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ORIGINAL ARTICLE

ANALYSIS OF THROMBOSIS ON POSTOPERATIVE DAY 5 OR LATER AFTER MICROVASCULAR RECONSTRUCTION FOR HEAD AND NECK CANCERS

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Abstract: *Background.* Because of the low incidence of late thrombosis in free flaps used for head and neck reconstruction, the risk factors, prognosis, and the optimal method of treatment are unclear

Methods. The timing of thrombosis, types of flaps, occluded vessels, causative factors, previous irradiation, and salvage rates were reviewed and compared between 79 patients who had thrombosis on postoperative day 4 or earlier (early-thrombosis group) and 24 patients who had thrombosis on postoperative day 5 or later (late-thrombosis group).

Results. The main causative factor for thrombosis in the late-thrombosis group was wound infection (54%), whereas wound infection was present in only 1% of cases of thrombosis in the early-thrombosis group None of the flaps could be salvaged in the late-thrombosis group.

Conclusion. Poor salvage rate in the late-thrombosis group is the most serious problem. Prevention, early detection, and appropriate management of wound infection are essential for avoiding late thrombosis © 2009 Wiley Periodicals, Inc. *Head Neck* **31:** 635–641, 2009

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Keywords: head and neck cancer; microvascular reconstruction; late thrombosis; wound infection; flap salvage

More than 80% of vascular occlusions occur 4 days or earlier after microvascular reconstruction; thus thrombosis on postoperative day 5 or later is rare, and few data summaries have been reported.[1–5] Therefore, flaps are rarely salvaged if thrombosis occurs on postoperative day 3 or later.[3] We are aware of few reports of successful salvage surgery of late thrombosis,[6,7] and the problem of the poor salvage rate has not been resolved.

In contrast, free flaps are believed to undergo revascularization via the surrounding tissue and to be able to survive without pedicle flow within several days after surgery.[3,8–10] If such revascularization occurs, late thrombosis will not always result in the loss of free flaps. Indeed, complete or partial survival of free flaps with late thrombosis treated conservatively, ie, without salvage surgery, has been reported.[3,8,11–13]

Because of the low incidence of late thrombosis in free flaps, the risk factors, prognosis, and the optimal method of treatment are unclear. The aim of this study was to investigate how to avoid late thrombosis and to improve the salvage rate. We reviewed all cases of thrombosis at our institution and examined the causes and outcomes of thrombosis after microvascular reconstruction for head and neck cancers. We then analyzed the differences between patients with early thrombosis and those with late thrombosis to clarify their characteristics and problems.

PATIENTS AND METHODS

All free-flap transfers after ablative surgery for head and neck cancers performed at the National Cancer Center Hospital East and Tokyo from June 1980 to December 2005 were included in this study. During this period, 1913 free flaps were transferred: rectus abdominis musculocutaneous flaps in 676 patients (35.3%); free jejunal grafts in 569 patients (29.8%); radial forearm flaps in 218 patients (11.4%); anterolateral thigh flaps in 210 patients (11.0%); osteocutaneous flaps, containing components of the fibula, scapula, or ilium, in 142 patients (7.4%); and other flaps in 98 patients (5.1%).

The reconstructive surgeons or specialized nurses monitored the color of transferred flaps every 2 hours until the morning of postoperative day 4. Thereafter, the flaps were monitored 2 or 3 times a day. As soon as a change in flap color, suggesting a vascular problem, was detected, emergent exploration around the anastomosed vessels was performed, and salvage surgery was performed if possible. Most flaps transferred to repair intraoral defects could be visualized and monitored directly in the oral cavity. Most jejunal grafts transferred to reconstruct the hypopharynx or cervical esophagus were monitored by means of an external isolated segment of the bowel. The few buried grafts without an external component were monitored with Doppler ultrasonography.

We reviewed the patients' charts and classified patients with thrombosis on postoperative day 4 or earlier as the "early-thrombosis group" and classified patients with thrombosis on postoperative day 5 or later as the "late-thrombosis group." In both groups, the timing of the detection of thrombosis, types of flaps transferred, occluded vessels, causative factors of thrombosis, history of irradiation, and the salvage rate of compromised flaps were investigated. We then compared the 2 groups to examine the characteristics and problems of late thrombosis. Statistical analysis was performed with the chi-square test and Fisher's exact probability test. Differences with a p value of less than .05 were considered statistically significant.

We grouped the expected causative factors as follows: compression (eg, by postoperative edema, hematoma, or tight wound closure), anastomotic thrombosis, kinking of the pedicle, occlusion of the internal jugular vein, lack of neck rest, wound infection, other (eg, tension, anatomic variance of the pedicle vessels), and unknown.

When complete or almost complete survival was achieved by means of reexploration, the flap was defined as "salvaged." When total or near total necrosis of the flap occurred, the flap was considered "nonsalvaged."

RESULTS

Postoperative thrombosis occurred in 103 of 1913 transferred free flaps (5.4%). From 1980 to 1995, the incidence of postoperative thrombosis was 5.6% (57 of 1015 flaps), but it decreased slightly to 5.1% (46 of 898 flaps) from 1996 to 2005. Thrombosis occurred after transfer in 29 of 676 rectus abdominis musculocutaneous flaps (4.3%), in 24 of 569 free jejunal grafts (4.2%), in 19 of 210 anterolateral thigh flaps (9%), in 11 of 142 osteocutaneous flaps (7.7%), in 10 of 218 radial forearm flaps (4.6%), and in 10 of 98 other flaps (10%).

Timing of Thrombosis Detection. Thrombosis was detected from the day of surgery to postoperative day 15. About half (46%) of all thromboses were detected on postoperative day 1 or earlier. Of the 103 thromboses, 79 (77%) were detected on postoperative day 4 or earlier (early-thrombosis group) and 24 (23%) were detected postoperative day 5 or later (late-thrombosis group; Figure 1). The characteristics of the patients in each group are shown in Table 1.

Type of Flap and the Timing of Thrombosis. The percentage of thromboses that were late was highest in free jejunal grafts (10 of 24 thromboses, 42%; Figure 2), followed by osteocutaneous flaps (4 of 11 thromboses, 36%). In the case of thin flaps, such as anterolateral thigh or radial

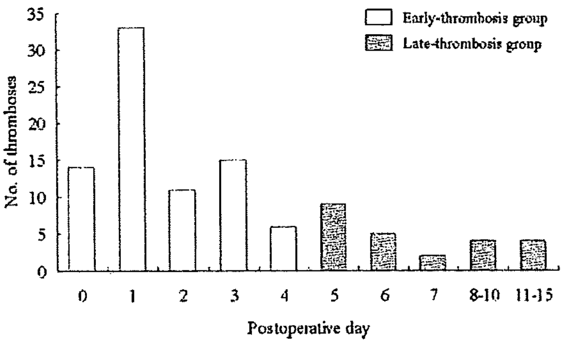

FIGURE 1. Timing of the detection of thrombosis in 103 patients. Of all thromboses, 23% were late.

forearm flaps, only 11% and 10%, respectively, of all thromboses were late. All possible combinations of flap types were tested against one another, and the percentage of thromboses that were late differed significantly between only free jejunal grafts and anterolateral thigh flaps (Fisher's exact test, $p = .039$).

Occluded Vessels. Occluded vessels were compared between the early-thrombosis group and the late-thrombosis group. In the early-thrombosis group, thrombosis was arterial in 21%, venous in 61%, and both arterial and venous in 18%. In the late-thrombosis group, thrombosis was arterial in 29%, venous in 42%, and both arterial and venous in 21%. The type of thrombosed vessel was not recorded in the charts of 8% of patients in the late-thrombosis group. Venous thrombosis was the most frequent cause of vessel occlusion in both groups, but the rate of venous thrombosis did not differ significantly

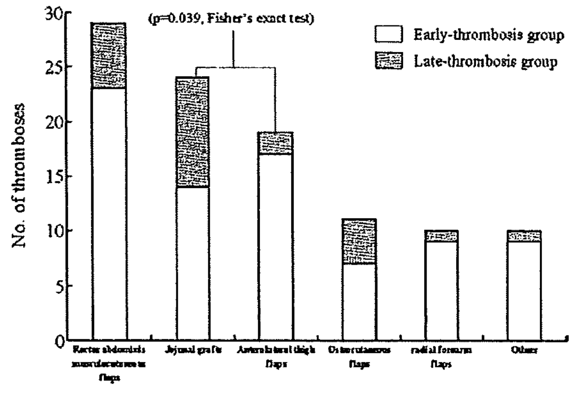

FIGURE 2. Types of flaps transferred with thrombosis are shown. The percentages of thromboses that were late were high for free jejunal grafts and osteocutaneous flaps (42% and 36%, respectively) but were low for anterolateral thigh flaps and radial forearm flaps (11% and 10%, respectively). A significant difference in the percentage of thromboses that were late was demonstrated only between the free jejunal grafts and anterolateral thigh flaps.

between the early-thrombosis and the late-thrombosis group (chi-square test, $p = .639$).

