

## ISOLATED PROFUNDOPLASTY, AS A LIMB SALVAGE PROCEDURE, A MODIFIED APPROACH

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*Purpose: To study the effect of isolated profundoplasty as a limb and foot salvage procedure in management of patients presented with limb threatening ischemia due to occlusion of SFA, and a stenosis in PFA, with their runoff formed of unreconstructable tibial arteries.*

*Material & Methods: For all the 14 patients included, arteriography was done, but in addition duplex study was used for better assessment of PFA pathology, to obtain the segmental pressures, ABI, PPCI&TAGI for all patients, and for postoperative follow up which was done after 1,3 and 6 months. Aggressive form of profundoplasty using a low-power magnification loop, in which endarterectomy down to the second perforator and involving the branches with patching, was done.*

*Result: Two groups of patients were identified, group A of successful outcome (42.9%) and in them the mean preoperative PPCI was 0.17, TAGI was 0.41 and their AP increase was 57%, 70% & 85% in three successive postoperative readings while their ABI increase was 44%, 54% and 65%.*

*In second group (B) there was failure of foot salvage (57.1%) and in them, the mean preoperative PPCI was, 0.46, TAGI was 0.64 and in the postoperative study the mean AP was 39.6, 44 and 46 mmHg and the mean of ABI was 0.27, 0.31 and 0.37 in the three successive recordings.*

*A subgroup (B)1 was also identified, and in them, failure of foot salvage, but knee salvage was obtained.*

*Discussion and conclusion: Isolated profundoplasty may be a possible form of revascularization in this particular group of patients, if properly selected.*

### Abbreviations:

EIA	: External iliac artery
CFA	: Common femoral artery
SFA	: Superficial femoral artery
PFA	: Profunda femoris artery
PPCI	: The profundopoplital collateral index
TAGI	: Thigh ankle gradient index
ABI	: Ankle-brachial index
AP	: Ankle pressure
UTP	: Upper thigh pressure
LTP	: Lower thigh pressure
BKP	: Below knee pressure
DM	: Diabetes mellitus
CHD	: Coronary heart disease
HTN	: Hypertension

Key words: profundoplasty-limb salvage

## INTRODUCTION

The PFA is not only the primary blood supply to the tissues of the thigh, but also serves as the major collateral channel for by passing the obstructed SFA, and restoration of flow through this vessel alone significantly improves limb perfusion in case of occluded SFA, as proved by Leeds and Gilfillan, and Morris and associates <sup>(1,2)</sup>.

Isolated profundoplasty may serve as an alternative to femoropopliteal or femorotibial bypass, in case distal bypass is not feasible <sup>(3)</sup>. It may provide the only potential for revascularization of a limb when neither the popliteal trunk nor the tibial arteries are suitable for bypass <sup>(4)</sup>.

Isolated profundoplasty is considered a relatively easy operation with minimal morbidity and mortality even when performed in high-risk patients who have undergone previous vascular procedures <sup>(5)</sup>.

Furthermore, it does not risk injury to genicular or tibial collaterals which may occur at the time of bypass to the knee or calf and which may jeopardize the healing of a below knee amputation if that should subsequently become necessary.

Although limb salvage may not be achieved in case of isolated profundoplasty, the level of anticipated amputation might be lowered from above to below the knee <sup>(6)</sup>.

Isolated profundoplasty seems to be a reasonable revascularization alternative if there is a stenosis of the PFA representing a reduction in vessel diameter of the 50% or more. Ideally, only the proximal one third of the artery should be affected, leaving the distal part relatively free of disease <sup>(7)</sup>.

Although the results of tibial bypasses improved over the last decade, due to technical modifications, the use of in situ bypasses near or at the ankle and performing arteriovenous fistulae, stenosis of the PFA should always be relieved before attempting tibial bypass <sup>(4)</sup>.

However, the controversy regarding isolated profundoplasty still exists, mainly due to difficulty of predicting which patients could benefit from the procedure <sup>(8,9)</sup>.

The purpose of the present study was to determine the effectiveness of an aggressive form of profundoplasty, as a limb salvage procedure and the factors that can predict its outcome, and so the criteria to select cases which can benefit from isolated profundoplasty, when used in a selected group of patients presented with severe limb-

threatening ischemia with unreconstructable infragenicular vessels.

## MATERIAL AND METHODS

### *Study Population*

It was elected to perform the present study on a group of patients <sup>(14)</sup> presented with limb threatening ischemia of category 4 (ischemic rest pain), 5 (minor tissue loss) and 6 (major tissue loss), according to revised version of recommended standards for reports dealing with lower extremity ischemia <sup>(10)</sup>, with three further pathoanatomical criteria. The first one was the absence of significant disease in the aortoiliac segment proximal to the CFA. The second one, the main disease affecting the CFA, SFA &/or PFA. The third one, the runoff was a unreconstructable infrageniculate artery, i.e.; there was neither patent popliteal artery, nor tibial arteries continuous with the pedal arch. So, during the period from January 1996 to January 2000 the study was performed on 14 patients, of whom (71.4%) was males and (28.6%) females, and the mean age of them was  $62.8 \pm 506$ . According to the presenting symptoms, 28.5% of them were of category 4, 35.7% of category 5 and 35.7% of category 6. The risk factors for this group of patients were, CHD in 64.3%, HTN in 50% and DM in 85.7%.

