

Lateral Thoracic Artery Can Stabilize Circulation in the Pectoralis Major Myocutaneous Pedicle Flap: Single-center, Prospective, Uncontrolled Case Series

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Background: Head and neck reconstructions using the pectoralis major myocutaneous pedicle flap (PMMF) with thoracoacromial artery alone are prone to hemodynamic instability, possibly leading to infection, prolapse, hematoma, seroma, and partial or total flap failure (6%–71%). Aside from unstable blood circulation, reported risk factors for these complications include feminine gender, smoking, and having diabetes mellitus. Preservation of the lateral thoracic artery in addition to the thoracoacromial artery has been suggested as a way to improve unstable blood circulation in the PMMF.

Methods: This is a single-center, prospective, uncontrolled case series. Circulation to the PMMF was studied intraoperatively with and without lateral thoracic artery clamping after harvest. Indocyanine green (ICG) angiopathy, a quantitative hemodynamic assessment method, was used to analyze three parameters: maximum intensity (Imax), time from start of ICG to maximum intensity (Tmax), and slope of intensity (Smax = Imax/Tmax). Hemodynamic parameters, such as pulse rate and blood pressure, were all within normal ranges. Allergy to contrast media was criterion for exclusion.

Results: Six patients all had oral cancer as their primary disease. Their background was characterized by established risk factors: four patients had a history of smoking, two had diabetes mellitus, and two were women. Postoperatively, no patients had complications at the recipient or donor sites. Mean results of the analysis were Imax: 60 ± 47 , Tmax: 91 ± 55 , Smax: 0.8 ± 0.5 in the clamped group and Imax: 85 ± 40 , Tmax: 73 ± 42 , Smax: 1.8 ± 1.5 in the un-clamped group. Significant difference was observed in Imax ($P = 0.03$) and Smax ($P = 0.03$).

Conclusion: Lateral thoracic artery preservation appears to be useful for stabilizing blood circulation to the PMMF, including in patients considered to be at high-risk for complications, such as women, smokers, and patients with diabetes mellitus. (*Plast Reconstr Surg Glob Open* 2021;9:e3860; doi: [10.1097/GOX.0000000000003860](https://doi.org/10.1097/GOX.0000000000003860); Published online 14 October 2021.)

INTRODUCTION

The pectoralis major myocutaneous pedicle flap (PMMF) method was originally developed for reconstruction of cardiothoracic tissue defects; its use for head and

neck reconstruction was reported in 1979.¹ The pectoral branch of the thoracoacromial artery (TAA) has been called the “workhorse” because of the ease of its harvest within the PMMF method. Three-dimensional anatomical vascular distribution to the PMMF to maintain stable blood circulation in the skin island was demonstrated by Rikimaru et al in 2005.² However, a major disadvantage is the reported instability of blood circulation to the skin island with associated complications.³ Among 84 cases of PMMF for head and neck reconstruction, Liete et al reported total flap losses of 2.4%, partial flap loss of 17.9%, and fistula of 38.7%. Overall complications of PMMF (infection, dehiscence, hematoma, seroma, and partial or total failure of the flap) were reported by Vartanian et al in 36.1%, Tripathi et al in 40%, and Liu et al in 35%, despite using surgical methods with stabilization using TAA.^{4–7} Jena et al reported that of their 140

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female patients with cancers in the oral cavity, 11.4% had skin necrosis.⁸ Smoking and diabetes have been shown to have an association with a high incidence of complications.⁸ Additionally, the inclusion of the intercostal perforating branch inside the nipple-areola complex in the flap is essential for blood circulation.⁹⁻¹¹ In female patients, some of those intercostal perforating branches are compromised by surgery, which makes blood flow unstable and increases the possibility of skin necrosis. Then, when we reconstruct the lingual apex, where the third intercostal perforator is not available and the skin island must be designed inferior to the chest, circulation in the PMMF is unstable because it relies upon circulation mediated by choke vessels.¹²

Cases of PMMF with a small TAA and a large dominant lateral thoracic artery (LTA) have also been reported. The LTA is typically described in anatomy textbooks as arising from the second part of the axillary artery, traveling to the lateral border of the pectoralis minor, and then passing along the deep surface of the pectoralis major. It supplies the axillary lymph nodes, the serratus anterior, the pectoral muscles, and the subcapularis muscle. Cadaver dissection has shown that the LTA is more dominant in the PMMF technique than the TAA in approximately 6% of cases.¹³ Onoda et al reported that in expanded PMMF, the skin island has a more stable blood flow as a result of the additional perfusion of the LTA. These reports have thus shown the importance of the LTA to the vessel anatomy and blood flow circulation and suitability.^{12,14,15}

We hypothesized that the use of LTA in addition to TAA may be important to the success of PMMF and in avoiding complications such as total flap failure. Here, we demonstrate the importance of preserved LTA in this procedure by quantitative hemodynamic evaluation with indocyanine green angiography (ICGA) of PMMF.