Causative Factors of Thrombosis. In the early-thrombosis group, compression, anastomotic thrombosis, and kinking were the main causative factors of thrombosis, accounting for 58% of cases. Wound infection was the cause of thrombosis in only 1 case (1%) in the early-thrombosis group. In the late-failure group, compression, anastomotic thrombosis, and kinking were causative factors in only 12% of cases. However, wound infection was the main causative factor in the late-thrombosis group, accounting for 54% of cases (Table 2). Most wound infections resulted from fistula formation or wound dehiscence.

Table 1. Characteristics of patients in the early- and late-thrombosis groups.

	Early-thrombosis group, $n = 79$	Late-thrombosis group, $n = 24$
Median age (range), y	61 (37–85)	57 (32–72)
Men/women	58/21	17/7
Primary site		
Oropharynx	17	7
Hypopharynx	15	5
Tongue	17	3
Lower gingiva	8	3
Cervical esophagus	2	3
Buccal mucosa	9	1
Oral floor	6	1
Maxilla	0	1
Other	5	0

Table 2. Comparison of causative factors of thrombosis in the early- and late-thrombosis groups.

	No. (%)	
Causative factors of thrombosis	Early-thrombosis group, $n = 79$	Late-thrombosis group, $n = 24$
Compression	19 (24)	1 (4)
Anastomotic thrombosis	18 (23)	2 (8)
Kinking of the pedicle	12 (15)	–
Occlusion of internal jugular vein	4 (5)	1 (4)
Lack of neck rest	3 (4)	–
Wound infection	1 (1)	13 (54)
Other	13 (17)	2 (8)
Unknown	9 (11)	5 (22)

Table 3. Number of salvaged flaps by date of thrombosis.						
	Early-thrombosis group by postoperative day					
	0	1	2	3	4	Late-thrombosis group, postoperative day 5+
Salvaged flaps/flaps	7/14	8/33	1/11	1/15	2/6	0/24
Salvage rate, %	50	24.2	9.1	6.7	33.3	0

Previous Irradiation. The frequency of a history of irradiation did not differ significantly between the early-thrombosis group (38%) and the late-thrombosis group (50%; chi-square test, $p = .244$). Furthermore, the frequency of a history of high-dose radiotherapy (more than 60 Gy) did not differ between the early-thrombosis group (19%) and the late-thrombosis group (38%; test, $p = .109$).

Salvage Rate. The overall salvage rate was 18%. The salvage rate was 15.8% from 1980 to 1995 and 21.7% from 1996 to 2005. In the early-thrombosis group, the salvage rate decreased for flaps with thromboses detected on the day of surgery (50%) to postoperative day 3 (6.7%), but was 33.3% for flaps with thromboses detected on postoperative day 4 (Table 3). In the early-thrombosis group the overall salvage rate was 24%; however, in the late-failure group, salvage surgery was never performed, and none of the flaps were salvaged. The difference in the salvage rate between the 2 groups was significant (Fisher's exact test, $p = .0055, <.01$).

DISCUSSION

Thrombosis on postoperative day 5 or later after microvascular reconstruction (late thrombosis) is reported to account for 10% to 28% of all thromboses.[1–5] The main problem of late thrombosis is the difficulty of early detection and flap salvage. The latest reported salvage by revision of the anastomosis of a free flap with arterial thrombosis was on postoperative day 11,[6] but successful salvage surgery on postoperative day 5 or later is rarely reported.[7]

Free flaps are believed to develop collateral revascularization from the surrounding tissue and can survive even if the vascular pedicle is subsequently occluded. Using a rat model, Acland[14] was the first to show complete survival of all flaps after the division of pedicle vessels if they were not interrupted until 3 weeks. Further experimental studies have supported these findings.[9,10,15–19] The success of free flap transfer is believed to be dependent on the maintenance arterial inflow and venous outflow through patent anastomoses until revascularization is established by the peripheral ingrowth of vessels. Thus, late thrombosis does not always result in late flap loss.

In experimental studies of musculocutaneous flaps, the vascular pedicle can be safely divided and total survival can be assured 6 to 8 days postoperatively.[9] With free jejunal grafts, the serosal layer is believed to interfere with the revascularization of intestinal segments, and total survival cannot be assured until at least 4 weeks after pedicle division.[19] However, clinical experience suggests that a free jejunal graft survives after arterial disruption as early as 12 days postoperatively without reanastomosis.[20] Clinical experiences and experimental models sometimes differ in the time needed for adequate revascularization.[8,11–13,21–23]

Compromised recipient beds (such as irradiated tissue), chronically infected wounds, and ischemic vascular disease are believed to interfere with free flap revascularization.[24] A decrease in free-flap survival after pedicle division has been demonstrated in experimentally irradiated recipient beds.[25] Some authors have doubted whether free flap revascularization occurs.[26,27] Kumar et al[28] have reported that free flaps do not receive significant blood flow through vessels across the flap inset and are significantly dependent on the original vascular pedicle for vascular perfusion even several years after free flap transfer. Jones et al[20] have suggested that if high-flow flaps are transferred to low-flow recipient areas, revascularization may take longer or may never occur. Thus, revascularization is not a uniform process.

Human free flaps are often placed on recipient beds that provide less than ideal conditions for rapid revascularization. Total necrosis of a latissimus dorsi musculocutaneous flap has been reported to last for 7 months after reconstructive surgery in a lower extremity with a chronically infected wound in the recipient bed.[29] The interval after surgery when total survival is assured after pedicle division remains uncertain in humans. The interval may ultimately depend on the condition of the recipient bed and the type of flap transferred.

In this study, thromboses were more likely to be late with free jejunal grafts and osteocutaneous flaps than with other flaps. Early revascularization is generally not considered to occur with free jejunal grafts. Many cases of late partial or total necrosis after pedicle disruption have been reported with free jejunal grafts, and flap loss has been reported to last for 3 months after transfer.[30–32] Free bone autografts usually require several months to be fully revascularized. Therefore, with osteocutaneous flaps, revascularization of bone segments would also be expected to occur later than with other flaps. Salgado et al[3] have reported total necrosis of a fibula osteocutaneous flap due to arterial thrombosis 42 days after transfer. In contrast, thin cutaneous flaps, such as radial forearm flaps and anterolateral thigh flaps, are considered to be revascularized early, and so these might not undergo necrosis if late thrombosis occur. More than 40% of patients with cancers of the buccal mucosa or oral floor at our institution underwent reconstruction with a radial forearm flap or a anterolateral thigh flap and had a low incidence of late thrombosis (Table 1). However, free jejunal grafts and osteocutaneous flaps, which are not revascularized early, might undergo necrosis if thrombosis occurs even a long time after transfer.

Patients in the late-thrombosis group were more likely to have a history of irradiation than were patients in early-thrombosis group, although the difference was not statistically significant. Previous irradiation of the recipient bed is not considered to significantly increase the risk of vessel thrombosis or flap loss.[33,34] As Clarke et al[25] have shown, however, the incidence of late flap loss in patients who have received radiotherapy might be increased because of delayed revascularization.

The main causative factor of thrombosis in the late-thrombosis group was wound infection (54%), which greatly increases the risk of vessel thrombosis. Experiments indicate that wound infection causes edema, hemorrhage, and necrosis in the media and adventitia of anastomosed vessels.[35] Vasospasm and vessel wall edema then occur and narrow the lumen, promoting thrombus formation. Animal studies have found that the incidence of thrombosis increases by 50% to 75% when anastomosis is performed in the presence of staphylococcus infection.[35,36] In patients, thrombosis due to wound infection has been reported from 8 days to 1 month after transfer.[7,11,13,30]

In head and neck reconstruction, wound infection is usually caused by fistula formation or wound dehiscence 4 or 5 days after surgery. Once fistula or wound dehiscence occurs, the skin edges of the transferred flaps lose contact with the skin edges and with the base of the recipient site. Revascularization is then delayed, and flap loss could occur even after several days when pedicle vessels thrombose. Thus, wound infection caused by fistula or wound dehiscence damages the anastomosed vessels and delays revascularization. For this reason wound infection is suggested to be the main causative factor of late thrombosis and late flap loss.

