Part XI

Reconstructive procedures, amputations and rehabilitation

The Role of Reconstructive Microsurgery in The Management of Critical Leg Ischemia

Andrea Ortensi, Stefano Trinchi

In the last years microsurgical technique evolution has allowed the accomplishment of a series of new operations that have transformed clinical results in traumatology and limb's critical ischemia.

Until 20 years ago, the technique of pedicled flap without distance transfer was the routine procedure; a present critical review shows the oldness of this technique especially for what concerns the long recovery time.

At the beginning of the '80s, due to the development of microsurgical techniques, in all the microsurgery units, the microsurgical free flaps techniques has started to be used.

In the latest years the making of microsurgical free flaps became possible by long and refined anatomical study in which the feature of many free flaps (with their vascular communications in donor site), and the anatomy of the receiving site pedicle were shown.

All this anatomical researches have allowed the researchers to get a clear knowledge of this techniques.

From there, the use of loco-regional pedicled flap, like Sural flap, supramalleolar, and others, starts.

The possibility of using pedicled flaps without the vascular anastomosis is an advantage, but for other hand there is still the problem connected with the ability of the surgeon to dissect and respect the vascular pedicle using a microsurgical technique. In this way loco-regional pedicled flaps can be used also in the management of critical leg ischemia.

Foot reconstruction

In plantar foot reconstruction, very important is the fact that no prominent bony elements can be tolerated. They have to be trimmed, to obtain a smooth bony plantar surface before putting in a free flap. No sensory flaps are performed on the weight-bearing areas of the foot. When the sensation is present on any part of the foot, deep sensation is sufficient to prevent the formation of pressure sores.

Myocutaneous free flaps are only placed on the foot when secondary wound healing is jeopardised such as in the patients with a kidney transplantation or diabetes, resulting in pressure sores from the hell-to-toe region.

Heel reconstruction

To reconstruct the heel area, the shape of the defect and lack of bone mass have to define the choice for correct flap. For larger defects the latissimus is selected. In some cases of open type III B fractures, revascularisation of the foot is performed by anastomosing the dorsalis pedis artery to the serratus anterior branch of the latissimus dorsi free flap, which is hocked to anterior tibial vessel and used to cover the distal tibio-talar region. In the majority of cases, however, the rectus abdominis flap is sufficient when crush injuries have removed a substantial part of the heel.

Arteriosclerosis desease

Arteriosclerotic patients presenting chronic ulcers of forefoot or heel were treated with a variety of flaps: temporalis fascia for the heel or ankle region and gracilis or rectus abdominis muscle flaps for the midfoot or forefoot.

In this way below-knee amputation can be avoided. Sometimes vascular reconstruction is performed 2 weeks before the free flap transfer; In some others, despite extensive arteriosclerosis, the free flap transfer could be performed without vascular reconstruction.

Clinical Series

1. Wide area with severe ischemic heel and plantar area lesion, dissection of the posterior tibial vessels (Figure 1). Confectioning latissimus dorsi free flap (Figure 2). Positioning of the flap on the recipient site (Figure 3). Ending with the end of vascular anastomosis between posterior tibial artery and torco-dorsal artery. Venous anastomosis is performed in end to end technique (Figure 4). – The Results – (Figure 5-6).
2. Severe traumatic lesion with exposure of fracture segments and devascularization of left limb (Figure 7). Preparation of right vascularized latissimus dorsi free flap (Figure 8). Postoperative results with healing of cutaneous coverage (Figure 9-10)

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FIGURE 1

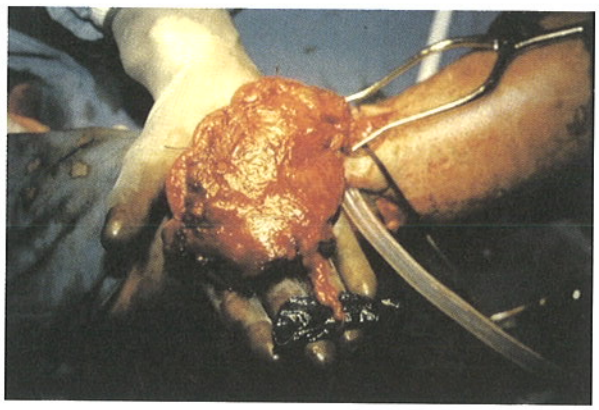

FIGURE 2

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FIGURE 7

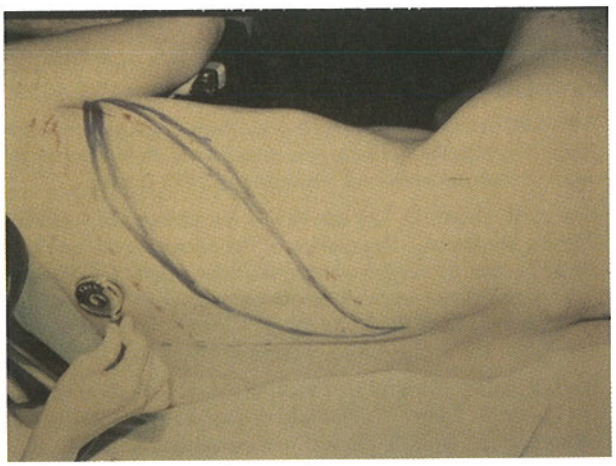

FIGURE 8

FIGURE 9

FIGURE 10

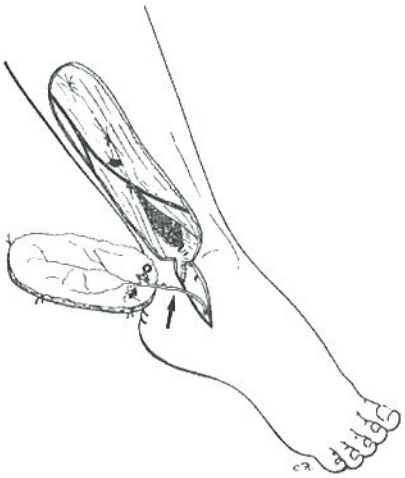

FIGURE 11

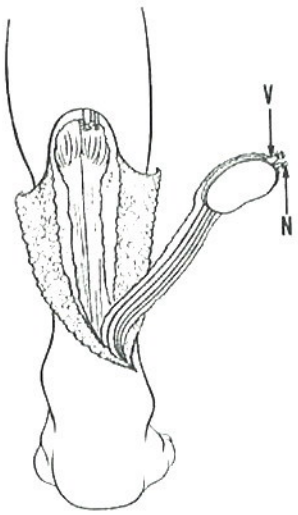

FIGURE 12

Pedicled Flaps

1. *Supramalleolar lateral flap*. Such a flap is designed in lateral lower third of the leg and it can be employed to cover dorsal lateral and plantar aspects of the feet. It can be used also in the last of risultance of the posterior heel area and medial lower portion of the leg. The flap is provided by anterograde flow of the peroneal artery perforant branch. (Figure 11).
2. *Sural flap*. All the ischemic critical areas of the lower extremity are at risk because the epidermic area is very thin. Sural flap can be used in many situations like exposed fractures, loss of substance, decubitus sores (Figure 12).