Takeaways

Question: How should we improve PMMF in order to prevent complications? What should be done to objectively evaluate these efforts?

Findings: Using ICGA, inclusion of LTA in PMMF objectively demonstrated hemodynamic enhancement to PMMF.

Meaning: Preservation of LTA is essential to avoid complications of PMMF.

METHODS

We reviewed the clinical records of the six patients who underwent PMMF between January 2017 and April 2019 at the Department of Plastic Surgery, Wakayama Medical University. All protocols, surveys, use of indocyanine green (ICG), and consent forms were approved by the Wakayama Medical University Institutional Review Board, and written informed consent was obtained from all patients. Indications for PMMF were old age, calcification of blood vessels and other cases at risk for vascular anastomosis, and salvage cases. Patients with allergy to contrast media were excluded (Fig. 1). Primary endpoint of this study was to show 50% increase in I_{max}/S_{max} in the un-clamped group versus in the clamped group at various timepoints during the surgery period. Secondary endpoint was a lower rate (0%) of complications than previously reported.

Surgical Procedures

A skin island was designed in the lower chest to reach the head and neck defect, always including the fourth and fifth intercostal perforating branches.² When harvesting the PMMF, the pectoral branch of the TAA was included in the flap in the conventional manner. The flap was lifted

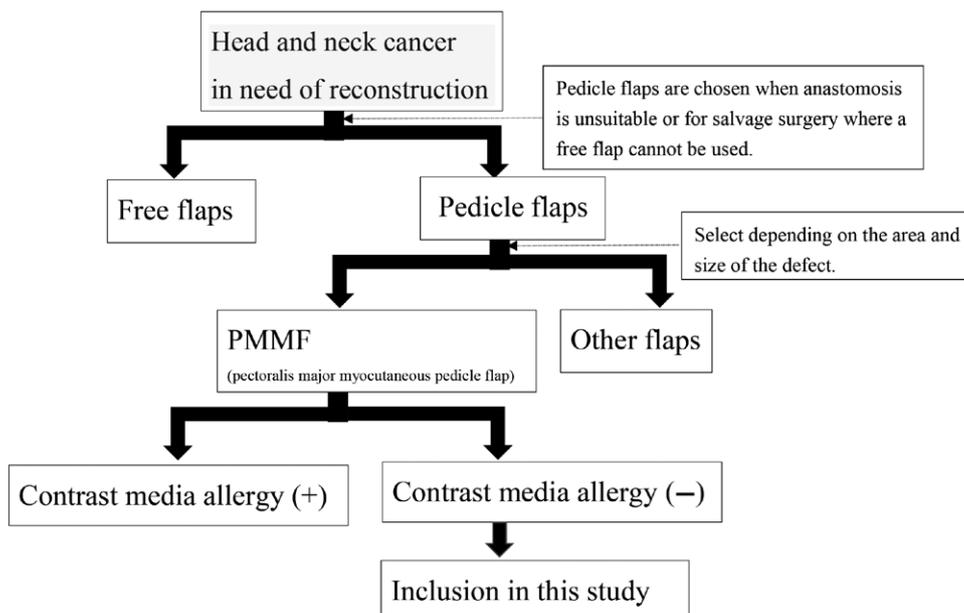


Fig. 1. Algorithm for performing ICGA on PMMF.

from the chest wall inferiorly to superiorly. The LTA, identified underneath the lateral border of the pectoralis muscle in the axillar region, comes out underneath the lateral border of the pectoralis minor muscle and enters the lateral part of the pectoralis major muscle. We completely dissected the pectoralis minor muscle overlying the LTA to release the LTA up to the clavicle.¹⁶ The LTA was preserved without any compromise of pedicle length. In all cases, PMMFs were harvested with preservation of the LTA (Fig. 2).

Blood Flow Dynamics Evaluation with ICGA^{14,17}

ICGA data are known to be affected by hemodynamic parameters such as pulse rate and blood pressure, and the infusion flow rate during measurement (Fig. 3). To minimize the variation in each patient, the anesthesiologists kept the hemodynamic parameters within the normal range and the infusion rate constant.

