

The Use of Arterio-Venous Loop in Microvascular Anastomosis in the Lower Extremity

AYMAN A. SHAKER, M.D.; MOHAMAD KHALED H. YOUSSEF, M.D. and
HAZEM M. MOHAMAD, M.D.

The Department of Plastic and Reconstructive Surgery, Faculty of Medicine, Ain Shams University.

ABSTRACT

The proper selection of the recipient vessels is essential for the success of the free tissue transfer, especially when the transfer is to the lower extremity. After trauma to the lower extremity, wide spread changes occur in the walls and perivascular tissues of the major vessels of the limb. The term Post Traumatic Vessel Disease (PTVD) was applied to these changes. It is extremely troublesome to operate on vessels affected by PTVD. They are easily damaged in dissection and prone to intractable vasospasm. In addition, their lining lacks the thromboresistant properties of a healthy vessel. So, to obtain a successful result with microvascular free tissue transfer, the surgeon should go to recipient vessels away from the injury beyond the zone of PTVD. This can be achieved by performing the anastomosis with a more proximal and healthy vessel using long vein grafts. This paper will demonstrate the techniques of arterio-venous loop in microvascular anastomosis. The recipient vessels, the sources of vein grafts, the timing of flap transfer and the problems of this technique will be thoroughly discussed.

INTRODUCTION

Selection of recipient vessels is one of the most important factors determining free flap success. It has become axiomatic that the selected vessels should be away from sites of previous trauma or severe irradiation [1].

After trauma to the lower extremity, wide spread changes occur in the walls and perivascular tissues of the major vessels of the limb. These changes have been conveniently called post-traumatic vessel disease (PTVD) [2]. Vessels affected by PTVD are more difficult to be dissected, are easily damaged during the dissection and prone to intractable vasospasm. Their linings also lack the thromboresistant properties of healthy vessels. Depending upon the magnitude of the traumatic insult to the extremity, the area in which PTVD is found can extend markedly beyond the original site of bony and soft-tissue damage.

Whenever possible, the surgeon should go to recipient vessels away from injury beyond the zone of PTVD. This can be achieved by either hooking up the flap with "Carrier" vessels in the contralateral non affected leg [3-8] or by performing the anastomosis with more proximal and healthy vessel using long vein graft [2]. This vein may be harvested locally and used in situ (Corlett loop) or transposed to distal vessels. With a locally used saphenous vein the distal end may be anastomosed to the femoral or popliteal artery.

Distal transfer requires the vein to be positioned so that the valves of the vein are not obstructing the arterial flow. This vein graft can be used in either 2 ways [2]:

1- Blind-loop inset of the graft:

The anastomosis between the vein graft and the flap vessels can conveniently be done on the side table with the flap iced down. The vein may be divided into two lengths right away or it can be kept intact and installed as a temporary blind loop (Fig. 1a). This loop arrangement helps to conserve useful vessel length and the decision on where to divide the loop can be deferred and made accurately once the flap is in the wound.

2- Proximal-loop inset of the graft:

In this method, the proximal anastomoses have to be done first, with the whole length of the vein graft intact, creating a temporary U-shaped loop of arteriovenous fistula (Fig. 1b). In this procedure clamps are released to allow a period of maturing flow past the anastomosis. While this maneuver offers some advantages in terms of ischemia time and patient positioning, it carries the risk for a high flow thrombus,

which sometimes forms at the arterial end of the graft and for this reason it is not recommended.

However, these vein grafts are believed to carry major risk of failure and this risk is believed to become greater as the graft lengthens [1].

In this paper the technique of arteriovenous loop in microvascular anastomosis will be demonstrated. The indications, recipient vessels, sources of vein grafts, timing of flap transfer as well as the problems of this technique will be thoroughly discussed.

PATIENTS AND METHODS

The study included 15 patients in whom arterio-venous loop is required to accomplish microvascular free tissue transfer due to lack of healthy recipient vessels. In three patients the procedure was not completed. In these patients there was no available vein graft as the contralateral long saphenous vein was previously cannulated or harvested for associated vascular injury and the upper limb veins could not be used due to their thrombosis from repeated cannulations. These patients were managed by conventional cross leg flap (two patients) and cross leg free latissimus dorsi myocutaneous flap (one patient).

