Intraoperative venous congestion in free transverse rectus abdominis musculocutaneous and deep inferior epigastric artery perforator flaps during breast reconstruction: A systematic review

Deok-Yeol Kim MD[1], Taik Jong Lee MD PhD[2], Eun Key Kim MD PhD[2], Jiyoung Yun MD[2], Jin Sup Eom MD PhD[2]

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3 THERAPEUTIC

BACKGROUND: Even with patent deep inferior epigastric vein anastomoses, venous congestion can occur during free transverse rectus abdominis musculocutaneous (TRAM) or deep inferior epigastric artery perforator (DIEP) flap surgery and lead to flap compromise if not recognized and managed.

OBJECTIVES: To identify the incidence of intraoperative venous congestion and describe the best available prevention and treatment methods.

METHODS: Systematic electronic searches of the PubMed database including Medline were performed to identify studies published until 2014. The following keywords were used: "DIEP" or "free TRAM" and "venous insufficiency" or "venous congestion". Supplemental searches were conducted to identify referenced studies. Statistical analysis using the χ^2 test was performed.

RESULTS: Nine studies representing 4747 free abdominal flaps cases were included and demonstrated an overall incidence of intraoperative venous congestion of 2.8%. The incidence in DIEP flaps (3.3%) was significantly higher than that in the free TRAM flaps (1.0%). All nine articles reported using the superficial inferior epigastric vein to treat venous insufficiency.

CONCLUSION: The risk for developing intraoperative venous congestion following free abdominal flap breast reconstruction is influenced by inadequate perforator selection and persistent dominance in the superficial venous system. The solution is establishing another venous draining route using the superficial inferior epigastric vein.

Key Words: *DIEP flap; TRAM flap; Venous congestion*

La congestion veineuse peropératoire des lambeaux libres du grand droit transverse musculocutané et des lambeaux perforants de l'artère épigastrique inférieure profonde pendant la reconstruction mammaire : une analyse systématique

HISTORIQUE : Malgré des anastomoses de la veine épigastrique inférieure profonde perméable, une congestion veineuse peut survenir pendant une chirurgie par lambeau libre musculocutané du grand droit transverse (MGDT) ou par lambeau perforant de l'artère épigastrique inférieure profonde (AEIP) et compromettre le lambeau si elle n'est pas décelée et prise en charge.

OBJECTIFS : Déterminer l'incidence de congestion veineuse peropératoire et décrire les meilleures méthodes préventives et thérapeutiques en place.

MÉTHODOLOGIE : Les chercheurs ont effectué des recherches virtuelles systématiques dans la base de données PubMed, y compris dans Medline, pour extraire les études publiées jusqu'en 2014. Ils ont utilisé les mots-clés suivants : *DIEP* ou free *TRAM* et *venous insufficiency* ou *venous congestion*. Ils ont mené d'autres recherches pour extraire les études des références. Ils ont effectué une analyse statistique au moyen du test du chi carré.

RÉSULTATS : Neuf études représentant 4 747 cas de lambeaux abdominaux libres ont été incluses, pour démontrer une incidence globale de congestion veineuse peropératoire de 2,8 %. L'incidence de lambeaux AEIP (3,3 %) était considérablement plus élevée que celle de lambeaux libres MGDT (1,0 %). Dans les neuf articles, la veine épigastrique inférieure profonde était utilisée pour traiter l'insuffisance veineuse.

CONCLUSION : Le risque de congestion veineuse peropératoire après une reconstruction mammaire par lambeaux abdominaux libres est influencé par une mauvaise sélection du lambeau perforant et une dominance persistante du système veineux superficiel. La solution consiste à établir une autre voie de drainage veineux au moyen de la veine épigastrique inférieure superficielle.

One of the preferred methods for autologous breast reconstruction is microsurgical reconstruction using abdominal tissue, including the free transverse rectus abdominis musculocutaneous (TRAM) and deep inferior epigastric perforator (DIEP) flaps because these result in the most natural-looking breast (1-3). Free TRAM flap reconstruction is the standard method; DIEP flap reconstruction was developed from TRAM and demonstrates less postoperative pain and morbidity at the donor site (1,3-5). Importantly, these two flaps share the same fundamental vascular structure.