In phase 1, the LTA was preserved but clamped, representing nonpreservation of the LTA. It was clamped with vessel clips, and 0.2 mg per kg ICG (Diagnogreen; Daiichi-Sankyo Pharmaceutical, Tokyo, Japan) was intravenously injected via a peripheral venous line (Fig. 4A). Immediately after injection of ICG, fluorescence images were obtained using an infrared camera system (Photodynamic Eye, Hamamatsu Photonics K.K. Hamamatsu, Japan). The light source for emission of ICG comprised 760 nm light-emitting diodes, and the detector was a charge-coupled device camera. The distance between the camera and the skin island was maintained at 20 cm (Fig. 4B). Real-time fluorescence images were displayed on a monitor and recorded using digital image processing in audio video interleave format.

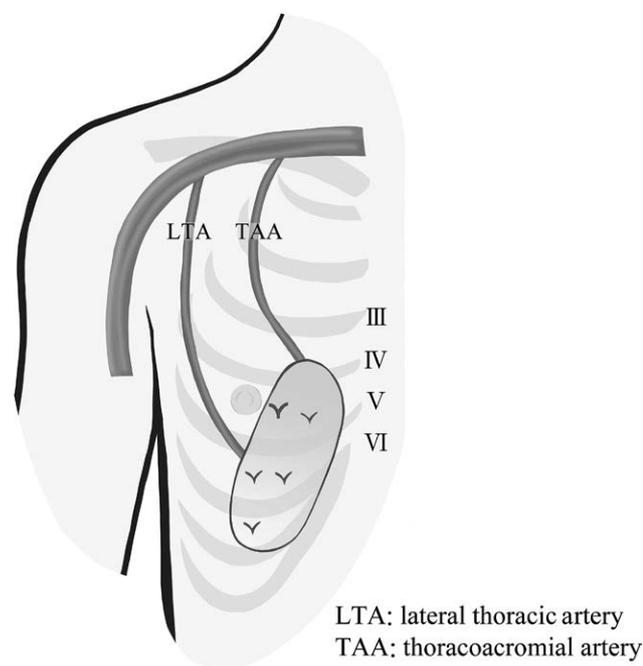


Fig. 2. PMMF schema. In addition to the TAA, the TA is included, and the perforating branches between the fourth and sixth ribs are included in the PMMF.

In phase 2, the LTA was un-clamped, representing preserved LTA, and 4% xylocaine was applied externally to calm vasospasm. After an interval of 10 minutes, ICG was injected again, and ICGA tests were performed, this time with the LTA un-clamped.

In quantitative evaluation of phases 1 & 2, a region of interest (ROI) was defined on the fifth intercostal perforating branches in the skin island to evaluate the ICGA data (Fig. 4C). Image processing and data analysis were performed using ROI ver. U11437 software (Hamamatsu Photonics K.K., Hamamatsu, Japan). In graphs of the relationship between time and intensity based on the intensity data at the ROI, all cases showed onset after approximately 30 seconds, with an initial rapid increase followed by a more gradual increase to a peak intensity, followed by a gradual decrease.

For comparative measurements, three parameters were analyzed to assess perfusion: the magnitude of the intensity from ICG onset to maximum intensity (Imax), the time from ICG onset to maximum intensity (Tmax), and the slope of the intensity increase from ICG onset to maximum intensity (Smax) (Fig. 5). After ICGA tests, the oral cavity was reconstructed in all cases and both the LTA and the TAA were preserved.

Statistical Analysis

Data are expressed as means \pm SD. Differences in parameters between preservation/nonpreservation of LTA conditions were evaluated using a two-sided paired *t* test, significance level of 0.05, with a *P* value less than 0.05 considered significant. Statistical analyses were performed using JMP version 11.0 software (SAS Institute Inc., Cary, N.C.). We calculate statistical power using G*Power 3.1.9.4.^{18,19}

RESULTS

Patient Information and Characteristics

All operative sites were in the oral cavity; patient characteristics are shown in Table 1. Among our six patients, the average age was 69 years. There were four men (mean age 67 years; age range 42–87 years), and two women (mean age 75 years; age range 73–76). Four patients had a smoking habit, a serious risk factor for flap loss. All patients were diagnosed with malignant lesions within the oral region, and resection of each tumor was performed. PMMF was applied to the left side in four patients, and to the right side in two patients. PMMF was performed as a salvage operation for three patients who had undergone previous unsuccessful operations, in one of which the free flap was lost. One patient underwent preoperative radiation therapy.

