British Journal of Plastic Surgery (1993), **46**, 122–126

BRITISH JOURNAL OF PLASTIC SURGERY

Prefabricated venous flaps: an experimental study in rabbits

T. Takato, Y. Komuro, H. Yonehara and R. M. Zuker

Department of Plastic Surgery, Faculty of Medicine, University of Tokyo and Division of Plastic Surgery, The Hospital for Sick Children, Toronto

SUMMARY. **Prefabrication is a method for creating donor flaps by implantation of a nourishing pedicle prior to harvesting the flap. Based on the concept that implantation of a "flow-through" vein results in sufficient vascularisation to support a skin flap, we used a rabbit model to investigate the viability of prefabricated total venous perfusion (TVP) flaps.**

Prefabrication of an abdominal wall donor site was performed using the left epigastric vein in 25 male New Zealand white rabbits. An 8 × 10 cm skin flap was elevated 1, 2, 3, 4, and 6 weeks after prefabrication (n = 5 per group). A silicone sheet was implanted under the skin flap. The mean survival rate of the skin flaps was 24%, 52%, 87%, 83%, 84%, respectively. Results of this study show that reproducible survival of a prefabricated TVP flap can be obtained when the flap is elevated more than 3 weeks after prefabrication.

A total venous perfusion (TVP) flap is defined as a composite flap of skin and subcutaneous tissue that is nourished only by venous blood flow (Nichter and Haines, 1985; Inada *et al.*, 1989). Honda *et al.*, in 1984, were the first to use TVP flaps in the replantation of amputated digits. Since then, several clinical and experimental series have been reported on TVP flaps (Ji *et al.*, 1984; Baek *et al.*, 1985; Thatte and Thatte, 1987; Tsai *et al.*, 1987; Fukui *et al.*, 1988; Amarante *et al.*, 1988; Sasa *et al.*, 1988; Fukui *et al.*, 1989; Inada *et al.*, 1989).

In all clinical reports, selection of a donor site with favourable blood circulation and the existence of a high efferent venous pressure at the recipient site were regarded as mandatory conditions for successful TVP flap transfer (Fukui *et al.*, 1989). In the majority of reported cases, slim TVP flaps were successfully transferred to skin defects in the fingers. These reports suggest that clinical applications of TVP flaps may be limited to these areas. But safe transfer of bigger flaps, particularly to areas which have poor blood circulation, is desirable. For this purpose, we used a prefabrication method in an attempt to make larger TVP flaps with reliable skin survival.

Prefabrication is a method of creating donor flaps by prior implantation of a nourishing pedicle. This technique may allow use of flap donor sites which are not limited by natural vascular territories. Several methods of prefabrication have been described in both experimental and clinical series. These include implantation of a segment of intestine, greater omentum or muscle as a pedicle (Washio, 1971; Erol and Spira, 1981; Shintomi and Ohura, 1982). Pedicles of blood vessels and arterio-venous (A-V) shunts have been used (Erol, 1976; Hori *et al.*, 1979; Erol and Spira, 1980; Yao, 1981; Erol *et al.*, 1981; Yao, 1983; Hirasé *et al.*, 1988; Hirasé *et al.*, 1989; Takato *et al.*, 1991). We reported that 8 × 10 cm skin flaps prefabricated by A-V shunts survived successfully in rabbits (Takato *et al.*, 1991). In this study, we used the same design of skin flap in an abdominal wall of rabbits, but prefabrication was performed using only the left epigastric vein. The aim of this study was to investigate the viability of large prefabricated TVP flaps and the appropriate timing of flap elevation.

Materials and methods

Thirty-three adult male New Zealand white rabbits weighing between 2700 and 3500 g were used. Anaesthesia was with a mixture of halothane, nitrous oxide, and oxygen.