Conclusions

In lower leg reconstructions, changing indications for flap selection were not only correlated to new anatomical developments, but mainly due to a better understanding of adaptability of known muscle or fascial free flaps. Reducing donor site morbidity and planning for saving donor sites for future reconstructions, are important. Morbidity is reduced by selection of free flaps ideally adjusted to shape of the defect. At final point, arteriosclerosis or diabetic ulcers were, in several cases, the indication for free flaps cover and never a contraindication. In some cases, a vascular bypass operatoon was performed prior to the free flap transfer.

REFERENCES

(1) MASQUELET A C, GILBERT A. *Lembi cutanei nella ricostruzione degli arti*. Ed. Delfino, 1997,206-210

(2) SCHULTES G, GAGGL A, KARCHER H. *Reestablishment of sensivity in the Latissimus dorsi transplant through anastomosis of the toracodorsal nerve with sensitive nerves*. Plast Reconstr Surg 1999 March; 103(3); 857-861.

(3) ORTENSI A, MARCHESE V, LENTINI A, MODESTI M ET AL. *Le lesioni traumatiche ed oncologiche degli arti inferiori: Risoluzioni microchirurgiche*. G It Derm Onc 1992 Oct; 1(2):51-54.

(4) STROMPO B E, STEVENSON T R. *Reconstruction of the traumatized leg: use of distally based free flaps*. Plast Reconstr Surg 1994 Apr.; 93(5). 1021-1025.

(5) HASEGAWA M, TORII S, KATOH H, ESAKI S. *The distally based superficial sural artery flap*. Plast Reconstr Surg 1994 Apr; 93(5):1012-20.

(6) NAKAJIMA H, IMANISHI N, FUKUZUMI S, MINABE T, FUKUI Y, MIYASAKA T, KODAMA T, AISO S, FUJINO T. *Accompanying artries of the lesser saphenous vein and sural nerve: anatomic study and its clinical applications*. Plast Reconstr Surg 1999 Jan; 103(1):104-20

(7) BOECKX W. *Les transplants libres.Reconstruction du talon sur radiolésion. Lettre d'information du Group pour Avancement de la Autotransplant avec micro-sutures vascularies*. Microchirurgie 1975; 2:1-10

(8) BOECKX W, DARIUS O, VAN DEN HOF B, VANDEVOORT M. *Scanning Elecron Microscopy. Evalutation of the microvascular anastomosis performed by nonpenetrating vascular stapling: Comparison with conventional microsuture technique*, in Pho R,Perreira B. (eds): Reconstructive Microsurgery: Current trends El.; ISRM: Singapore, 1996, Gok Bros : Enterprise Humanities Press.

(9) PORTINCASA A, MORETTI B, PESCE V, PATELLA V, GALANTE V N, DIOGUARDI D, SIMONE C. *The role of free flaps in inferior limbs osteomyelitis: state of the art and perspectives*. G. I. O. T. 2000;26(suppl.1): S52-S57.

Amputation Surgery in the Patient With Vascular Disease

Roberto Tersigni, Stefano Bartoli, Luciano Alessandroni

Nothing is worst for a vascular surgeon than amputation, especially after unsuccesful revascularization attempts. Lower limb amputation due to vascular disease is considered a final destroying surgical procedure, which eliminates tissue, pathology and symptoms and changes patient's life definitely.

Amputation can be considered one of the oldest surgical procedures (1). The earliest knowledge about it dates from the Samnite wars of 300 B.C. We also know that amputation of limbs was used in the Italy of Communes as penalty for different crimes. The surgeon had among his duties the medication by means of caustication and sprinkling of honey on the stump to keep the prisoners alive. Though we have to date back to Ambroise Paré (1510-1590) to talk about surgical techniques of amputation: he was the first one to use vascular ligatures and to develop guidelines for the selection of appropriate levels of amputation, having in mind the fitting of a prosthesis. Many of Paré's descriptions are still valid today. Further attention upon the techniques of amputation was concentrated by Jean Larrey (1776-1842) during the Napoleonic wars. Amputations were mainly performed for traumatic injuries and we owe to Larrey the idea of tissue debridement around the bone stump and the dissection of the latter in order to cover it completely with the muscular flap. Furthermore Larrey advocated early rehabilitation after amputation in order to avoid post-procedure ankylosis. The idea of early fitting of a prosthesis was of Berlemont (1958) and Weiss (1963). In 1965 Burgess observed that early rehabilitation made the acceptance of the prosthesis easier and lowered the psychological trauma following the loss of the limb.

All that led to the current scientific approach to amputation that included a reasoned selection of the levels of amputation, the functional drawing of the muscular flap, the geometric shape bone stump, the section of the nerve to avoid post-surgical pain and plastic skin suture (2). The careful observance of the above mentioned rules and the use of particularly light and resisting prosthetic materials and the application of still more sophisticated articular prostheses allows to restrict more and more the "disability" due to amputation.

Therefore, amputation surgery must not be considered a destructive procedure but rather the first step of a reconstructive procedure. Thus the aim of amputation becomes a surgical procedure that removes necrotic tissue, relieves pain, allows immediate healing of the lowest possible amputation level and achieves the maximum rehabilitation compatible with the patient's general conditions (age, presence of orthopaedic pathology and/or previous neurologic pathology, malnutrition, etc.).

Epidemiology

On the grounds of the current demographic trend, Italian population over the age of seventy is increasing over the 30% (3). Among the diseases, the incidence of which has risen for the protraction of lifetime we find peripheral obliterating artheriopathy which represents the most frequent complication of atherosclerosis after coronary ischemia.

In the countries of high socio-economic standard of the western world the prevalence of atheroslerotic disease is 2% in the sixth life's decade, 7% in the seventh and eight decade.

6-15% of the patients affected by arteriopathy undergo to amputation surgery, while critical ischemia leads to 44% of amputation at one year. Unifocal chronic arterial obstruction is normally not associated to the loss of the limb.