Of 24 patients in the late-thrombosis group, 13 had wound infections surrounding the thrombosed vessels. The other 11 patients did not have wound infections, but 7 of them had poorly revascularized flaps (free jejunum and osteocutaneus flaps) and 2 of them had received more than 60 Gy of radiation to the recipient beds. Thus, most of the patients in the late-thrombosis group had risk factors for late thrombosis, as described earlier.

The most serious problem in our series was that none of the flaps could be salvaged in the late-thrombosis group. Although 2 flaps were salvaged on postoperative day 4, these were recent cases in which the flaps were carefully monitored and reexplored by an experienced reconstructive surgeon. In addition, the high salvage rate on postoperative day 4 might be due to the small number of cases of thrombosis (6 flaps). Late thrombosis is difficult to detect early because transferred flaps are usually monitored less frequently after a certain period postoperatively, which is 4 days at our institution. We believe that the failure to detect thrombosis early is the main reason for the low salvage rate in the late-thrombosis group. Flaps at high risk for late thrombosis, such as free jejunal grafts, osteocutaneous flaps, and flaps transferred to irradiated recipient beds, should be monitored carefully for 5 days or more postoperatively to increase the chance of salvage.

Although we believe our flap-monitoring system is effective and the salvage rate was higher in the last 10 years, the overall salvage rate was still low. The salvage rate continues to be poor, especially in the late-thrombosis group. This outcome suggests possible limitations of our monitoring method, which is based on flap color. Sakurai et al[37] have monitored changes in venous pressure in composite tissue and have successfully monitored the viability of transferred tissue by means of elevated venous pressure. Hölzle et al[38] have reliably predicted venous congestion and arterial occlusion by monitoring microcirculatory variables of blood flow, hemoglobin concentration, and oxygen saturation. These new methods of monitoring flap deserve more widespread use.

Preventing late thrombosis is also important. Because more than half of the patients in the late-thrombosis group had wound infections, preventing wound infection would help prevent late thrombosis. In head and neck reconstruction, especially in oral and pharyngeal reconstruction, the operative field is easily contaminated because of the communication between the oral cavity or the pharynx and the cervical skin during the operation. Once a fistula or wound dehiscence develops, infection is inevitable in the contaminated area. Operative procedures to decrease the rates of fistula formation and wound dehiscence must be developed. To decrease the rate of fistula formation after free-jejunal transfer, we have attempted to conform the diameter of the oral end of jejunal graft to that of the pharyngeal defect by means of a paramesenteric incision.[39] In oral and oropharyngeal reconstruction, decreasing the volume of dead space in the submandibular region is important for decreasing the rates of fistula formation and wound infection. We have attempted to fill the dead space with the muscular portion of transferred musculocutaneous flaps. Furthermore, to maintain good oral health before operation we are now developing methods of preoperative oral care for all patients with head and neck cancer.

In addition, the early detection and careful management of wound infection after free-flap transfer are essential for avoiding late thrombosis and flap loss.

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The Laryngoscope

Larynx-Preserving Esophagectomy and Jejunal Transfer for Cervical Esophageal Carcinoma

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Objectives/Hypothesis: To examine the efficacy and safety of free jejunal transfer after larynx-preserving esophagectomy in patients with cervical esophageal carcinoma, especially with a high tumor involving the hypopharynx.

Study Design: A retrospective analysis of patients with cervical esophageal carcinoma who underwent free jejunal transfer after larynx-preserving esophagectomy.

Methods: The subjects were 32 patients who underwent larynx-preserving cervical esophagectomy and microvascular jejunal transfer. Fifteen patients had a high cervical esophageal carcinoma that involved the hypopharynx (high-tumor group), and 17 patients had a low cervical esophageal carcinoma that did not involve the hypopharynx (low-tumor group). For each group, mortality, morbidity (anastomotic leakage, wound infection, stricture, and recurrent laryngeal nerve palsy), functional outcomes (time to start oral intake, achieve complete oral intake, decannulation, and rate of larynx preservation), and oncologic outcomes (survival and local control rate) were reviewed and compared.

Results: No perioperative deaths occurred in either group. The incidence of postoperative complications did not differ between the groups. Oral intake started significantly later in the high-tumor group (14.9 days) than in the low-tumor group (10.4 days), but all patients in the high-tumor group could finally achieve oral intake without aspiration. Decannulation was possible in patients who underwent tracheostomy, and laryngeal function was completely preserved in the high-tumor group. Both survival and local control rate did not differ between the groups.

Conclusions: Free jejunal grafts in larynx-preserving surgery can be performed safely and reliably in patients with low cervical esophageal carcinomas and in selected patients with high tumors involving the hypopharynx.

Key Words: Carcinoma of the cervical esophagus, larynx preservation, hypopharyngeal involvement, free jejunal transfer.

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INTRODUCTION

Carcinoma of the cervical esophagus is a rare neoplasm accounting for 2% to 10% of carcinomas of the esophagus.[1,2] Various treatment modalities have been reported, but standard therapies have not yet been established. Definitive chemoradiotherapy is now preferred not only for early esophageal carcinomas, but for advanced tumors.[3] In our institution, however, surgery is the first choice for locally advanced, resectable tumors.

Because the proximal cervical esophagus is adjacent to the larynx, laryngectomy has often been considered a necessary addition to resection of carcinomas of the upper cervical esophagus, both to obtain an adequate upper surgical margin and to avoid postoperative aspiration. Larynx-preserving surgery have performed since the 1980s,[4,5] but only for patients with low cervical esophageal carcinomas without hypopharyngeal involvement. Because larynx preservation in patients with high cervical esophageal carcinoma involving the hypopharynx is believed to increase the duration of cannulation and the risk of fatal pneumonia due to persistent aspiration, performing both esophagectomy and laryngectomy is usually recommended.[6,7]

In order to decrease postoperative complications, including aspiration, the choice of reconstructive

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procedure plays an important role. The surgical defect after esophagectomy is generally repaired with a gastric tube, colon interposition, skin flaps, or a free jejunal graft. Of these methods, the gastric tube and the jejunal graft are preferred and have often been compared with each other, and free jejunal transfer is now reported to be associated with a similar or lower incidence of postoperative complications.[8–10] Although microsurgical anastomoses are required, reconstruction with a free jejunal graft is associated with lower overall surgical stress than is gastric pull-up and, if successful, preserves gastric function.

An inability to speak markedly decreases postoperative quality of life. Larynx preservation should be actively pursued, but the selection of candidates for larynx-preserving surgery and the optimal reconstructive procedure remain controversial. We have tried whenever possible to preserve the larynx in all patients, including those who have high cervical esophageal carcinomas that involve the hypopharynx, by performing free jejunal reconstruction. In this study, we retrospectively divided the patients into two groups whether the tumor involved the hypopharynx or not, then compared the mortality, morbidity, functional outcomes, and oncologic outcomes between the groups. Our goal was to examine to what extent larynx preservation can be safely performed with free jejunal reconstruction, especially for patients who have high cervical esophageal carcinomas that involve the hypopharynx.

MATERIALS AND METHODS

Patients

We reviewed 32 patients with cervical esophageal carcinoma who had undergone larynx-preserving cervical esophagectomy and microvascular free jejunal transfer at the National Cancer Center Hospital and Hospital East from 1984 through 2005. The basic eligibility criteria of our larynx-preserving surgery are as follows: the proximal extent of tumor invasion is limited to two subsites (usually the piriform sinus and the posterior wall) of the hypopharynx, and the lower rostral end of the esophagus can be accessed from the neck. Patients who had a history of a swallowing disorder (e.g., that due to brain infarction or neuromuscular disease) and patients with an American Society of Anesthesiologists performance status of III or more were not candidates for this surgery. Approximately 130 patients of cervical esophageal carcinoma were treated in our institute during this period, indicating that about 25% of the patients were eligible for this larynx-preserving surgery.

The patients were 27 men and 5 women ranging in age from 36 years to 82 years (mean age, 62.6 years). The mean follow-up period from the day of surgery until death or the most recent follow-up investigation was 46.1 months, ranging from 3.4 months to 88.9 months. Of these patients, 28 had received no other treatment before surgery and four had a history of previous irradiation to the neck for another malignant neoplasm (metachronous malignant lymphoma of the neck in two patients, metachronous oropharyngeal carcinoma in one patient, and cervical lymph node metastases from an unknown primary lesion in one patient). Two patients received postoperative radiotherapy, and three patients received postoperative chemotherapy.