Statement of the Main Result/finding

All cases were evaluated based on a comparison of the ICGA test results between clamped LTA and un-clamped LTA (Table 2). In the ROI, the mean results of the analysis were Imax: 60 ± 47 , Tmax: 91 ± 55 , Smax: 0.8 ± 0.5 in the clamped group, and Imax: 85 ± 40 , Tmax: 73 ± 42 , Smax: 1.8 ± 1.5 in the un-clamped group. Significant difference was observed in Imax ($P = 0.03$) and Smax ($P = 0.03$).

1. PMMFs were harvested with preservation of the TAA and LTA
2. LTA was clamped (Phase 1)
3. ICG was injected via a peripheral venous line
4. Real-time fluorescence images were displayed on a monitor and recorded in an audio video interweave system
5. LTA was un-clamped (Phase 2)
6. Waited until the PDE camera detects that the brightness of the flap has decreased sufficiently
7. ICG was injected via a peripheral venous line
8. Real-time fluorescence images were displayed on a monitor and recorded in an audio video interweave system

Fig. 3. Method of ICGA.

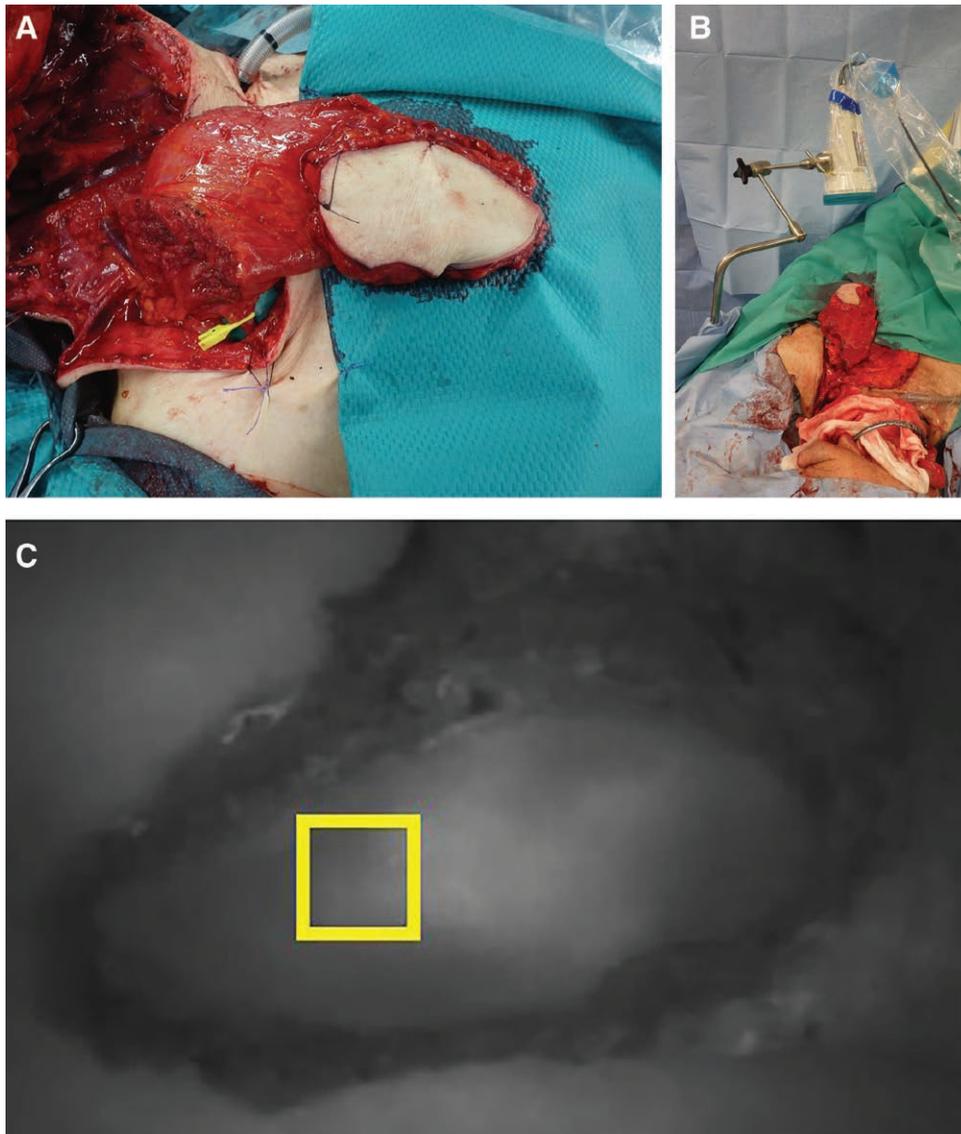


Fig. 4. A, After PMMF, elevation the LTA is clamped with a yellow clip. B, During ICGA, the PMMF and camera are fixed at 20cm. C, During ICGA analysis. The yellow frame shows the analysis area.