Experimental design

The rabbits were divided into two groups as follows:
Group 1: TVP flap group – 8 rabbits
Group 2: Prefabricated TVP flap group – 25 rabbits

Experimental method

Group 1: TVP flap group. A flap measuring 8 × 10 cm was designed on the abdomen of the rabbits (Fig. 1). The skin and panniculus carnosus were elevated together with the left epigastric vessels, which were identified on the undersurface. With the aid of high magnification, a segment of the epigastric artery was removed proximally. At both the top and the bottom of the flap, approximately 5 mm of the epigastric vein was stripped of the surrounding panniculus carnosus. This manipulation ensured nutrition was only by the epigastric vein. The flap simulated an island flap (Fig. 2). A silicone sheet was placed under the flap which was replaced on its bed in 5 rabbits.

The remaining 3 rabbits were killed and an angiogram was done immediately after flap elevation.

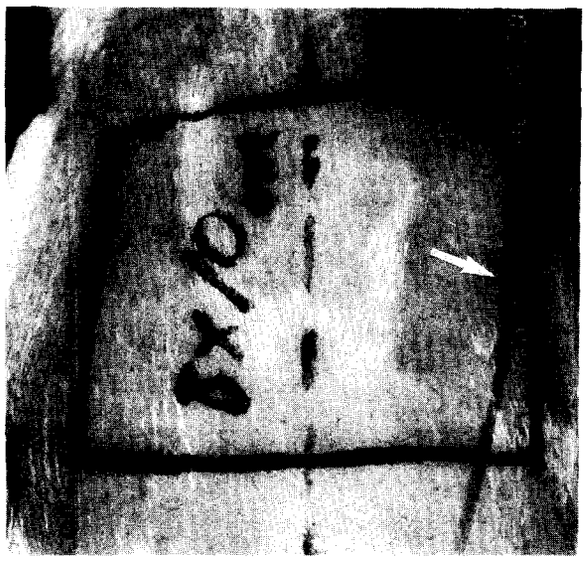

Fig. 1

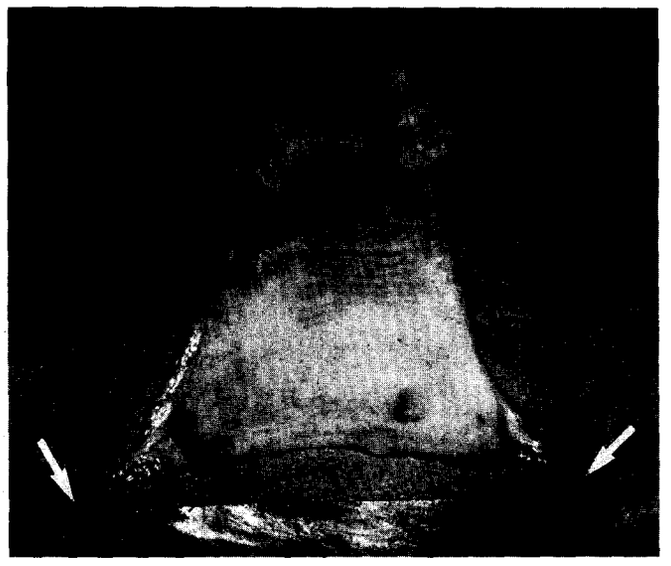

Fig. 2

Figure 1—The design of a flap measuring 8 × 10 cm on the abdomen: An arrow indicates the surface marking of the left epigastric vessels. **Figure 2**—The elevated TVP flap nourished by the left epigastric vein: Arrows indicate the parts of the vein which are stripped of the surrounding panniculus carnosus.