TABLE I.
Patient Characteristics.

	High-Tumor Group (n = 15)	Low-Tumor Group (n = 17)
Age (yr)		
Mean	61.5	63.5
Range	53–72	36–82
Sex		
Male	13	14
Female	2	3
Previous irradiation		
Yes	2	2
No	13	15
Postoperative irradiation or chemotherapy		
Yes	4	1
No	11	16

High-tumor group: patients with high cervical esophageal carcinomas involving the hypopharynx. Low-tumor group: patients with low cervical esophageal carcinomas not involving the hypopharynx.

The successful larynx preservation surgery is considered to depend on whether the hypopharynx is invaded by the tumor at its upper end. Therefore, we divided the patients by the involvement of the hypopharynx: 15 patients who had high cervical esophageal carcinomas with hypopharyngeal involvement (high-tumor group), and 17 patients who had low cervical esophageal carcinomas without hypopharyngeal involvement (low-tumor group). In majority of the institutes, larynx preservation would be contraindicated in the high-tumor group, whereas selected patients in the low-tumor group may have their larynx preserved. Thus, by comparing these two groups it should be possible to reveal whether larynx preservation has negative prognostic effects in patients whose hypopharynx is invaded by the tumor. Characteristics of the patients of each group are shown in Table I.

Surgery

Operations were performed via the cervical approach. Lateral pharyngotomy was performed to better expose the hypopharynx and the upper end of the cervical esophagus in the high-tumor group, in which the proximal edge of the tumor had directly invaded the hypopharynx. In this method, the pharynx was entered after the lateral portion of the thyroid cartilage was resected and the fibers of the ipsilateral cricopharyngeal muscle were dissected, whereas the superior laryngeal nerve was preserved.[11] Partial resection of the hypopharyngeal mucosa was then performed. The number of subsites of the hypopharynx that were resected was one in 11 patients, two in three patients, and three in one patient. Resected subsites in the high-tumor group are shown in Table II.

If the distal edge of the tumor had extended to the thoracic inlet, partial upper median sternotomy to the third intercostal region was performed to better expose the distal margin. Bilateral paratracheal lymph node dissection was performed aggressively to the level of the upper mediastinum, whereas the recurrent laryngeal nerves were spared, except in the case of direct tumor invasion. If the risk of postoperative airway disturbance was considered high, temporary tracheostomy was performed during the operation.

After extirpation of the tumor, a jejunal segment was harvested and transferred to the surgical defect. When the

TABLE II.
Resected Parts of the Hypopharynx in the High-Tumor Group.

Subsite	Number (n = 15)
Piriform sinus	6
Posterior wall	3
Postcricoid	2
Piriform sinus + posterior wall	2
Piriform sinus + postcricoid	1
Piriform sinus + posterior wall + postcricoid	1

esophageal defect was circumferential, the jejunal graft was transferred as conduit. In the case of partial esophagectomy and a noncircumferential defect, the jejunal graft was used as a patch graft. When partial resection of the hypopharynx had also been performed, the rostral end of the hypopharynx was usually wider than if hypopharyngeal resection had not been performed, because the hypopharynx usually has a larger diameter than the cervical esophagus. To conform the diameter of the oral end of jejunum to that of the pharyngeal defect, a longitudinal incision was made in the oral border of jejunal segment, and the oral side of the jejunum was dilated without narrowing the jejuno-pharyngeal anastomosis.[12] The anastomosis of the graft was usually handsewn, although a mechanical suture instrument was used in a few cases. An intraoperative view of a transferred jejunal graft is shown in Figure 1.

Most recipient vessels for microsurgical anastomoses were found in the cervical region. Otherwise, internal mammary vessels or thoracoacromial vessels were selected. Table III gives details of the operations for each group.

Fig 1 Free jejunal graft in position at the left side of the neck after larynx-preserving cervical esophagectomy. Jejuno-pharyngeal anastomosis is located at the level of the hypopharynx (arrow). The left recurrent laryngeal nerve is preserved. A = common carotid artery; C = cricopharyngeal muscle; J = transferred jejunal graft; R = recurrent laryngeal nerve; T = trachea; V = internal jugular vein.

TABLE III.
Details of Surgery.

	High-Tumor Group (n = 15)	Low-Tumor Group (n = 17)
Jejunal transfer		
Conduit	13	17
Patch	2	0
Upper median sternotomy		
Yes	2	10
No	13	7
Temporary tracheostomy		
Yes	11	4
No	4	13
Neck dissection		
Bilateral	7	11
Unilateral	5	6
None	3	0
Recipient artery		
Superior thyroidal	4	13
Superficial cervical	11	2
Other*	0	2
Recipient vein		
Internal jugular	11	11
Common facial	2	0
External jugular	1	1
Superior thyroidal	1	1
Superficial cervical	0	2
Other*	0	2

*Other includes internal mammary and thoracoacromial vessels.

Analyzed Factors and Statistical Analysis

Postoperative mortality and morbidity (anastomotic leakage, wound infection, stricture of the jejunal anastomosis, and recurrent laryngeal nerve palsy), functional outcomes (time to start oral intake, achieve complete oral intake, and decannulation, and the rate of larynx preservation), and oncologic outcomes (margin status, survival rate, and local control rate) were analyzed and compared between the high-tumor and low-tumor groups. Before starting oral intake, video fluorography by barium swallow was performed from 7 days to 14 days postoperatively to detect anastomotic leakage and to evaluate swallowing function. Larynx preservation was considered successful when patients could speak and breathe without tracheal stoma and could achieve oral intake without tube feeding postoperatively. The disease free survival and local control rate was calculated using the Kaplan-Meier method. Fisher exact probability test, Mann-Whitney U test, and log-rank test were used for statistical analyses. A P value of $<$ .05 was considered to indicate statistical significance.

RESULTS

Mortality and Morbidity

The overall mortality and morbidity rates in each group are shown in Table IV. No perioperative deaths or

TABLE IV.
Mortality and Morbidity.

	High-Tumor Group (n = 15)	Low-Tumor Group (n = 17)	P Value
Death	0	0	1 (NS)
Graft necrosis	0	0	1 (NS)
Anastomotic leakage	3 (20%)	1 (5.9%)	.228 (NS)
Local wound infection	2 (13.3%)	2 (11.8%)	.893 (NS)
Anastomotic stricture	5 (33.3%)	3 (17.6%)	.539 (NS))

These results were compared by means of Fisher exact probability test.
NS = not significant.

life-threatening systemic complications (e.g., respiratory failure, myocardial infarction, brain infarction, and renal failure) occurred, and all transferred jejunal grafts survived completely in both groups.

Anastomotic leakage occurred in four patients (12.5%), always at the jejuno-pharyngeal anastomosis. The incidence of leakage was 20% in the high-tumor group and 5.9% in the low-tumor group, which did not differ significantly between the groups (Fisher exact test, $P = .228$). Three of four patients with anastomotic leakage healed conservatively, but one patient in the high-tumor group required two additional surgical treatments, formation and closure of external fistula.

Local wound infection occurred in four patients (12.5%), with the rates in the high-tumor group (13.3%) and the low-tumor group (11.8%), not differing significantly (Fisher exact test, $P = .893$). All wound infections were around the tracheal stoma or the lower part of the neck. The rate of wound infection did not differ significantly (Fisher exact test, $P = .228$) between patients who underwent tracheostomy (three of 15 patients, 20%) and those who did not (one of 17 patients, 5.9%). Wounds healed with conservative treatment in three of four patients, but one patient in the low-tumor group who had upper mediastinitis and osteomyelitis of the sternum as a result of stomal leakage required surgical debridement.

Stricture of the jejunal anastomosis developed in eight patients (25%); but the rate of stricture did not differ significantly (Fisher exact test, $P = .539$) between the high-tumor group (33.3%) and the low-tumor group (17.6%). All strictures developed in patients who underwent conduit jejunal reconstruction. Strictures were at the jejuno-esophageal anastomosis in seven patients and at both the jejuno-esophageal and jejuno-pharyngeal anastomoses in one patient. The rate of stricture was higher at the jejuno-esophageal anastomosis (26.7%, eight of 30 anastomoses) than at the jejuno-pharyngeal anastomosis (3.3%, one of 30 anastomoses; Fisher exact test, $P = .03$). The rate of stricture did not differ significantly between handsewn sites (five of 50, 10%) and mechanically sutured sites (four of 10, 40%; Fisher exact test, $P = .052$). All strictures were successfully treated with endoscopic balloon dilation.