Twelve patients with different lower limb defects were operated upon. Their ages ranged from 8 to 38 years. Nine patients were males and three were females. All defects were traumatic in origin except one that was due to post operative irradiation for sarcoma of the upper end of the fibula. Nine of these defects were in the chronic stages (more than 3 months and up to 11 years after the injury) and the other three were in the subacute stage (between 3 days and 3 months after the injury). The defects were involving the whole leg in the form of circumferential scarring with or without ulceration with oedema of the dorsum of the foot in 6 patients (Fig. 2). Upper 1/3 leg defects with bone exposure and stiff knee joint was present in 3 patients. Middle 1/3 leg defect with bone loss and extensive scarring was present in one patient. Lower 1/3 leg defects with bone exposure and tendoachillis rupture was present in 2 patients. In only two patients the defect was mainly involving the lateral aspect of the leg. Patients' data are shown in Table (1).

Operative technique:

The A.V. loop was done with the superficial femoral vessels in 7 patients, with the descending branch of the lateral circumflex femoral vessels in 2 patients having defects on the lateral aspect of the leg, with the popliteal vessels in 2 patients and with the anterior tibial vessels in one patient (Table 1). The technique of proximal loop inset of the graft was done in all patients.

When the femoral vessels were used (7 patients), they are exposed in the subsartorial canal through medial thigh incision. A good segment from the artery and the vein is dissected. The long saphenous vein is also exposed in the upper most part of the leg and followed to the lower most part of the thigh.

Simultaneous harvesting of a vein graft is done by another team. In all cases the contralateral long saphenous vein was used except in one patient the cephalic vein was used. The graft is harvested under tourniquet with loupe magnification. All tributaries are ligated. The graft is distended by applying a microvascular clamp on the outflow end of the graft and injecting at the inflow end of the graft. This important preparatory step removes the possibility of segmental spasm and detect any leaks that have to be repaired. The distal end is then divided and the graft is irrigated with heparinized saline. The distal end is tagged by suture for identification. The shortest vein graft was 25 cm and the longest was 45 cm (Table 1).

The venous anastomosis was done firstly followed by the arterial anastomosis. In the first 2 patients the venous anastomosis was done between the proximal end of the vein graft and the femoral vein (end to side anastomosis) in one case and with one of its muscular tributaries (end to end anastomosis) in the other case (Fig. 3 a,b). In the next 5 patients the anastomosis was done between the proximal end of the vein graft and the divided end of the saphenous vein in the upper most part of the leg or in the lower most part of the thigh (end to end anastomosis) (Fig. 4a,b). All arterial anastomoses were done between the distal end of the graft after being reversed and the femoral artery (Cobra-head anastomosis).

For defects on the lateral aspect of the leg (2 patients) end to end anastomosis was done between the proximal end of the vein graft and

one of the venae comitants of the descending branch of the lateral circumflex femoral artery and between the distal end of the vein graft and the descending branch of the lateral circumflex femoral artery (Fig. 5).

When the popliteal vessels were used (2 patients) end to side anastomosis was done. When the anterior tibial vessels were used (one patient) end to end anastomosis to the divided ends of the vessels was done.

In one patient after making the loop and elevation of the flap, the loop was not patent despite repeated trials of anastomotic revision. This flap was not transferred and resutured to its original donor site and the defect was covered by conventional cross leg flap. In the eleven patients with the AV loop, immediate flap transfer was done in 8 of them and postponed in the other three where patience of the loop was doubtful. In two of them the flap was transferred after 2 days and in the third one flap transfer was not feasible due to loop occlusion 4 days post operatively.

So, a total number of 10 flaps were transferred, five of them were Latissimus dorsi myocutaneous flaps with skin paddle allowing direct closure of the flap donor site and the other five were rectus abdominis muscle flap (2) and rectus abdominis myocutaneous flaps (3) (Table 1). For the patient who had middle 1/3 leg defect with bone loss, the bone was reconstructed simultaneously by non vascularized fibula and covered by rectus abdominis muscle flap (Fig. 6).

RESULTS

Of the fifteen patients in whom the AV loop was planned to be done, only twelve patients had this procedure. In one of these patients the loop was initially patent but soon became thrombotic with a patent anastomosis at its arterial end. Repeated revisions of the thrombotic segments failed to make the loop patent. The raised flap was resutured to its original donor site and the defect was covered by conventional cross leg flap.

In the other 11 patients immediate flap transfer was done in 8 of them and they survived completely (100% success) (Figs. 7-10) with partial loss of the skin island of one rectus abdominis myocutaneous flap. In the other three patients flap transfer was delayed for maturation of the loop.