The incidence of amputation surgery after revascularization procedures might be summarized as follows:

1. 5-19% after proximal direct surgical procedures;
2. 12-34% after percutaneous transluminal angioplasty(PTA);
3. 17-51% after prostanoid drugs;
4. 30-60% after distal surgical procedures;
5. 30-60% after peridural stimulator;
6. 40-60% after sympathectomy.

In Italy the estimated incidence is around 220 amputations/million patients/year, 15 times greater in diabetic patients.

Two thirds of the patients undergoing amputation have diabetes mellitus and for these patients the risk of amputation of the inferior controlateral limb as well at 5 years from the first amputation is around 27% and nearly one half of them die prior to second amputation.

Approximately one half of the amputees have

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symptoms of cardiorespiratory disease and smoking addict doubles the risk of amputation.

Mortality rate of patients with critical ischemia of the inferior limbs after one year is around 20% and only one half of the affected patients undergoing amputation below the knee have two legs after one year. Mortality rate in the 30 days ensuing amputation is around 15% after amputation below the knee and 25% after thigh amputation, after 2 years on the whole 25-30% and after 5 years 50-75%.

The British study of the eighties has shown that out of 400 ischemic limbs, 61% was submitted to revascularization and 17% to direct amputation with a mortality rate in the ensuing year of 18%, but mortality after revascularization was one half compared to amputees. Also other studies emphasize that revascularization substantially decreases mortality, whereas it does not significantly decrease the incidence of amputation surgery.

Cost evaluation (4) has shown that amputation is more expensive than revascularization. In Myhre's study (Norway) the cost of a successful bypass was 5,700$, while direct amputation was 13,000$ and amputation after unsuccessful revascularization procedure was 25,000$.

Vascular disease and amputation

Vascular diseases influence in different way the surgical approach. We present three general categories to highlight the differences in the treatment (5).

Acute ischemia

To evaluate whether an arterial tree in a patient with acute ischemia is unreconstructable is very difficult and burdened with the high morbidity of the stump and sistemic morbidity when the choice is an emergency amputation. The factors which mainly govern the degree of urgency for amputation are the extent of the muscle mass involved by ischemia, the duration and presence of signs of systemic toxicity (myoglobinuria and leukocytosis). As a matter of fact if the affected area is limited (such as toes) pain will be easily controlled and the absence of systemic signs will enable to postpone amputation to allow maximum development of collateral circulation. The deferring of amputation often enables to limit it to more peripheral levels compared to the initial evaluation. Pharmacologic pain control, including the use of heparin and fibrinolytic agents, may facilitate the limitation of the necrotic area.

Clinical evaluation of the skin above the frank ischemic area, reactivity to stimuli (in diabetic patients evaluation can be invalidated by previous neuropathy), monitoring of diuresis and possible signs of systemic toxicity (sleepiness, derangement or hallucination), represent indications to postpone amputation or not, allowing in this way also a more thorough evaluation of vascular reconstruction, that will enable to limitation of the amputation area or even limb salvage.

Progressive chronic ischemia

Patients with rest pain, non-healing skin lesions or ulceration and gangrene may be considered at an advanced stage of the chronic pathology and progressive atherosclerotic disease, and are mostly evaluated to attempt revascularization. They are mainly diabetic patients and symptom onset often occurs in a very advanced stage of the pathology (diabetic neuropathy that delays awareness of ulceration especially at those pressure points such as heel, malleolus etc.) (6). In general, they are patients who are already under medical control and the progression of some pathologic stages is subdued by narcotic, antiaggregant, fibrinolytic and anticoagulant therapy to properly evaluate and prepare the patient for revascularization or amputation procedure. Evaluation must allow for combined pathologies (diabetes, bronchopulmonary disease, etc.), and organ dysfunctions (cardiomyopathies, renal insufficiency, etc.) (7). Instrumental evaluation by means of preoperative angiography that evaluates the abdominal aorta circle down to the pedal arches is mandatory. If the profunda femoris artery is patent distal revascularization might be attempted. Though there is continuing controversy on revascularization it is the author's opinion that distal revascularization should always be tried if general and local conditions of the patient make it possible, especially as the patient is ambulatory in the preoperative phase. Against it there is the opinion mutual to those who are interested in limb salvage that an unsuccessful revascularization certainly leads to a higher level of amputation because of the thrombosis of previous patent vessels, alteration of the collateral vessels and/or onset of infection.

Gangrene complicated by infection

The association of infection to necrosis represents a clinical aspect to be carefully evaluated for possible revascularization. The change of dry necrosis, that perhaps is distal, into a wet necrosis, must modify the physician's attitude, especially in a diabetic patient (8) because the treatment of such modified clinical aspect might become a limb- and life-threathening emergency. The attempt to treat a wet necrosis by means of antibiotic therapy especially in the initial phase, possibly on culture basis and surgical debridement, results often unsuccessful, above all in diabetic patients, who represent the majority. A careful monitoring of the patient including evaluation of the arterial flow, of immunitary response

to infection (9), of extension of the signs of infection and/or systemic toxicity, must be associated to the evaluation of the used antibiotic therapy, with the aim of promptly evaluate the adequacy of an emergency amputation to eliminate the infection and allow the drainage of the contaminated area, which leads to a two-stage surgical approach decreasing infection rate from 22 to 3%.

Amputation level selection

The purpose of amputation level selection is to determine the most distal area, fit to heal (10-11-12). The requirements for this are that:

1. the amputation removes alla necrotic tissue, pain and the possibile associated infective process;
2. the amputation stump must be fitted with the prosthesis without pain and ulcerative contact lesions;
3. the vascularization of the amputation stump must be optimal to allow effective and lasting healing.

Proper determination of amputation level is of critical importance because if right:

- allows immediate fitting of prosthesis;
- enables to early rehabilitation;
- avoids further surgery burdened by an increase in morbidity and mortality rate.

The chance of mantaining the knee articulation enables an effective rehabilitation (13). In fact, to ambulate with a below-knee amputated limb requires an energy increase of 10-40% more than to ambulate on two limbs, whereas walking on an above-.knee prosthesis requires a 50 to 70% increase in energy expenditure. This consideration explains why in geriatric patients, often affected by coronary artery and/or bronchopulmonary disease, rehabilitation can achieve effective results only if it requires small efforts.

The evaluation of blood supply in the amputation stump is mandatory for amputation level determination. None of the available selection means (clinical evaluation, doppler, arteriography, oxygen tension, etc.) (14-15) has been showed to be fully effective, with a 10-20% revision percentage for below-knee stumps and 25% for above-knee stumps. Consequently there is a need for particularly sensitive preoperative diagnostic methods. Among these photoplethysmography and partial transcutaneous oxigen pressure have shown a predictability of approximately 100% for the amputation of toes and feet. For below-knee amputation level determination systolic pressure measurement (never less than 60 mmHg) by means of doppler at different levels (heel, calf and thigh) resulted reliable.