The recurrent laryngeal nerve of one side was sacrificed because of tumor invasion in five patients of the high-tumor group (33.3%) and in two patients of the low-tumor group (11.8%). However, both recurrent laryngeal nerves were preserved in the other 25 patients (10 of the high-tumor and 15 of the low-tumor group). Despite the preservation of both nerves, unilateral palsy was observed postoperatively in four patients (40%) of the high-tumor group and six patients (40%) of the low-tumor group. Bilateral palsy was also observed in one of 15 patients (6.7%) in the low-tumor group. The incidence of postoperative unilateral and bilateral recurrent laryngeal nerve palsies did not differ significantly between the two groups (Fisher exact test, $P = 1$). All recurrent laryngeal nerve palsies healed spontaneously between 2 weeks to 5 months postoperatively (mean, 2.3 months) if the nerves had been preserved.

Functional Outcomes

Postoperative aspiration was absent or transient for most of the patients. In some patients, severe aspiration was experienced for a few weeks after initiation of oral intake, but the aspiration was conquered with swallowing training, and all patients eventually achieved complete oral alimentation without tube feeding.

The overall mean interval from the day of surgery to the start of oral intake was 12.5 days. It was significantly longer in the high-tumor group (14.9 days) than in the low-tumor group (10.4 days; Mann-Whitney U test, $P = .028$; Table V). The mean time from the start of oral intake to the achievement of complete oral alimentation without tube feeding was 17.1 days in all patients. It was also significantly longer in the high-tumor group (23.4 days) than in the low-tumor group (11 days; Mann-Whitney U test, $p = .012$; Table V).

The mean interval from the day of surgery to the start of oral intake was 13.5 days in four patients with a history of previous irradiation and 12.3 days in other patients without previous irradiation, which was not statistically significant (Mann-Whitney U test, $P = .24$). The mean time from the start of oral intake to the achievement of complete oral alimentation was 24.5 days in four patients with a history of previous irradiation and 16 days in other patients without previous

TABLE V.
Functional Outcomes.

	High-Tumor Group	Low-Tumor Group	P Value
Interval to start of oral intake (d)			
Mean	14.9	10.4	.028
Range	8–41	7–20	
Interval to achieve complete oral intake			
Mean	23.4	11	.012
Range	7–57	2–22	
Interval to decannulation			
Mean	11 5	13.5	1 (NS)
Range	1–22 (n = 11)	1–36 (n = 4)	

These results were compared by means of the Mann-Whitney U test.
NS = not significant.

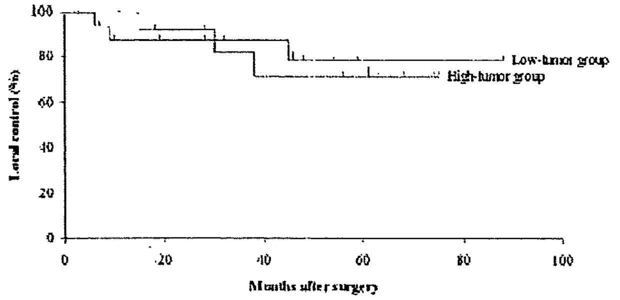

Fig. 2. Local control in patients in the high- or low-tumor group.

irradiation, which was not also statistically significant (Mann-Whitney U test, $P = .376$). In five patients with postoperative irradiation or chemotherapy, the mean time from the start of oral intake to the achievement of complete oral alimentation was 28.6 days, whereas it was 14.9 days in those without postoperative treatment, which was not also statistically significant (Mann-Whitney U test, $P = .31$).

Decannulation was possible in all patients in both groups who underwent tracheostomy. The mean time to decannulation did not differ significantly between the high-tumor group (11.5 days) and the low-tumor group (13.5 days; Mann-Whitney U test, $P = 1$). Finally, laryngeal function was completely preserved in all patients in both groups.

Oncologic Outcomes

In pathological study, surgical margin of the oral side was affected by the tumor in one of 15 patients (6.7%) of the high-tumor group, and two of 17 patients (11.8%) of the low-tumor group. As for the anal side, surgical margin was affected in two of 15 patients (13.3%) in the high-tumor group, and two of 17 patients (11.8%) in the low-tumor group. During the postoperative follow-up, local recurrence of the oral side occurred in one patient (6.7%) of the high-tumor group, and in one patient (5.9%) of the low-tumor group. Local recurrence of the anal side occurred in one patient (6.7%) in the high-tumor group, and in two patients (11.8%) of the low-tumor group. In total, the 5-year local control rate was 71.8% in the high-tumor group and 79.1% in the low-tumor group, which was not statistically significant (Log-rank test, $P = .831$; Fig. 2). The 5-year disease-free survival was 33.3% in the high-tumor group and 45.8% in the low-tumor group, which was not also statistically significant (Log-rank test, $P = .824$; Fig. 3).

DISCUSSION

Re-establishing pharyngoesophageal continuity without aspiration after larynx-preserving cervical esophagectomy is a challenging problem in the treatment of carcinoma of the cervical esophagus; to date, only a few successfully treated cases have been reported.[13,14] In particular, patients with high cervical esophageal carcinomas involving the hypopharynx are usually not considered candidates for larynx-preserving surgery. Many surgeons believe that larynx preservation is possible in only carefully selected cases and that total laryngectomy is usually necessary.[6,7] The safety and reliability of larynx-preserving cervical esophagectomy has not been established.

A gastric tube or a free jejunal graft is usually preferred for reconstructing surgical defects after the resection of esophageal tumors. In larynx-preserving cervical esophagectomy, however, the choice of procedures for re-establishing esophageal continuity and for avoiding postoperative aspiration remains controversial. Gastric pull-up has the advantage of requiring only a single intestinal anastomosis. This procedure also avoids the possibility of carcinoma remaining in the thoracic esophagus because the entire esophagus is removed. However, thoracic esophagectomy and manipulation of the mediastinum can lead to fatal cardiopulmonary complications.[8] Reported perioperative death rates with gastric pull-up have ranged from 6.3% to 7.3%.[7,8,10,14] Another disadvantage of gastric pull-up is that the loss of function of the lower esophageal sphincter causes gastroesophageal reflux, which may result in persistent aspiration if the larynx is preserved.[13,14] Tu et al.[14] reconstructed the cervical esophagus, most often with a gastric tube, and preserved the larynx in 26 patients: 16 patients (61.5%) required long-term cannulation, and one patient (3.8%) died of aspiration pneumonia after surgery. Free jejunal transfer, on the other hand, does require two intestinal anastomoses, but the risk of anastomotic leakage is similar to or lower than that with gastric pull-up.[8-10] Furthermore, free jejunal transfer preserves the function of the lower esophageal sphincter so that reflux of digestive fluid can be avoided. Jejunal segments also function as a valve and prevent reflux of the digestive fluid.[15] Therefore, free jejunal transfer might be a more appropriate reconstruction technique after larynx-preserving cervical esophagectomy in terms of avoiding postoperative aspiration and decreasing the rates of mortality and morbidity.[9,15]

In the present study, there were no perioperative deaths in patients with either high or low esophageal tumors. Free jejunal transfer, which is a less traumatic procedure, might minimize the burden upon patients and decrease the perioperative mortality rate. Furthermore, none of our patients had graft necrosis, which is the most severe complication after microvascular

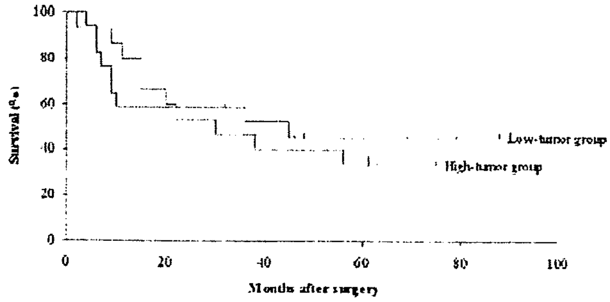

Fig. 3 Disease-free survival in patients in the high- or low-tumor group

Fig. 4. One month after transfer of the jejunal graft. A part of transferred jejunal graft (arrow) is seen in the posterior side of the hypopharynx. No pooling of intestinal fluids or saliva is seen around the larynx.

reconstruction. Recent studies have reported high success rates of microsurgical anastomosis (95% or more) in head and neck reconstruction.[16,17] Because microsurgical reconstruction has become a safe and reliable technique, the need for microsurgical anastomosis is no longer a reason for avoiding free jejunal transfer.

