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Comparison of Cost Affecting Parameters and Costs of the "Closed" and "Open" *in situ* Bypass Technique

L. C. van Dijk[1], R. Seerden[3], H. van Urk[3] and C. H. A. Wittens*[4]

[1]Department of Radiology, [2]Financial Department and [3]Department of Vascular Surgery of the University Hospital Rotterdam "Dijkzigt" and [4]Department of Surgery, St Franciscus Gasthuis, Rotterdam, The Netherlands

Objectives: *The "closed"* in situ *bypass results in a reduction of wound complications compared to the "open" technique. This advantage is partly diminished by extra costs for the "closed" procedure and a larger percentage of residual arteriovenous (AV)-fistulae. This aim of this study was to analyse costs related to "closed" and "open" procedures.*
Methods: *The cost affecting parameters: (1) duration of operation; (2) length of hospital stay; and (3) number of treated residual AV-fistulae, were analysed in a randomised group of 73 patients (35 "closed" and 38 "open") in two centres. In addition, costs of the operation, nursing care and treatment of AV-fistulae were analysed.*
Results: *The "closed" and "open" group showed a median duration of operation of 210 min (range 105–570) and 154 min (range 90–355) ($p<0.05$), length of hospital stay of 16 days (range 5–51) and 25 days (range 12–65) ($p<0.01$), and a percentage of patients treated for residual AV-fistulae of 40% and 5%, respectively ($p<0.01$). The median "closed" operation was US$ 798 more expensive than the "open". Median postoperative care was US$ 2664 less for the "closed" group. Mean estimated costs for treatment of AV-fistulae was US$ 9 in the "open" and US$ 167 in the "closed" group.*
Conclusion: *The "closed"* in situ *vein bypass technique is cost-effective in comparison with the "open" technique.*

Key Words: in situ *bypass; Costs analysis; Embolisation; Peripheral vascular disease; Atherosclerosis; Randomised controlled trial.*

Introduction

Several studies have shown that femorodistal reconstructions for critical lower limb ischaemia are cost-effective compared to primary amputation.[1,2] One of the preferred operating techniques for vascular reconstruction in the lower extremity is the *in situ* vein bypass technique. The problem of the standard or "open" *in situ* bypass technique is the high incidence of postoperative wound complications, which has been reported by Reifsnyder *et al.* as being 44%.[3] Recently "closed" *in situ* bypass techniques have been developed to reduce the length of the skin incision and thereby reduce the number of postoperative wound complications.[4,5] Rosenthal *et al.* showed a decrease in wound complication rate and a reduction of the length of hospital stay in a group of patients receiving a "closed" *in situ* bypass compared to a concurrently operated group of patients receiving an "open" *in situ* bypass.[6] In a prospective randomised study we showed that the "closed" technique resulted in a significant reduction in postoperative wound complications compared to the "open" technique.[7] However, despite this clear advantage the technique has not been widely adopted. One of the reasons could be the extra costs of the disposable materials required. The operation time is also reported to be prolonged[8] and the percentage of patients in which additional procedures in the early postoperative period are necessary for residual arteriovenous (AV)-fistulae has been reported to be 6–42% in three studies.[7,9,10] These consequences of the "closed" technique could result in increased costs compared to the "open" technique. On the other hand, if lower wound complication rates result in a reduced length of hospital stay, the "closed" technique could indeed be cost-effective.

The purpose of this study was to compare three important cost affecting parameters in the "closed" and "open" technique in a randomised group of patients: (1) the duration of operation; (2) the length of hospital stay; and (3) the number of patients treated postoperatively for residual AV-fistulae. A cost analysis of the operation, nursing care costs

* Please address all correspondence to: C. H. A. Wittens, Department of Surgery, St Franciscus Gasthuis, Kleiweg 500, 3045 PM Rotterdam, The Netherlands.

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Table 1. Patient characteristics in the "closed" and "open" groups.

	"Closed" ($n=35$)	"Open" ($n=38$)
Male/female	77%/23%	58%/42%
Age (years)	71	71
Diabetes	14%	32%
Smoking	51%	37%
Hypertension	34%	37%
Ischaemic heart disease	37%	34%

Table 2. Indication for operation in the "closed" and "open" groups.