In short we can assert that for the amputation level determination, in those cases in which it is not possible to attempt revascularization, the use of diagnostic techniques is mandatory, when possibile, but it must be anyway preceded by clinical judgement measuring palpable arterial pulse, skin temperature along the whole involved limb and eventual variations, draining capability of the venous circulation, presence of colour alterations, as well as presence of infection or diabetes, besides the evaluation of patients'general condition with regard to the possibility of prosthesis fitting (cardiopathy, bronchopulmonary disease, dementia, previous amputations, etc.) (16) to achieve a stump that can heal primarily, without pain and capable of early prosthesis fitting.

Follow we shortly describe the amputation levels of interest for patients with obliterans vascular disease, which enable the effective prosthetic fitting. Therefore, we omit the description of Chopart's, Lisfranck's and Boyd's amputations that are fraught with controversies for healing problems, prosthetic fitting and statics.

Toe amputation

It represents the most frequent peripheral amputation, especially in diabetic patients (17).

In the case of dry necrosis the surgeon is allowed to await for the natural toe ablation with natural stump healing. Indications for surgery are wet necrosis, infection, ulceration and secondary osteomyelitis.

Palpable pedal pulses guarantee about 98% of successful amputation, which, instead, must be vanished in the case of cellulitis of the forefoot, that is a sign of spread of the infective process.

The amputation of single toe should never be performed by disarticulation but through transection of the proximal phalanx, leaving a small piece of bone to protect the metatarsal head. Amputations through the metatarsophalangeal joint or interphalangeal joint must be avoided for the avascular nature of cartilage which might cause healing failure and infections. The skin flap, which must never undergo a trauma, can be of different shapes, but it must be long enough to cover the bone stump without tension.

Generally this amputation surgery does not require prosthetic fitting and rehabilitation rate is 100%.

Metatarsal amputation or ray amputation

Ray amputation is indicated when cutaneous lesions include the metatarsal head, hazarding healing. Such amputation is contraindicated when the ischemic lesion involves multiple toes or the first toe, because it leaves an unstable stump inadequate to ambulation without proper shoe orthotics. Performing the "blade" incision the surgeon must carefully avoid to injure the artery and the digital nerves. After removal of the ischemic area a thorough hemostasis must be performed and if there is a doubt of infection the wound can be left open and irrigated with antibiotic solution.

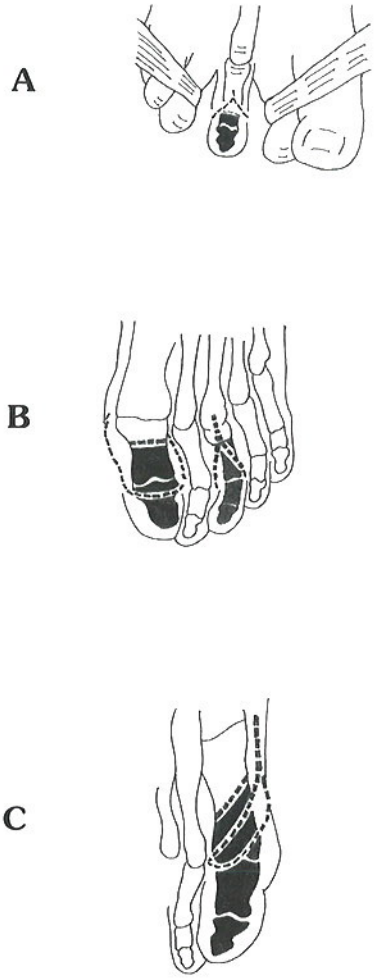

FIGURE 1a, b, c
Toe amputation

Transmetatarsal amputation

This amputation surgery is indicated when the ischemic process and/or infection involve the base of the first toe or multiple toes, or when the process has extended past the metatarsal heads (18-19). It is contraindicated when the infective process has massively compromised plantar skin. The skin incision is designed to obtain a wide plantar flap. All metatarsal heads are removed, leaving the musculature attached to the plantar flap. A careful hemostasis avoids dehiscence that may seriously jeopardize the amputation level. The use of a closed drainage system is suggested whereas bone wax must not be used to avoid foreign body reaction or infections. Stump dressing must prevent edema and control possible trauma. Therefore ambulation is delayed (4-6 weeks). Disability is minimal and the prosthetic fitting fairly easy. Though this amputation is fraught with a considerable percentage of stump complication.

Syme's amputation

This amputation, described by Syme in 1843, still plays its role if some technical details are observed. It is indicated when the lesion forbids transmetatarsal amputation, but it is contraindicated when the necrosis process involves the heel or if the skin alterations extend on the ankle, such as in diabetic patients with neurophatic foot (loss of heel sensation). When the posterior tibial artery is palpable, its preservation becomes mandatory as to the success of amputation which is anyway around 75% of cases.

Dissection of the heel represents the most difficult step of the surgical procedure since great attention must be payed during dissection of the bony surface to avoid damages to the subcutaneous heel tissue, to the posterior tibial artery and prevent injury to the posterior skin should Achilles' tendon be transected instead of being

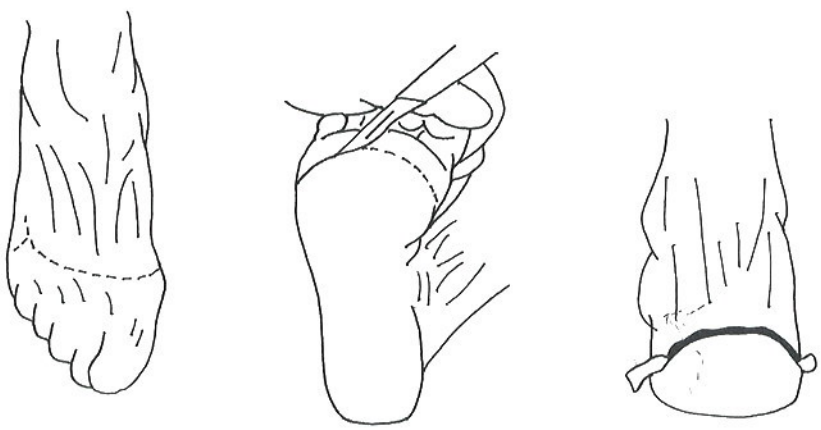

FIGURE 2
Transmetatarsal amputation

anchored to the tibia. The procedure can be performed in two stages as well (resection of the malleoli after healing) to reduce the risks. The stump resulting from this amputation is extremely stable. For external ambulation a prosthetic fitting is essential, but the energy expenditure required to ambulate is 10% above normal.