In the present study the rates of postoperative complications did not differ significantly between patients with high esophageal tumors involving the hypopharynx and patients with low tumors. A major complication that required additional surgery developed in one patient of each group, major leakage in a patient of the high-tumor group (6.7%) and sternal osteomyelitis in a patient of the low-tumor group (5.9%). In the high-tumor group, jejunal anastomosis to the edge of the hypopharyngeal mucosa was more complicated because the preserved larynx can obstruct suturing; this increased complexity was considered the cause of major leakage. The patient with osteomyelitis in the low-tumor group had undergone simultaneous tracheostomy and partial sternotomy. The operative field is never clean in this kind of clean-contaminated surgery, especially around the tracheal stoma. Tight suturing around the tracheal stoma to close the communication between the trachea and the cervical skin was considered necessary to avoid this complication. We believe that the overall incidence of major complications in each group was acceptable.

Aspiration was absent or only transient and was not an obstacle to larynx preservation in either the low-tumor group or the high-tumor group. Although oral intake started later and complete oral intake was achieved later in the high-tumor group, it eventually became possible in all patients, and decannulation was performed. In some patients of the high-tumor group, the transferred jejunum was seen near the larynx along with pooling of intestinal fluids during the early postoperative period. However, the pooling gradually decreased after several months, as shown in Figure 4, and ultimately did not affect postoperative swallowing function.[18] Precautions to take during the operation in patients with high esophageal tumors are to dilate the oral end of jejunal segment to conform it to the pharyngeal defect and to avoid the loss of laryngeal sensation by securely preserving the superior laryngeal nerve. We believe that these procedures are the key to minimizing postoperative aspiration. Our experiences suggest that, by means of free jejunal transfer, the larynx can be preserved if tumor invasion is limited to two subsites of the hypopharynx. To date, we have preserved the larynx in only one patient who had a tumor involving three subsites of the hypopharynx; preserving the larynx of such patients will continue to present an enormous challenge.

The incidence of recurrent laryngeal nerve palsy was high in both groups of patients, perhaps because of aggressive dissection of the paratracheal lymph nodes. However, all patients, including those who had permanent palsy, could finally achieve oral alimentation without aspiration. If patients have a good performance status and no history of a swallowing disorder, the aspiration associated with ipsilateral recurrent nerve palsy could be overcome with swallowing training, despite the palsy being permanent. We believe our eligibility criteria for larynx-preserving surgery are appropriate.

Contrary to previous reports, encouraging treatment outcomes of radiotherapy have recently been demonstrated for carcinoma of the cervical esophagus.[3] Although we have experienced only two patients who received postoperative radiotherapy, they both finally achieved complete oral intake. We assume that postoperative radiotherapy only causes temporary dysphagia and the postoperative swallowing function will be recovered in a few months, but further investigation on the influence of radiotherapy would be inevitable. If postoperative radiotherapy has minimal negative influence on the postoperative swallowing function, it would be of great value to perform postoperative radiotherapy to achieve better local control rate.

Poor prognoses have been reported for patients with cervical esophageal carcinoma, even when treated with both laryngectomy and esophagectomy.[19,20] However, survival rates are similar in patients who undergo cervical esophagectomy regardless of whether laryngectomy is performed.[13,14,21] Therefore, preservation of the larynx does not decrease survival but does improve postoperative quality of life. Complications of our larynx-preserving surgery were acceptable, and functional outcomes were excellent in both patients with high esophageal tumors and those with low tumors, and oncologic outcomes were similar in both patients. These results suggest that this surgical procedure is indicated for a wider set of patients, including those with hypopharyngeal involvement. For avoiding postoperative aspiration, a free jejunal graft is more effective than a gastric tube.

CONCLUSION

Larynx-preserving cervical esophagectomy and reconstruction using free jejunal grafts are safe and reliable procedures for patients with carcinoma of the cervical esophagus. These procedures can be used to treat eligible patients with tumors that involve part of the hypopharynx.

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Monitoring the Changes in Intraparenchymatous Venous Pressure to Ascertain Flap Viability

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Background: Disruption of venous outflow can lead to tissue necrosis. Thrombosis of a venous channel at the coaptation site in instances of free tissue transfer could cause death of the transplanted tissues. Although various techniques have been used to monitor the viability of transferred tissues, there has been no technique designed specifically to check the flow within and the patency of the venous channel. The authors have devised an approach with which to monitor the changes in venous pressure in a composite tissue transferred by means of microsurgical technique for bodily reconstruction.

Methods: The status of the venous system in various composite tissue grafts was monitored at the time of surgery or for 3 days after the completion of surgery by placing a small-caliber catheter in the vein within the transferred tissue. A total of 52 patients participated in the study.

Results: The venous pressure noted in grafts with a patent venous channel remained constant within a range between 0 and 35 mmHg. Venous insufficiency was detected in three of the 52 cases, with unmistakable findings of an elevated venous pressure of over 50 mmHg.

Conclusions: The technique of measuring the venous pressure by means of an indwelling venous catheter to monitor changes was found to accurately assess the patency of the venous channel and, by inference, the viability of the transferred tissue. No morbidity was associated with the technique. (*Plast. Reconstr. Surg.* 119: 2111, 2007.)

The success rate of free tissue transfer has been improved since its introduction more than three decades ago. Increasing experience among microsurgeons, the development of more reliable flaps, and improved microsurgical techniques and instruments have contributed to reduce the failure rate of free tissue transfer. Despite improved initial success rates of over 95 percent,[1–3] anastomotic failure may occur on either the arterial side or the venous side and remains a major cause of tissue loss. Because necrosis of a transferred tissue is a costly disaster and salvage of the affected tissue largely depends on the time to reexploration,[1,3] accurate assessment of flap circulation is essential.

Various methods have been described for assessing the adequacy of blood flow to a transplanted tissue. These include laser Doppler flowmetry,[2,4,5] color duplex sonography,[6,7] noninvasive ultrasound Doppler,[8] implantable Doppler,[9,10] hydrogen clearance,[11] pH measurement,[12] photoplethysmography,[13] transcutaneous oxygen tension,[14] and temperature.[15] An ideal monitoring method should be continuous, instantaneous, reliable, reproducible, and easily interpretable. Although the above methods have proven useful in judging the adequacy of the arterial blood flow, they have not specifically indicated blood flow disturbance in venous channels.

Veins are susceptible to trauma of various sorts because of their thin walls and fragile structures. It is well known that venous thrombosis is more common[1] and more harmful to a flap than arterial thrombosis.[16,17] Because the very first event that occurs after venous occlusion is an increase in venous pressure, monitoring this parameter may provide instantaneous information about venous insufficiency after free tissue transfer. Pressure changes within a venous channel can be monitored by placing a catheter inside the vein. We used this technique in 52 patients who un-

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derwent free flap transplantation between 1999 and 2004 to determine the usefulness of venous pressure measurement and monitoring as a method for ascertaining venous channel patency. The experience gained from this group of patients formed the basis of this report.

PATIENTS AND METHODS

Between 1999 and 2004, a total of 52 patients underwent free tissue transfer with monitoring of the intraparenchymatous venous pressure. There were 19 female patients and 33 male patients. Patient ages ranged from 17 to 76 years, with a mean age of 54 years. Initially, we used this method for patients who developed venous thrombosis postoperatively, and the catheter was inserted during the reoperation, with the intent of salvaging the transferred tissue. Recognition of the versatility and safety of venous catheterization subsequently led us to expand the indication to primary cases with free tissue transfer, especially those considered to be at high risk of venous thrombosis. The criteria for indication of in situ venous catheterization included heavy smoking, tissue with irradiation sequelae, reconstruction of traumatized lower extremities, buried flap, bony reconstruction, intraoperative vascular thrombosis, and usage of long-vein grafting for venous anastomosis (Table 1). The specific donor sites used and their distribution among the recipient sites are listed in Tables 2 and 3.

Description of Indwelling Venous Catheter Placement

The patients were fully informed concerning the reasons, the technique of catheter placement, the details of the monitoring procedure, and the consequences and possible complications associated with catheter placement. The possible problems included bleeding, hematoma formation, and persistent pain.