### *Methods:*

The work-up for all patients included history taking, and recording the period of complaint prior to presentation, duplex study and duplex derived pressure studies, mainly ABL, segmental pressure study and two pressure indices, mainly the PPCI & TAGI.

All duplex examinations were performed after 20 minutes of rest with the patient lying in a comfortable supine position. The leg was slightly externally rotated to get best delineation of the femoral bifurcation. The examinations were carried out with a Sonoline Elegra (Siemens). After the examination of the distal EIA, CFA, the femoral bifurcation, and of the proximal part of the SFA by duplex scanning, the PFA was examined along most of its course using a 7.5 MHz multiple frequency probe. A B-mode image was used to visualize the artery and to recognize anatomic variations. Colour Doppler was then used to detect jets caused by significant stenotic lesions and to place the sample volume of the pulsed Doppler in the center stream of the PFA distal to the orifice, and to correct for the angle between the Doppler beam and the blood vessel axis. The peak systolic blood flow velocity was then measured.

The Doppler flow velocity pattern of the PFA in a

healthy individual with intact PFA and SFA is triphasic with a somewhat dampened velocity waveform compared to the velocity pattern of a normal SFA. In the presence of SFA occlusion, the velocity waveform in a nonstenotic PFA orifice is monophasic with only forward flow component. In patients with SFA occlusion and concomitant PFA orifice stenosis, the velocity waveform in the orifice is monophasic with markedly increased peak systolic velocity and an extensive spectral broadening. (Fig: 1&2).

For every patient, segmental pressure measurements was done using 4cuffs, 2 above knee and 2 below knee. The ankle/brachial index, the TAGI and PPCI indices were calculated as follows<sup>(5)</sup> :

$$\text{TAGI} = \frac{\text{LTP-AP}}{\text{LTP}} \quad \text{PPCI} = \frac{\text{LTP-BKP}}{\text{LTP}}$$

### *Operative Procedure*

General anesthesia was used in four patients (28.6%), while in ten patient (71.4%), epidural anesthesia was applied. A vertical incision which extended 5cm proximal to the inguinal crease, and as far distally as necessary to provide easy access to the distal part of the PFA was used. The incision was made directly over the femoral pulse or the hard cord of the occluded femoral artery, and was parallel to the medial border of the sartorius. The inguinal ligament was routinely divided to allow exposure of the CFA, and its junction with the EIA. The occluded SFA was dissected free for a distance of several centimeters, and the lateral circumflex femoral vein was divided to expose the distal part of the PFA<sup>(4)</sup>. This also required incision of the adductor longus muscle. After dissection of the CEA, SFA, PFA, intravenous heparin was given for the patient in a dose of 100 units per kg. and the three arteries and their branches were controlled with vascular clamps and slings of heavy silk. The arteriotomy always started in the CFA and extended into the orifice of the PFA, and downwards. It was intended in all cases of this study to extend the arteriotomy down to the second perforator regardless of the extent of the disease proximal to this muscle perforator. The aim of this was to create an arterial pouch which is long and wide enough, from which the three important branches; namely the circumflex and the two perforators, originate, insuring a reasonable inflow for them. Moreover, the arteriotomy incision should extend beyond the second perforator in two cases; number one if the pathology extended beyond it, and number two, if an intimal flap was left after endarterectomy and so had to be fixed. In this particular case, the arteriotomy and patch should extend at least one cm distal to the point of fixation, as the effect of fixation of both intimal flap and patch at the same point may produce a purse-string like effect, producing narrowing of the PFA at this point, a lesson learned from the experience of carotid endarterectomy and used here, and

these modifications was applied in all cases.

After arteriotomy was done, the extent of disease was estimated as follows: in 10 cases (71.5%), the disease involved areas 1,2,3, i.e., the CFA, SFA,& the origin of PFA, in 3 cases (21.4%), the disease involved areas 2,3,&4, i.e., SFA, PFA & circumflex artery, while in one case (7.1%), the disease was diffuse involving areas 1:7,i.e., CFA, SFA & diffuse affection of PFA and its branches, down to and involving the second perforator<sup>(9)</sup>. The endarterectomy was done in the plane of mid-media of the vessel, and fine tacking sutures were applied to stabilize the distal intima, if a clean break can not be achieved distally.

A type of eversion "evagination" endarterectomy was used to remove the obstructing atherosclerotic plugs from the branches of PFA, since the disease usually extends few mm beyond junction of the branches with main channel<sup>(4)</sup>.