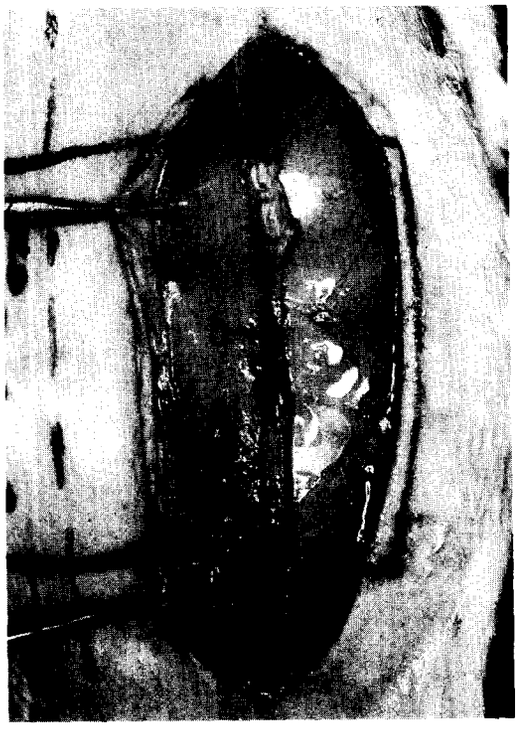

Fig. 3

Fig. 4

Figure 3—The epigastric vein and the attached strip of panniculus carnosus (Arrow). **Figure 4**—The epigastric vein shifted and affixed to the centre of the elevated skin flap. The epigastric vein is indicated by an arrow.

Twenty percent Micropaque with 10% gelatin was injected through the left epigastric vein at a pressure of 100 mmHg.

Group 2: Prefabricated TVP flap group. (i) Prefabrication. A flap measuring 8 × 10 cm was planned on the abdomen of the rabbits in a similar fashion to Group 1 animals. An incision was made along the left side of the proposed flap and extended both superiorly and inferiorly. The panniculus carnosus on either side of the epigastric vessels was incised and the vessels, together with a strip of panniculus carnosus, were dissected away from the skin. With the aid of high magnification, a segment of the proximal epigastric artery was removed leaving the epigastric vein *in situ* (Fig. 3). The skin and panniculus carnosus were elevated 1 cm beyond the centre of the abdomen. The epigastric vein and the attached strip of panniculus carnosus were translocated and affixed near the centre of the flap (Fig. 4). The incision line was sutured. The rabbits were then housed in an air-conditioned cage and fed with dry feed.

(*ii*) *Flap elevation.* The previously planned 8 × 10 cm skin and panniculus carnosus were elevated together with the vein graft in a similar fashion to animals in Group 1. At both top and bottom of the flap, approximately 5 mm of the epigastric vein was stripped of the surrounding panniculus carnosus under microscope. Groups with 5 rabbits in each underwent flap elevation at 1, 2, 3, 4, and 6 weeks after the first operation. A silicone sheet was implanted under the elevated flap and it was replaced in its bed.

Assessment

(i) Viability of the flaps was assessed 10 days after flap elevation using a previously described method (Takato *et al.*, 1991).

(ii) An angiogram of each flap was performed to investigate vascularisation at the time of viability assessment of the skin flap. Twenty percent Micropaque with 10% gelatin was injected through the vein pedicle at a pressure of 100 mmHg.

Results

TVP flaps in Group 1 became slightly congested and notably swollen following elevation, but this gradually subsided over a period of 5 days. Prefabricated TVP flaps in Group 2 showed a similar postoperative course. The epigastric vein had become slightly dilated and tortuous at the time of assessment of flap survival. The viability of the skin flaps (% of flap area) was as in Table 1.

Skin viability of prefabricated TVP flaps elevated more than 2 weeks after prefabrication was significantly higher than that of TVP flaps ($p < 0.05$). Prefabricated TVP flaps elevated more than 3 weeks after prefabrication showed significantly higher skin survival, compared with those elevated at 2 weeks or less ($p < 0.05$). Where there was only partial survival of the flap, the area surviving in both groups 1 and 2 was overlying the venous pedicle. The angiograms of TVP flaps performed immediately after elevation (3

Table 1 Viability of skin flaps (% survival): Black areas show necrosis.