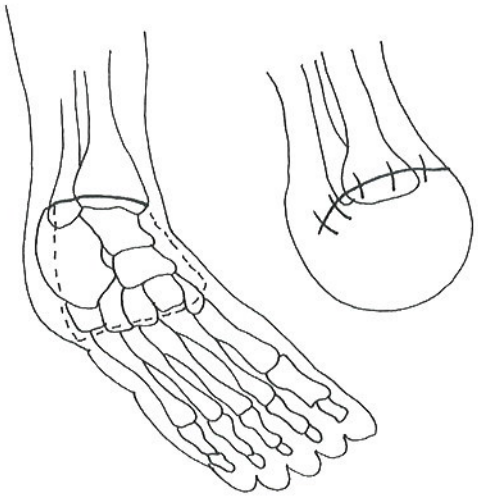

FIGURE 3
Syme's amputation

Below-knee amputation

This is the most common amputation level performed when the ischemic and/or infective processes do not allow more distal amputations (20). If the amputation level is selected according to the previous described parameters we can expect a success rate of approximately 94%. It is contraindicated when the wound tissue is 4-5 cm below tibial tuberosity, when flexion contracture (in the case of patients who are bedridden for long periods) is greater than 20 degrees, when also the profunda femoris artery is occluded and in those patients with previous stroke or neurologic disease, in whom muscle spasticity might preclude prosthethic rehabilitation.

Among the surgical technique elements that have drastically decreased failure rates we have to consider the control of infection (possibility of preventive distal amputation), the long muscolo-cutaneous posterior flap (8-10 cm more than anterior flap) and the use of a rigid dressing incorporating the articulation to avoid flexion contracture during the immediate postoperative period. For a good prosthetic fitting it is important that the stump is not inferior than 5 cm below the tibial tuberosity. Long hospitalization and protracted rehabilitation are required for this type of amputation. For this reasons its cost is very high and therefore the evaluation of the efficacy of this amputation level must be made on the grounds of a potential rehabilitation and prosthetic fitting, taking also into consideration that ambulation with a below-knee prosthesis entails an increased energy expenditure of 40-60% compared to normal ambulation. Also for these reasons rehabilitation must be early and intensive, to achieve good results of prosthetic fitting at 6-8 weeks, such as to climb stairs and overcome other obstacles.

Above-knee amputation

Often amputation represents the treatment of choice for life salvage, above all at this level of amputation that boasts a healing success superior to 90%, though the preservation of functionality of the knee articulation must always be taken into consideration (21-22). The patients undergoing above-knee amputation are frequently elderly and they present multiple combined pathologies. Therefore, in order to achieve satisfying results, the surgeon must be careful about the patient's treatment on the whole. The indication for this amputation is given by the inadequate vascularization at the level of the thigh and by the patients's bad general conditions which do not support the preservation of the knee articulation. This amputation level is certainly contraindicated for the patients in whom the infective process has involved the thigh and the hip. Other contraindications are represented by the absence of femoral groin pulsatility and by the obstruction of the superficial femoris artery combined with close stenosis of the homolateral profunda femoris artery; in these cases if the patient's general conditions make it possible, it is mandatory to attempt an improvement of the femoral circulation system at the site of the bifurcation (angioplasty, stent, cross-over by-pass, etc.).

This amputation counts on three levels of amputation, but certainly the longer is the amputation the more likely will be the possibility of prosthetic fitting, also because it prevents the flexion contracture at the site of the hip.

The use of electrocautery for the division of the muscles is not to be banished but the vessel ligature must be performed with accuracy. If the hemostasis is sufficient there is no need for drainage. Prophylaxis for deep venous thrombosis must always be established.

Unfortunately this level of amputation is burdened by a low percentage of prosthetic fittings; in fact, if around 80% of the patients undergoing uni- or bilateral below-knee amputation are able to ambulate with a prosthesis, only 50% of the unilateral above-knee amputees can ambulate with a prosthesis, also because of the enormous energy requirement increased 90-120% compared with normal ambulation.

Early complications

Pain

The literature reports that the incidence of stump pain and phantom limb pain ranges from 5 to 70%. This variability is given by an uncorrect, delayed and non-intensive rehabilitation; in fact, the best results have been achieved by those physicians who have established for their amputees adequate multidisciplinary programms.

Stump infection

The incidence of stump infection ranges from 12 to 28% in the major amputations; it is connected with the preexisting conditions of the patient and therefore it is important to provide a wide curettage of the infected tissues and to establish an appropriate and prolonged antibiotic therapy, as well as to perform a drainage amputation prior to definitive amputation. Stump infection may result as a consequence of postoperative hematomas, therefore hemostasis in amputation surgery represents a basic stage and the vessels must be ligated all separately.

Dehiscence

Dehiscence of an amputation must be prevented because it results in more than 90% of the cases in an amputation at a higher level. Nonhealing incidence ranges from 3 to 28% and is mainly due to inadequate vascularization, inadequate intraoperative handling of tissues, postoperative hematomas, infection.

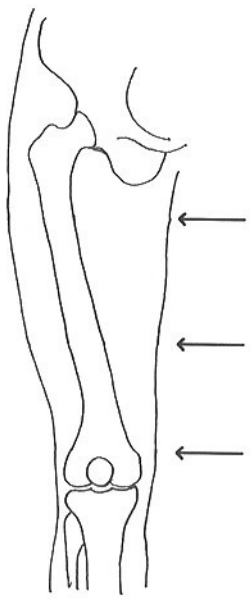

FIGURE 4
Three most common levels of above-knee amputation

Flexion contracture

This complication may cause the failure of a perfect prosthetic fitting. It may easily occur in elderly patients and it becomes rapidly irreversible. To avoid this complication it is important that the stump is long enough to hinder the flexion, as well as to use in the immediate postoperative period a rigid device which can obstacle it (splint, rigid dressing, etc.) and to begin a passive rehabilitation activity in the immediate postoperative period.

Death

The incidence of postoperative mortality after major amputations, is around 30%, with a considerable decrease when the evaluation of the amputation level takes into account the patient's general conditions.

Nevertheless the death rate of below-knee amputees (3-10%) must be differentiated from the death rate of above-knee amputees (20-40%), considering that two thirds of all deaths are due to cardiovascular complications (myocardial infarction, stroke, congestive heart disease, visceral ischemia, etc.) and furthermore that two thirds of major amputations are performed on patients over the age of 75 years.