Special attention was given to endarterectomy of the circumflex artery, which required extension of the patch down its crifice in one case.

A tapered patch of autogenous tissue was used to close the arteriotomy and in this study, saphenous vein patch was used in 10 cases (71.5%) while an endarterectomized part of occluded SFA was used in the other four cases. (28.5%). A low-power magnification was used during the whole operation. (Fig : 3)

### *Post Operativefollow.*

The main follow up period was about 9 months, the maximum period of follow up was 15 months (2cases), and the minimum period was 6 months (3cases). The degree of improvement in the distal perfusion was monitored by clinical examination, estimation of the quality of flow in the pedal arteries by doppler examination, measurement of the segmental pressure and ABI at 1,3 and 6 months. For estimation of degree of improvement, the recommended scale for gauging changes in clinical status was used<sup>(10)</sup>.

Postoperative angiography was done for one of the cases, in which although clinical examination and pressure studies proved successful outcome, there was persistent ischemia localized only to one toe Angiography revealed development of collateral circulation down the limb (Fig: 4 & 5).

## **RESULTS**

There was no operative mortality, but two patients developed wound hematomas, after which suction drains were used in the subsequent cases, and one superficial wound infection (7.1%) occurred.

According to the outcome of the operation we could identify two major groups; group A (successful outcome) and group B (failure of foot salvage), and this latter group has two subgroups (B1 = below knee amputation and B2= above knee amputation)

In group A (6patients,42.9%) there was clinical evidence of improvement of symptoms i.e. disappearance or at least improvement of rest pain, healing of foot ulcers and/or appearance of demarcation line proximal to the gangrenous patch.

The mean *UTP* for this group was  $84.16 \pm 10.68$  while the mean *LTP*, *BKP* and *AP* were  $68.33 \pm 9.8$ ,  $55.83 \pm 8.01$  and  $40.33 \pm 6.53$  respectively. The mean preoperative *ABI*, *PPCI* & *TAGI* were  $0.30 \pm 0.024$ ,  $0.17 \pm 0.02$  and  $0.40 \pm 0.05$  respectively.

The post operative pressure studies in this group of patients were as follows, the mean *UTP* was  $113.8 \pm 8.3$ , the mean *LTP* was  $90.83 \pm 7.3$ , the mean *BKP* was  $76.1 \pm 6.1$ , and the increase in the last two readings were  $34 \pm 10\%$  and  $37.8 \pm 15\%$ , while the mean post operative *AP* was  $57.5 \pm 9.6$  and the mean postoperative *ABI* was  $0.44 \pm 0.05$  in the immediate post operative period.

The improvement in the ankle pressures and the *ABIs* in this group was slow but progressive. This is evidenced by noting that the mean *AP* and *ABI* at the mid-follow up period were  $70 \pm 8.8$  and  $0.54 \pm 0.05$  respectively, and these measurements were  $75.5 \pm 9.64$  and  $0.64 \pm 2$  respectively at the end of the follow up period. The difference between the preoperative *AP* at the *AP* at the three follow up readings were  $42 \pm 15.4\%$ ,  $75.2 \pm 20.9\%$  and  $112.9 \pm 25.2\%$ . The similar differences as regards to the *ABI* were  $46.4 \pm 14.5\%$ ,  $80.8 \pm 19.02\%$  and  $115.3 \pm 23\%$ .

It is important to note here, that the presenting symptoms in this group were either ischemic rest pain (category 4) or minor tissue loss (non-healing ulcer, focal gangrene with diffuse pedal ischemia category 5), and no cases of category 6 (major tissue loss). Considering that the *ABI* did not become "normalized" in any of these patients and so pedal pulses were not felt, but there were categorical improvement from category 4&5 to 2&3, the outcome in this group of patients was essentially of +2 (moderate improvement). In group B<sub>1</sub> (4 patients, 28.6%), the mean preoperative *UTP*, *LTP*, *BKP* and *AP* were  $114.75 \pm 16.04$ ,  $95.25 \pm 21.80$ ,  $55 \pm 5.8$  and  $35.75 \pm 4.30$ . The mean *ABI*, *PPCI* and *TAGI* were  $0.26 \pm 0.05$ ,  $0.38 \pm 0.11$  and  $0.60 \pm 0.05$ .