Two of them were reexplored after 48 hours, one loop of them was patent and the flap was transferred and it survived completely. The other one that had had a thrombosed segment at the initial time of making the loop developed the same problem and became thrombotic, again though it had a patent anastomosis at its arterial end. The thrombosed segment was resected again followed by flap transfer that was completely lost. In the third patient, in whom the defect was due to irradiation, the loop became thrombosed after 4 days. On exploration the whole loop, both arterial and venous anastomoses and a part from the recipient artery (descending branch of the lateral circumflex femoral artery) were thrombosed. The loop was irrigated, both arterial and venous anastomoses were revised. Flap transfer was postponed but the loop became thrombosed again after 24 hours. Flap transfer was cancelled and above knee amputation was decided for the patient.

So, the overall incidence of thrombosis was 3 out of 12 (25%). Two of them were most probably due to a pathological vein graft and the third one was due to high flow thrombus at the arterial end of the graft. Success rate of flaps that were transferred immediately was 100%, while that of the flaps that were transferred after AV loop maturation was 50% (one out of 2 flaps). The overall success rate of flap transfer was 90% (nine out of ten) (Table 1). The results can be summarized in the following flowchart:

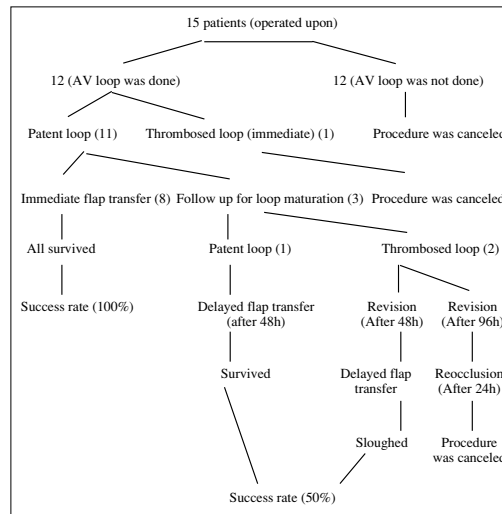


Table (1): Patients' data.

No.	Age	Sex	Etiology	Defect	Recipient vessels	Source of vein grafts	Length of vein graft	Stages	Flap	Outcome	Notes
1	36	M	P.T.	Bony defect of the left tibia and adherent scarring involving most of the skin of the leg	Femoral a. femoral V.	Long saphenous vein (right leg)	45 cm	Two stages 48 hours interval	R.A. muscle flap	Complete flap survival	-
2	16	M	P.T.	Circumferential scarring of the left leg and lymphedema of the dorsum of the foot	Femoral a. tributary of the femoral vein	Long saphenous vein (right leg)	45 cm	One stage	L.D. myocutan flap 22x8 cm (skin paddle)	Procedure was canceled because the loop was not patent. Flap resutured to its site	Pathological vein graft
3	26	M	P.T.	Circumferential scarring and ulceration of the left leg with contracture of the ankle, dorsum, toes of the foot	Femoral a. long saphenous V.	Long saphenous vein (right leg)	41 cm	One stage	L.d. myocutan. flap 35x8 cm (skin paddle)	Complete flap survival	-
4	38	M	P.T.	Circumferential scarring of the left leg with ulceration of the medial and lateral malleoli and lymphedema of the dorsum of the foot	Femoral a. long saphenous V.	Long saphenous vein (right leg)	40 cm	One stage	L.D. myocutan flap 32x8 cm (skin paddle)	Complete flap survival	-
5	15	M	P.T.	Chronic leg ulcer over the left ankle and unstable circumferential scarring of the leg and lymphedema of the dorsum of the foot	Femoral a. long saphenous V.	Cephalic vein (left forearm)	35 cm	One stage	L.D. myocutan flap 25x8 cm (skin paddle)	Complete flap survival	-
6	16	M	P.T.	Exposed upper third of the right tibia with stiff knee joint	Femoral a. long saphenous V.	Long saphenous vein (left leg)	30 cm	One stage	L.D. myocutan flap 20x10 cm (skin paddle)	Complete flap survival	-
7	16	M	P.T.	Circumferential scarring of the lower 2/3 of the right leg and contracted right knee region	Femoral a. long saphenous V.	Long saphenous vein (left leg)	38 cm	Two stages 48 hours interval	L.D. myocutan flap 30x8 cm (skin paddle)	Complete flap loss (ischemia 8 hours post operatively)	Pathological vein graft
8	16	F	Post irradiation	Defect over the lateral aspect of the upper 1/3 left leg with exposure of the upper tibia and stiff knee in flexion	Descending branch of the lateral circumflex femoral a. vena comitant	Long saphenous vein (right leg)	25 cm	Two stages (exploration after 96 hours)	-	Loop is not patent > revision > reocclusion one day later on > procedure was canceled	Exploration > thrombosis of the whole loop and arterial & venous anastomoses
9	34	M	P.T.	Exposed left knee and upper 1/3 tibia (anteriorly and laterally) with non-united fracture tibial plateau	Descending br. of the lateral circumflex femoral a. vena comitant	Long saphenous vein (right leg)	35 cm	One stage	R.A. myocutan flap 20x8 cm (skin paddle)	Complete flap survival	-
10	8	F	P.T.	Exposed shaft of the lower 1/3 right tibia with rupture and exposure of tendoschillis	Popliteal a. popliteal v.	Long saphenous vein (left leg)	30 cm	One stage	R.A. myocutan flap 12x5 cm (skin paddle)	Complete flap survival with partial loss of the skin island	-
11	31 3	F	P.T.	Exposed lower 1/3 (ant and medial sides of the right tibia)	Popliteal a. popliteal v.	Long saphenous vein (left leg)	30 cm	One stage	R.A. muscle flap	Complete flap survival	-
12	6	M	P.T.	Circumferential scarring and ulceration of the lower 1/3 of the left leg with lymphedema of the foot	Anterior tibial a. anterior tibial vena comitant at the junction of the upper and middle 1/3 of the leg	Long saphenous vein (right leg)	25 cm	One stage	R.A. myocutan flap 20x8 cm (skin paddle)	Complete flap survival	-