Despite improvements in microsurgical techniques, venous congestion still occurs in up to 5% of flaps and remains an important cause of flap loss if not recognized and managed (2,6,7). While most venous complications are associated with microsurgical problems, some cases of venous congestion develop without microsurgical errors, which can be apparent immediately after flap elevation (Video 1) or successful deep inferior epigastric vein (DIEV) anastomoses. The entire flap is typically involved, and the perforators and main vessels show no signs of venous outflow problems such as dilated veins filled with dark-coloured blood. This is mostly accompanied by an engorged superficial inferior epigastric vein (SIEV). This type of venous congestion in the TRAM or DIEP flap can be termed 'intraoperative venous congestion', which is assumed to be associated with an ineffective venous structure of the flap. Recent studies report that intraoperative venous congestion without microsurgical failure could be due to inappropriate perforator selection or poor connection between the DIEV and SIEV systems, which is believed to predominate in venous drainage of the lower abdominal integument (7-10). Several studies describe various strategies for salvage of the DIEP flap with intraoperative venous congestion, including the use of secondary alternate pathways or supercharging the venous drainage of the congested flaps (5,6,11-17). However, intraoperative venous congestion is not always recognized and its incidence has not been investigated.

Herein, we review the current literature regarding intraoperative venous congestion in the free TRAM and DIEP flaps, with a particular

[1]*Department of Plastic and Reconstructive Surgery, Korea University Guro Hospital;* [2]*Department of Plastic Surgery, Asan Medical Center, University of Ulsan, College of Medicine, Seoul, Korea*

Correspondence and reprints: Dr Jin Sup Eom, Department of Plastic Surgery, Asan Medical Center, University of Ulsan, College of Medicine, 388-1, Pungnap-dong, Songpa-gu, Seoul, 138-736, South Korea. Telephone 82-2-3010-3602, fax 82-2-476-7471, e-mail jinsupp@amc.seoul.kr

TABLE 1
Incidence of intraoperative venous congestion in deep inferior epigastric artery perforator (DIEP) and free transverse rectus abdominis musculocutaneous (TRAM) flaps

	DIEP flap		Free TRAM flap		Free abdominal (TRAM + DIEP) flap	
Author (reference), year	Total, n	Venous congestion, n (%)	Total, n	Venous congestion, n (%)	Total, n	Venous congestion, n (%)
Ali et al (19), 2010	162	14 (8.6)			162	14 (8.6)
Blondeel et al (7), 2000	249	5 (2.0)	271	0 (0.0)	520	5 (1.0)
Figus et al (19), 2006	16	1 (6.3)			16	1 (6.3)
Lundberg and Mark (20), 2005	50	3 (6.0)			50	3 (6.0)
Ochoa et al (24), 2013	2618	87 (3.3)			2618	87 (3.3)
Sbitany et al (21), 2012	421	1 (0.2)	780	10 (1.3)	1201	11 (0.9)
Schaverian et al (22), 2010	54	5 (9.3)			54	5 (9.3)
Smit et al (23), 2010	26	1 (3.8)			26	1 (3.8)
Tran et al (11), 2007	100	5 (5.0)			100	5 (5.0)
Total	3696	122 (3.3)*	1051	10 (1.0)*	4747	132 (2.8)

