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The Importance of Indocyanine Green Near-Infrared Fluorescence Angiography in Perfusion Assessment in Vascularized Omentum Lymphatic Transplant (VOLT)

M Coriddi, MD, E Kenworthy, MD, A Weinstein, MD, BJ Mehrara, MD, and JH Dayan, MD
Memorial Sloan Kettering Cancer Center, Department of Surgery, Division of Plastic Surgery

Abstract

Background and Objectives—The vascularized omentum lymphatic transplant (VOLT) for treatment of lymphedema has become popular because of no risk of iatrogenic lymphedema and abundant lymphatic tissue. However, perfusion to the omentum can be difficult to assess clinically. The purpose of this study was to clarify the incidence and degree of ischemia in the omentum.

Methods—A retrospective study was conducted to review ICG perfusion findings on patients undergoing VOLT. Patients were placed into 4 categories based on percentage surface area of omentum that was ischemic: normal, less than 25%, between 25–50%, and greater than 50% ischemic. Spearman correlation was performed to determine whether an association exists between prior abdominal surgery and the presence of ischemia. Results: Twenty-six patients underwent VOLT for treatment of extremity lymphedema. Twelve (46.2%) patients had normal perfusion, 8 patients (30.8%) had less than 25% ischemia and 6 patients (23.1%) had 25–50% ischemia. Prior abdominal surgery was not significantly associated with the presence of ischemia.

Conclusion—Normal flap perfusion is a requisite for successful VOLT harvest. However, over half the patients had some degree of abnormal perfusion irrespective of prior abdominal surgery. ICG angiography is an important tool in ensuring a healthy lymphatic reconstruction.

Graphical Abstract

Synopsis for Table of Contents: Adequate perfusion to the omentum during vascularized omentum lymphatic transplant (VOLT) cannot be reliably assessed clinically. Indocyanine green angiography during omentum harvest revealed over half the patients in this study had some degree of ischemia even though they did not have prior abdominal surgery making this an important tool for lymphatic reconstruction.

Keywords

lymphedema; vascularized lymph node transplant; vascularized omentum lymphatic transplant; omentum; indocyanine green angiography

Corresponding author: Joseph H. Dayan, MD, Co-director, Lymphatic Surgery & Research Program, Director, Facial Nerve Program, Memorial Sloan Kettering Cancer Center, Department of Surgery, Division of Plastic Surgery, 1275 York Avenue, Box 435, New York, NY 10065, (212) 639-8095, dayanj@mskcc.org.

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Introduction

The vascularized omentum lymphatic transplant (VOLT) is an appealing option for treating lymphedema as it eliminates the risk of iatrogenic lymphedema.[1–5] The VOLT also provides an abundance of lymphatic tissue reliably based on the right gastroepiploic vessels. However, the quality of the omentum can vary significantly because of scarring from prior abdominal surgery or other inflammatory process which may negatively impact perfusion. Clinical assessment of perfusion of the omentum is difficult because there is no skin paddle. Therefore, we routinely utilized indocyanine green (ICG) near-infrared fluorescence angiography to visualize the circulation of the omentum following anastomosis. We were surprised to find a significant number of omentum flaps that had areas of ischemia requiring partial excision even in the absence of gross scarring. The purpose of this study was to evaluate the incidence and degree of ischemia in the omentum in patients undergoing VOLT.

Materials and Methods

After institutional review board approval, IRB 18-057, a retrospective study was conducted on all patients who underwent VOLT. All cases were performed using an open technique with microsurgical instruments and bipolar cautery. Exposure was obtained through a 6 – 8 cm epigastric midline incision. All available intra-operative ICG near-infrared fluorescence angiography images were reviewed. Patients received a standard intravenous injection of 4 ml of indocyanine green dye followed by a 10 ml saline flush and images were acquired on the SPY Elite® (Stryker, Kalamazoo, MI). Perfusion of the omentum was assessed based on the percentage surface area of the omentum that was severely ischemic. This was determined as any portion of the omentum that was completely black on ICG angiography. Patients were stratified into the following 4 groups: (1) normal perfusion throughout, (2) less than 25% ischemic, (3) 25–50% ischemic, and (4) greater than 50% ischemic.

