Chronic Haemodialysis with PTFE Arterio-Venous Grafts

K H Chia, H S Ong, M K Teoh, T T Lim, S G Tan

ABSTRACT

Background/Aim of Study: End-stage renal failure (ESRF) patients requiring long-term haemodialysis need a durable vascular access. The arterio-venous fistula (AVF) with its long patency rate and low complication profile is usually the first choice procedure for vascular access creation. However when superficial veins are not suitable for AVF creation or have all been exhausted as a result of repeated AVF procedures, arterio-venous grafts (AVG) using polytetraflouroethylene (PTFE) to bridge arteries and veins is an alternative for provision of continued vascular access for haemodialysis. This study is a review of our experience in using PTFE AVGs for vascular access in patients requiring chronic haemodialysis.

Methods and Materials: A retrospective review was done on 92 grafts in 77 patients placed by 3 vascular access surgeons at the Singapore General Hospital from January 1989 to December 1994.

Results: There were 58 female and 19 male patients with a median age of 43 years (range 15 – 76 years). Twelve patients (16%) were diabetic and 6 patients (8%) had systemic lupus erythematosis requiring long-term steroids. Seventy-three percent of patients had up to 2 previous AVF creations before placement of AVG over the forearm (64%), upper arm (23%) or thigh (6.5%). Complications include graft infection (19), pseudoaneurysm formation (10), graft thrombosis (24), steal syndrome (1), venous congestion (1) and venous end stenosis (1). Diabetic status and long-term steroid therapy did not significantly increase the incidence of graft infection. The patency rates at 24 months and 36 months were 77% and 58% respectively. However serviceability rates were 61% at 2 years and 38% at 3 years mainly due to infective complications.

Conclusion: PTFE AVGs offer reasonable patency and serviceability rates as a vascular access modality but in view of their complication profile, the native vein arteriovenous fistula should continue to be the first choice procedure for vascular access in patients requiring chronic haemodialysis.

Keywords: arterio-venous fistula, arterio-venous graft, arterio-venous bridge graft, haemodialysis, vascular access

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INTRODUCTION

The Cimino and Bresia internal wrist arterio-venous fistula (AVF)[1] is now the first choice procedure for vascular access in patients undergoing chronic haemodialysis. This involves joining the superficially located cephalic vein to the radial artery. Partial shunting of arterial blood into the cephalic vein causes it to dilate so that the dialysis nurses can cannulate the vein along the whole arm for haemodialysis. Patency rates of up to 72% at 3 years[2] is possible for these durable vascular accesses and one of the early wrist arterio-venous fistulas created by the original team lasted 22 years after more than 5000 cannulations[3]. Unfortunately, when the superficial veins are too small or have been exhausted by repeated arterio-venous fistula creations, chronic vascular access then becomes a problem.

Conduits placed superficially under the skin of the arms or legs connecting various arteries and veins to act as shunts called arterio-venous grafts (AVG) or arterio-venous "bridge" fistulas then become necessary to provide for long-term vascular access. Various materials have been used for grafts including the long saphenous vein and bovine carotid artery but they have been superceded by the polytetraflouroethylene (PTFE) graft first introduced by Gore in 1975. PTFE has been found to be pliable, resistant to aneurysm formation even after repeated punctures and poorly thrombogenic. These qualities make it an ideal material for the creation of AVGs[4].

Singapore has 479 new cases of ESRF patients every year[5] and as their life expectancy (except diabetics and those with hypertension) with chronic haemodialysis and renal transplantation has been found to be comparable with that of the general population[6], long-term vascular access is necessary to enable them to continue haemodialysis either indefinitely or until they have had a renal transplantation. Currently there are approximately 550 patients on the transplant waiting list[7].

The Department of Surgery of the Singapore General Hospital has been involved in AVG creations using PTFE as an alternative in vascular access since 1989. The aim of our study was to review our experience using this modality of access.

MATERIALS AND METHODS

One hundred and two PTFE arterio-venous grafts were placed for chronic haemodialysis at the Singapore General Hospital from January 1989 to December 1994. Of these, 92 grafts in 77 patients were available for review. All the grafts were done by 3 vascular access surgeons under general anaesthesia. AVG status was evaluated by clinical examination during follow-up visits and telephone interviews. Life table analysis and Kaplan-Meier patency curves were done using the SPSS 6.0 statistical package. The chi-square test was used to test for significant associations with $p < 0.05$ considered statistically significant.

RESULTS

There were 58 female and 19 male patients, with a female to male ratio of 3.1: 1. Twelve patients (16 %) were diabetic and 6 patients suffering from systemic lupus erythromatosis (8%) were on regular steroid therapy. Their median age was 43 years (range 15 – 76 years) and the median follow-up period was 18 months (range 0.1 – 68 months).

Seventy-three percent of patients had up to 2 previous arterio-venous fistula creations before having PTFE grafts placed in the forearm (64%) which is the most common site (Fig 1). They were mostly of the loop configuration and 6 mm diameter grafts (Table I).