In the immediate postoperative period the mean *UTP*,

*LTP* and *BKP* were  $133.75 \pm 11.5$ ,  $111.75 \pm 20.1$ ,  $75 \pm 10.8$  and the increase in the last two readings were  $18.5 \pm 8\%$  and  $36.24\%$ . The mean *AP* was  $45.25 \pm 5.9$  and the mean *ABI* was  $0.32 \pm 0.061$ . The second postoperative *AP* and *ABI* were  $45 \pm 5.7$  and  $0.32 \pm 0.06$ , while the third readings were done for the only one patient who was still not amputated & they were 46 and 0.37 respectively. The ankle differences at the three readings were  $28.32 \pm 26\%$ ,  $27.7 \pm 26.7$  and  $15\%$ , while the *ABI* differences were  $23.03 \pm 5.8\%$ ,  $23.03 \pm 5.8\%$  and  $15.62\%$ . In this group of patients, the presenting symptoms were minor tissue loss-category 5 in 3 patients and major tissue loss category 6 in one patient, with no patients of category 4 (rest pain), and there were clinical evidence of improvement of perfusion only to the below knee level. As this study was done for patients with unreconstructable tibial arteries, the secondary procedure done for all of the patients in this group was below knee amputation.

In group B<sub>2</sub> (4 patients, 28.8%), failure of the procedure to improve the below knee circulation was recorded in all of the patients. Moreover, in one patient, immediate postoperative thrombosis of PFA occurred as evidenced by clinical & duplex examination. The preoperative mean *UTP*, *LTP*, *BKP* and *AP* for this group were  $117.5 \pm 10.4$ ,  $101.5 \pm 12.5$ ,  $52 \pm 10.2$  and  $33 \pm 7.8$  respectively. The *PPCI*, *TAGI* and *ABI* were  $0.54 \pm 0.02$ ,  $0.67 \pm 0.08$  and  $24 \pm 0.06$ .

The postoperative *UTP*, *LTP* and *BKP* pressures were  $100 \pm 67.2$ ,  $85 \pm 57.8$  and  $56.7 \pm 3.9$  and the percentage increase in the last two pressures were  $18.4 \pm 54.35$  and  $11.98 \pm 20$  respectively. The mean first postoperative *AP* was  $34 \pm 5.1$  and second was 40, and there was no third reading. The percentage increase was  $7.8 \pm 29\%$  and  $14.28\%$ . The first postoperative mean *ABI* was  $0.23 \pm 0.07$  and the second was 0.27 and the percentage increase was 3.8 and 17.39%. For the four patients of this group, above knee amputation was done, in the immediate postoperative course in one case, and after failure of improvement of pressure readings in the other three cases.

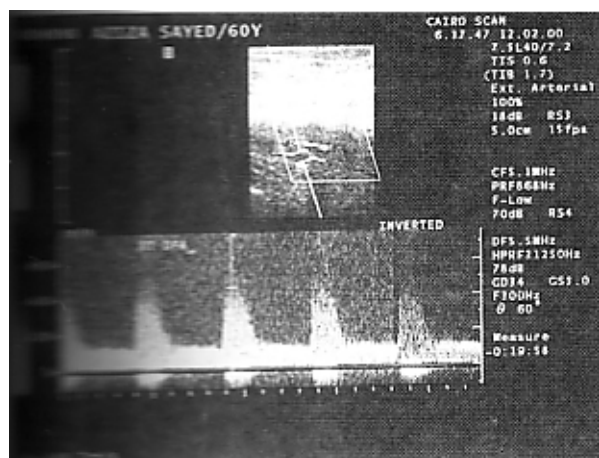
The aim of any revascularization procedure and of isolated profundoplasty is foot salvage, which is considered also the successful outcome (group A) of this procedure, comparing both successful and failure groups B1&B2, we found that sex, DM, CHD, HTN, extent of pathology in PFA, type of patch used and postoperative complications was insignificant factors while the preoperative *ABI*, *PPCI*, *TAGI*, and postoperative *AP*<sub>1,2,3</sub> and *ABI*<sub>1,2,3</sub> are significant factors (Tables 1&2). (Fig: 6: 9) shows trend analysis of pressure measurements in groups A, B1, and B2.