Group	Skin viability (%) and Areas of viable skin				
Group 1	20.3%	22.4%	24.4%	26.4%	32.4%
Group 2					
(i) 1 wk	16.4%	18.6%	21.2%	24.0%	41.0%
(ii) 2 wks	24.8%	48.8%	58.4%	59.6%	66.3%
(iii) 3 wks	78.6%	81.2%	88.8%	93.6%	94.0%
(iv) 4 wks	66.7%	73.3%	85.6%	92.0%	94.4%
(v) 6 wks	72.4%	82.4%	84.0%	90.2%	92.6%

Group 1:		
TVP Flap (Fig. 5)		25.2% ± 2.1 (Mean ± *SEM)
Group 2:		
Prefabricated TVP flap		
(i)	1 week group	24.2% ± 4.4
(ii)	2 weeks group	51.6% ± 7.2
(iii)	3 weeks group	87.2% ± 3.2 (Fig. 6)
(iv)	4 weeks group	82.5% ± 5.3
(v)	6 weeks group	84.3% ± 3.5

(*SEM: Standard Error of the Mean)

Fig. 5

Fig. 6

Figure 5—Group 1: TVP flap 10 days after elevation: An arrow indicates the viable skin overlying the left epigastric vein. **Figure 6**—Group 2 (3 weeks group): a prefabricated TVP flap 10 days after elevation.

Fig. 7

Fig. 8

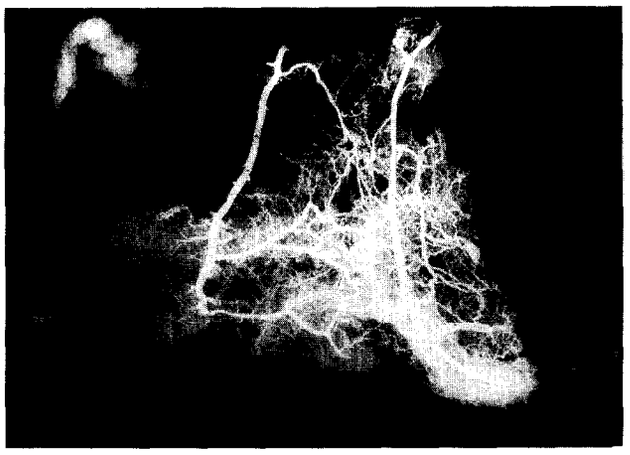

Fig. 9

Fig. 10

Figure 7—An angiogram of a TVP flap immediately after elevation (Group 1). **Figure 8**—An angiogram of a TVP flap 10 days after elevation (Group 1). **Figure 9**—An angiogram of a prefabricated TVP flap elevated 2 weeks after prefabrication: Note the dilated vein and extensive vascular network (Group 2: 2 weeks group). **Figure 10**—An angiogram of a prefabricated TVP flap elevated 3 weeks after prefabrication: Note the intricate vascular network within the whole flap (Group 2: 3 weeks group).

rabbits) showed venous networks within the whole flap (Fig. 7). Angiograms of TVP flaps 10 days after elevation in 5 rabbits did not show such extensive networks even in the surviving areas. In the other regions, no vascularity was observed (Fig. 8). Angiograms of prefabricated TVP flaps showed the left epigastric vein at the left margin of the flap and an extensive vascular network in each flap. The pedicle, originally near the centre, had retracted laterally, probably due to the movement of the abdomen and the tension. A slightly dilated and tortuous venous pattern and its accompanying straight and slender arterial pattern were observed in the area of the viable flaps (Figs 9, 10).

Discussion

In their studies using saphenous TVP flaps in dogs, Baek *et al.* (1985), Thatte and Thatte (1987), and Amarante *et al.* (1988) reported reproducible skin survival. Several authors reported that TVP flaps survived even when blood circulation in the recipient bed was poor (Baek *et al.*, 1985; Fukui *et al.*, 1988; Inada *et al.*, 1989). Contrary to these successful results, Ji *et al.* (1984) reported only partial survival (15%–30%) of TVP flaps in the rabbit ear. Sasa *et al.* (1988) reported that only 14% of saphenous TVP flaps survived and 75% of cephalic TVP flaps survived in dogs. These differences are probably due to the blood circulation of the donor site and the venous pressure at the recipient site. The presence of good blood circulation in a flap and the existence of high efferent venous pressure are preferable for a successful TVP flap transfer (Sasa *et al.*, 1988; Fukui *et al.*, 1989).