General complications

Renal insufficiency, mostly due to dishydration in geriatric patients, to non-monitored antibiotic therapies and in major amputations following acute ischemia to untreated myoglobinuria.

Deep venous thrombosis (4-38%) and pulmonary embolism (1-3%) must be prevented especially in the postoperative period for major amputations. These complications are due to prolonged bed stay, to alteration of blood flow for previous revascularization attempts, blood staunching in the sutured venous branches during amputation. Prevention must foreseen a persevering preoperative activity and the monitoring of the contralateral limb activity (elastic sock, active mobility) as well as the establishment of a low molecular weight heparin therapy in the preoperative period.

Long-term complications

Stump revision (2-3%): may occur also after prosthetic fitting for inadequate preparation of the *amputation level* or for impaired distribution of the weight.

Contralateral amputation: it has been estimated that its incidence ranges from 15 to 33% during the 5 years following the loss of a contralateral limb, due to obliterans vascular pathology which is multifocal and to chronic smoking addiction.

Death: around one third of the patients submitted to major amputations die within 5 years after amputation and two thirds of these deaths are due to cardiovascular causes; among the diabetic patients only 40% survive after 5 years.

REFERENCES

(1) CODDINGTON T. *Major amputation in England and Wales.* In: *The durability of Vascular and Endovascular Surgery.* RM Greenhalgh Ed. Saunders 175-180; 1999

(2) WHITTAKER L, WIJESINGHE LD, BERRIDGE DC, SCOTT DJ. *Do patients with critical limb ischaemia undergo multiple amputations after infrainguinal bypass surgery?* Eur J Vasc Endovasc Surg. 2001 May;21(5):427-31.

(3) TRABALLESI M, BRUNELLI S., PULCINI M. *Protocollo riabilitativo del paziente geriatrico vasculopatico amputato di coscia.* I Quaderni della Fondazione Santa Lucia

(4) NORGEN L. *Life expectancy for critical ischaemia. In: The durability of Vascular and Endovascular Surgery.* RM Greenhalgh Ed. Saunders 163-173; 1999

(5) MALONE JM. *Lower Extremity Amputation. In Vascular Surgery. A Comprehensive Review Fifth Edition.* Saunders Ed. 844-884, 1998

(6) CONTE MS, BELKIN M, UPCHURCH GR, MANNICK JA, WHITTEMORE AD, DONALDSON MC. *Impact of increasing comorbidity on infrainguinal reconstruction: a 20-year perspective.* Ann Surg. 2001 Mar;233(3):445-52

(7) LUTHER M, KANTONEN I, LEPANTALO M, SALENIUS J, GROUP KY. *Arterial intervention and reduction in amputation for chronic critical leg ischaemia.* Br J Surg. 2000 Apr;87(4):454-8.

(8) EBSKOV B. *Relative mortality and long term survival for the non-diabetic lower limb amputee with vascular insufficiency.* Prosthet Orthot Int. 1999 Dec;23(3):209-16

(9) TREIMAN GS, ODERICH GS, ASHRAFI A, SCHNEIDER PA. *Management of ischemic heel ulceration and gangrene: An evaluation of factors associated with successful healing.* J Vasc Surg. 2000 Jun;31(6):1110-8.

(10) BOSSE MJ, MACKENZIE EJ, KELLAM JF, BURGESS AR, WEBB LX, SWIONTKOWSKI MF, SANDERS RW, JONES AL, MCANDREW MP, PATTERSON BM, MCCARTHY ML, CYRIL JK. *A prospective evaluation of the clinical utility of the lower-extremity injury-severity scores.* J Bone Joint Surg Am. 2001 Jan;83-A(1):3-14.

(11) DORMANDY J, HEECK L, VIG S. *The fate of patients with critical leg ischemia.* Semin Vasc Surg. 1999 Jun;12(2):142-7. Review.

(12) DORMANDY J, HEECK L, VIG S. *The natural history of claudication: risk to life and limb.* Semin Vasc Surg. 1999 Jun;12(2):123-37. Review.

(13) DORMANDY J, HEECK L, VIG S. *Major amputations: clinical patterns and predictors.* Semin Vasc Surg. 1999 Jun;12(2):154-61. Review.

(14) PROVAL JL. *Noninvasive methods of determining amputation levels In: Current Therapy in Vascular Suurgery Ernest-Stanley.* Ed Mosby 669-672; 1999

(15) MISURI A, LUCERTINI G, NANNI A, VIACAVA A, BELARDI P. *Predictive value of transcutaneous oximetry for selection of the amputation level.* J Cardiovasc Surg (Torino). 2000 Feb;41(1):83-7.

(16) CAMPBELL WB, MARRIOTT S, EVE R, MAPSON E, SEXTON S, THOMPSON JF. *Anaesthesia and analgesia for major lower limb amputation.* Cardiovasc Surg. 2000 Dec;8(7):572-5.

(17) FISHER FD. *Toe and foot amputation. In: Current Therapy in Vascular Suurgery.* Ernest-Stanley. Ed Mosby 672-674; 1999

(18) THOMAS SR, PERKINS JM, MAGEE TR, GALLAND RB. *Transmetatarsal amputation: an 8-year experience.* Ann R Coll Surg Engl. 2001 May;83(3):164-6.

(19) GER R, ANGUS G, SCOTT P. *Transmetatarsal amputation of the toe: an analytic study of ischemic complications.* Clin Anat. 1999;12(6):407-11.

(20) JACOBS LA, DURANCE PW. *Below the knee amputation. In: Current Therapy in Vascular Suurgery.* Ernest-Stanley. Ed Mosby 674-677; 1999.

(21) ENDEAN ED. *Above the knee amputation and hip disarticulation. In: Current Therapy in Vascular Suurgery. Ernest-Stanley.* Ed Mosby 677-680; 1999.

(22) VIGIER S, CASILLAS JM, DULIEU V, ROUHIER-MARCER I, D'ATHIS P, DIDIER JP. *Healing of open stump wounds after vascular below-knee amputation: plaster cast. socket with silicone sleeve versus elastic compression.* Arch Phys Med Rehabil. 1999 Oct;80(10):1327-30.

The Rehabilitation of Patients with Critical Lower Limbs Ischemia: Principles of Treatment

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After the ischemic heart disease, the peripheral occlusive arterial disease (PAOD) is one of the most frequent atherosclerosis complication, and is an important epidemiologist factor of disability which is socially and professionally confirmed, with consequent increase on public sanitary expense. The PAOD classification, defined from Fontaine in the 4 stages that go from the I asymptomatic to the IV with trophycs lesions and gangrene, can be simplified, above all for a proper therapeutic formulation, in 2 stages: the claudicatio intermittens (the stage not always recognized in differential diagnosis) and latter the stage of critical ischemia, whose symptoms are expression of absolute arterial insufficiency.