**Table 1: pressure studies & Inices in groups A,B,B<sub>1</sub>&B<sub>2</sub>**

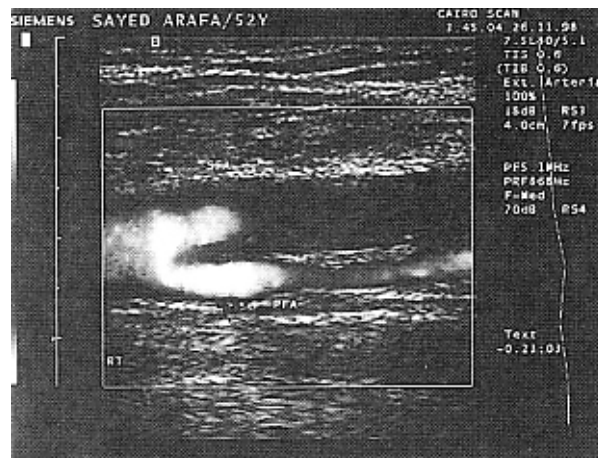
		UTP	LTP	BKP	AP			PPCI	TAGI	ABI		
GPA	Preeop	84.16 ±10.68	68.33 ±9.8	55.83 ±8.01	40.33 ± 6.5			0.17±0.02	0.40 ±0.05	0.30 ± 0.024		
	Postop	113.8 ± 8.3	90.83 ± 7.3	76.1 ±6.1	57.5 ± 9.6	70 ± 8.8	75.5 ±9.64			0.44 ±0.05	0.54 ±0.05	0.64
GPB	Preeop	116.13 ±12.6	98.38 ±16.8	53.5 ± 7.9	34.38 ± 6			0.46±0.11	0.64±	0.25		
	Postop	116.88 ±48.14	98.37 ±42.6	65.87 ±12.3	39.6 ±7.9	44±5.4	46			0.27	0.31	0.37
GPB <sub>1</sub>	Preeop	114.7 ±16.04	95.25 ±21.8	55 ±5.8	35.75 ± 4.3			0.38 ± 0.11	0.60 ±0.05	0.26±0.05		
	Postop	133.75 ±11.5	111.75 ±20	75± 10.8	45.25 ±5.9	45± 5.7	46			0.32 ±0.06	0.32 ±0.06	0.37
GPB <sub>2</sub>	Preeop	117.5 ±10.4	101.5 ±12.5	52± 10.2	33±7.8			0.54±0.02	0.67± 0.08	24±0.06		
	Postop	100 ±67.2	85± 57.8	56.7± 3.9	34± 5.1	40	---			0.23± 0.07	0.27	-- --

**Tables 2s: AP&ABI Differences (%)**

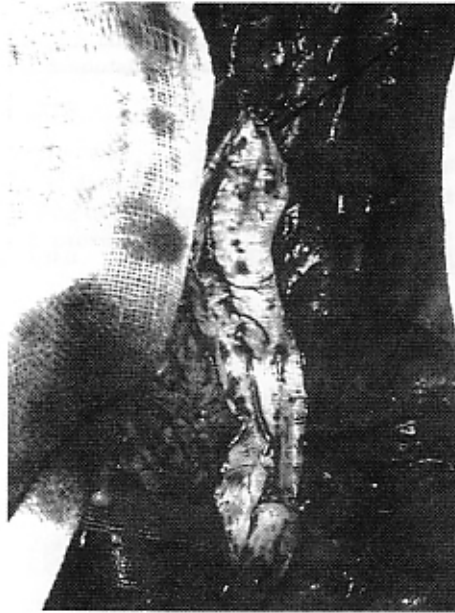
	AP <sub>1</sub>	AP <sub>2</sub>	AP <sub>3</sub>	ABI <sub>1</sub>	ABI <sub>2</sub>	ABI <sub>3</sub>
GPA	24.9±15.4	75.24±20.9	112.9±25.2	46.4±14.5	80.81±19.02	115.3±23
GPB <sub>1</sub>	28.32±26	27.7±26.7	15.0	23.03±5.8	23.03±5.8	15.62
GPB <sub>2</sub>	7.8±29	14.28	-----	3.8	17.39	----



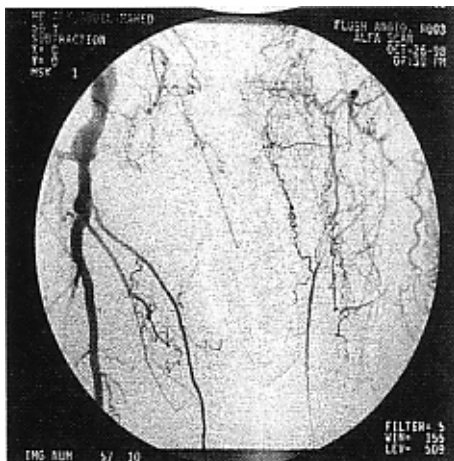
**Fig.(1): Duplex study; stenosis of the PFA with concomitant SFA occlusion.**



**Fig.(2): Duplex study; occlusion of SFA, with long stenotic segment of PFA.**



*Fig.(3): Extensive endarterectomy of PFA.*



*Fig.(4&5): Development of collateral circulation between the PFA (after profundoplasty) and the infragenicular vessels.*

