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Quantitative assessment of the free jejunal graft perfusion

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ABSTRACT

Background: Reconstruction with free jejunal graft (FJG) is often performed for patients with hypopharyngeal or cervical esophageal cancer. During reconstruction with an FJG after pharyngoesophagectomy, it is critical to intraoperatively detect venous anastomotic failure and subsequent venous malperfusion to avoid postoperative FJG necrosis. This study introduces a novel method for assessing blood perfusion in FJGs by using indocyanine green (ICG) fluorescence angiography.

Methods: We used ICG fluorescence angiography to quantitatively assess FJG blood perfusion in archived fluorescence video files from 26 patients who had undergone FJG transfer. A software program "ROIs", was used to create a time-fluorescence intensity curve. We retrospectively measured the maximum fluorescence intensity at the terminal ileum and the duration (T1/2max) between when the intensity began rising and when it reached half of the maximum.

Results: Among the 26 patients, 5 patients suffered venous anastomotic failure. In three of these cases, anastomosis was corrected intraoperatively; the other two patients underwent a second FJG transfer. Retrospective assessment showed that the mean T1/2max at the FJG serosae was significantly longer in these five patients than that in FJGs with good blood perfusion. Our analysis revealed that a T1/2max >9.6 s may be a good indicator of FJG venous malperfusion.

Conclusions: Quantitative analysis of ICG fluorescence angiography proved useful for detecting venous anastomotic failure of FJG, and may help to reduce vascular problems in FJG reconstruction.

1. Introduction

In radical surgery for hypopharyngeal and cervical esophageal cancer, reconstruction after pharyngolaryngoesophagectomy is performed using a skin flap, colon, or jejunal graft. Of these methods, free jejunal graft (FJG) transplantation is most widely performed [1–4]. However, the procedure is complex, requiring both microvascular and intestinal anastomoses, and

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the success of the reconstruction is primarily dependent on the FJG blood flow. Although microvascular techniques are becoming more advanced, the anastomoses of the jejunal blood vessels to the cervical vessels are often challenging.

Failure of vascular anastomosis causes FJG necrosis. To avoid this, FJG blood flow should be intraoperatively assessed. Conventionally, surgeons judge the FJG blood flow by observing the graft's serosal color, peristaltic movement, pulsation of the vasa recti, and Doppler ultrasound of mesenteric arteries. However, none of these techniques are sufficient to assess the FJG blood flow accurately [3]. Recently, tissue blood flow has been intraoperatively visualized by using indocyanine green (ICG) fluorescence angiography in various surgical fields, such as cardiac surgery [5–7], and transplantation [8]. This technique has also been applied to esophageal reconstruction, including FJG transplantation, but it has failed to reduce the incidence of anastomotic leakage [9,10]. Intraoperative assessment of arterial blood flow is relatively easy using the techniques described previously, but it is difficult to identify venous malperfusion of the graft caused by the failure of venous drainage. A previous study of ICG fluorescence angiography in microsurgical breast reconstruction could not detect the graft's venous congestion because the ICG fluorescence signal was detected as a result of arterial perfusion [11].

To detect venous malperfusion in FJGs after pharyngolaryngoesophagectomy, we used newly developed software that can quantify the fluorescence intensity in the desired area of the surgical field. With this program, we assessed changes in ICG fluorescence intensity and created a time-florescence intensity curve of the ICG fluorescence angiography using archived video files. In this study, we retrospectively analyzed the data of our surgical cases with FJG, seeking a pharmacokinetic parameter that can predict FJG venous malperfusion intraoperatively.

2. Material and methods

2.1. *ICG fluorescence angiography*

ICG fluorescence angiography was performed using a near-infrared camera system (PDE; Hamamatsu Photonics K. K., Hamamatsu, Japan) that activates ICG with emitted light (wavelength: 760 nm) [12]. ICG (1 mL, Diagnogreen 0.5%; Daiichi-Sankyo Pharmaceutical, Tokyo, Japan) was intravenously injected, after which it instantly bound to globulins in the plasma. ICG absorbs light in the near-infrared range, with a maximum wavelength of 805 nm; it fluoresces with a maximum wavelength of 840 nm in plasma [13].

2.2. *Intraoperative monitoring of ICG fluorescence angiography in patients*

All procedures used in this study were approved by the Ethics Committee of Clinical Research of the Hamamatsu University School of Medicine and with written consent was obtained from each patient. Between February 2007 and November 2011, 26 consecutive patients (24 male and 2 female) underwent FJG transfer after pharyngolaryngoesophagectomy for hypopharyngeal cancer, cervical esophageal cancer, or thyroidal cancer. The tumors were located in the hypopharynx in 22 patients, the cervical esophagus in 2 patients, the middle thoracic esophagus in 1 patient, and the thyroid in 1 patient (Table). The anastomotic vessels are shown in Table. Figure 1C shows an intraoperative view of ICG fluorescence angiography of FJG. A surgeon directly handled the camera unit and observed the real-time image on a laptop computer (Fig. 1A). After the pharyngolaryngoesophagectomy, reconstruction with an FJG was performed. The superior thyroid artery was used as the feeding artery with end-to-end anastomosis, whereas the jugular vein was used as the drainage vein with end-to-side anastomosis. Esophago-jejunal anastomosis was performed after the vessel anastomoses (Fig. 1B and D). The video files of the ICG fluorescence angiography were stored on a computer hard drive and retrospectively analyzed with the newly developed ROIs software (Hamamatsu Photonics K. K.). In the quantitative analysis of ICG fluorescence angiography, a time curve of fluorescence intensity at the serosae of the middle portion of the FJG was created and retrospectively analyzed in each case. The maximum fluorescence intensity in thee serosal surface in the FJG was recorded as FIMAX. T1/2max was defined as the duration between when the intensity began rising and when it reached half of FIMAX (Fig. 2). FIMAX and T1/2max were calculated as discussed previously, and we compared the differences in either FIMAX and T1/2max between successful cases and venous malperfusion cases.

2.3. *Statistical analysis*

The data are expressed as the mean ± standard deviation. Statistical significance was assessed using the two-sided Student *t*-test. Statistical analyses were performed using StatView 5.0 (SAS Institute, Tokyo, Japan).

Table – Patients characteristics and anastomotic vessels.

Characteristics and anastomotic vessels	*n*
Age (range)	63.1 (49–75)
Sex	
Male	24
Female	2
Location	
Ph	22
Ce	2
Mt	1
Thyroid	1
Operative procedure	
FJG	24
Gastric pull-up and FJG	2
Feeding artery	
Superior thyroidal artery	15
Transverse cervical artery	9
Carotid artery	2
Drainage vein	
Internal jugular vein	22
External jugular vein	4