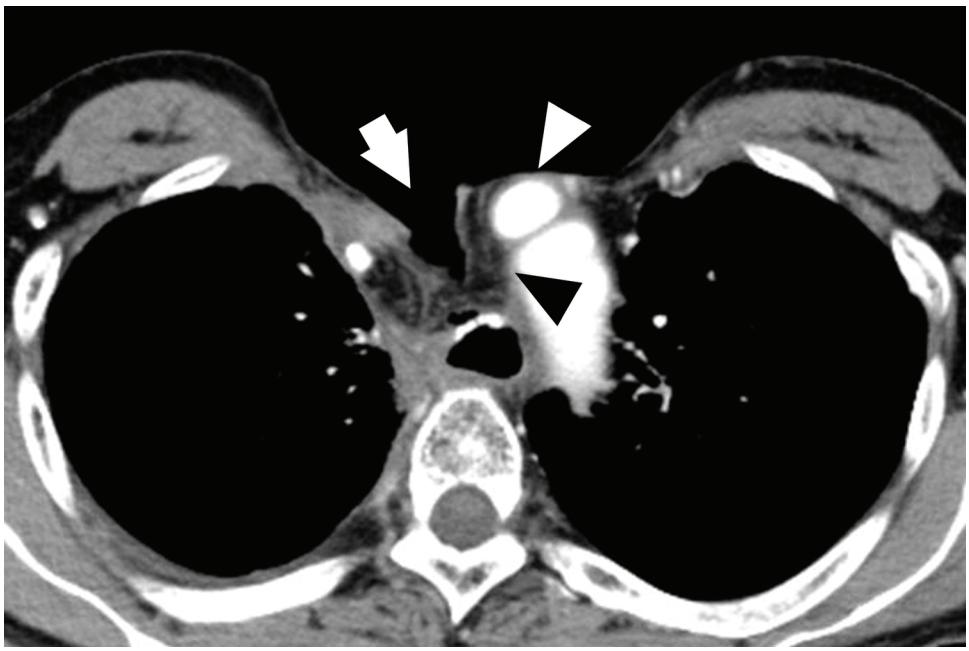

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Table 1 Recipient vessels used for anastomoses

Artery	Number	Vein	Number
Transverse cervical	30	External jugular	21
Superior thyroid	30	Common facial	14
Internal mammary	9	Transverse cervical	12
Inferior thyroid	1	Internal mammary	9
Thoracoacromial	1	Internal jugular	4
		Middle thyroid	3
		Superior thyroid	2
		Anterior jugular	2
		Anterior vertebral	1
		Thoracoacromial	1

Table 2 Overall complications

Clavien–Dindo grade	Patients
Grade I	4 (11.8%)
Grade II	9 (26.5%)
Grade IIIa	7 (20.6%)
Grade IIIb	3 8.8%)
Grade IVa	0 (0%)
Grade IVb	0 (0%)
Grade V	1 (2.9%)

Table 3 Major compilations classified as Clavien–Dindo grades IIIa, IIIb, and V

Complications	Number
Grade IIIa	
Pleural effusion	8
Pneumothorax	1
Mild stenosis of jejunoesophagostomy site	1
Hematoma in the neck	1
Grade IIIb	
Thoracic empyema	1
Intraabdominal abscess	1
Hemorrhage from the intercostal muscle	1
Dehiscence of remnant larynx	1
Partial necrosis of the trachea	1
Grade V	
Innominate artery rupture	1

Table 4 Influence of preoperative radiotherapy on the occurrence of major complications classified as Clavien–Dindo grades IIIa, IIIb, and V

Patient group	Major complications	
	Yes	No
Irradiated	10	10
Non-irradiated	1	13