Statistical Analysis

Data were summarized as counts, percentages, means $\pm$ standard deviations, and medians and interquartile ranges as appropriate. Continuous variables were compared using two-sample t-tests when parametric assumptions were satisfied, and Wilcoxon rank-sum tests otherwise. Categorical variables were compared using chi-squared tests. Spearman correlation was performed to determine whether an association exists between prior abdominal surgery and the presence of omental ischemia observed with near-infrared fluorescence angiography. The level of statistical significance for hypothesis testing was set at $\alpha = 0.05$. Statistical analyses were performed using JMP® version 13.2 (SAS Institute, Inc., Cary, N.C.).

Results

Twenty-six patients underwent VOLT for treatment of extremity lymphedema and had intra-operative ICG near-infrared fluorescence angiography available for review. While all patients who undergo VOLT at this institution have routine intra-operative ICG near-infrared fluorescence angiography performed, not all images were saved after intra-operative use.

Therefore only a fraction of our total patients had images available for review and were included in this study. Mean age at presentation was 54.0 years old (SD $\pm$ 12.4) and mean BMI at presentation was 25.5 (SD $\pm$ 3.0). Etiology of lymphedema was breast cancer in 19 patients, gynecologic related cancer in 4 patients, melanoma in 1 patient, sarcoma in 1 patient and primary lymphedema in 1 patient. Twenty-one patients had upper extremity lymphedema, and 5 had lower extremity lymphedema. Twenty-two patients (84.6%) had adjuvant radiotherapy. The majority of patients (88.5%) developed stage 2 lymphedema and the median duration of lymphedema prior to VOLT was 20 months. Fourteen patients had previous abdominal surgery with some having more than one: 5 patients had appendectomy, 5 had hysterectomy, 4 had bilateral salpingo-oophorectomy, 4 had cesarean sections, 1 uterine ablation and 1 had tubal ligation (Table I).

Using ICG near-infrared fluorescence angiography intra-operatively, 12 (46.2%) patients were observed to have normal perfusion of the omental flap and 14 (53.8%) patients were found to have partial ischemia of the omental flap. Of those 14 patients, 8 patients (30.8%) had less than 25% ischemia and 6 patients (23.1%) had 25–50% ischemia (Table II, Figures 1 & 2, Video 1). Typically, omentum with abnormal perfusion appears black on ICG imaging and is clearly distinguished from omentum with normal perfusion. This may be a reflection of the segmental arcuate blood supply of the omentum which does not generally exhibit a perfusion gradient like perforator flaps such as a deep inferior epigastric perforator (DIEP). Interestingly, partial ischemia occurred in 8 (30.8%) patients with and 6 (23.1%) patients without a history of abdominal surgery, $p=0.716$. As such, prior abdominal surgery was not found to be significantly associated with the presence of omental ischemia.

Discussion

The results in this study demonstrated that over half of all patients, regardless of history of abdominal surgery, had some degree of ischemia in the omentum requiring debridement. In the 12 patients who did not have prior abdominal surgery, 6 had significant ischemia requiring flap trimming. This surprisingly high prevalence counters our previously presumption that a virgin abdomen yields a normal omentum. Other inflammatory processes such as diverticulitis, endometriosis or subclinical appendicitis could explain these findings although this is a subject of further investigation. It was plainly clear that clinical evaluation of the omentum was inadequate and unreliable as it is essentially a carpet of fat without a skin monitor. ICG angiography plainly revealed demarcated regions of the flap, underscoring the importance of this technology to ensure only well-perfused lymphatic tissue is left in the patient. Initially, ICG was used in the authors' practice as an excessively cautious measure. However, based on these findings it is now an essential component of omentum harvest. Necrotic omentum unknowingly left in a patient can have serious consequences in terms of infection and outcome.

