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Breast

An Appraisal of Internal Mammary Artery Perforators as Recipient Vessels in Microvascular Breast Reconstruction—An Analysis of 515 Consecutive Cases

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Background: The usage of internal mammary artery perforators (IMAPs) has been described in autologous breast reconstruction although IMAPS are not yet considered standard recipient vessels. It remains unclear if these vessels can be safely used in large flaps after radiation therapy or in delayed breast reconstruction.

Methods: Over a 2-year period, 515 free flaps for autologous breast reconstruction were performed on 419 patients by 2 surgeons (S1 and S2). In a retrospective analysis, time of reconstruction, ischemia time, flap weight, diameter of couplers, and complications were analyzed. All 515 flaps were compared in a subset with regard to the 2 surgeons: S1 who always used the IMA as a recipient vessel and S2 who attempted IMAP use if possible.

Results: Of all 515 flaps, 424 were abdominal flaps and 91 flaps were from the upper thigh. Three hundred six cases were immediate reconstructions, and 112 were delayed reconstructions. In 97 cases, implants were converted to autologous tissue. In 112 cases, the IMAPs were used; of these, 82 were immediate and 17 were delayed reconstructions, and in 13 cases, implants were removed. Thirty-five percent of all anastomoses to IMAPs had previous radiation therapy. The flap failure rate was 1.9%. In none of these cases, the IMAPs were used. S1 never used the IMAP, and S2 used the IMAP in 37% of all of his flaps.

Conclusions: IMAPs were safely used in all kinds of reconstructions and after radiation therapy, with no flap failure or negative effects on mastectomy skin flap perfusion. Using the IMAPs as recipient vessels is a further step toward simplifying microsurgical breast reconstruction. *(Plast Reconstr Surg Glob Open 2016;4:e1144; doi: 10.1097/GOX.0000000000001144; Published online 13 December 2016.)*

Microvascular autologous breast reconstruction is a standard procedure with survival rates well above 95%.[1] The aim is to create a well-shaped breast with minimum morbidity at the donor and recipient sites. The pedicled transverse rectus abdominis muscle flap was refined to become the free flap and finally the deep inferior epigastric artery perforator (DIEP) flap, supposedly reducing the rates of abdominal herniation.[2–4] Today, computed tomographic angiographic scans facilitate operation planning.[5,6] Furthermore, precise patient medical history and preoperative screening may identify thrombophilia.[7] Standard recipient vessels have also changed. Although earlier, the thoracodorsal artery (TDA) and its branches were the preferred recipient vessels, nowadays, the internal mammary artery (IMA) serves as a standard vessel. To reduce morbidity, many surgeons aim for a rib-sparing approach.[8] IMA usage has nevertheless been questioned mainly because of the fact that the artery may be needed for a possible coronary bypass.[9,10] Intercostal perforating vessels (IMA perforators [IMAPs]) from the IMA have already been described as recipient vessels for immediate breast reconstruction.[11–16] The superficial location allows a less invasive dissection and improves accessibility. This technique has, however, not yet become a standard procedure and only described in a few studies, with small case loads. Additionally, concerns about the perfusion of skin flaps after skin-sparing mastectomy and the ability of these vessels to perfuse even bigger flaps remain when the IMAP is used. It has not yet been shown if these vessels

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may be considered as safe recipient vessels after radiation therapy and in delayed breast reconstructions.

We, therefore, evaluated whether the IMAP may be considered as a safe recipient vessel not only in immediate breast reconstructions but also in delayed cases and after previous radiation therapy.