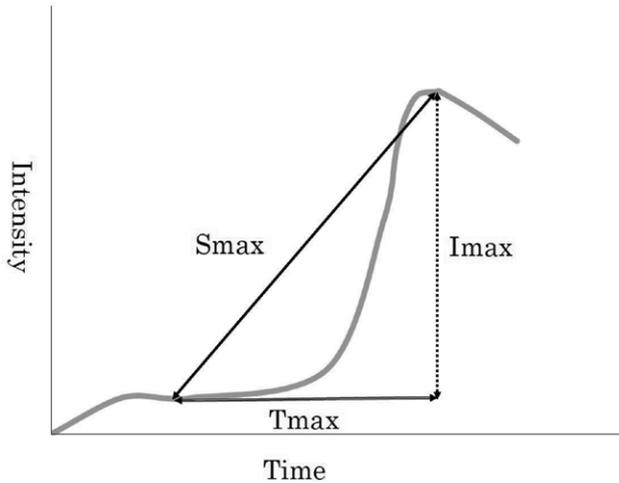


Fig. 5. ICGA test parameters were defined graphically. Imax, magnitude of intensity from ICG onset to maximum intensity. Tmax, time from ICG onset to maximum intensity. Smax, slope of intensity increase from ICG onset to maximum intensity.

(Table 2). In phase 2, inclusion of the blood flow from the LTA into the flap caused a significant increase in Imax and Smax, which implies improved blood supply to the PMMF under this condition. Postoperatively, none of the patients had complications at the recipient or donor sites.

Case Reports

We present a typical case (Case 1) and an atypical case (Case 2) of PMMF reconstruction.

Case 1 (Patient No. 1)

A 67-year-old man with squamous cell carcinoma of the left-side of the tongue (pT2N0M0) underwent surgical resection, including excision of the floor of the mouth, marginal mandibulectomy, and bilateral modified radical

neck dissection. The defect was then planned to be reconstructed by PMMF, for which the size of the skin island was 12 × 7 cm (Fig. 6A). Both the TAA and LTA were included in the flap harvesting method of the PMMF, as described in the Surgical Procedures section (Fig. 6B).

ICGA evaluation was performed to check the flow under both clamped and un-clamped LTA conditions. Imax (72) and Smax (3.7) in the un-clamped LTA condition were higher than Imax (26) and Smax (1.4) in the clamped LTA condition. The time-intensity curve in the un-clamped LTA had a steeper slope than in the clamped LTA condition, implying that flap perfusion was improved by inflow through the LTA (Fig. 7). No vascular insufficiency of the skin island and no fistula formation were observed 3 weeks after the operation (Fig. 8).

Case 2 (Patient No. 4)

A 70-year-old man with squamous cell carcinoma (pT2N0M0) of the oral floor underwent surgical resection, which included total glossectomy, laryngectomy, and bilateral modified radical neck dissection. A skin island designed in the lower chest included the fourth and fifth intercostal perforating branches. The pectoralis minor muscle was dissected to release tension in the pedicle and to preserve the LTA.

Evaluation using ICGA was performed to check the flow under both clamped and un-clamped LTA conditions. In the clamped LTA condition, no perfusion to the flap was observed, and the flap was palpably very cold. Imax and Smax were consistently close to zero. In the un-clamped LTA condition, Imax (38) and Smax (0.3) were much higher than in the clamped LTA condition (Imax 11, Smax 0.2), implying that inflow through the LTA contributed to improvement of perfusion of the flap (Fig. 9). Reconstruction was performed using PMMF with preserved LTA. Postoperatively, no skin necrosis or formation of fistula was observed (Fig. 10). In this

Table 1. Summary of Patients and Lesions

Case	Age/Sex	Diagnosis	Previous Illness	Smoking History	Size of Skin Island (cm)
1	67/Man	Tongue SCC (L) pT2N0M0, (re)	Ureteral calculus	+	12 × 7
2	76/Woman	Tongue SCC (R) pT1N0M0	—	—	7 × 6
3	87/Man	Gingival SCC (L) pT4aN2bM0	Hypertension	—	10 × 7
4	70/Man	Oral floor SCC (L) pT2N0M0	Hypertension, IHD Diabetes mellitus	+	8 × 7
5	73/Woman	Tongue SCC (L) pT3N0M0	Hypertension	+	11 × 7
6	42/Man	Oral floor SCC (R) pT3N2bM0 (re)	Diabetes mellitus	+	14 × 7