In our study using the rabbit abdomen, an 8 × 10 cm TVP flap under which a silicone sheet was implanted showed partial survival (20%–32%). These flaps survived solely on venous blood flow along the left epigastric vein. With prefabrication it was possible to increase survival area in a flap.

The delay phenomenon may be an important factor in obtaining a more intricate vascular plexus in prefabrication. The prefabricated flaps were half elevated before later total elevation. Ueda *et al.* (1991) reported that delay was an effective method to increase

the survival area of TVP flaps. In our study, mean survival rate at 3 weeks post-prefabrication was nearly 90%, and there were no significant differences between survival rates for the flaps elevated after 3 weeks. This shows that about the third week was the optimum transfer time for maximal flap survival. Similar prefabricated flaps with an arterial blood supply were successful after only 10 days delay (Takato *et al.*, 1991).

Angiograms of prefabricated TVP flaps showed a far more extensive vascular network than those of standard TVP flaps. Accompanying arterial networks as well as venous networks were observed. The increase of the number of arterial and venous connections is postulated to contribute to the survival of large skin flaps. In this study, a strip of panniculus carnosus was preserved around the buried epigastric vein pedicle. It is our hypothesis that the panniculus carnosus may contain fine vessels like a fascia and play a role in establishing vascular connections. In clinical cases, we think that a strip of the surrounding soft tissue and fascia should be preserved around the vein pedicle.

The ability to prefabricate a flap using a vein has numerous advantages. This technique makes it possible to create a thin and large skin flap. The freedom to prefabricate flaps unrestricted by vascular territories and to select donor sites that result in more aesthetic donor defects is another advantage. Further to our previous work with free prefabricated venous flaps with arterial blood input (Takato *et al.*, 1991), this report shows that similar experimental local flaps can be successfully used with a venous blood input.

References

Amarante, J., Costa, H., Reis, J. and Soares, R. (1988). Venous skin flaps: an experimental study and report of two clinical distal island flaps. *British Journal of Plastic Surgery*, **41**, 132.

Baek, S., Weinberg, H., Song, Y., Park, C. and Biller, H. F. (1985). Experimental studies in the survival of venous island flaps without arterial inflow. *Plastic and Reconstructive Surgery*, **75**, 88.

Erol, Ö. O. (1976). The transformation of a free skin graft into a vascularized pedicle flap. *Plastic and Reconstructive Surgery*, **58**, 470.

Erol, Ö. O. and Spira, M. (1980). New capillary bed formation with a surgically constructed arteriovenous fistula. *Plastic and Reconstructive Surgery*, **66**, 109.

Erol, Ö. O. and Spira, M. (1981). Utilization of a composite island flap employing omentum in organ reconstruction: an experimental investigation. *Plastic and Reconstructive Surgery*, **68**, 561.

Erol, Ö. O., Parsa, F. D. and Spira, M. (1981). The use of the secondary island graft-flap in reconstruction of the burned ear. *British Journal of Plastic Surgery*, **34**, 417.

Fukui, A., Inada, Y., Tamai, S., Mizumoto, S., Yajima, H. and Sempuku, T. (1988). Skin graft including subcutaneous vein: experimental study and clinical applications. *Journal of Reconstructive Microsurgery*, **4**, 223.

Fukui, A., Inada, Y., Maeda, M., Tamai, S., Mizumoto, S., Yahima, H. and Sempuku, T. (1989). Pedicled and "flow-through" venous flaps: clinical applications. *Journal of Reconstructive Microsurgery*, **5**, 235.

Hirasé, Y., Valauri, F. A. and Buncke, H. J. (1988). Prefabricated sensate myocutaneous and osteomyocutaneous free flaps: an experimental model. *Plastic and Reconstructive Surgery*, **82**, 440.

Hirasé, Y., Valauri, F. A. and Buncke, H. J. (1989). Creation of neovascularised free flaps using vein grafts as pedicles: a preliminary report on experimental models. *British Journal of Plastic Surgery*, **42**, 216.