PATIENTS AND METHODS

A retrospective review of all free flaps conducted for breast reconstruction over a 2-year period was executed. The flaps were performed in our center between January 2014 and December 2015 by the 2 senior surgeons. We examined the following parameters: type of flap (DIEP, superficial inferior epigastric artery [SIEA], and transverse myocutaneous gracilis [TMG]), immediate or delayed breast reconstruction, ischemia, flap weight, coupler size, previous radiation therapy, rate of fat necrosis, revision surgery, flap failure, and skin flap necrosis of more than 2 cm^2. Indications for breast reconstruction were breast cancer, preventive mastectomy, capsular contracture, implant failure, and chronic mastitis. The mastectomies in immediate breast reconstruction were always performed by the plastic surgeons who did the subsequent reconstruction. When the present IMAP (mainly in the second and third intercostal space [ICS]) seemed to have a sufficient artery and vein, they were used for anastomosis (Figs. 1, 2). Although the final decision was always made clinically, an IMAP was generally considered as sufficient when the artery had a diameter equal to or bigger than 1 mm and presented a good pulsation or flow in the milking test. However, it is more important to judge the vein. It should be at least 1.5 mm in diameter or have a comparable diameter to the flap vessel. The best technique is to locate the IMAP and then do dissect it from distal to central. Before surgery, attention was paid to the veins visible through the skin, indicating the course of an IMAP. The position of the IMAP is an additional factor. If it is to high in relation to the desired flap position, planned flap inset, or pedicle length, it cannot be used. For example, if a good IMAP is seen at the upper breast border in the first intercostal space (ICS), it is possibly suitable for a DIEP flap, but it cannot be used for a TMG flap that has a shorter pedicle. In that case, the new breast would be positioned too cranially. When no IMAP was found subcutaneously, the pectoralis muscle was divided along its fibers, and attention was paid to intramuscular perforators. In some cases, the vessels described by Würinger et al[17] were dissected. These vessels usually originate from the IMA along the fourth to sixth ICS (Fig. 3), perforate the pectoralis major muscle more laterally, and run in a ligamentous suspension called the Würinger's septum.[17] If no IMAPs were found or they were not considered as sufficient, the IMA was prepared.

The dissection of the IMAP may lead to vasospasm, which is normally reversible by using topic dilative agents (we routinely use papaverin hydrochlorid). This was only

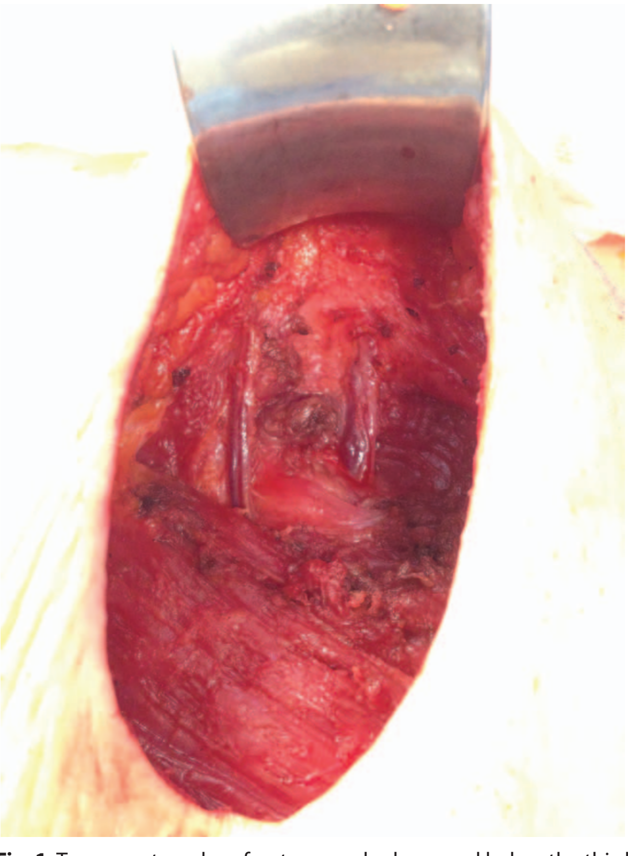

Fig. 1. Two parasternal perforator vessels above and below the third rib, left breast after mastectomy.