Table 2. Comparison of Parameters in the Clamped/Un-clamped LTA Condition

Case	Imax		Tmax(s)		Smax	
	Clamped LTA	Un-clamped LTA	Clamped LTA	Un-clamped LTA	Clamped LTA	Un-clamped LTA
1	26	72	19	20	1.4	3.7
2	45	43	163	107	0.3	0.4
3	100	137	91	52	1.1	2.7
4	11	38	60	122	0.2	0.3
5	119	134	121	63	1.0	2.1
6	58	66	65	44	0.9	1.9
Average	60 ± 47	85 ± 40	91 ± 55	73 ± 42	0.8 ± 0.5	1.8 ± 1.5
P		0.0312*		0.33		0.0306*

*P < 0.05

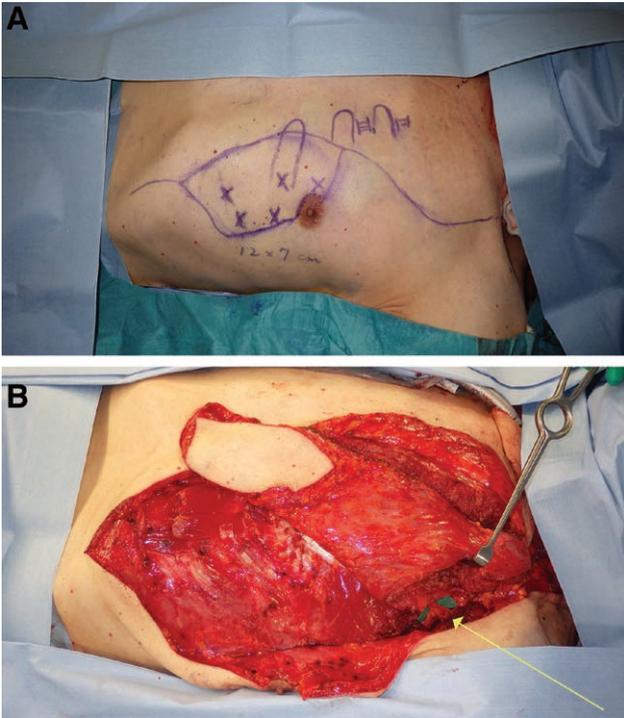


Fig. 6. A, Design of PMMF. B, After elevation of PMMF. The yellow arrow indicates the LTA.

case, blood flow to the flap was thought to be inadequate without preservation of the LTA.

DISCUSSION

General Discussion

In head and neck reconstruction, when free flaps are not available because of vascular damage due to comorbidities, old age, etc., or in salvage cases, PMMF is selected

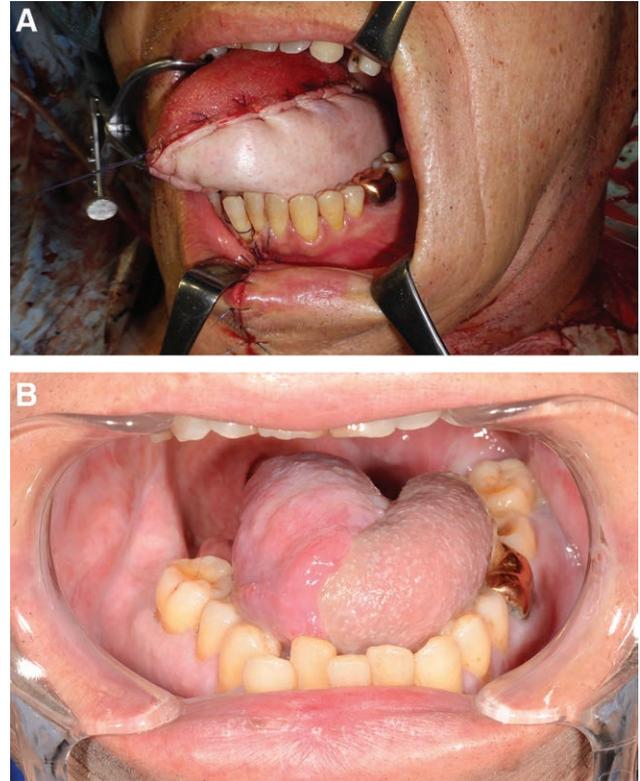


Fig. 8. A, After sewing the PMMF. B, Three weeks after surgery. No complications were observed.

as the first choice of flap. Even minor complications must be avoided, as these cases often do not allow for revision surgery. Our patients included four smokers, of whom two had diabetes, and the other two were women, but there was no skin necrosis or wound dehiscence. There were also no technical limitations or complications in relation to preserving the LTA. Also, no unfavorable events were observed in performing this study.