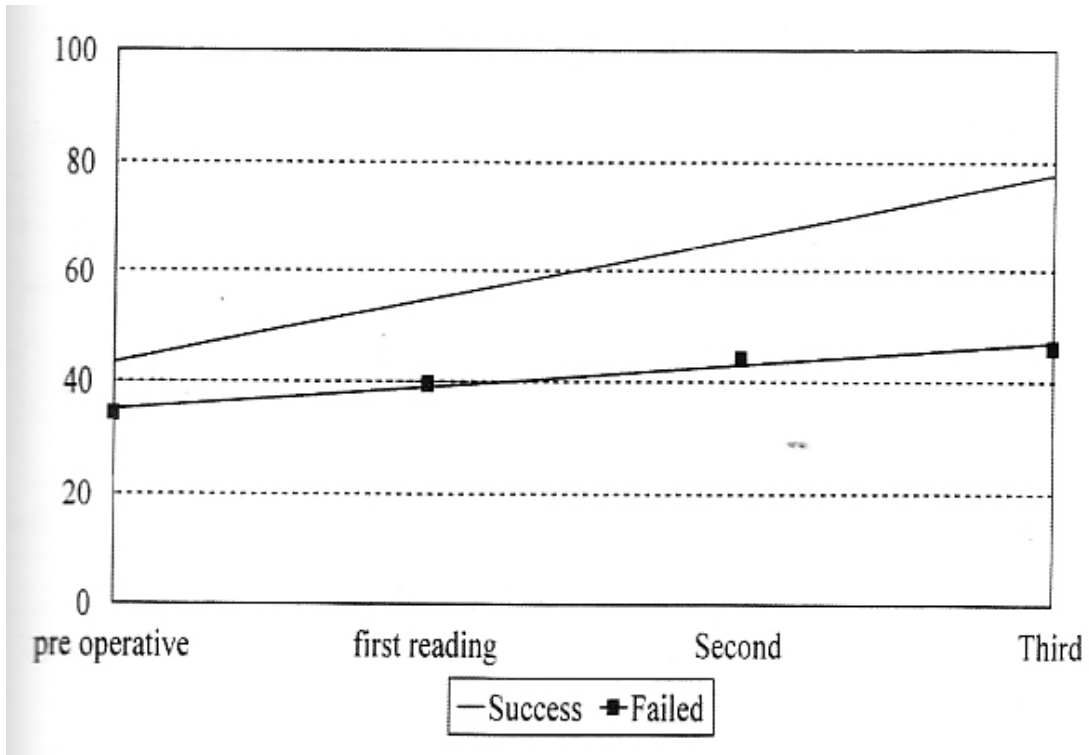


Fig (6): Trend Analysis of Ankle Pressure Readings

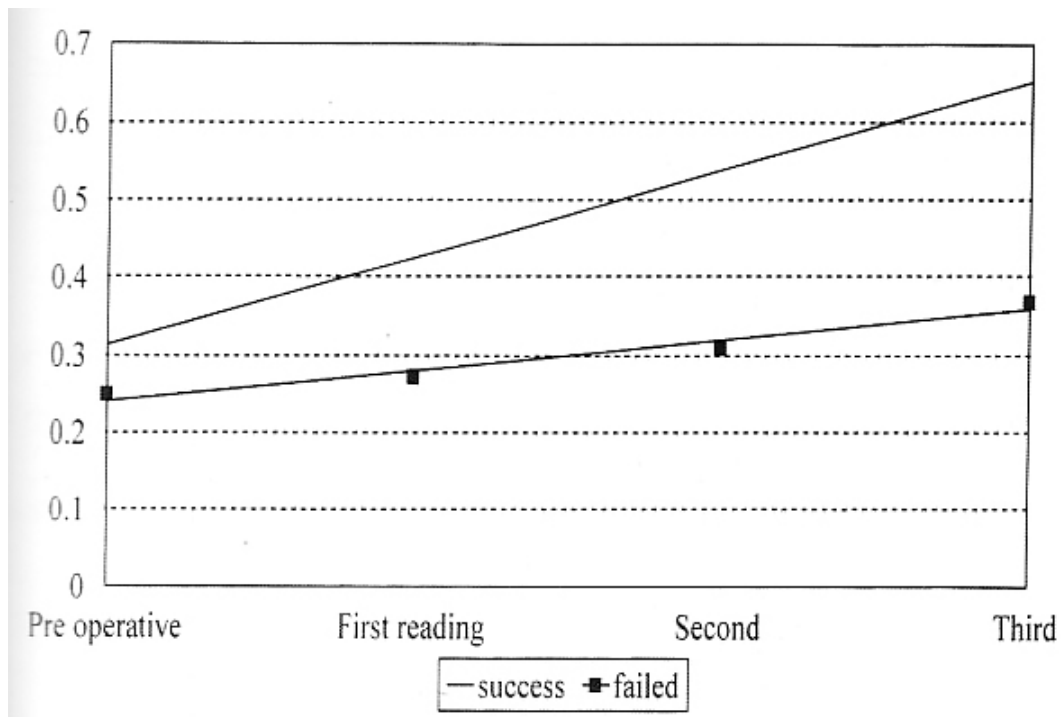


