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Postoperative patency of the retrograde internal mammary vein anastomosis in free flap transfer☆

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Summary *Background and aim:* A caudal limb of the internal mammary vein (IMV) can be used as an additional venous drainage route in free flap transfer. However, there remains the possibility that unrecognised occlusion of the retrograde IMV occurs in the early postoperative period due to non-physiologic flow, thus affecting venous drainage. There are no reports regarding the postoperative patency rates of the anastomosed retrograde IMV. This study aimed to clarify the efficacy of the retrograde IMV as an additional venous drainage route in the case of two-vein anastomosis in free flap transfer.
Patients and methods: We performed a hospital-based prospective case series study to clarify the patency rates of retrograde IMV anastomoses as an additional venous drainage route in cases of two-vein anastomosis in free flap transfer. Both antegrade and retrograde IMV anastomoses were performed in patients who underwent free flap transfer using the IMV as a recipient vein. The postoperative flow vector and peak blood velocity of the retrograde IMV anastomosis were examined using two-dimensional phase contrast magnetic resonance imaging (2D PC-MRI) and colour Doppler imaging.
Result: A total of five retrograde IMV anastomoses in five patients were performed in the study period. The postoperative patency rate of the retrograde IMV was 60%. In the patent group, the postoperative peak venous blood velocity of the retrograde IMV was significantly slower than that of the antegrade IMV (4.6 ± 0.5 vs 7.2 ± 0.8 cm s^{-1}, $P < 0.05$).

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Conclusion: We described the postoperative patency rate of retrograde IMV anastomosis in cases of two-vein anastomosis in free flap transfer. Further study is needed to evaluate the reliability of the retrograde IMV as an additional venous drainage route.

Background

Use of a caudal limb of the internal mammary vein (IMV) as an additional venous drainage route was first reported by Kerr-Valentic et al., with subsequent reports from other authors.[1–4] Initially, the efficacy of the retrograde IMV anastomosis was based on the hypothesis that because the IMV has no valves, venous blood should flow from the flap vein into the retrograde IMV in accordance with pressure gradients insofar as venous pressure of the flap vein is higher than that of the retrograde IMV. However, this hypothesis was disproven by Mackey et al., who showed that 44% of cadavers had valves in at least one IMV.[5] Mohebali et al. reported that intra-operative flow into the retrograde IMV occurred a few seconds later than that into the antegrade IMV in a study using laser-assisted indocyanine green angiography.[3] Venturi et al. reported that intra-operative mean blood flow in the retrograde IMV was less than that in the antegrade IMV in a study using a Doppler ultrasound technique.[2] This evidence suggests that non-physiologic flow from the retrograde IMV may generate an increased pressure gradient that needs to be overcome. No reports are available regarding the postoperative flow of the anastomosed retrograde IMV. We prospectively investigated the postoperative patency of such anastomoses.

Objective

The objective of this study is to clarify the efficacy of the retrograde IMV as an additional venous drainage route in the case of two-vein anastomosis in free flap transfer.

Study design, setting

We performed a hospital-based prospective case series study. The study protocol was approved by the ethical committee of Chiba University. All patients provided written informed consent to participate in this study.

Patients and methods

Patient selection and study protocol

Patients who underwent free flap surgery at Chiba University Hospital from August 2011 to March 2012 using the IMV as a recipient vein with both of the following conditions were included in the study:

A) only one IMV suitable for microanastomosis and
B) more than one flap vein suitable for microanastomosis.

Patient data regarding age, sex, body weight, height, medical co-morbidities, type of surgery, radiation, type of flap, number of perforators, donor vein, coupler size, postoperative course and postoperative patency and peak blood velocity of the retrograde IMV were collected prospectively.

Surgical procedure

Under general anaesthesia, internal mammary vessels were exposed via resection of one or two rib cartilages. The deep inferior epigastric artery (DIEA) was anastomosed to the internal mammary artery (IMA) in an end-to-end fashion. The IMV was cut at the mid-point of the exposed area. One of the free flap veins which had the largest calibre was anastomosed to the cephalad end of the IMV (antegrade IMV) in an end-to-end fashion using a coupler. One of the free flap veins, which had the second largest calibre, was anastomosed to the caudal end of the IMV (retrograde IMV) in an end-to-end fashion using a coupler. Intra-operative venous flow into the retrograde IMV was observed by microscope-integrated near-infrared indocyanine green angiography.[3,6]