Generally, the objective of PAOD treatment are:

1. Autonomy improvement in the stage of the claudicatio intermittens;
2. Performance of the risk factor prevention with limitation of the progression of atherosclerotic disease;
3. Limitation of the evolution in critical cronic ischemia in order to delay the complications and to avoid the amputation of limb.

The possibilities of therapeutic operation in the PAOD are represented by the pharmacological therapy, by the application of a personalized plan of physical therapy, and when is possible, by revascularization surgery.

In particular the indications to the physical theraphy of the vascular patient are:

1. Improvement of the deambulation by means of therapeutic exercise;
2. Preparation of the patient for surgery partecipation;
3. Improvement of the residual disability after surgery partecipation;
4. Reeducation of the protesized patient after amputation;
5. Performance of the strategies for the overcoming of handicap (Home care).

The rehabilitation of the artheriopatic patient can be limited or compromised by the following morbids pictures:

- Serious cardiopathies;
- Serious respiratory insufficiency;
- Motor neurological deficits;
- Invalidating poliarthropathies.

The age of the patient does not represent a contraindication to the physical training, while smoking it seriously compromises the possibility to rehabilitation of the artheriopatic patient. The possible therapeutics procedures, pharmacoloogical, surgical and physical, must be complementary to determine a substantial cumulative effect on the clinical improvement and on the autonomy of the patient in the activities of daily life (ADL). In this context are summed up the principles of critical physical treatment in chronic ischemia (the III and IV stage of Fontaine) which, as pointed out, it must be planned and opportunely set for every single patient. Infact the pain and the functional impotence tied to the serious ischemia, the trophycs lesions and the syndrome from immobilization to which these patients run into, determine very serious disabilities and handicaps that can add up to other concomitant pathologies, such as diabetes, obesities and respiratory disease, which if are not dealt at the same time in physical participation, can represent for the old artheriopatic patient, the cause of death.

We can deduce that the physical plan in chronic critical ischemia must include the following parameters of participation:

- Control of the ischemic pain and the trophics lesions in the hit district;
- carefully dosed therapeutic exercise of the hit limb;
- therapeutic exercise to maintenance of the general tonotrophism;
- respiratory training of the bronchial fluid water-drainage;
- releasing respiratory training also for anxiolitic scope;
- instrumental physical therapy use (transcutaneous electrical nerve stimulation [TENS], magnetic therapy);
- prevention of decubitus and its treatment;
- correct nutritional control for the best tissue state;
- occupational therapy and personal education to the ergonomics in the ADL.

Therefore physical procedures becomes fundamental not only for the control of the pain, but also for the maintenance of the physical functionality that often in the immobilized old patient can be compromised. In the patients subordinates to revascularization's procedures, a physical protocol based on repeated isotonic therapeutic exercise can be put into effect, previewing the gradual intensification of the workload and interesting

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all the muscular districts of the inferior limbs and the pelvic crawler track (contraindicated in these patients the isometric exercice). It's important to emphasize that, because of the slow functional impotence caused by the ischemic pain, it is fundamental to subject these patients to exercise, in order to recovery of the proprioception of the river basin and the main fulcrums of the inferior limbs, and to correct static and dynamic posture.

All the active workloads must begin with an advanced intensity not superior to 50% of the maximal possibility of the subject (estimated at the moment of possible motorial resumption), with a reduced number of repeated and in the respect of the intervals of compensatory rest. Useful, the exercises of respiratory education to improve diaphragmatic action and the costal excursion (together with the mobilization of the shoulder girdle), and to concur the improvement of the lymph and venous circulatory, overload from phlebolymphedema. Autogenous techniques or the employement of sitting training for patient's relax, are often practiced for the improvement of the performance.

In patients with coronary artery disease and/or cerebrovascular pathologies, for the control of the chronic ischemic pain, can be necessary to avoid anesthesiology with any surgical procedures. In these cases, physical partecipation is limited to the conservation of autonomy in the personal ADL, in the attempt to slow down both the progress of ischemy and the pharmacological therapy.

Therapeutical excercice, facilitated by an adapted control of the pain, carries out with passive techniques (posturals exercises declivities and alternated posture, passive mobilizations and manual) because it is not possible to execute any training loaded in patient with sanguimotor lack of balance. The accomplishment of personalized protocols of limb mobilization allows to maintain and, some times, to improve the immobilized ischemic trophysm of limb for the pain and the trophyc lesions, slowing down or preventing the processes of atrophy from inactivity of the muscular and osteo-articular structures. With the mobilization of the patient and exercises of respiratoria reeducation are prevented the pulmonary and thrombotic complication of the venous circle, which accelerate negative evolution of ischemic pathology.

Parallely, the physical therapy can use some methods (TENS and magnetic fields) to support the control of the pain and hit the evolution of the disturbance trophic limb.

The TENS concur to the control of the pain from deafferentation and allow to induce increments of the partial oxygen pressure thanks to a vasodilatative effect on the small peripheral arteries.

The mechanisms of action of these analgesic currents are reassumed in the control of the nociceptives afferents by means of the mechanism of gate control and in activation of the endorphinic system.

The electrodes monotype can be applied locally on the area of greater pain and along the distance of the peripheral nerves going back to the spinal zone of origin. As far the employement of magnetic fields is concerned, the majority of the authors agrees on the importance of the magnetotherapy in vascular pathology. The described therapeutics effects in literature regard the recovery process of atonic ulcers and plagues, thanks to the influence exercised from the magnetic field on the differentiation of the primitive mesenchyme cell in fibroangioblastic sense.

Therefore, by means of variable magnetic fields the processes of neoangiogenesis can be favorited, and ulterior improvements are obtained with the hyperemization that concur also to the oxygen contribution and to the reduction of the interstiziale pressure with acceleration of the repair processes.

In the subjects in which it obtains a positive result with remission of the rest pain and positive evolution of the trophyc lesions, the actives therapeutics exercises can be advised to re-establish the abilities to active movement of limb that, sometimes, also concur to recover the erected station and the deambulation in atmosphere to domicile. In the cases that unfortunately are manifested resistant to the described treatments, the physical program becomes conservative and concentrates the attention on the prevention of the bedsore, to the maintenance of the polmonary ventilation and of the nutritional adequacy and to the control of the syndrome from immobilization. The physical training is oriented to the preparation of the patient to the amputation of hit limb and to the psychological support. The choice of prosthesis and orthesis must be taken in consideration when the ischemic limb is amputated, or when the time demanded for medical assistance and sheltering becomes an important factor.