**Significant difference (P<0.001, Pearson's χ^2test)*

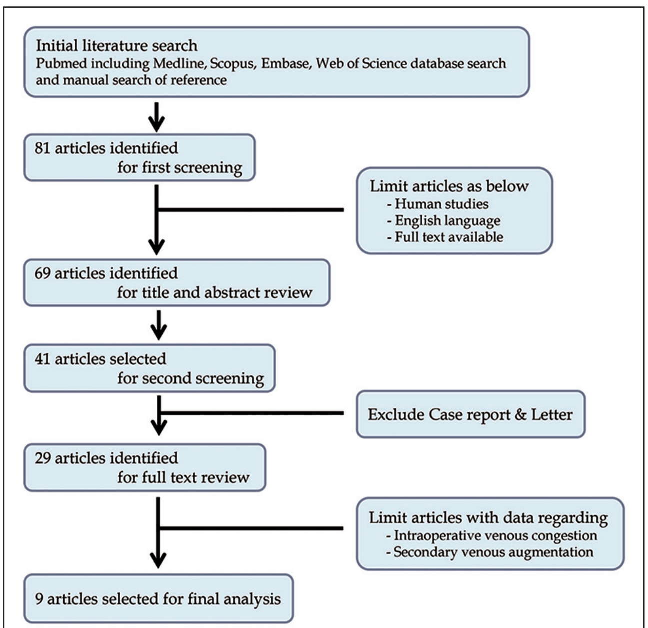

Figure 1) *Identification of relevant articles included in the present review*

focus on clinical incidence, preventable findings and salvage strategies. We believe our efforts provide awareness of intraoperative venous congestion and comprehensive information to improve flap success.

METHODS

An electronic search of PubMed, including Medline, Scopus, Embase and Web of Science, and a manual search of references were conducted to identify studies published until 2014 that reported intraoperative venous congestion or venous insufficiency despite patent DIEV anastomosis in free DIEP or TRAM flaps breast reconstruction. The following keywords were used: "DIEP" or "free TRAM" and "venous insufficiency" or "venous congestion". Articles were considered to be relevant if they described intraoperative venous congestion or widespread venous insufficiency without pedicle compromise. Each article had to report the incidence of intraoperative venous congestion. Our search was limited to studies on humans that were published in English. Case reports, isolated abstracts, reviews, editorials, communications, correspondence, discussions and letters were excluded. The reference lists of relevant studies were evaluated to identify studies that were missed during the initial database search. A single reviewer performed the initial article search and subsequent selection. After deletion of duplicates, each abstract was reviewed for inclusion criteria. If the abstract did not provide clear inclusion or exclusion criteria, the full text was reviewed before final categorization.

The full text of each relevant article was obtained; the ready accessibility of the full-text articles made immediate evaluation possible. Only studies that successfully passed both levels of screening were included (Figure 1). To be included, cases had to meet the following conditions: whole flap congestion was recognized by the authors during the operation, either after flap elevation or vessel anastomosis; and an additional procedure was performed to augment venous outflow. Collected data included the following: lead author, year of publication, type of reconstruction, total number of reconstructions and total number of identified cases of intraoperative venous congestion.

RESULTS

Nine retrospective comparative studies were included (7,11,18-24). Table 1 compares the identified series of cases with free DIEP or TRAM flaps. In total, 3696 DIEP flap cases and 1051 free TRAM flap cases were pooled for further study; 122 DIEP flaps and 10 free TRAM flaps were reported to develop intraoperative venous congestion. The overall mean rate of intraoperative venous congestion was 2.8% (3.3% in DIEP flap cases and 1.0% in free TRAM flap cases). The venous congestion rates of the individual studies were variable and ranged from 0% to 9.3%. Statistical analysis using the Pearson's χ^2 test confirmed that intraoperative venous congestion occured more frequently in the DIEP flap (P<0.001).

Eight of nine articles reported findings associated with intraoperative venous congestion (Table 2); all reported an engorged SIEV with a diameter >1.5 mm and rapid capillary refill <1 s. Two studies reported preconditions before the diagnosis of intraoperative venous congestion. Ali et al (18) established the diagnosis of intraoperative venous congestion only after conservative treatment for 30 min. Before diagnosis, Tran et al (11) required that there should not be any instance of pedicle torsion, compression or thrombosis.

Various salvage techniques were reported, but they shared common elements. All of the identified studies in the present systematic review report the use of SIEV to provide an additional venous outflow. The differences among them are recipient: the internal mammary vein, DIEV, cephalic vein or chest wall vein. The salvage procedures and outcomes are summarized in Table 3. Four of nine studies report no complications after salvage (19-21,23), and three of these emphasized that the secondary venous outflow should be independent of the DIEV-internal mammary vein drainage (19,20,23). Other studies describe salvage procedures involving DIEV, and reported three cases with partial flap loss and 13 cases with fat necrosis (11,18,22,24).