Blood flow analysis

Analyses determining the patency and direction of flow were performed 6 months after the operation. Peak venous blood velocity was measured using colour Doppler imaging in all patients using the EUB-7500 ultrasound system (Hitachi Medical Corporation, Tokyo, Japan) with a 4–16-MHz linear probe held at an angle of 45° to the vein.[7]

Antegrade IMV

The flow vector of the antegrade IMV was determined by Doppler spectrum using the accompanying artery as a reference.[8]

Retrograde IMV

The flow vector of the retrograde IMV was determined by one or two imaging modalities, namely colour Doppler imaging and two-dimensional phase contrast magnetic resonance imaging (2D PC-MRI).[9–13] This technique was used if the superficial inferior epigastric vein (SIEV) was anastomosed to the retrograde IMV. It was not adopted if two deep inferior epigastric veins (DIEVs) were used for anastomosis because their close proximity decreases the technique's validity.

Table 1 Characteristics of the patients who underwent the retrograde internal mammary vein anastomosis in free flap transfer.

Patient	Sex	Age	BMI[a]	Co-morbidity	Purpose of surgery	Radiation	Type of flap	Number of perforators
1	Female	65	19	None	Reconstruction of chest radiation ulcer	Yes	VRAM[b]	3
2	Female	49	21	Cigarette smoker	Breast reconstruction	No	DIEP[c]	1
3	Female	63	19	Diabetes mellitus	Breast reconstruction	No	DIEP	1
4	Female	57	25	None	Breast reconstruction	No	MS-TRAM[d]	2
5	Female	45	28	Cigarette smoker, hyperlipidaemia	Breast reconstruction	No	DIEP	1

[a] BMI denotes body mass index. BMI was calculated as follows: Body weight (kg)/Height (m)/Height (m).
[b] VRAM denotes vertical rectus abdominis muscle.
[c] DIEP denotes deep inferior epigastric perforator.
[d] MS-TRAM denotes muscle sparing transverse rectus abdominis muscle.

Statistical analysis

Continuous variables were compared with the Student's *t*-test under the condition that equal variances could be assumed by Levene's test. Welch's *t*-test was used if equal variances could not be assumed by Levene's test. All *P* values quoted are two tailed. *P* values <0.05 were considered to indicate statistical significance. Statistical analyses were conducted using SPSS software (version 13.0J; SPSS, Chicago, IL, USA).

Result

A total of five patients met the criteria for the study in the study period (Table 1). Five retrograde IMV anastomoses were performed in five flaps in five patients (Tables 1 and 2). Intra-operative venous flow into the retrograde IMV was confirmed by microscope-integrated near-infrared indocyanine green angiography in all patients[3,6]; all flaps survived. Postoperative measurement of the blood flow of the IMV was performed easily with the EUB-7500 ultrasound system in all patients.

Postoperative flow

Antegrade IMV

The flow vector from the DIEV to the antegrade IMV was confirmed by Doppler spectrum using the accompanying artery as a reference in all patients (Figures 1A and 2).[8]

Retrograde IMV

In three of five patients, postoperative patency of the retrograde IMV anastomosis was confirmed (patent group, patients 1, 2 and 3), whereas postoperative occlusion of the retrograde IMV anastomosis was confirmed in two patients (occluded group, patients 4 and 5) (Table 2).