L.D.: Latissimus dorsi.
R.A.: Rectus abdominis.

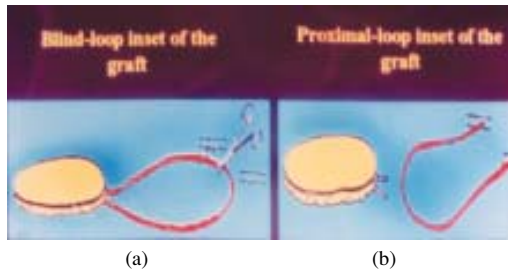


Fig. (1): (a) Blind-loop inset and (b) proximal-loop inset of the graft (Acland 1990).

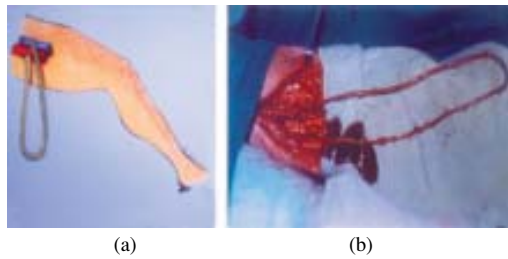


Fig. (3): End to side arterial and venous anastomoses between the graft and the femoral vessels:
a- Diagrammatic presentation. b- Intra-operative view.



Fig. (5): Intra-operative view showing the A-V loop done with the descending branch of the lateral circumflex femoral artery and its venae comitant.



Fig. (2): Pre-operative view of a patient showing circumferential scarring, ulceration of the whole leg and edema of the dorsum of the foot.

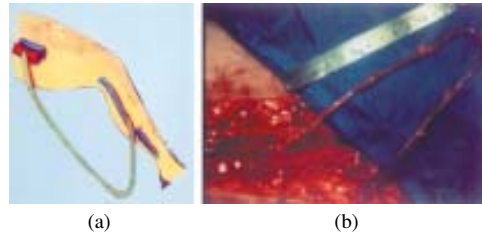
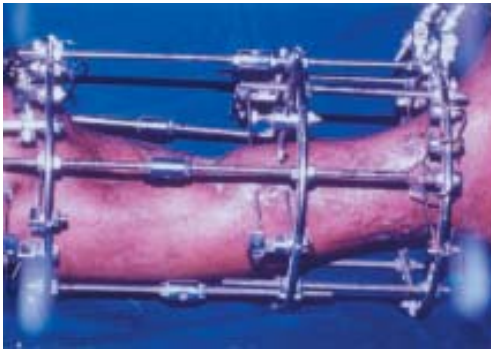