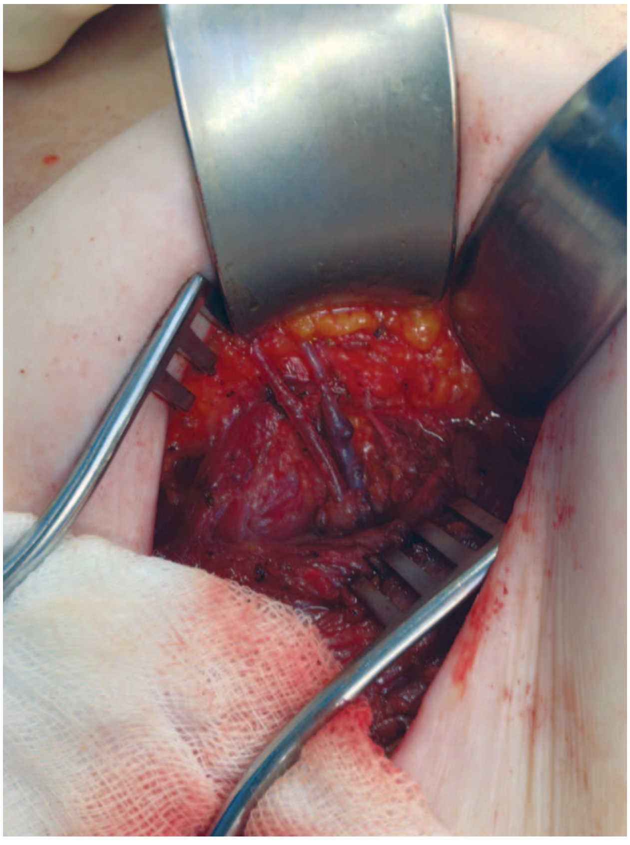

Fig. 2. Dissected perforating vein and artery in the third ICS.

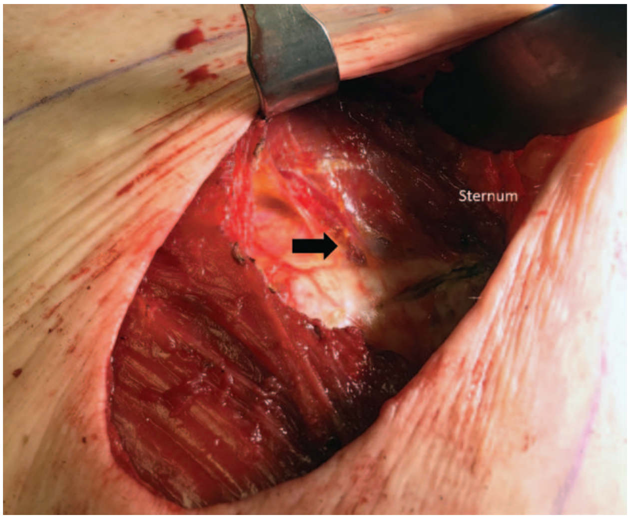

Fig. 3. Arrow indicates more lateral IMA perforator in the fourth ICS. Usually, these perforators contribute to the Würinger-septum.

Fig. 4. Anastomosis of a DIEP flap to a parasternal perforating artery and vein. Coupler size, 2.5 mm.

applied after the dissection of the vessels and if necessary after the anastomosis. No other drugs were used afterward. The veins were always anastomosed using coupling devices (Synovis, Birmingham, Ala.). Afterward, the arterial anastomoses were performed using interrupted nylon sutures (Figs. 4, 5). For postoperative anticoagulation, prophylactic dosages of low-molecular heparin and aspirin (100 mg