In fact the frequent hospitalizations and the status of exercise's absence for one year, can represent 20% of the period of residual life of a patient 70 years old.

The study of Wolfe et al. in 1988 emphasizes that a corrected physiatric organization concurs with therapeutics protocols to the recovery of the autonomy and that it actively participates to the functional recovery of the patient, joining its contribution to the other therapeutics strategies.

It is famous that the unfavorable evolution of the critical ischemia is the expression of the presence of extended arterial disease, not only of the district of primary lesion but also of the inflow and outflow vessels.

The rehabilitative possibilities in the critical stage of ischemia are therefore important, becoming a valid support to the surgical and/or pharmacological treatments, and conserving the quality of life of the artheriophatic

patients and exceeding the handicap induced from the described disability. The optimal outcomes of the physical therapy occur when the patient and the family have received the necessary education with the psychologist and subordinated to training autogenous or other type of release exercises. The patients must be informed about the correct use of aid, above all when the patient is disabled, and the modifications of home environment like the equalization of sanitary. The patient is educated to the development of independent ADL and invited to play therapy that, beyond carrying out anxiolitic action, concur the conservation of the attentive faculties. In fact, in the old patient immobility can arise with a reduction of the concentration, an alteration of the sleep-waking rhythm and the loss of interest in the main activities with decline of the cognitive faculties. We emphasize that the patients with critical leg ischemia does not differ, under these aspects, from patients with problematic due to the immobility and that the rehabilitative program must always be guided from the individual psycho-physical possibilities.

In conclusion it appears superfluous to emphasize the vastness and importance of physiatric partecipation in the treatment of critical leg ischemia. As shortly reassumed in this chapter, they are many reason offered by the rehabilitative medicine for its use with social effect and cost reduction fighting the disability in complex patients.

The rehabilitative training must be considered as a drug and therefore given with a personalized program, that has the aim of the conservation of the dignity of the person in the best quality of the life.

REFERENCES

(1) Abram SE. Bonica Lecture. *Advances in chronic pain management since gate control.* Reg Anesth 1993; 18: 66-81.

(2) Birkhan J, Carmon A, Meretsky P, Zinde H. *Modification of TENS by costant energy stimulation delivered throudh multiple electrodes: method and evaluation. In Bonica JJ, Liebeskind JC, Albe-Fassard DG: Advances in pain research and therapy.* II World Congress Pain. New York, Raven Press, 1979; 3; 607-613.

(3) Buonocore M, Mortara A, Larovere MT, Casale R. *Cardiovascular effects of TENS: heart rate variability and plethysmographic wave evaluation in a group of normal subjects.* Funct Neurol 1992; 7; 391-394.

(4) DeWeese JA, Leather R, Porteer J: practice guidelines: *Lower extremity revascularization.* J Vasc Surg 1993; 18:280.

(5) Ekroth R, Dahllof AG, Gundevall B, Holm J, Schersten T. *Physical training of patients with intermitten claudication: indication, methods and results.* Surgery 1978; 84: 640-643.

(6) Erickson RP, McPhee MC. Clinical Evaluation. In: DeLisa JA, editor. *Rehabilitation medicine: principles and practice.* Philadelphia: JB Lippincott Co, 1993; 51-95.

(7) European Working Group on Critical Limb Ischemia. Eur. J. Vasc. Surg. 1992; 6 (Supplement A): 1-32.

(8) Govoni E, Criscuolo M, Fabbri FR, Donà M, Perbellini A, Rastelli A, Magnolfi G, Vannini M. *The relationship between low-frequency pulsed electromagnetic fields treatment and time course appereance of cellular and extracellular events during skin wound healing: the role of hyaluronic acid.* J Bioelectricity, 1989; 8; 310-313.

(9) Gardner AW, Poehlman, ET. *Exercise rehabilitation prognosis in the treatment of claudication pain. A meta analisys.* JAMA 1995; 274 (12): 975-979.

(10) Hammond MC, Merli GJ, Zieler RE. *Rehabilitation of the patients with peripheral vascular disease of the lower extremity.* In: DeLisa JA, editor. *Rehabilitation medicine: principles and practice.* Philadelphia: JB Lippincott Co, 1993; 1082-1098.

(11) Haimosvici N. *4 years experience with ELF pulsed magnetic fields in venous and arterial diseases of the extremities.* JEC, 1985.

(12) Hertzer NR. *The natural history of peripheral vascular disease: implication for its management.* Circulation 1991; 83 (suppl 1): 1-12.

(13) Hiatt W, Regensteiner J, Hargarten M, Wofel E, Brass E. *Benefit of exercise conditioning for patients with peripheral arterial disease.* Circulation 1990; 81 (2): 602-609.

(14) Jeans ME. *Relief of chronic pain by brief, intensive transcutaneous electrical stimulation: a duble blind study.* In Bonica JJ, Liebeskind JC, Albe-Fessard DG (eds): *Advances in pain research and therapy.* New York, 1979; 3, 601-606.

(15) Jonason T, Jonzon B, Ringquist I, et al. *Effect of physical training on different categories of patients with intermittent claudication.* Acta Med Scand 1979; 206:153.

(16) Long DM, Campbell JN, Gucer G. *Transcutaneous electrical nerve stimulation for relief of chronic pain.* In Bonica JJ, Liebeskind JC, Albe-Fessard DG (eds): *Advances in pain research and therapy.* New York, 1979; 3, 593-599.

(17) Long DM, Campbell JN, Taub A. *Local analgesia from percutaneous electrical stimulation.* Arch Neurol 1973; 28; 347.

(18) Marchese A, Selvanetti A, Caruso I. TENS. *Collana di Riabilitazione* – 2° Clinica Ortopedica Università degli Studi di Pisa (ed) N. Marchetti; 1996.

(19) The European Study Group – *Intravenous pentoxifylline for the treatment of chronic critical limb ischaemia.* Eur J Vasc Endovasc Surg 1995; 9: 426-436.

(20) Pappas CJ, O'Donnel TF. *Long term results of compression treatment for lymphedema.* J Vasc Surg 1992; 16:555.

(21) Pastore A, Spinelli S. *Evaluation of effects of low frequency PMF on peripheral artheriopathies.* JEC 1985.

(22) Pizzetti M, Caruso I. *Medicina Fisica e Riabilitativa.* 1987 Edilombardo 4° Ed. 149-150.