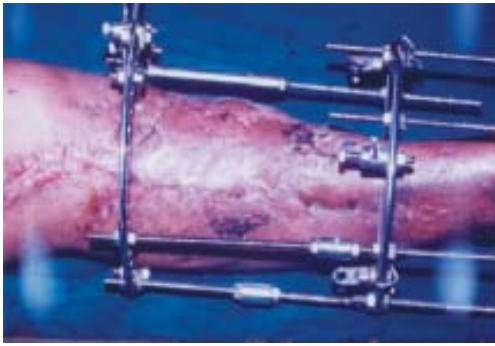
Fig. (4): End to side arterial anastomosis between the graft and the femoral artery and end to end venous anastomosis between the graft and the long saphenous vein.
a- Diagrammatic presentation. b- Intra-operative view.



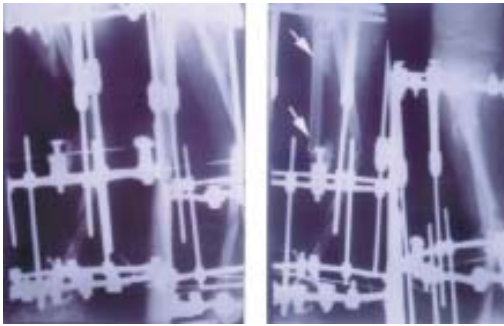
Fig. (6): Intra-operative view of patient No. (1) showing the rectus abdominis muscle flap anastomosed to the A-V loop and the non vascularized fibular graft.



(a)



(b)



(c)

Fig. (7):

- a- Pre-operative view of patient No. (1) with extensive leg scarring and bone loss of the middle 1/3 of the left tibia.
- b- Post-operative view of the same patient with stable wound coverage by rectus abdominis muscle flap.
- c- Pre and post operative X-ray showing solid union of the transferred fibula.



(a)



(c)

Fig. (8):

- a- Pre-operative view of patient No. (4) with circumferential scarring of the left leg with marked edema of the dorsum of the foot.
- b- Three years post-operative view showing stable wound coverage by latissimus dorsi myocutaneous flap with subsidence of the foot edema.

Fig. (9):
a- Pre-operative view of patient No. (5) with chronic left leg ulcer, circumferential scarring and edema of the dorsum of the foot.
b- Two years post-operative view showing coverage of the defect by latissimus dorsi myocutaneous flap.

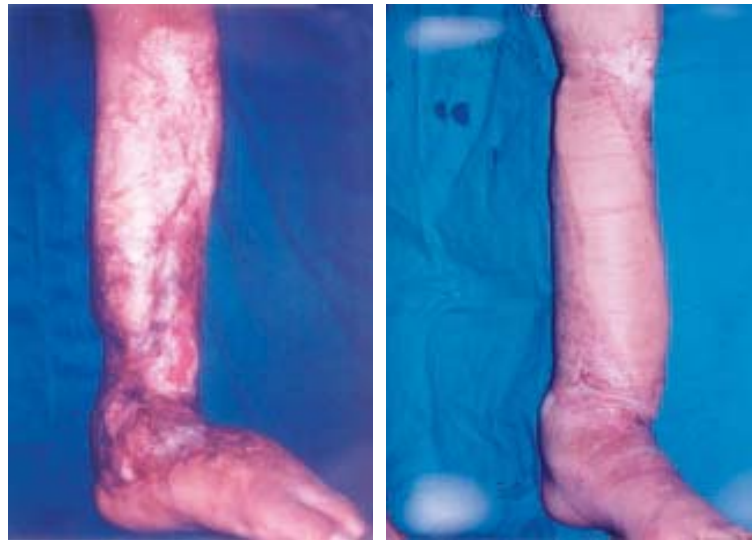


Fig. (10):
a- Pre-operative view of patient No. (6) with exposed upper 1/3 of the right tibia and stiff knee joint.
b- Post-operative view showing coverage of the defect by latissimus dorsi myocutaneous flap.



DISCUSSION

Free flap transfer to the lower limb in chronic post-traumatic conditions is known to have a higher complication rate with flap loss in up to 10% of cases, mainly due to the recipient vessel [9]. The dissection of these vessels often leads to refractory spasm, due to the so-called post-traumatic vessel disease (PTVD) [2].