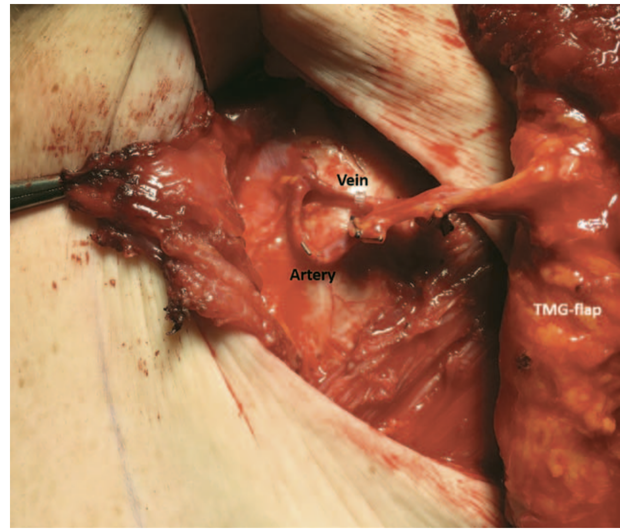

Fig. 5. Anastomosis of a TMG flap to a lateral IMA perforator (same as Fig. 3) in the fourth ICS before flap inset. Coupler size, 1.5 mm. The flap pedicle is approximately 5 cm long.

p.o.) were given once a day. All patients were mobilized on the day of surgery. Follow-up was done at weeks 1 and 8 and after 6 months. If a palpable induration was detected or a fat necrosis was suspected, an ultrasound examination was carried out by a radiologist.

We also analyzed the recipient vessels with regard to the 2 senior surgeons. All patients of group 1 were operated on by surgeon 1 (S1) who always used the IMA as the standard recipient vessel and only performed abdominal flaps. All patients of group 2 were operated by surgeon 2 (S2) who intended to use the IMAP when possible. S2 performed abdominal flaps and TMG flaps.

RESULTS

Between January 2014 and December 2015, 515 free flaps for breast reconstruction were performed on 419 patients (Table 1). Four hundred twenty-four flaps from the abdomen (DIEP and SIEA flaps) and 91 flaps from the thigh (TMG flaps) were harvested. Three hundred six (59%) cases were immediate reconstructions, and 112 (22%) were delayed reconstructions. In 97 (19%) cases, implants were exchanged for autologous tissue.

Of all 515 flaps, 112 (22%) were anastomosed to IMAPs. Of these 112 flaps, 76 (68%) were abdominal flaps and 36 (32%) flaps were from the thigh. Eighty-two (73%) of these 112 flaps were immediate reconstructions, and 17 (15%) were delayed reconstructions. Thirteen flaps (12%) anastomosed to an IMAP were used for breast implant replacement.

In 48 patients, a bilateral reconstruction was performed (78 abdominal flaps and 18 TMG flaps; Tables 2 and 3). Of those 96 flaps, the IMAPs were used for both sides in 12% (n = 11) and for 1 side only in 23% (n = 22).

Two Surgeons

S1 carried out 213 flaps (only DIEP flaps) and always used the IMA (Table 4). One hundred twenty-eight of the

Table 1. Overview of TMG and Abdominal Flaps

	Flaps (n = 515), n (%)	Abdominal Flaps, n (%)	TMG, n (%)	IMA, n (%)	IMAP, n (%)
Total		424 (82.3)	91 (17.7)	403 (78.3)	112 (21.7)
Immediate reconstruction	306 (59.4)	253 (49.1)	53 (10.3)	224 (43.5)	82 (15.9)
Delayed reconstruction	112 (21.7)	99 (19.2)	13 (2.5)	95 (18.4)	17 (3.3)
Implant exchange	97 (18.8)	72 (14)	25 (4.9)	84 (16.3)	13 (2.5)

Table 2. Overview Abdominal Flaps

	Flaps (n = 424), n (%)	IMA, n (%)	IMAP, n (%)
Total		348 (82.1)	76 (17.9)
Right	216 (50.9)	178 (42)	38 (9)
Left	208 (49.1)	170 (40.1)	38 (9)
Immediate reconstruction	253 (59.7)	199 (46.9)	54 (12.7)
Delayed reconstruction	99 (23.3)	84 (19.8)	15 (3.5)
Implant exchange	72 (17)	65 (15.3)	7 (1.7)
Bilateral flaps	78 (18.4)	53* (12.5)	8† (1.9)

*Both anastomosis to IMA.
†Both anastomosis to IMAP.