Graft infection, pseudoaneurysm and blockage constituted the main bulk of complications of PTFE arterio-venous grafts (Table II). Graft infection was associated with pseudoaneurysm in 5 cases. Fig 2 shows the outcome of those with graft infection. Graft infection took place at a median time of 41 weeks (range 2.5 – 157 weeks). Of the 17 infected grafts which had to be removed, all were working except for one which was blocked at the same time. There was no statistical difference in the rate of infection between diabetics and non-diabetics (p = 0.262). The same is true also between those on steroids and those not taking steroids (p = 0.984) (Table III).

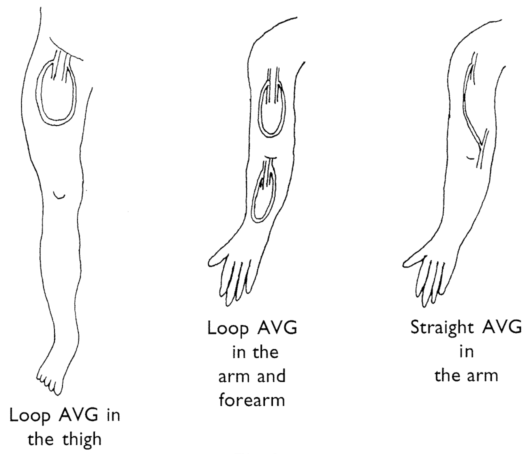


Fig 1

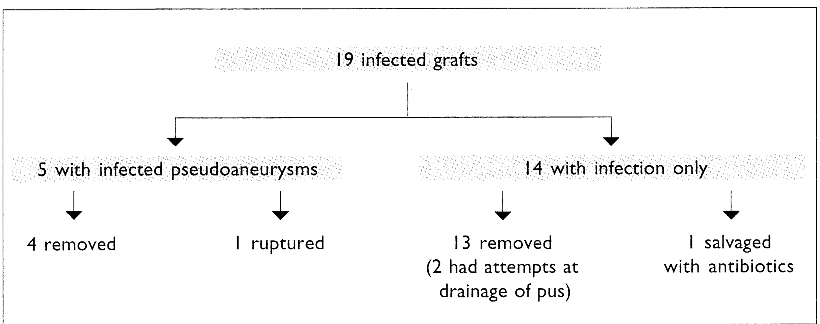


Fig 2 – Outcome of infected arterio-venous grafts

Table I – Characteristics of arterio-venous grafts and the number of prior arterio-venous fistulas before placement

No. of arterio-venous fistulas created before placing dialysis graft		**Patients No.**	**(%)**
0		8	(10)
1		32	(42)
2		24	(31)
3		8	(10)
4		4	(5)
5		1	(1)
	Total	77	(100)
Graft site		No.	(%)
Forearm		59	(64)
Upper arm		21	(23)
Thigh		6	(6.5)
Unknown		6	(6.5)
	Total	92	(100)
Graft configuration		No.	(%)
Loop		86	(93)
Straight		6	(7)
	Total	92	(100)
Graft size (mm)		No.	(%)
6		81	(88)
7		11	(12)
	Total	92	(100)

Table II – Complications of arterio-venous grafts

Complications	**No.**	**(%)**
Graft infection	19	(21)
Pseudoaneurysm	10	(11)
Blockage	24	(26)
Steal syndrome	1	(1)
Venous congestion	1	(1)
Venous end stenosis	2	(2)

Fig 3 shows the outcome of those with pseudoaneurysms. Salvage was only possible if no infection was present.

Twenty-four patients had blocked grafts. Table IV shows 11 of the blocked grafts for which no remedial measures were taken. The median time to blockage was 14.4 months. Three of them already had renal transplants. Venous causes were cited as the reason for blockage where information was available.

Table IV also shows 8 grafts which were successfully salvaged. The grafts functioned for a median time of 6.5 months before reblockage or infection.

Salvage of 5 grafts was attempted but failed (Table IV). Venous causes were again the reasons for blockage