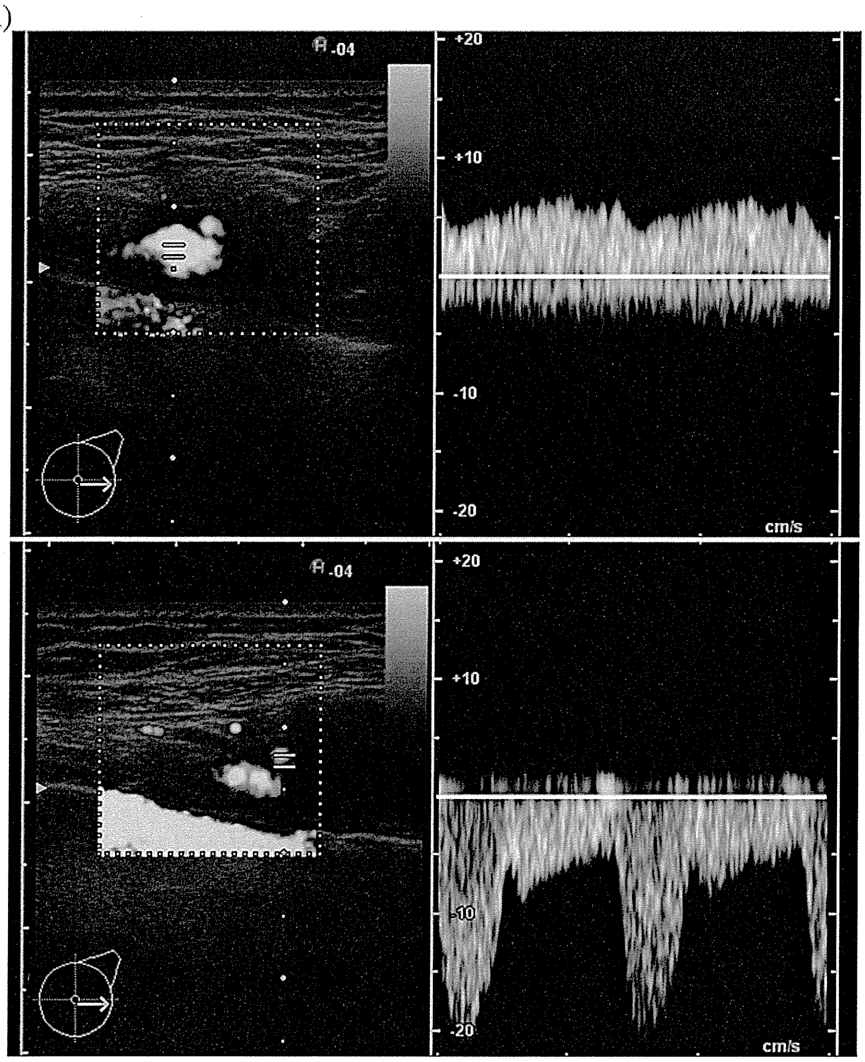
In the patent group, the postoperative course was uneventful and the flow vector from the flap vein to the retrograde IMV was confirmed by colour Doppler imaging in all patients (Figures 1B and 2). The peak venous blood velocity of the retrograde IMV was significantly slower than that of the antegrade IMV (4.6 ± 0.5 vs 7.2 ± 0.8 cm s^{-1} (mean $\pm$ standard deviation (SD)), $P < 0.05$). In patient 1, 2D PC-MRI showed that blood flowed in the direction from the SIEV to the retrograde IMV (Figure 1B); 2D PC-MRI also showed dilation of the SIEV.

Table 2 Postoperative flow of the retrograde internal mammary vein anastomoses.

Patient	Flap vein and coupler size (mm)				Postoperative patency of retrograde IMV[a] and confirmation procedure		Postoperative peak venous blood velocity (cm/s)		Postoperative course
	Antegrade IMV		Retrograde IMV				Antegrade IMV	Retrograde IMV	
1	DIEV[b]	2.0	SIEV[c]	2.0	Patent	US[d] and 2D PC-MRI[e]	6.5	4.2	Uneventful
2	DIEV1	2.0	DIEV2	2.0	Patent	US	7.0	5.1	Uneventful
3	DIEV1	2.0	DIEV2	2.0	Patent	US	8.1	4.6	Uneventful
4	DIEV1	2.5	DIEV2	2.5	Occluded	Exploration	11.7	—	Slight congestion
5	DIEV1	3.0	DIEV2	2.0	Occluded	US	15.2	—	Uneventful

[a] IMV denotes internal mammary vein.
[b] DIEV denotes deep inferior epigastric vein.
[c] SIEV denotes superficial inferior epigastric vein.
[d] US denotes ultrasound.
[e] 2D-PC MRI denotes two dimensional phase contrast magnetic resonance imaging.

(A)



(B)