Table 3. Overview of TMG Flaps

	Flaps (n = 91), n (%)	IMA, n (%)	IMAP, n (%)
Total		55 (60)	36 (40)
Right	50 (55)	32 (35.2)	18 (19.8)
Left	41 (54)	23 (25.3)	18 (19.8)
Immediate reconstruction	53 (58.2)	25 (27.5)	28 (30.8)
Delayed reconstruction	13 (14.3)	11 (12.1)	2 (2.2)
Implant exchange	25 (27.5)	19 (20.9)	6 (6.6)
Bilateral flaps	18 (19.8)	10* (11)	3† (3.3)

*Both anastomosis to IMA.
†Both anastomosis to IMAP.

Table 4. Comparison of all Flaps of Surgeons 1 and 2

	Surgeon 1 (n = 213)	Surgeon 2 (n = 302)
Mean age, y (range)	53 (27–77)	50 (23–79)
Immediate reconstruction, n (%)	128 (60.1)	178 (58.9)
Delayed reconstruction, n (%)	50 (23.5)	62 (20.5)
Implant exchange, n (%)	35 (16.4)	62 (20.5)

Table 5. Flaps of Surgeon 2

	Surgeon 2 (n = 302)	IMA	IMAP
Mean age, y (range)	50 (23–79)	50 (23–79)	48 (27–74)
n (%)		190 (62.9)	112 (37)
Immediate reconstruction, n (%)	178 (58.9)	96 (50.5)	82 (73.2)
Delayed reconstruction, n (%)	62 (20.5)	45 (23.7)	17 (15.1)
Implant exchange, n (%)	62 (20.5)	49 (25.8)	13 (11.6)

213 flaps in group 1 were immediate reconstructions and 50 were delayed reconstructions. Thirty-five cases were implant exchanges. Senior S2 has attempted to use the IMAP if possible (Table 5). S2 carried out 302 flaps (DIEP, SIEA, and TMG flaps). In group 2, 178 of the 302 flaps were immediate reconstructions, 62 were delayed reconstructions, and another 62 were implant exchanges. A total of 112 anastomoses (37%) of the 302 flaps in group 2 were to the IMAPs. Eighty-two (73%) of these were done in immediate and 17 (15%) were done in delayed reconstructions. Thirteen (12%) implant changes were anastomosed to an IMAP.

Distribution of Flaps

The abdominal flaps were distributed almost equally to the right (50.9%) and left (49.1%) sides. On each side, 38 of these flaps were anastomosed to the IMAP (Table 2). In the TMG-flap group, 18 of the right and left sides were anastomosed to an IMAP, respectively. Fifty (56%) of the TMG flaps were performed on the right side and 41 (44%) on the left side. No difference in IMAP distribution was observed (Table 3).

Flap Ischemia

The mean ischemia time was 35 minutes (14–118) in all abdominal flaps. Using an IMAP took 4 minutes longer (39 minutes [15–75]). The mean time for anastomosis of a TMG flap was 39 minutes (18–57). When an IMAP was used, 2 more minutes were needed (41 minutes [20–63]). Anastomosis to an IMAP took slightly longer; however, no large differences between using the IMA or an IMAP could be observed.

Vessel Size

The median diameter of the coupling devices in abdominal flaps for venous anastomosis to the internal mammary vein was 2.5 mm (1.5–3.5). When the perforating vein was used, the median diameter was also 2.5 mm.[2,3] The median diameter for venous coupling rings in TMG flaps anastomosed to the internal mammary vein was 2.5 mm (1.5–3) as well. However, when the perforating vein was used, the median size reduced to 2 mm (1.5–2.5).

Flap Weight

The mean weight of all abdominal flaps anastomosed to the IMA was 587 g (146–1,838). When the IMAP was used, the mean flap weight was 567 g (180–1,173). The mean size of TMG flaps anastomosed to the IMA was 265 g (163–375). When the IMAP was used, they were slightly heavier (mean, 296 g; 185–921).