After completion of vascular anastomoses, an intravenous catheter (3 French, 1.0-mm outside diameter; Atom Medical Co., Tokyo, Japan) was inserted into a side branch of the anastomosed vein. The more peripheral side branch was preferable, provided that the catheter could be inserted. In the case of a radial forearm flap or a fibular osteocutaneous flap, the catheter was inserted by means of the distal end of a comitant vein of the radial or fibular artery.

Table 1. Indications for Monitoring the Intraparenchymatous Venous Pressure

Indication	No. of Occurrences (%)
Reexploration for venous thrombosis	8 (15.4)
Intraoperative thrombosis	7 (13.5)
Traumatized lower extremity	14 (26.9)
Buried flap	9 (17.3)
Bony reconstruction	5 (9.6)
Vein grafting	5 (9.6)
Postirradiation therapy	7 (13.5)
Heavy smoking	8 (15.4)

Table 2. Types of Transferred Tissue

Flap Type	No. of Patients
Rectus abdominis	12
Radial forearm	8
Anterolateral thigh	7
Groin	6
Fibula	5
Latissimus dorsi	4
Jejunum	3
Deep inferior epigastric perforator	3
Omentum	2
Saphenous	1
Fillet	1
Total	52

ALT, anterolateral thigh; DIEP, deep inferior epigastric perforator.

Table 3. Flap Destination

Flap Location	No. of Patients
Head and neck	20
Trunk	14
Upper extremity	4
Lower extremity	14
Total	52

Pressure Measurement

The venous catheter was connected to a fluid pressure transducer (P23ID; Statham Gould, Oxnard, Calif.) and to a physiologic recorder (BSS-9800; Nihon Kohden Co., Tokyo, Japan). Zero calibrations were taken at the level of the right atrium. To ascertain the functional integrity of the monitoring system, the venous outflow was occluded manually at a site proximal to the coaptation site once the catheter was in place (Fig. 1).

The venous pressure monitoring was performed in conjunction with local delivery of an anticoagulant agent using a flushing device. The line solution of the venous catheter contained heparin (10 units/ml) in 0.9% sodium chloride, and the flow rate of the flush solution was approximately 3 ml/hour,[18] resulting in continuous infusion of the heparin at 720 units/day. Three days after surgery, the catheter was locked and disconnected from the transducer but left in position for a further 4 days. Thereafter, the catheter was

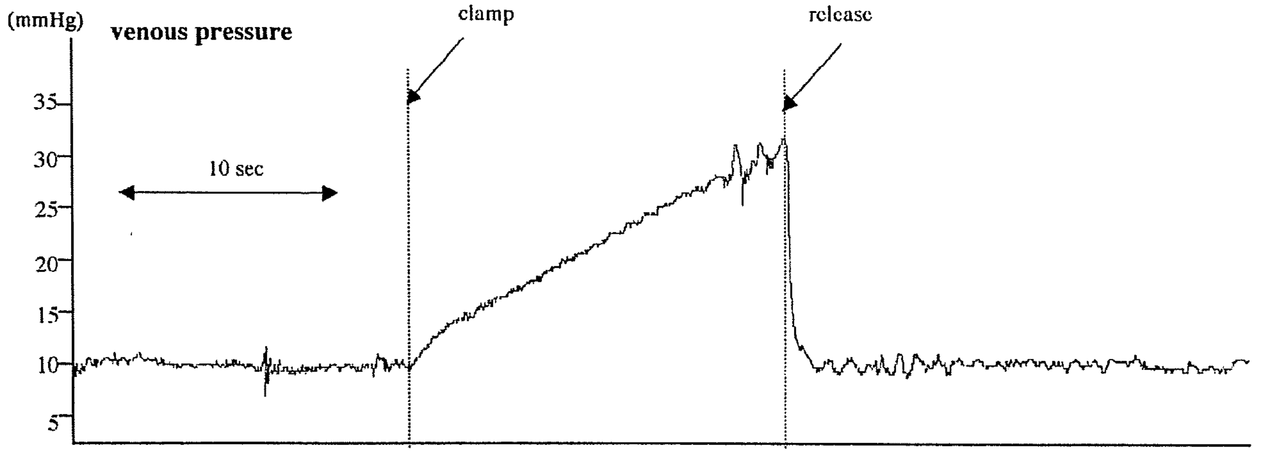

Fig. 1. Transient clamping of an anastomosed vein gradually increased the venous pressure. Release of the venous clamp led to an immediate drop in the venous pressure to the baseline level.

gently tugged at and withdrawn from the flap. No bleeding occurred.

Laser Doppler Flowmetry

In addition, the blood flow was continuously monitored in 23 of the patients using a laser Doppler flowmeter (Laserflo BPM 403; TSI, Inc., St. Paul, Minn.) with a standard right-angle probe with a head diameter of 19 mm (model P-430). This apparatus measures a Doppler shift in reflected laser light, which is related to the number and velocity of moving red blood cells, providing flow values in milliliters per minute per 100 g of tissue. Inherently, this method could not be applied to cases of a buried flap or mucosal reconstruction, unless the grafted tissue was partially exteriorized.

Data Acquisition

Both the venous pressure and surface blood flow were continuously recorded with a computerized data acquisition system (PowerLab; AD Instruments Pty. Ltd., Australia) for later analysis. The recording of the parameters was continued for 3 days, and the mean values for each 24-hour period were analyzed with the software. The alarm for an elevated venous pressure was set at 50 mmHg using the physiologic recorder. Because the parameters were automatically recorded, the nurses did not need to record the venous pressure or the flow values manually. They were instructed to check the monitoring devices and flap color, in cases with a cutaneous component, every 2 hours for 3 days.

The values for the venous pressure and laser Doppler flowmetry on each postoperative day are reported as means ± SD. Statistical evaluation was performed using analysis of variance with repeated measures across time. A value of $p < 0.05$ was considered statistically significant.

RESULTS

Of the 52 flaps, two developed venous thrombosis intraoperatively, and another case developed venous thrombosis 15 hours after surgery. In these three cases, venous insufficiency was detected easily on the basis of an elevated venous pressure of over 50 mmHg, and reanastomosis of the vein led to complete survival of the transferred tissue. There were no cases of free flap loss.

The normal pressure range in uncomplicated free tissue transplants was established by analyzing the data. Among the multiple tissue types and recipient sites, the venous pressure value was relatively constant within the range of 0 to 35 mmHg. The venous pressure during the first postoperative day was 17.5 ± 8.8 mmHg (Fig. 2). The venous pressure tended to decline on days 2 and 3, although it did not reach statistical significance (Fig. 2). The flow rate with laser Doppler flowmetry varied from 0.8 to 13.1 ml/minute/100 g tissue. The flow rate during the first postoperative day was 3.75 ± 1.97 ml/minute/100 g. The flow rate was virtually unchanged during the next 2 postoperative days (Fig. 3).

CASE REPORT

A 55-year-old woman presented with intraosseous carcinoma arising from an impacted third molar. A fibular osteocutaneous flap was used to reconstruct the bony and soft-tissue defect that resulted from segmental mandibulectomy with concomitant radical neck dissection (Fig. 4). Because the cutaneous flap was

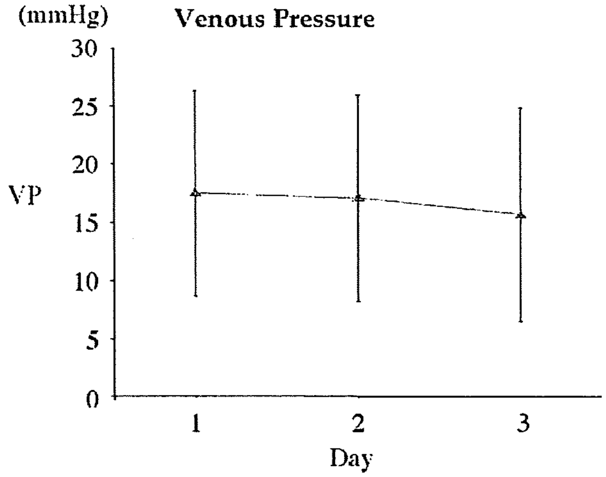

Fig. 2. Changes in intraparenchymatous venous pressure after free tissue transfer. Values are given as means ± SD ($n = 51$).