DISCUSSION

One of the primary purposes of the present study was to heighten awareness of the idiopathic venous congestion of the TRAM or DIEP

TABLE 2
Descriptions of intraoperative venous congestion provided by the included studies

Author (reference), year	Findings of intraoperative venous congestion
Ali et al (18), 2010	A purplish or plethoric fullness of the flap associated with brisk capillary refill (1 s)
	Rapid and dark venous bleeding on puncture
	No improvement to conservative treatment for 30 min intraoperatively
	Engorged (tense and dilated) SIEV
Blondeel et al (7), 2000	Severe diffuse venous congestion that involved the entire flap
	Particularly large SIEV (>1.5 mm)
Figus et al (19), 2006	A turgid superficial vein
Lundberg and Mark (20), 2006	Capillary refill that took <2 s
Ochoa et al (24), 2013	Brisk capillary refill
	Cutaneous discolouration that improves promptly with release of venous blood through the SIEV
	Predominant venous bleeding with peripheral flap incisions
Sbitany et al (21), 2012	Subjectively engorged SIEV
	Brisk SIEV bleeding when opened
	Positive strip test
	Positive venous flow on Doppler ultrasound
Smit et al (23), 2010	The SIEV is ≥1.5 mm
Tran et al (11), 2007	Intraoperative congestion despite patent deep inferior epigastric venous anastomoses
	Rapid capillary refill <1 s and a blue flap
	No pedicle torsion, compression and thrombosis
	The SIEV is ≥1.5 mm

SIEV Superficial inferior epigastric vein

TABLE 3
Salvage procedures and outcomes of intraoperative venous congestion.

Author (reference), year	Salvage procedure	Salvage outcome
Ali et al (18), 2010	Additional SIEV outflow to thoracodorsal, IMV or DIEP vena comitantes	1 partial loss, 1 fat necrosis
Blondeel et al (7), 2000	Additional SIEV outflow to IMV	No information available
Figus et al (19), 2006	Additional SIEV outflow to chest wall perforating vein	100% survival
Lundberg and Mark (20), 2016	Additional SIEV outflow to cephalic vein	100% survival
Ochoa et al (24), 2013	Additional SIEV outflow to IMV or DIEP vena comitantes	11 fat necrosis
Sbitany et al (21), 2012	Additional SIEV outflow to DIEP vena comitantes	100% survival
Schaverien et al (22), 2010	Additional SIEV outflow to DIEP vena comitantes	2 partial loss
Smit et al (23), 2010	Additional SIEV outflow to cephalic vein	100% survival
Tran et al (11), 2007	Additional SIEV outflow to thoracodorsal or DIEP vena comitantes	1 fat necrosis

DIEP deep inferior epigastric perforator; IMV Internal mammary vein; SIEV superficial inferior epigastric vein

flaps. Specifically, we intended to investigate flaps that have irreversibly lost the ability to drain the blood effectively; however, the congestion should not be caused by anastomosis failure or vessel damage. Among the many studies reporting the outcome of breast reconstruction using free abdominal flaps, only nine presented data from cases with intraoperative venous congestion. However, it is difficult to confirm that all those cases were true intraoperative idiopathic venous congestion. While two of the studies (11,18) made clear that they distinguished intraoperative venous congestion from the temporary congestion that would recover with time, the other seven did not. Not all studies reported checking patent DIEV anastomoses. Therefore, to obtain consistent data, we only included cases in which an additional venous augmentation procedure was performed. The authors' decision to perform venous augmentation shows that they must have been convinced that the congestion was not temporary. If the anastomotic problem was the cause of venous congestion, they would easily recognize it and revise the anastomosis. By excluding cases without venous augmentation procedures, we could differentiate from temporary congestion and anastomotic problems.

In several studies reporting the outcome of the breast reconstruction, there is no report of intraoperative venous congestion. If the authors were not aware of the existence of the intraoperative venous congestion, it would be difficult to recognize the problem during the operation. Another explanation may be the rare occurrence of intraoperative venous congestion, which can be found only in reports with a large number of cases. It should be sufficient evidence of the existence of the idiopathic intraoperative venous congestion that nine studies with larger series of free abdominal flap breast reconstruction reported its incidence and management. We systematically reviewed those studies by pooling and analyzing results from different institutions. In total, 4747 free abdominal flaps cases were pooled and demonstrated an overall incidence of intraoperative venous congestion of 2.8%. The incidence in DIEP flaps (3.3%) was significantly different from that in the free TRAM flaps (1.0%).