Hospital Stay

After breast reconstruction using the IMA, the median time patients stayed in the hospital was 7 days.[4–24] When the IMAP was used, the median stay reduced to only 6 days.[4–12] After TMG-flap reconstruction, the median stay for both the IMA and the IMAP was 6 days (IMA, 3–10; IMAP, 4–9).

Table 6. Previous Radiation Therapy Information for All Flaps Anastomosed to the IMAP

	Total (n = 112)	Abdominal Flaps	TMG
Previous radiation therapy, n (%)	39 (34.8)	33 (29.5)	6 (5.5)
Breast conserving therapy, n (%)	21 (18.8)	17 (15.2)	4 (3.6)
Breast amputation, n (%)	12 (10.7)	12 (10.7)	0
Implant exchange, n (%)	6 (5.4)	4 (3.6)	2 (1.8)
Time,* y		3.2 y	2.9 y

*Time between radiation therapy and surgery.

Table 7. Flap Complications

	Total (n = 515), n (%)	Abdominal Flaps (n = 424)		TMG (n = 91)	
		IMA	IMAP	IMA	IMAP
Revision	32 (6.2)	27	1	3	1
Salvage	22 (4.3)	17	1	3	1
Flap failure	10 (1.9)	10	0	0	0
Fat necrosis	7 (1.4)	2	4	1	0
Skin necrosis*	5 (1)	4	0	0	1

*Mastectomy skin flap necrosis.

Radiation Therapy

Thirty-nine (34.8%) of all 112 flaps anastomosed to an IMAP had radiation therapy before reconstructive surgery (Table 6). The mean period between radiation and reconstruction was 3.2 years (3 months to 13 years) in abdominal flaps and 2.9 years (10 months to 7 years) for TMG flaps. Thirty-three of these 39 flaps were abdominal flaps and 6 were TMG flaps.

Complications

Revision surgery for vascular problems was necessary in 32 cases (6.2%) of all 515 flaps (Table 7). Twenty-eight cases were DIEP flaps, and 4 were TMG flaps. In 22 cases, the perfusion could be improved, and the flap was saved (68.75%). The most common reason for flap revision was venous congestion. In 2 cases, an additional venous anastomosis was performed in the axilla. In 1 case, an additional arterial in-flap anastomosis was performed. Only 2 of the 32 revisions affected an anastomosis to an IMAP. In these cases, perfusion could be salvaged permanently. All other revisions were done in anastomoses to the IMA.

Flap failure occurred in 1.9% (n = 10; DIEP flaps; survival rate, 98.1%) of all flaps. None of these flaps were anastomosed to a perforating vessel.

Mastectomy skin flap necrosis of more than $2\,cm^2$ occurred in 5 cases (0.97%). In these cases, the mastectomy was combined with an inverted T-reduction pattern. Thus, it is more likely to attribute skin flap necrosis to the incision type. Only 1 of these flaps was anastomosed to an IMAP. In 1 patient, a partial flap necrosis of zone IV according to Holm occurred; in another, flap necrosis of zone III occurred.[18] Both flaps were anastomosed to IMA vessels.

Palpable fat necrosis that was detectable by ultrasound was observed in 1.6% (n = 7) of all cases (6 DIEP and 1 TMG). Four of those (only DIEP flaps) were anastomosed to an IMAP. Only 1 of the 7 flaps with fat necrosis had radiation therapy before surgery. In this case, an IMAP