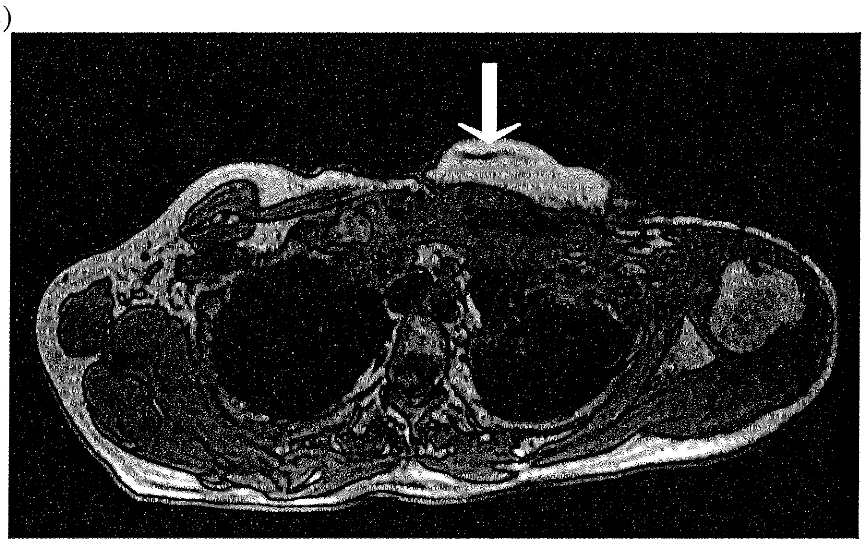


Figure 1 (A) Doppler spectrum of the DIEV (*above*) anastomosed to the antegrade IMV and the DIEA (*below*) six months post-operatively in patient 1. Doppler spectrum of the DIEV was opposite to that of the accompanying DIEA. This indicates that the flow direction is from the DIEV to the antegrade IMV. (B) Phase contrast two-dimensional magnetic resonance imaging six months postoperatively in patient 1. An arrow indicates a dilated SIEV anastomosed to the retrograde IMV running in the subcutaneous tissue of the flap. Parameter (not shown) indicates the direction of flow is from the SIEV to the retrograde IMV.

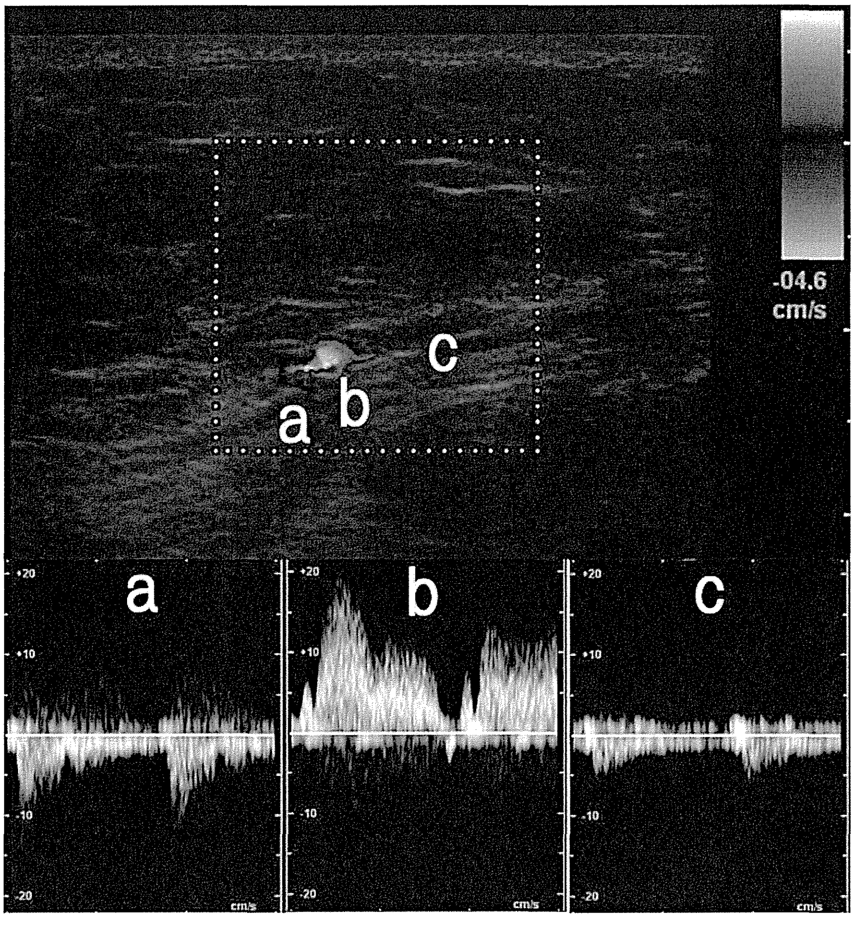


Figure 2 Doppler spectrum of the DIEA (b) and DIEVs (a and c) in patient 2 six months postoperatively. DIEV1 (a) was anastomosed to the antegrade IMV and DIEV2 (c) was anastomosed to the retrograde IMV. The wave pattern shows that the direction of flow of the DIEVs (a and c) and DIEA (b) are opposite. The flow velocity of the DIEV2 (c) anastomosed to the retrograde IMV is lower than that of the DIEV1 (a) anastomosed to the antegrade IMV.