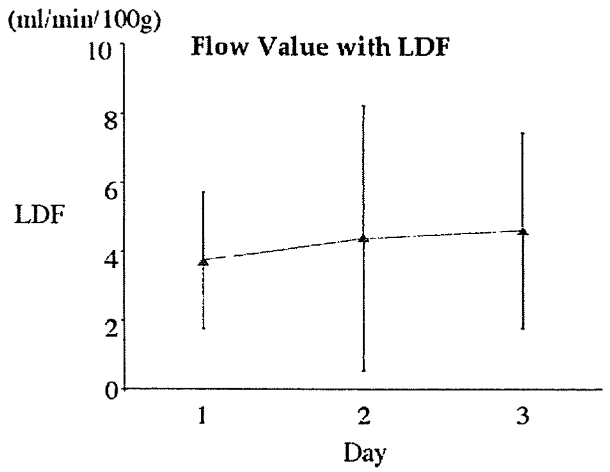

Fig. 3. Changes in surface blood flow as represented by flow value with laser Doppler flowmetry (*LDF*; in milliliters per minute per 100 g) after free tissue transfer. Values are given as mean ± SD ($n = 23$).

located in the oral cavity, laser Doppler flowmetry was not applicable. Therefore, we inserted a catheter into the distal end of the peroneal artery and the comitant vein (Fig. 4). Although the venous pressure was found to be stationary at approximately 25 mmHg for the first 15 hours after surgery, it began to rise incrementally over the next 2 to 3 hours (Fig. 5). We decided to reexplore the wound at 18 hours after surgery because of venous hypertension, even though the color of the flap was judged to be normal. A thrombotic occlusion at the venous coaptation site was found during reexploration of the wound (Fig. 6).

During the reoperation, venous pressure was monitored continuously using the catheter, which was also useful for flushing the vessel in an attempt to remove the clot from inside the vasculature. The venous hypertension disappeared after the clot was removed from the lumen. The continuity of the venous channel was reestablished by using a vein graft. The patient showed no further signs of venous flow impediment, and recovery from the procedure was uneventful (Fig. 7).

DISCUSSION

Early surgical intervention to eliminate any blood flow impediment is the key factor in "rescuing" an ailing flap.[1] Clinical indications for wound reexploration, however, are difficult to define. Over the years, many methods have been advocated for monitoring the blood flow in a transplanted flap.[3–15] However, the information obtained with those various monitoring techniques is rarely helpful to surgeons in determining the need for reexploration of the operative site, especially if a venous outflow disturbance is involved. It is essential, in this regard, for surgeons to have a monitoring technique that is simple and yields information that clearly defines the indication for wound reexploration.

Of the various modalities advocated for postoperative monitoring of flap circulation, the laser Doppler flowmetry technique was thought to be the most useful for assessing interstitial blood flow. It is noninvasive and designed to monitor capillary perfusion. Although this method can deliver objective data, the flow values vary greatly depending on the patient, type of tissue, equipment, type of probe, and recipient site.[2,4,19] Therefore, one must not rely on absolute values, and current reports emphasize the importance of observing the trend of the perfusion value rather than the absolute value.[2,4] This is particularly important in the case of venous occlusions, for which experimental studies have shown that the drop in flow values is not as abrupt and steep as in the case of arterial obstructions.[20] In the clinical setting, Mailaender et al.[19] demonstrated the difficulties in diagnosing venous thrombosis by means of laser Doppler flowmetry caused by nonspecific alterations in the laser Doppler flowmetry signals. In addition, difficulty in placing the monitoring probe in certain parts of the body, as in our patient with intraoral structure reconstruction, can render the use of this technique impossible.

It is well known that venous congestion is more common[1] and more harmful[16,17] than arterial insufficiency. Considering the difficulty in early detection of venous thrombosis with previous monitoring methods, it makes sense to focus on venous thrombosis, attempting to reduce the failure rate of free tissue transfer. Hudson et al.[21] reported the use of a catheter inserted into a side branch of the vein in the transferred tissue. Through this catheter, heparin (500 units/hour) was infused effectively to the venous anastomotic site.[21] However, we believed that the infusion rate for catheter heparinization (30 units/hour) was sufficient to

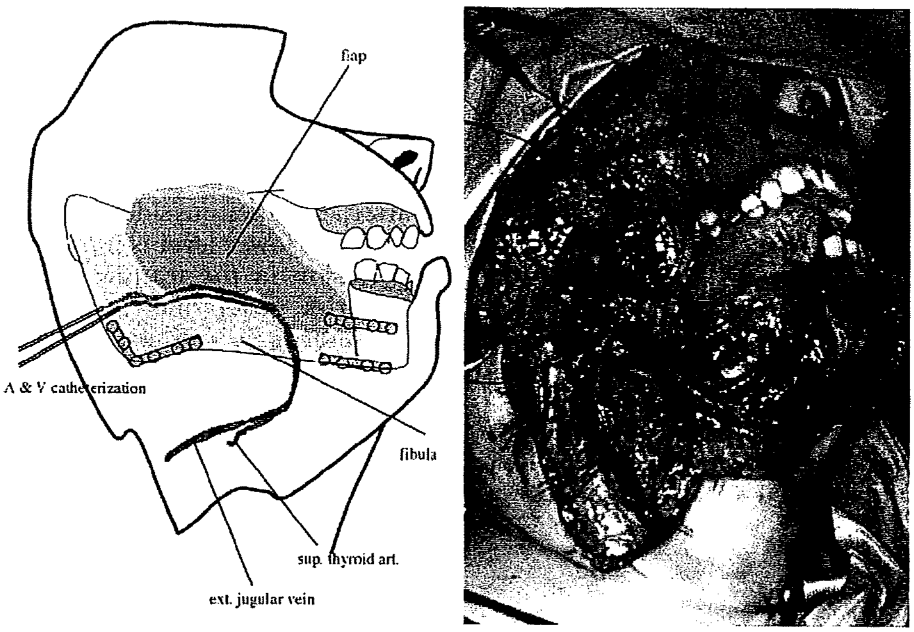

Fig. 4. Free osteocutaneous fibular flap with intraparenchymatous arterial and venous pressure monitoring.

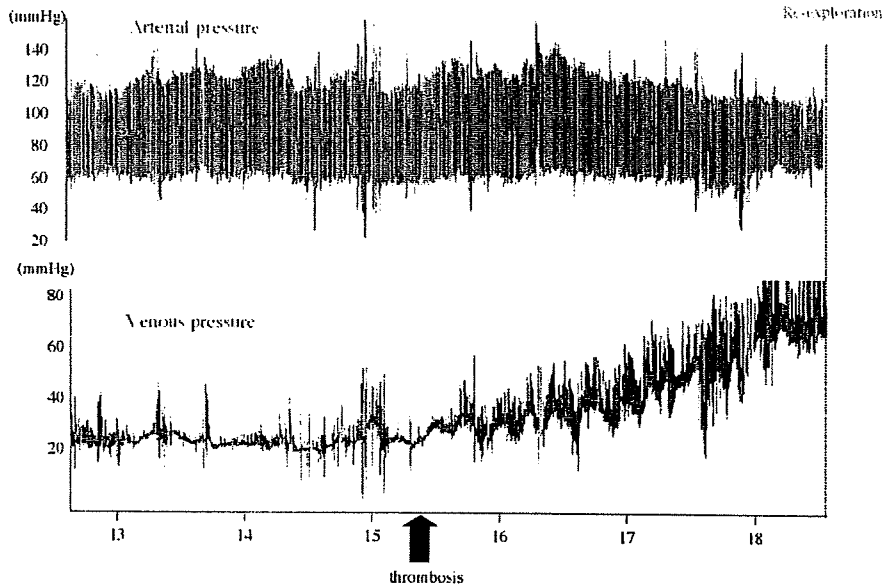

Fig. 5. Changes in intraparenchymatous arterial and venous pressures after venous thrombosis.

reduce coagulability at the local anastomotic site, because the blood flow perfusing the transferred tissue was less than 5 ml/minute in most cases (data not presented). Moreover, we considered that this catheter could be used as a sensitive monitoring device to detect venous thrombosis after free tissue transfer.

In contrast to laser Doppler flowmetry, venous pressure monitoring was able to provide us with instantaneous evidence of venous occlusion. In all three flaps that sustained venous occlusion, the venous pressure elevated to over 50 mmHg before any clinical signs became obvious. The absolute values for venous pressure were easily interpretable even by the nursing staff and inexperienced residents. In addition, continuous monitoring of venous pressure allowed us to identify the onset time of venous pressure elevation, as noted in the described case.