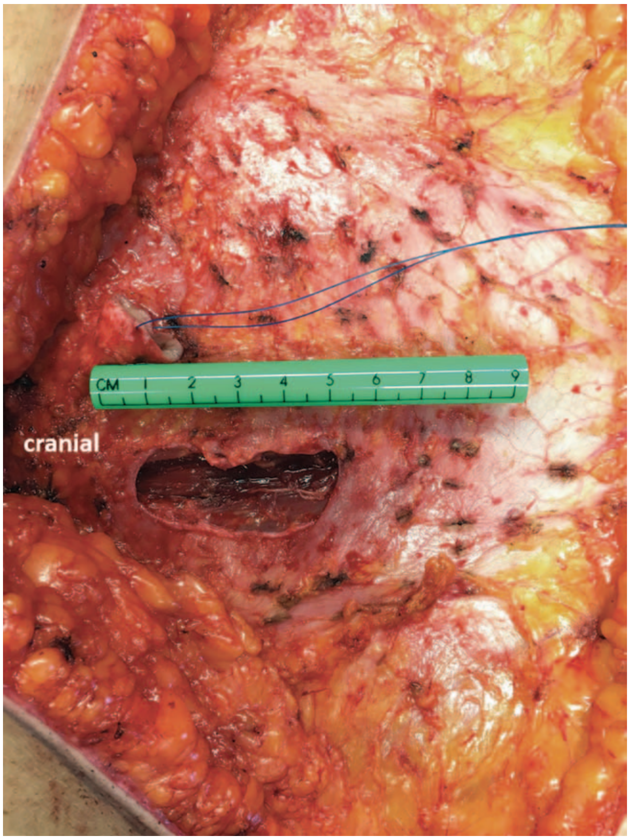

Fig. 6. If flap positioning is not compromised, short flap pedicles can be used because of the superficial position of the IMAP. In this example, the incision of rectus sheath for a single perforator DIEP flap harvest was less than 5 cm and the pedicle measured 8 cm.

was used. The mean weight of abdominal flaps anastomosed to an IMAP and developed fat necrosis was 805 g (611–1,028). Abdominal flaps with fat necrosis anastomosed to the IMA had a mean weight of 819 g (587–1,051). In both cases, the mean flap size was larger than the flaps without fat necrosis (abdominal flaps anastomosed to IMA: mean, 587 g; anastomosed to IMAP: mean, 567 g), which could not be observed in the 1 TMG flap that developed fat necrosis (254 g) and which was smaller than the average TMG size (mean, 265 g).

DISCUSSION

The reason we began to use the IMAPs as recipient vessels was not only to spare the IMA vessels for a future bypass operation but also to facilitate the anastomoses and the fitting of short pedicled flaps (TMG and SIEA flaps) and to be able to dissect DIEP flaps with shorter pedicles. This limits donor-site exploration and may shorten operation times (Fig. 6).[12,14,16,19] Initially, the usage of IMAP vessels was not expected in delayed reconstructions. However, thoracic computed tomographic angiography showed that IMAP vessels were still present in patients who had had previous surgery and after radiation therapy.[20] We began, therefore, to look for and to use these vessels in secondary surgery as well. Today, imaging is no longer conducted. A cautious dissection to preserve potential vessels is the only action taken to locate an IMAP. The decision for or against using IMAPs was clinical and depended on the surgeon's preference.

In a total of 112 of 515 cases (22%), IMAP vessels were used for all flaps of both senior surgeons. If all flaps of S2 are taken into account, it rises to 37%. If all delayed reconstructions are left aside and attention is just paid to immediate reconstructions, it rises further to 46%.

In other studies, these numbers vary between 5.5% and 39%. Hamdi et al[13] published a retrospective study in which they used an IMAP in 9% of cases. Saint-Cyr et al[15] used IMAP vessels in a total of 5.5% of cases. In a subset, they analyzed 114 cases from just 1 surgeon who always attempted to use the IMAP: the percentage increased to 27%. Munhoz et al[16] analyzed 40 immediate reconstructions and used the IMAP in 13 cases (32.5%). Haywood et al[12] published 54 reconstructions in which the IMAP was used in 39% of cases. Follmar et al[14] used in a retrospective study of 100 abdominal flaps the IMAP in 23%. Over a third of our reconstructions performed to an IMAP had previous radiation therapy, and in 13.4% of all implant exchanges, the perforating vessels could be used despite earlier surgery.