In one patient in the occluded group, the postoperative course was uneventful and there were no signs of venous congestion. However, occlusion of the retrograde IMV was confirmed by colour Doppler imaging 6 months postoperatively (patient 5). In the other patient in this group, occlusion of the retrograde IMV was confirmed during re-exploration of the anastomosis site, which was performed 18 h after the original operation for slight congestion of the flap (patient 4). It was unclear whether valves were present in the retrograde IMV in this case. We did not perform an additional venous anastomosis. The slight congestion of the flap lessened over time in the postoperative period.

Discussion

The underlying hypothesis for performing a retrograde IMV anastomosis is that because the pressure of the retrograde IMV is lower than that of the flap vein, and because the IMV lacks valves, venous blood from the flap can flow into the retrograde IMV according to a pressure gradient.[1] However, an increased pressure gradient due to non-physiologic flow from the retrograde IMV was suggested by Mohebali et al. and Venturi et al.[2,3] Our measurements showing that the peak venous blood velocity of the flap vein anastomosed to the retrograde IMV was slower than that of the flap vein anastomosed to the antegrade IMV suggest that there is high resistance of the retrograde IMV as a venous drainage route. In our study, dilation of the SIEV anastomosed to the retrograde IMV also suggests a high gradient into the retrograde IMV.

A limited number of reports are available describing venous pressure values of the IMV and the pedicle vein of the free flap.[14–16] Our study shows that at least in some patients, the venous pressure of the flap vein remains higher than that of the retrograde IMV under the condition that the antegrade IMV is patent. According to one report of accidental insertion of a central venous catheter into the IMV, the intravascular pressure of the IMV was 5 mmHg.[14] Sakurai et al. reported that the venous pressure of the vein of a transferred free flap measured by catheter was anywhere from 0 to 35 mmHg.[15] Smit et al. reported that the venous pressure of the SIEV which is ipsilateral to the pedicle of the deep inferior epigastric perforator (DIEP) flap ranged from 0 to 24 mmHg.[16]

It was difficult to infer the presence or absence of valves in the retrograde IMV in our study. Mackey et al. reported that 14 of 32 cadavers had valves in the IMV, whereas Al-Dhamin et al. reported that there were no valves in five cadavers.[4,5] Timmons hypothesised that three conditions occurring simultaneously were necessary for reverse flow through a valve: denervation, higher proximal venous pressure than distal and constant blood supply.[17] Torii et al. reported that reflux of venous blood through a valve occurred at pressures of 66–77 mmHg.[18] These conditions suggest that reverse flow through a valve in the retrograde IMV is difficult when venous blood can flow into the antegrade IMV.[14] Collateral vessels play a critical role in venous drainage through the retrograde IMV.[4,5,19,20] An increased pressure gradient caused by a valve or by insufficient collateral vessels can lead to decreased patency rate of the retrograde IMV anastomosis, as found in our study. Further investigation is needed to determine the postoperative patency rate of the retrograde IMV and its relationship to the valves and collateral pathways of the IMV.

Based on our findings, retrograde IMV anastomosis is not reliable enough to be routinely performed. We prefer performing an anastomosis of only the antegrade IMV rather than performing anastomoses of both the antegrade and retrograde IMVs even in the case of two DIEVs and only one IMV. One of the drawbacks of using the retrograde IMV is a short working length of the antegrade and the retrograde IMVs as they are cut at the mid-point of the exposed IMV. Using only an antegrade IMV by cutting the caudal edge of the exposed IMV can ensure adequate working length for an easy anastomosis.[21–27] Hanasono et al. argued against routinely performing two venous anastomoses, explaining that venous blood velocity in flaps in which two venous anastomoses were performed was significantly slower than that in flaps in which one venous anastomosis was performed.[7] Measurements in our study showed that peak venous blood velocity of the antegrade IMV in the patent group in which both the antegrade and retrograde IMVs functioned was lower than that in the occluded group in which only the antegrade IMV functioned; these results are consistent with the report by Hanasono et al.[7] In the cases in which double venous systems (namely, an SIEV system and a DIEV system) are required, the use of other antegrade veins is reported as an additional venous drainage route rather than a retrograde IMV.[28–31]

Conclusion

The postoperative flow vector and peak venous blood velocity of retrograde IMV anastomosis in two-vein anastomosis cases were studied for the first time, to our knowledge. Our study showed a 60% patency rate of the retrograde IMV anastomosis under two-vein anastomosis operations. The peak venous blood velocity of the free flap vein anastomosed to the retrograde IMV was significantly slower than that of the free flap vein anastomosed to the antegrade IMV. Further study is needed to evaluate the efficacy of the retrograde IMV as an additional venous drainage route.

Funding

None.

Conflicts of interest

None declared.

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