Although it may be too early to conclude, we believe that the causes of intraoperative venous congestion are the combination of persistent dominance of the superficial venous system and accidental selection of an inadequate perforator. Most cases of intraoperative venous congestion resolved after successful SIEV anastomosis. As reported by Carramenha e Costa et al (25), the SIEV is the largest vein that drains the skin paddle of the DIEP flap or free TRAM flap, suggesting that venous drainage preferentially takes place through this vessel. Retrograde flow from the superficial to deep venous system occurs through the communicating veins that link the two systems, as illustrated by Rozen et al (26). When the DIEP flap is harvested, the SIEV is interrupted and all the venous drainage is redistributed into the deep system by the small venae comitantes that accompany the perforator. In their excellent study, Schaverien et al (22) used

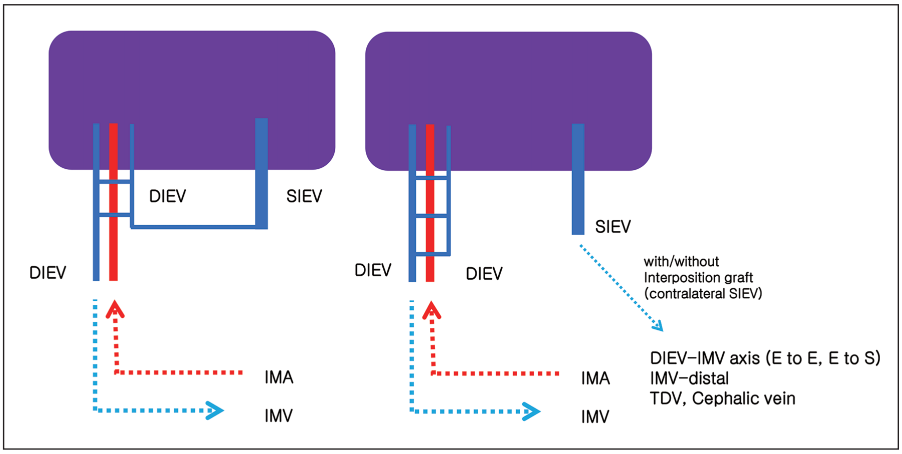

Figure 2) *Intraoperative salvage procedures can be performed utilizing preserved superficial inferior epigastric vein (SIEV).* **Left** *Turbocharging technique. To enhance venous drainage for intraoperative venous congestion, a superficial to deep venous loop can be created.* **Right** *Supercharging technique. The ipsilateral SIEV is anastomosed directly to deep inferior epigastric vena comitantes-internal mammary vein (DIEV-IMV) axis, distal end of IMV, Thoracodorsal vein (TDV), or cephalic vein with or without interposition vein graft. E to E End-to-end anastomosis; E to S End-to-side anastomosis; IMA Internal mammary artery; IMV-distal Distal end of internal mammary vein*

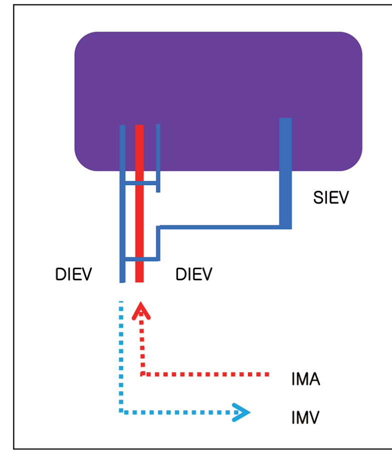

Figure 3) *The authors' method of intraoperative salvage technique using preserved superficial inferior epigastric vein (SIEV). One of the venae commitantes of the deep inferior epigastric artery is dissected toward the flap and its proximal end is connected to SIEV. DIEV Deep inferior epigastric vena comitantes; IMA Internal mammary artery; IMV Internal mammary vein*

magnetic resonance angiography to evaluate numerous perforators in the lower abdomen, and found that not all perforators were directly connected to the superficial venous system. If an abdominal flap is elevated based on perforators that are not connected to the superficial venous system, the flap can develop venous insufficiency even with perfectly patent perforators and main pedicles. Schaverien et al (22) report that perforators with direct communication to the superficial venous system tend to be larger and more frequently located on the medial row. Although there are contrasting opinions regarding the best number of perforators, the decisive factor that prevents venous insufficiency is selection of the perforators with the direct connection to the superficial venous system. The more perforators included, the larger the chance to connect with the superficial venous system. Differences in the incidence of venous congestion between the DIEP flap and the free TRAM flaps can be explained within the same context. By incorporating multiple perforators into the free TRAM flap, there is a higher chance of direct connection to the superficial venous system; in contrast, the DIEP flap often only has a single or fewer than three perforators.