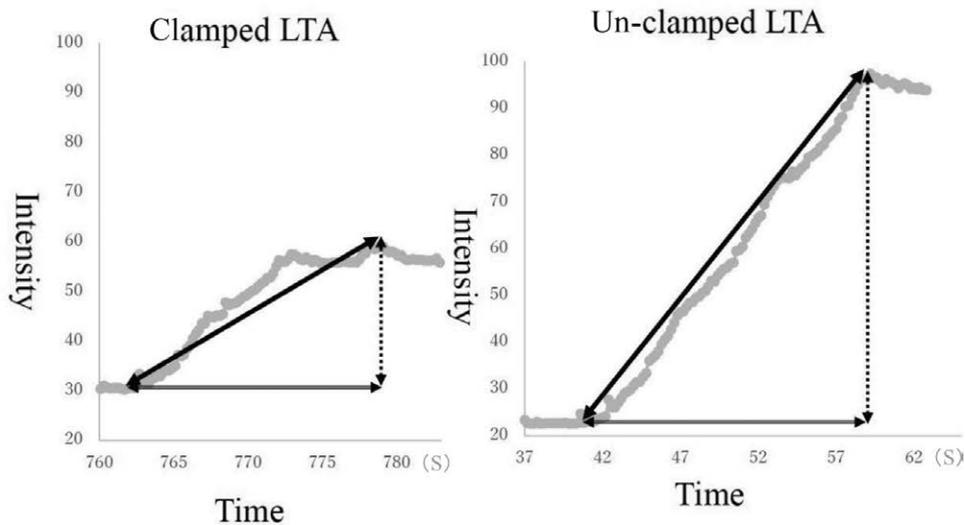


Fig. 7. Case 1, ICGA evaluation I_{max} (72) and S_{max} (3.7) in the un-clamped LTA condition were higher than I_{max} (26) and S_{max} (1.4) in the clamped LTA condition. The time-intensity curve of the un-clamped LTA showed a steeper slope than that of the clamped LTA.

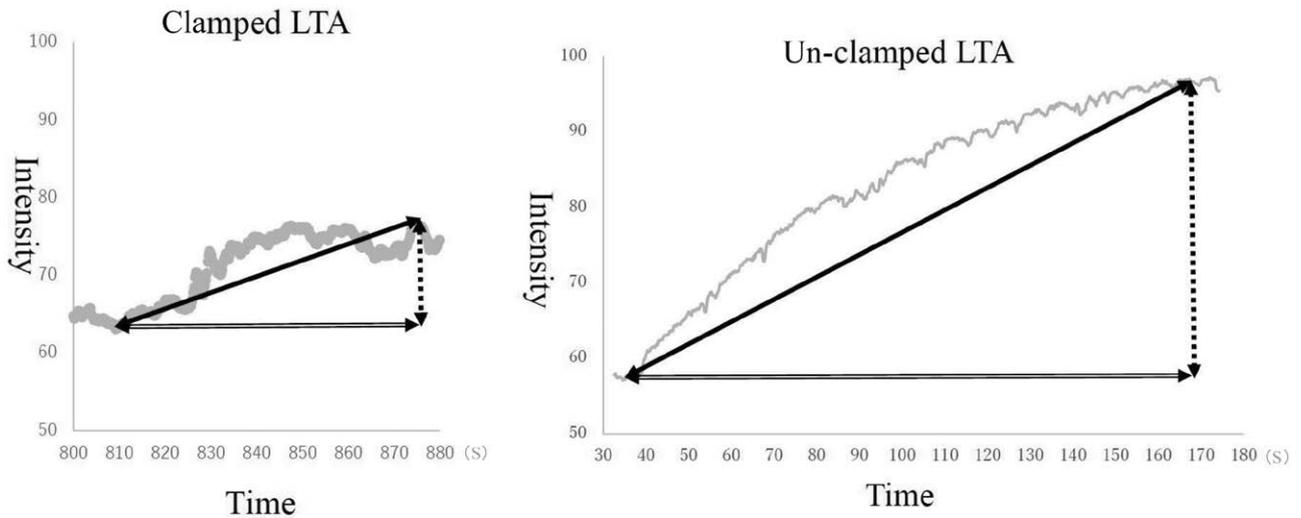


Fig. 9. Case 2. ICGA evaluation in the clamped LTA condition, no perfusion to the flap was observed. I_{max} and S_{max} were consistently close to zero. In the un-clamped LTA condition, I_{max} (38) and S_{max} (0.3) were much higher than in the clamped LTA condition (I_{max} 11, S_{max} 0.2).