Fig (7): Trend Analysis of ABI Readings

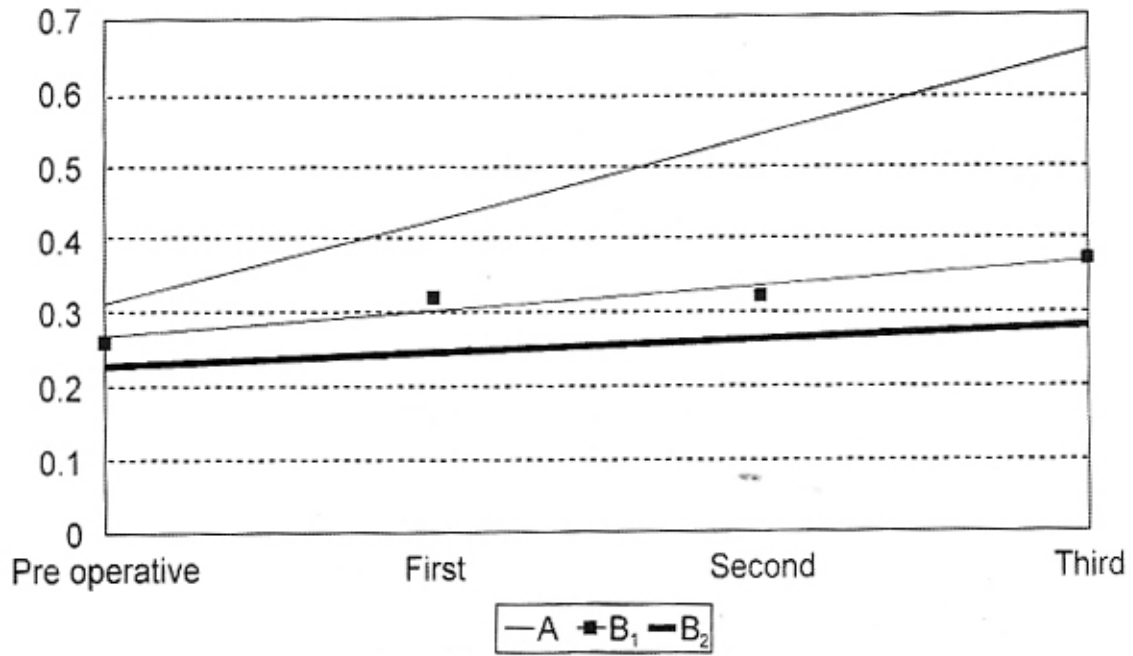
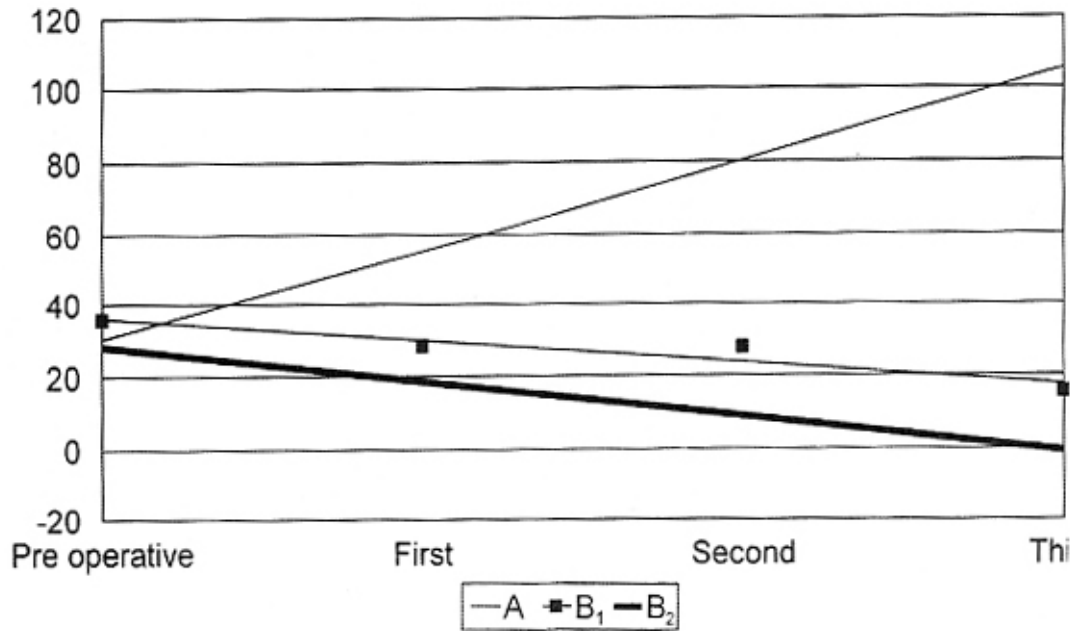