	"Closed" ($n=35$)	"Open" ($n=38$)
Disabling IC	13 (37%)	13 (34%)
Restpain	8 (23%)	8 (21%)
Ulcers and/or necrosis	14 (40%)	17 (45%)

IC = intermittent claudication.

Table 3. Distal anastomosis in the "closed" and "open" groups.

	"Closed" ($n=35$)	"Open" ($n=38$)
Popliteal artery b.k.	21 (60%)	23 (61%)
Tibioperoneal trunk	2 (6%)	1 (2.5%)
Anterior tibial artery	3 (8.5%)	6 (16%)
Posterior tibial artery	6 (17%)	7 (18%)
Peroneal artery	3 (8.5%)	1 (2.5%)

and costs of treatment of residual AV-fistulae was also performed.

Patients and Methods

Patients

From May 1st 1992 to June 30th 1994, 73 patients (49 male, 24 female) in two centres were randomised to the "closed" or "open" technique, after informed consent has been obtained. The randomisation was stratified per centre and the surgeons were randomised with the patients, i.e. all of the five vascular surgeons involved in this study performed both techniques. During the embolisation procedure of a "closed" *in situ* bypass operation a surgeon experienced in this embolisation technique assisted the main operator. The study was performed with approval of the ethical committees of both hospitals. Thirty-five "closed" and 38 "open" procedures were analysed in this study. Patient characteristics, indications for operation and the locations of the distal anastomoses are shown in Tables 1–3. Risk factors were equally distributed.

Operative technique

During the "open" technique the valvulotomy procedure and the ligation of the venous tributaries were performed after exposure of the entire vein via one long skin incision. The "closed" technique as described by Wittens *et al.*[5] was used. The valvulotomy procedure was performed "blindly" with a disposable valve cutter with a variable diameter (Vavacut, Cook Europe, Denmark) and the side branches of the vein were embolised with coils via a co-axial embolisation catheter (Cook Europe, Denmark) under fluoroscopic control.

Cost analysis

Three parameters affecting cost were analysed: (1) duration of operation measured from the first skin incision to the last skin closure, (2) length of hospital stay after operation and (3) number of patients receiving treatment for residual AV-fistulae.

For calculation of the median costs of the operation and nursing care, the financial data of a subgroup of 26 patients operated on in one of the two centres (University Hospital Rotterdam) were used. Because we were interested in differences between two comparable operation techniques, only direct costs of manpower and materials were included. Cost analyses of the operation included the price per minute for personnel costs and costs of disposable materials. Cost analyses of postoperative care included the personnel costs (including doctor's fees) and costs of disposable materials per day of hospitalisation.

Mean direct costs for treatment of AV-fistulae were estimated. Mean costs of surgical ligation were based on the assumption of an average duration of the procedure of 30 min and US$ 90 costs for disposable materials. Mean costs of postoperative percutaneous coil embolisation of AV-fistulae were based on an average duration of the procedure of 120 min and US$ 320 costs for disposable materials. For both methods of treatment the direct costs per minute calculated for the "open" *in situ* bypass operation were used. All cost calculations were based on financial data of 1994 and calculated in Dutch Guilders. Conversion rate in this study: 1US$ = 1.70 Dutch Guilders.

Statistics

Possible differences were tested for statistical significance by calculation of the p-value using the

Table 4. Median cost affecting parameters duration of operation and length of hospital stay and numbers of patients treated for residual AV-fistulae after the "Closed" and "Open" techniques.

	"Closed" ($n=35$)	"Open" ($n=38$)
Duration of Operation (min) (range)	210 (105–570)	154 (90–355)
	$p<0.05$*	
Length of Hospital stay (days) (range)	16 (5–51)	25 (12–65)
	$p<0.01$*	
Residual AV-fistulae treated postoperatively	14 (40%)	2 (5%)
	$p<0.01$**	

* Mann–Whitney U-Test.
** Chi-squared test with Yates' correction.

Mann–Whitney test. For the numbers of patients treated postoperatively for residual AV-fistulae the Chi-squared test with Yates' correction was used.

Results

Cost parameters

The median duration of operation, the median length of hospital stay and the number of patients treated for residual AV-fistulae are shown in Table 4. The median duration of operation of the "closed" procedure was 56 min longer than the "open" procedure ($p<0.05$). The median length of hospital stay was 9 days less for the "closed" group ($p<0.01$). The percentage of patients treated postoperatively for residual AV-fistulae after "closed" *in situ* bypass grafting was 40% compared to 5% after "open" procedures ($p<0.01$).