One could argue that the harvest technique is to blame for the high rate of partial ischemia. The authors have harvested over 100 omentum flaps within the last 2 years using an open technique through a limited 6 – 8 cm incision. The rationale for the open technique is to allow for the use of fine microsurgical instruments including micro bipolar to ensure atraumatic technique, which can be challenging when limited to larger instruments currently

available in an endoscopic suite. The authors have observed various degrees of scarring present prior to flap elevation in a variety of patients. Based on these observations and particular attention paid to microsurgical harvest technique, it is unlikely that the method of flap elevation was the underlying cause of partial flap ischemia in this study.

To our knowledge, there have been no such studies using ICG angiography to assess intraoperative perfusion of the omentum flap after anastomosis. The findings of this study warrant further investigation into the anatomy and physiology of the omentum after flap harvest. The omentum has bi-directional venous drainage[6] and historically, omentum flap anastomosis included a single artery and vein. Perhaps this contributed to the high incidence of partial ischemia observed in this study. VOLT is now routinely performed with a second venous anastomosis distally to restore native bi-directional outflow, maximizing perfusion.

Limitations of this study include a relatively small sample size of 26 patients. Additionally, this study would best be performed in the future using a quantitative analysis of percent surface area ischemia with a standardized approach. Taking these limitations into account, the high rate of ischemia observed does warrant further investigation and highlights the need for intraoperative flap perfusion assessment beyond purely clinical evaluation. The authors approach evaluation of the omentum similarly to ICG assessment of a DIEP flap where ischemic zones are identified and removed to avoid fat necrosis. Ensuring normal perfusion of the omentum during lymphatic reconstruction is the rationale for this approach and is a further refinement of the author's recent description of restoring bi-directional venous drainage toward that end.

Conclusions

In conclusion, the results in this study demonstrate that abnormal perfusion is common even in patients without prior abdominal surgery with partial ischemia noted in 54% of all patients. Use of intra-operative near-infrared fluorescence angiography is useful in examining flap perfusion and ensuring that only well-vascularized tissue is transplanted into the patient.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.
ICG angiography of an omentum flap with abnormal perfusion and between 25–50% ischemia of the flap. This patient had a prior cesarean section and total abdominal hysterectomy.

Figure 2.
ICG angiography of an omentum flap with abnormal perfusion and less than 25% flap ischemia. This patient had a prior tubal ligation.

Table 1

Patient demographics

Variable	Overall
Age (mean and SD)	54.0 ± 12.4
Body mass index (kg/m ²) (mean and SD)	25.5 ± 3.0
Former smoker	4 (15.4%)
Prior abdominal surgery	14 (53.8%)
Primary malignancy	
Breast	19 (73.1%)
Gynecologic	4 (15.4%)
Other	3 (11.5%)
Full lymph node dissection	20 (76.9%)
Adjuvant radiation	22 (84.6%)
Lymphedema stage	
0	1 (3.8%)
1	2 (7.7%)
2	23 (88.5%)
Duration of disease (median and IQR)	20 (25.5)
Preoperative cellulitis episodes (median and IQR)	0 (1.25)
Postoperative cellulitis episodes (median and IQR)	0 (0)
Double omental lymph node transplant	14 (53.8%)
Laser angiography	
Normal perfusion	12 (46.2%)
<25% ischemia	8 (30.8%)
25–50% ischemia	6 (23.1%)

SD, standard deviation. IQR, interquartile range

Table 2

Flap ischemia and prior abdominal surgery

	No ischemia (n=12)	Partial Ischemia (n=14)	p-value
<i>Patient characteristics</i>			
Age (mean and SD)	50.4 ± 11.5	57.1 ± 12.7	0.169
Body mass index (kg/m ²) (mean and SD)	24.8 ± 2.7	26.0 ± 3.2	0.286
Former smoker	3 (11.5%)	1 (3.9%)	1.000
<i>Prior abdominal surgery</i>			
Yes	6 (23.1%)	8 (30.8%)	0.716
No	6 (23.1%)	6 (23.1%)	

SD, standard deviation