This term was used to describe the widespread changes that occur in the walls and perivascular tissues of the major vessels of the limb

following trauma to the lower extremity. Its cause is unknown but it can be hypothesized that PTVD is the result of wound exudates tracking up the perivascular sheath. The area in which PTVD is found, often misleadingly referred to as the zone of trauma, extends markedly beyond the original site of bony and soft tissue damage. Established PTVD may be encountered as early as one week after the injury. There are three hallmarks of the established condition: (1) loss of the normal easy planes of dissection between vascular sheath and artery

and between artery and vena comitant; (2) loss of vasa vasorum and (3) a marked tendency to vasospasm [2].

It is extremely troublesome to operate on vessels affected by PTVD. They are easily damaged in dissection and prone to intractable vasospasm. Their linings also lack the thromboresistant properties of healthy vessels. The use of these vessels as recipient vessels for a free flap should be strongly avoided [1,2].

So, the surgeon should go to recipient vessels away from the injury beyond the zone of PTVD. This can be achieved by either hooking up the flap with "carrier" vessels in the contralateral non affected leg [3-8] or by performing the anastomosis with a more proximal healthy vessel using long vein graft [2].

The concept of a pedicled free flap that employs "carrier" vessels anastomosing to distally located recipient vessels was practised by many surgeons [3-6]. The disadvantages of this cross leg microsurgical free flap technique are the multiple operative stages required, the prolonged immobilization (4-7 weeks) and the costs of extended hospitalization [7]. However, it has all the advantages of free flaps as regards type of tissues and donor site morbidity.

Using a long vein graft to perform the anastomosis away from the zone of PTVD can be also another solution. In this series, the local use of the saphenous vein graft was not feasible as it was not available due to extensive trauma and scarring. In all patients the vein grafts were harvested from far and transferred to create the arteriovenous loop. The technique of proximal loop inset of the graft was selected because all the used flaps were muscle and musculocutaneous flaps that could not tolerate long ischemia time.

The femoral artery in the subsartorial canal was preferred over the popliteal artery as a recipient vessel in most of the cases for many reasons:

- 1- It is more far from the area of the trauma and the PTVD.
- 2- Most of the defects are on the anterior aspect of the leg while the popliteal vessels are located in the posterior region of the knee.
- 3- The popliteal vessels are deep making anastomosis with them more difficult.

- 4- End to side anastomosis might possess a potential danger to the popliteal artery, which is an end artery of the leg [10].

In defects involving the lateral aspect of the leg the descending branch of the lateral circumflex femoral artery is the only available recipient vessel.

Many veins can be used as a source for vein grafts. The short saphenous vein was preferred by Acland [2] because it has a more suitable diameter and a thinner wall than the long saphenous and is less affected by previous damage. In this series the long saphenous vein was used instead of it as it can give length up to 45 cm which is required in most cases. It can be also simultaneously harvested during recipient vessels exposure that save some operative time. When the long saphenous vein was not available, the cephalic vein can be used.

In anastomosing the arterial end of the graft, the technique of Cobra-head anastomosis, which is widely used by macrovascular surgeons, was preferred because it has two advantages: First, the ready access of an abundance of freely deformable vessel edges makes it easy to produce a truly everting suture, thus minimizing the exposure to the blood stream of raw tissue and suture material. Second, the way the sides of the arteriotomy bulge apart once blood fills the vessel gives a true incidence in anastomotic diameter thus a reduced risk for the formation of an occlusive thrombus [2].

When the arterio-venous loop was done with the femoral vessels, the venous anastomosis was done between the graft and the femoral vein or its tributaries in the subsartorial canal in the early 2 cases. Later on the long saphenous vein in the lower most part of the thigh was preferred for many reasons: (1) Technically is much easier; (2) It avoids exposure and dissection of the deep venous system of the limb; (3) It conserves the length of the vein graft.

Vein grafts are believed to carry major risk of failure and this risk is believed to become greater as the graft lengthens [1]. In this series thrombosis of the loop occurred in 3 cases out of 12 (25%) which is quite high incidence. This high incidence of thrombosis can be related to the length of the graft and its pathological state and to the use of the proximal-loop inset of the grafts. In this series the length of the required

vein graft reached 45 cm in some cases. On exploration of the two of three cases that had thrombosis, the anastomosis at the arterial end of the graft was patent. Thrombosis occurred in the graft itself and it recurred despite repeated resections of these thrombosed segments indicating pathological vein graft. In the third case thrombus was formed at the arterial end of the graft. This is the major disadvantage of the technique of the proximal-loop inset of the graft [2], which is even not recommended by him for this reason. However, the role of irradiation in this patient could not be excluded.