Cost analysis

The personnel costs per minute operating time were US$ 2.86 for the "closed" group and US$ 2.83 for the "open" group. The mean price of disposable materials was US$ 818 for the "closed" group and US$ 185 for the "open" group. The disposable set we used for the "closed" procedure, consisting of the co-axial embolisation catheter with guide wire, 10 embolisation coils and a valvecutter (Cook Europe, Denmark), cost US$ 588. The difference in operation costs between the two groups was US$ 798 per operation in favour of the "open" technique.

The mean cost of postoperative care was US$ 296 per patient day of hospitalisation. The difference in care costs was US$ 2664 per patient in favour of the "closed" technique. The estimated direct costs of treatment of residual AV-fistulae were US$ 175 for surgical ligation and US$ 660 for percutaneous coil embolisation per procedure. In the "open" group two patients were treated surgically. In the "closed" group seven patients were treated percutaneously and seven surgically. Therefore the mean costs for AV-fistulae treatment per patient were US$ 9 in the "open" and US$ 167 in the "closed" group. Table 5 shows the median costs of the operation, postoperative care and treatment of AV-fistulae.

Table 5. Direct costs of the median patient in the "Closed" and "Open" groups (US$).

	"Closed" ($n=35$)	"Open" ($n=38$)
Operation costs	1419	621
Postoperative care costs	4736	7400
Treatment of AV-fistulae (*)	167	9
Total	6322	8030

* Estimated values.

Discussion

In this study we found a significantly shorter length of hospital stay for patients after a "closed" *in situ* bypass compared to an "open" *in situ* bypass ($p<0.01$). However the duration of the operative procedure was longer ($p<0.05$) and the number of patients treated for residual AV-fistulae larger ($p<0.01$).

The effects on the costs of different types of treatment cannot be analysed reliably by using hospital charges.[11,12] To illustrate the economic effects of these differences we calculated the direct costs of the operation and postoperative care for each group. The costs for treatment of residual AV-fistulae were estimated. Overheads were expected to be equal, therefore these indirect costs were not taken into account in this study. In our hospital the average indirect cost per bed per day on the surgical department was US$ 270 and the average cost per minute operating time was US$ 1.93. Since these costs are less than half of the total costs their influence would not essentially alter the outcome of the relative differences in costs. This study indicates that the median direct costs of the "closed" operation were US$ 798 more compared to the "open" technique, mainly due to the disposable materials and the increased duration of the operating time. The slightly higher price per operation min in the "closed" group was caused by the additional time the radiology technician was needed during the embolisation procedures. The 9 days' shorter hospital

stay in the "closed" group results in a median postoperative care cost reduction of US$ 2664. It is reasonable to assume that the shorter length of hospital stay after "closed" *in situ* bypasses was mainly caused by the lower frequency of wound complications. In both groups the length of hospital stay was relatively long due to concomitant diseases. We did not take into account additional care costs after discharge. However, it is reasonable to assume that care costs at home were also higher after "open" *in situ* bypasses since mean total wound healing time is reported to be significantly longer, namely 42 days after "open" procedures compared to 18 days after "closed" procedures.[7]

The advantages of the "closed" technique could be diminished by the costs involved with treatment of residual AV-fistulae. In this study 40% of patients required additional treatment for residual AV-fistulae. Our recent experiences, however, indicate that only 6% of patients need treatment for residual AV-fistulae after "closed" *in situ* bypass grafting.[10] If, in this study, only 6% of the patients had been treated for residual AV-fistulae instead of 40%, it would account for an even smaller percentage of the total treatment costs. We did not calculate the costs of AV-fistulae treatment, since they strongly depend on the treatment modality. One of the options, percutaneous coil embolisation as described by Kalman *et al.*,[13] is an expensive procedure with high costs depending on technique and different types of embolisation catheters and materials. Surgical ligation, however, especially when performed on an outpatient basis, is a less expensive procedure. Although we realise that estimation of costs is not exact and prone to bias, we think that we did not underestimate these costs. Moreover, the disadvantage in terms of treatment costs for AV-fistulae in the "closed" group could have been less if all AV-fistulae were treated surgically.

In conclusion we have shown that the "closed" *in situ* vein bypass technique is cost-effective compared to the standard "open" technique.

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