None of the 10 flap failures (1.9%) were anastomosed to an IMAP, which means a survival rate of flaps anastomosed to an IMAP of 100% and of all other flaps anastomosed to the IMA of 97.5%. These rates are comparable with other studies that published flap failure rates between 1% and 3%.[12–14] Haywood et al[12] reported revision rates of 7.4%, and Follmar et al[14] reported revision rates of 2.6%. However, in both studies, complications occurred only when the IMA or TDA was used.[12,14] From these data, one can speculate that the IMAP anastomosis seems to be safer than the IMA anastomosis.

We observed palpable and ultrasound detectable fat necrosis in 1.4%. Four (all DIEP flaps) of them were anastomosed to an IMAP. The fact that 4 of 112 flaps (3.6%) anastomosed to the IMAP developed a fat necrosis, but only 3 of the 403 IMA anastomosed flaps indicates a trend toward a slightly increased rate of fat necrosis in IMAP anastomosed flaps. However, the rate is over all very low, and the mean weight of abdominal flaps anastomosed to an IMA and to an IMAP that developed fat necrosis was larger than the average flap weight of their counterparts anastomosed to the IMA/IMAP without fat necrosis. It never occurred in bilateral DIEP flaps, which are always smaller and do not include distant zones. Furthermore, the appearance of fat necrosis is not due only to recipient vessel choice or its caliber. Internal flap perfusion and the quality of included perforators play an important role as well. Saint-Cyr et al[15] described a rate for fat necrosis of 8%, which is twice the rate of ours. Hamdi et al[13] recorded fat necrosis in 3.3%. and Follmar et al[14] recorded fat necrosis in 4.3% if the IMAP was used and 6.5% if the IMA or the thoracodorsal vessels were used. Flap weight was not mentioned in these studies, and all fat necrosis rates published exceeded ours. Despite careful follow-up, not all fat necrosis may have been detected. Small areas of necrotic tissue in larger flaps may remain undiscovered when they do not disturb.

The median length of hospital stay of our patients with DIEP flaps was reduced by 1 day when the IMAP was used as the recipient vessel. Patients with TMG flaps showed no difference in duration of hospital stay in relation to recipient vessel choice, which may be because of more discomfort in the thigh than in the breast.

Today, the IMA is the first choice of most surgeons. However, the IMA vessels themselves are not free of disadvantages. Thoracic contour irregularities, postoperative pain and impaired breathing, pneumonia, and pneumothorax are known complications.[13–15,23] The dissection of IMA vessels can be difficult after radiation therapy and especially after chronic inflammation and capsular contracture because of implant reconstruction. Additionally, when used as a recipient vessel in breast cancer patients, the IMA cannot be later used for cardiac bypasses.[14]

Sparing the IMA for a cardiac bypass may be achieved by an end-to-side-anastomosis.[24] However, this technique requires a long pedicle and takes significantly longer time. Another study suggested to use the IMA below the fifth ICS on the right and in the fourth ICS on the left side.[10]

By using the IMAP, the IMA is not only spared for bypass operations or, more interesting, possible revisions, but limited dissection also reduces operation time.[14,16] Using the IMAP as recipient vessels underlines the idea of perforator flaps, which are meant to reduce morbidity in reconstructive surgery.

CONCLUSIONS

When adequate IMAP vessels were available, they provided consistent blood supply (100% survival rate) in immediate and delayed breast reconstructions. Even large flaps and previous radiation therapy did not cause increased complication rates. Complication rates were lower when the IMA was used. Patients with DIEP or SIEA flaps went home 1 day earlier after anastomosis to an IMAP. None of these patients had costal cartilage removed, and the superficial position of the IMAP vessels allow shorter pedicles, which reduces exploration when raising the flap and thus decreases donor-site morbidity. Using the IMAPs as recipient vessels is a further step toward simplifying microsurgical breast reconstruction. This technique is a further refinement of perforator-based surgery although it cannot be applied in every patient.

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