Close observation of the SIEV is a reliable way to diagnose intraoperative venous congestion during flap elevation. Six of the nine studies reviewed herein mentioned intraoperative venous congestion in association with SIEV dilation. The size of the SIEV at the beginning of DIEP flap dissection can be an indicator of the predominance of the deep or superficial drainage system, with larger SIEVs demonstrating superficial dominance rather than deep system dominance (27). Therefore, the SIEV should be identified at the beginning of flap elevation and ligated with clips to ensure the easy detection of engorgement. However, SIEV diameter may not be an absolute predictor of venous congestion. A recent study (28) did not show a direct correlation between vessel diameters in the superficial and deep inferior epigastric systems, meaning that the SIEV diameter can be relatively large, but the deep venous system is still large enough to drain the complete flap. Another important clinical finding is a rapid capillary refill in <1 s. In four of the articles we assessed, capillary refill of the flap itself was introduced as an easily assessable way to diagnose venous congestion. Most of all, however, the diagnosis of intraoperative venous congestion is made after confirming the absence of pedicle compromises, as described by Tran et al (11).

If intraoperative venous congestion is noticed during surgery, venous outflow augmentation is required, rather than revising the original anastomosis. Several successful venous augmentation methods have been introduced (29-31), and all authors prefer using the SIEV as the secondary route for venous drainage. Eight articles in the present study report the outcomes of salvage procedures that used SIEV outflow to treat intraoperative venous congestion. Four of these studies reported excellent results of 100% salvage rate, and minor complications were reported in four articles (11,18,22,24). Using turbo- and supercharging to augment the vascularity of the DIEP flap and the free TRAM flap have been described (Figure 2). Turbocharging requires connecting separate vascular sources within the flap territory using a single recipient pathway, such as bypass between the SIEV and DIEV (29). The concept of connecting the SIEV and DIEV was also proposed by Rohde and Keller (32) and Liu et al (13). However, the effective length of the pedicle is shortened, which can limit flap positioning (33). Supercharging is defined as any vascular augmentation that uses additional recipient vessels, such as the cephalic vein, thoracodorsal vein, lateral thoracic vein or intercostal veins, to provide alternative flow to the flap (6,29,34). The drawbacks of this approach include flap-shaping and inset limitations and the need for an additional recipient vein. Another option for additional venous outflow is to anastomose the SIEV to another internal mammary vein (if available), or to the distal end of the internal mammary vein, to provide anterograde or reverse venous drainage, respectively (7,35). However, our simplest suggestion, which has not been introduced to date, is to dissect one of the venae commitantes of the deep inferior epigastric artery and anastomose the proximal end to the ipsilateral SIEV (Figure 3).

Venous insufficiency is best addressed by early diagnosis and quick, effective intervention (27). The early establishment of a second route for venous outflow, especially during surgery, leads to the best outcomes. A common necessity of all these techniques, however, is the preservation of an adequately long SIEV, which is worth the extra time and labour. It usually requires <50 min to dissect the SIEVs, prepare the recipient vein and perform microsurgical anastomosis (36). The best timing for additional vein anastomosis is after inset and flap-shaping because the anastomosed SIEV can limit flap mobility.

CONCLUSION

According to the available evidence, intraoperative venous congestion of the free abdominal flap during breast reconstruction demonstrates an incidence of 2.8%. Intraoperative venous congestion is caused by the persistent dominance of the superficial venous system and disconnection between the superficial and deep venous systems, which results from perforators that are not connected to the superficial venous system. The solution is establishing another venous draining route using the SIEV. Thus, dissecting and preserving a long SIEV is crucial for treating intraoperative venous congestion.

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