Honda, T., Nomura, S., Yamauchi, K., Shimamura, K. and Yoshimura, M. (1984). The possible application of a composite skin and subcutaneous vein graft in the replantation of amputated digits. *British Journal of Plastic Surgery*, **37**, 607.

Hori, Y., Tamai, S., Okuda, H., Sakamoto, H., Takita, T. and Masuhara, K. (1979). Blood vessel transplantation to bone. *Journal of Hand Surgery*, **4**, 23.

Inada, Y., Fukui, A., Tamai, S. and Masuhara, K. (1989). Experimental studies of skin flaps with subcutaneous veins. *Journal of Reconstructive Microsurgery*, **5**, 249.

Inada, Y., Fukui, A., Tamai, S., Maeda, M. and Mizumoto, S. (1990). An experimental study of the venous flap: investigation of the recipient vein. *Journal of Reconstructive Microsurgery*, **6**, 123.

Ji, S. Y., Chia, S. L. and Cheng, H. H. (1984). Free transplantation of venous network pattern flap: an experimental study in rabbits. *Microsurgery*, **5**, 151.

Nichter, L. S. and Haines, P. C. (1985). Arterialised venous perfusion of composite tissue. *American Journal of Surgery*, **150**, 191.

Sasa, M., Xian, W., Breidenbach, W., Tsai, T. M., Shibata, M. and Firrell, J. (1988). Survival and blood flow evaluation of canine venous flaps. *Plastic and Reconstructive Surgery*, **82**, 319.

Shintomi, Y. and Ohura, T. (1982). The use of muscle vascularized pedicle flaps. *Plastic and Reconstructive Surgery*, **70**, 725.

Takato, T., Zuker, R. M. and Turley, C. B. (1991). Prefabrication of skin flaps using vein grafts: an experimental study in rabbits. *British Journal of Plastic Surgery*, **44**, 593.

Thatte, R. L. and Thatte, M. R. (1987). A study of the saphenous venous island flap in the dog without arterial inflow using a non-biological conduit across a part of the length of the vein. *British Journal of Plastic Surgery*, **40**, 11.

Tsai, T. M., Matiko, J. D., Breidenbach, W. and Kutz, J. E. (1987). Venous flaps in digital revascularization and replantation. *Journal of Reconstructive Microsurgery*, **3**, 113.

Ueda, K., Harada, K., Nagasaka, S., Inoue, T. and Harashina, T. (1991). Experimental study of delay of venous flap. Abstract of the 18th Annual Meeting of Japanese Society of Reconstructive Microsurgery, December 1991, p59.

Washio, H. (1971). An intestinal conduit for free transplantation of other tissues. *Plastic and Reconstructive Surgery*, **48**, 48.

Yao, S. T. (1981). Vascular implantation into skin flap. Experimental study and clinical application: a preliminary report. *Plastic and Reconstructive Surgery*, **68**, 404.

Yao, S. T. (1983). Free transfer of reconstructed musculocutaneous flap. *Plastic and Reconstructive Surgery*, **72**, 576.

The Authors

Tsuyoshi Takato, MD, Assistant Professor, Department of Plastic Surgery, Faculty of Medicine, University of Tokyo.

Yuzo Komuro, MD, Plastic Surgeon, Department of Plastic Surgery, Faculty of Medicine, University of Tokyo.

Hiroyuki Yonehara, MD, Plastic Surgeon, Department of Plastic Surgery, Faculty of Medicine, University of Tokyo.

Ronald M. Zuker, MD, FRCS(C), FACS, Head, Division of Plastic Surgery, The Hospital For Sick Children, Toronto.

Address correspondence to: Dr. Takato, Department of Plastic Surgery, Faculty of Medicine, University of Tokyo, 7-3-1, Hongo, Bunkyo-ku, Tokyo 113, Japan.

Paper received 3 April 1992.
Accepted 18 August 1992, after revision.