Initially the use of the AV loop was staged. The vessel was transferred and then allowed to mature for 10 days. After maturation, the loop was divided and anastomosed to the recipient free flap [11]. We followed this method in three cases where there was doubt about the patency of the loop. Success rate in the flaps that were immediately transferred was 100%, while for those flaps that were transferred after loop maturation was only 50%. However, the failure in these cases could be attributed to the loop itself rather than the delay which is supposed to be better for loop maturation. So, most surgeons including us are preferring immediate division of the loop and flap transfer at the initial setting provided that the loop is perfectly patent to avoid considerable scarring and thrombosis that may occur in it [11].

The overall success rate of flap transfer in this series was 90% which is even comparable with the results of other reports of lower extremity free flaps under normal circumstances [12]. This is greatly accepted in reconstruction of such types of extensive defects in the subacute and chronic stages. Codina [9] had a failure rate of 12% and 9.5% in reconstruction of lower extremity defects in the subacute and chronic stages. However, their defects were not complicated like the defects in this series.

In conclusion the use AV loop is strongly indicated for lower extremity free flap surgery whenever there is any doubt about the availability of healthy recipient vessels. This will allow the anastomosis to be performed away from the area of PTV and could eliminate the failure that occurs when the anastomosis is done in the area of trauma and scarring. Though the proximal-loop inset of the graft has the dis-

advantage of occurrence of high flow thrombus at the arterial end of the graft, it is still recommended in consideration of saving ischemia time which is crucial to flap survival especially muscle flaps. Immediate loop division and flap transfer has a higher success rate than delayed flap transfer. So, it should be done wherever possible if there is no doubt about the patency of the loop.

REFERENCES

- 1- Khouri R.K.: Avoiding free flap failure. *Clinics in Plastic Surgery*, 19: 773, 1992.
- 2- Acland R.D.: Refinements in lower extremity free flap surgery. *Clinics in Plastic Surgery*, 17: 733-744, 1990.
- 3- Taylor G.I., Townsend P. and Corlett R.: Superiority of the deep circumflex iliac vessels as the supply for free groin flaps. *Plast. Reconstr. Surg.*, 64: 745, 1979.
- 4- Townsend P.L.G.: Indications and long-term assessment of 10 cases of cross-leg free DCIA flaps. *Ann. Plast. Surg.*, 19: 225, 1987.
- 5- Chen H.C., Mosely L.H., Tang Y.B., Wei F.C. and Noordhoff M.S.: Difficult reconstruction of an extensive injury in the lower extremity with a large cross-leg microvascular composite tissue flap containing fibula. *Plast. Reconstr. Surg.*, 83: 723, 1989.
- 6- Brenman S.A., Barber W.B., Pedersen W.C. and Barwick W.J.: Pedicled free flaps: Indications in complex reconstruction. *Ann. Plast. Surg.*, 24: 420, 1990.
- 7- Yamada A., Harii K., Ueda K., Asato H. and Tanaka H.: Versatility of a cross leg free rectus abdominis flap for leg reconstruction under difficult and unfavourable conditions *Plast. Reconstr. Surg.*, 95: 1253, 1995.
- 8- Chen H.C., El-Gammal T.A., Wei F.C., Chen H.S., Noordhoff M.S. and Tang Y.B.: Cross-leg free flaps for difficult cases of leg defects: Indications, pitfalls and long-term results. *J. Trauma*, 43: 486, 1997.
- 9- Codina M.: Early microsurgical reconstruction of complex trauma of the extremities. *Plast. Reconstr. Surg.*, 78: 285-299, 1986.
- 10- Park S. and Eom J.S.: Selection of the recipient vessel in the free flaps around the knee: The superior medial genicular vessels and the descending genicular vessels. *Plast. Reconstr. Surg.*, 107: 1177, 2001.
- 11- Weiss D.D. and Pribaz J.J.: *Microsurgery chapter in: AChauer, B.M. and Eriksson E.: Plastic surgery indications, operations and outcomes. 1st Ed. Vol. I. Mosby, Inc., p. 163, 2000.*
- 12- Benacquista T., Kasabian A.K. and Karp N.S.: The fate of lower extremities with failed free flaps. *Plast. Reconstr. Surg.*, 98: 834-840, 1996.