Fig (8): Trend Analysis of Ankle Pressure Readings in the Three Groups



A Improved B<sub>1</sub> Below Knee Amp B<sub>2</sub> Above Knee Amp

Fig (9): Trend Analysis of ABI Readings in the Three Groups



## DISCUSSION

Profundoplasty in conjunction with other procedures remains an important adjunct in lower limb revascularization allowing for a high rate of limb salvage in patients with severe vascular occlusive disease<sup>(11)</sup> The best clinical results are obtained if there is a preoperative total occlusion or severe stenosis of the proximal part of the PFA, when its distal part is relatively free of disease and if the popliteal runoff is good with two or more patent leg arteries<sup>(8)</sup>. In this study, isolated profundoplasty was applied in selected indication which was foot salvage in patients presented with rest pain and/or gangrene, for a selected group of patient with very severe vascular occlusive disease with complete occlusion of SFA, stenosis or limited occlusion of PFA, with the runoff consists of unreconstructable tibial arteries not continuous with the pedal arteries. Practically speaking this group of patients were doomed to above knee-amputation, as tibial bypass in this group has a very high rate of failure. As profundoplasty may represent the only available revascularization procedure in this special group of patients, aggressive form of endarterectomy and patching-as described-was performed in this study. The success rate was 42.9%, which was lower than the results reported by other authorities and about there of others. The success rate for isolated profundoplasty done for patients with intermittent claudication, with good popliteal distal runoff ranged between 83% in Jennings & Wood (1985)<sup>(12)</sup> series to 100% in Miami et al(1995)<sup>(13)</sup> series.

In patients with limb-threatening ischemia. Ward and Morris-Jones (1977)<sup>(14)</sup> obtained 40% success rate and their indication was rest pain  $\pm$  minor local gangrene and/or ulcers, while Iliopoulos et al (1985)<sup>(15)</sup> obtained 65% success rate when the operation involving the proximal PFA, was done for limb salvage in limbs with poor runoff and 20% when profundoplasty was done for diffuse or distal PFA with the same indication & runoff. Bernard<sup>(4)</sup> concluded that the degree of improvement in limb perfusion is directly proportional to the patency of the popliteal and tibial vessels, in his series in operation performed for limb salvage, success was achieved in 85% of those patients with moderate disease of the popliteal and tibial outflow while the success rate was 46% when the popliteal artery was occluded and filling of the tibial vessels was meager. A result similar to that obtained in this study. In spite of the low success rate obtained in this study, above knee-amputation was avoided and substituted by the less dramatic below knee-amputation in 28.6% of patient in whom isolated profundoplasty was performed. A result which means that improvement of the collateral flow through the profunda system in patients in whom it fails to achieve foot salvage, by increasing below-knee pressures probably enough to retain the knee and heal a below-knee amputation.<sup>(6)</sup>

The most important problem regarding isolated profundoplasty, is the selection of patients suitable for it. This study revealed that the presence or absence of risk factors (CHD, DM, HIW), sex, zones affected and type of patch had insignificant effect on the outcome of profundoplasty. It was not surprising to find that the zones affected by atherosclerotic disease had insignificant effect on profundoplasty, as the aggressive endarterectomy even involving the branches-as described-probably appolished the effect of this factor. The clinical category at presentation was significantly different in both groups. In group A the clinical categories was either of category 4 (4patients = 28.6%) or category 5(2patients = 14.3%), while in group B there was three patients (21.4%).of category 5, and five patients (35.7%) of group 6. Many authorities concluded that the results of profundoplasty are better in absence of digital or foot gangrene. It is widely held that the adequacy of the profundopopliteal collateral system, as well as the severity of the tibial disease, are the most important determinants of success of profundoplasty<sup>(16)</sup>, The *PPCI* is the index that estimates the resistance of the profundopopliteal collaterals and the *TAGI* is the index that estimates the resistance of the tibial vessels<sup>(6)</sup>.

A low *PPCI* (<0.5) was considered by Boren et al<sup>(16)</sup>, the most important predictor of success of profundoplasty, while a low *TAGI* (<0.55) was considered by McCoy et al<sup>(6)</sup> the index most predictive of success. In this study we found that both *PPCI* & *TAGI* were significantly lower in group A than B [*PPCI* = 0.17 (*GP<sub>A</sub>*) and 0.46(*GP<sub>B</sub>*), *TAGI*=0.40 (*GP<sub>A</sub>*) and 0.63 (*GP<sub>B</sub>*)], while by looking to *GP<sub>B1</sub>* the *PPCI* was less than 0.5 and in spite of this foot salvage was not obtained, as *TAGI* was high (0.60). This proved that both indices together are the most important predictors of success and this is one of the important results of this study. The mean *ABJ* was significantly higher in group A than B, and it was difficult to obtain foot salvage if the preoperative *ABI* was lower than 0.3. This study also showed that contrary to bypass surgery in which the revascularization effect may be expected in the early postoperative course, the effect of profundoplasty is slow but progressive. However this progressive improvement can be expected if a positive difference in *AP* and *ABI* of more than 40% was obtained after one month.

Isolated profundoplasty also can lower the amputation level from the above-knee to the below-knee level. In this study profundoplasty permitted salvage of the knee joint in patients of group B<sub>1</sub> as it improved the below knee pressure to more than 60 mm Hg the pressure that can guarantee healing of a below knee amputation<sup>(16)</sup>.

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