ICGA is widely used for vasculature imaging and for estimation of tissue perfusion, for which it provides informative images. Until now, however, it has not been used to quantitatively evaluate blood flow, but Igari et al suggested it as a new parameter for quantitative evaluation of skin tissue perfusion using ICGA.¹⁷ Meanwhile, T_{max} is determined by the absolute values of change and is affected by individual differences, such as wash out time for ICG, blood pressure, and albumin. T_{max} may not, therefore, be an appropriate parameter for quantitative assessment. I_{max} may also be affected by retention of ICG because it is determined by subtraction of the onset intensity from the maximum intensity. Waiting until the ICG is completely drained from the initial injection is the ideal for accurate assessment, but in practice this is difficult because of the need to minimize surgery time, and power of the test in I_{max} is 0.5. We therefore focused on the slope of intensity increase from ICG onset to maximum intensity. This simple and quantitative evaluation of S_{max} with and without

clamping of the LTA in each patient showed a distinct difference. S_{max} reflects improved peripheral perfusion, enabling reliable estimation of perfusion. A simple index to quantitative evaluation of skin island circulation for PMMF was thus established by using ICGA.

The importance of LTA in PMMF has been demonstrated. In the present study, we suggest that preservation of the LTA appears to be useful for both clinically and statistically stable blood circulation to the PMMF. Preserving the LTA is not surgically difficult, and there is no sacrifice associated with it. We recommend preserving the LTA for all PMMFs, but consider it especially useful for women, smokers, and those with diabetes mellitus.

Limitations and Recommendations for Future Research

A main limitation of this study is that it is not possible to clamp the TAA because the PMMF is hemo-dominantly controlled by the TAA. Confirming the hemo-dominant

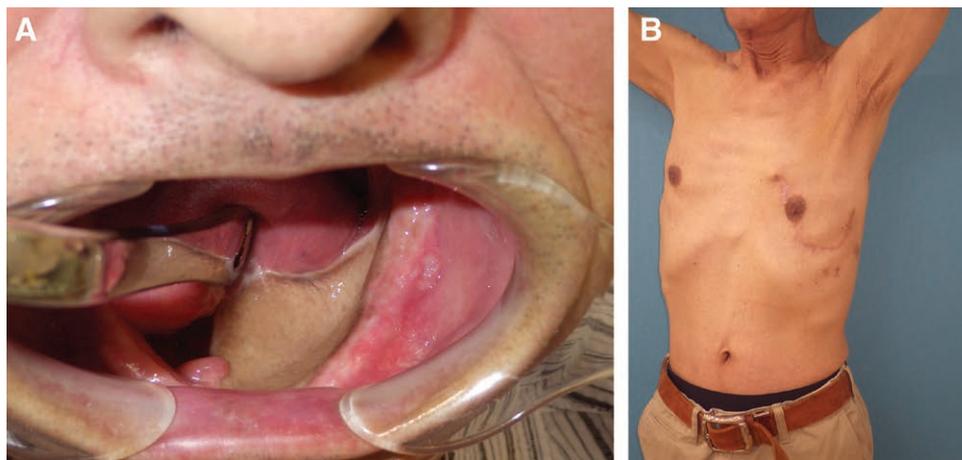


Fig. 10. A, Six months after surgery. No complications were observed. B, PMMF sampling area. There was no significant scarring and no abnormalities in shoulder elevation.

area of the LTA in isolation is therefore difficult. Other limitations are there being no control, that the sample was small, and that there was no formal analysis of covariables. PMMF was not often chosen, and our department has a strategy of preserving LTA in all cases; so we were unable to create a control group. Future studies will aim to increase the number of cases and to analyze the difference between the hemodynamic regions of the TAA and LTA using ICGA.

CONCLUSIONS

Stable blood circulation is necessary for PMMF in patients in whom a free flap cannot be used, especially in women and in patients with vascular disease due to diabetes mellitus or smoking. For this purpose, preservation of the LTA can be effective. In the present study, a significant difference was observed in maximum intensity and slope of intensity. Future analysis with a larger number of cases will aim to further clarify the difference in the blood circulation area between TAA and LTA.

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