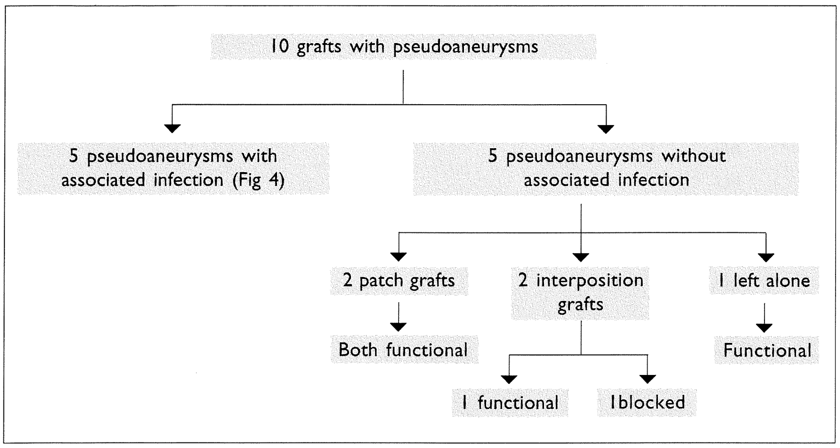


Fig 3 – Outcome of arterio-venous grafts with pseudoaneurysms

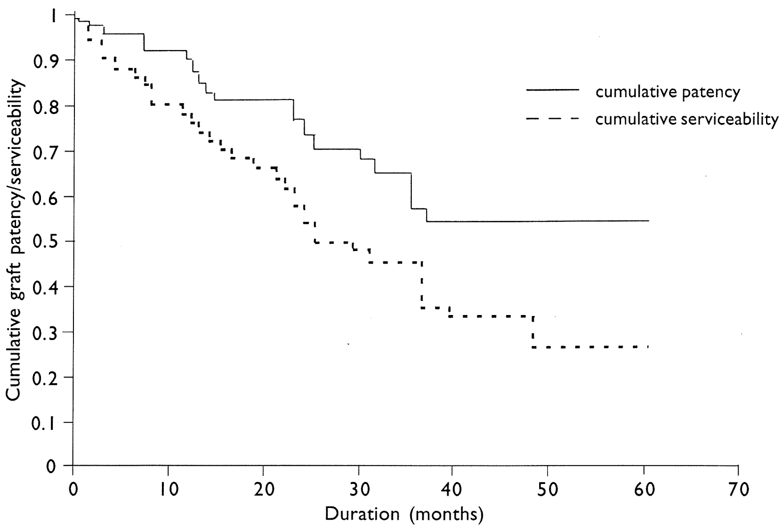


Fig 4 – Cumulative graft patency and serviceability

Table III – Relationship between infected grafts and diabetes and steroid therapy

Patients	No.		Infected grafts
Diabetic	12		5
Non-diabetic	65		14
Total	77	Total	19
On steroids	6		1
Not on steroids	71		18
Total	77	Total	19

where information was available. One patient had diseased forearm vessels and he developed a steal syndrome which required removal of his graft. Another patient had her graft removed after developing venous congestion. Both had attempts at "clipping" of the grafts to reduce the diameter of the graft but these attempts failed.

Two patients had stenoses of the graft at the venous ends which were discovered early and successful revisions were done.

Fifty-eight percent of the arterio-venous grafts were still patent at 3 years (Table V, Fig 4). Complications like graft infection and formation of pseudoaneurysms resulted in lower serviceability rates than patency rates (Table VI, Fig 4).

DISCUSSION

Wrist and elbow AVFs with their long patency rates of up to 72% at 3 years[2] and 51.2% at 4 years[8] respectively together with their low complication rates are always first choice procedures for dialysis access in ESRF patients. Our practice is consistent with this access strategy as 73% of them had up to 2 previous AVFs before embarking on AVG placement.

We favour the loop configuration as this provides the dialysis nurses with more room on each limb of the graft for cannulation compared to the straight graft. It has been reported that the patency rates for both configurations are the same though straight grafts in the forearm may require more attempts at thrombectomy to maintain secondary patency[9].

Seven millimetre grafts are easier to cannulate but their use is limited by the size of the native artery and vein available for grafting and the fact that grafts greater than 6 mm have a slower velocity and are therefore more prone to thrombosis. Most vessels however are amenable to standard 6 mm PTFE grafts even in women who presumably have smaller superficial veins or have adequate veins embedded in their thicker subcutaneous fat, form 63% of our graft recipients.

Graft infection is the "Achilles heel" of vascular access surgery[10]. Twenty-one percent of our grafts eventually were infected at a median time of 41 weeks. This points to secondary infection as the main causative factor as these grafts are already being used for dialysis. Renal patients are usually to some extent immunocompromised with defective polymorphornuclear granulocyte function, monocyte activity and cell mediated immunity. Uraemia has been called "nature's immunosuppressant."[11]. As many as 60% to 70% of dialysis patients are nasal carriers[12] of *Staphylococcus aureus* and with regular cannulation of up to three times a week for dialysis, this provides ample opportunity for ingress of organisms. Cannulation sepsis is reported to be twice as common as sepsis originating from the original procedure[13]. *Staphylococcus aureus* is the principal organism involved resulting in redness, swelling and pain over the graft as well as fever and leucocytosis.

When the entire graft is infected, it has to be removed completely in order to eradicate the sepsis. Salvage of up to 60% of locally infected grafts (infection confined to one part of the graft only) has been reported[14,15] involving drainage of pus, partial removal of the infected segment of the graft and interposition of a new piece of graft in uninfected tissue. However our experience with conservative treatment has been disappointing with all but one graft requiring complete removal.

When the infection is associated with a false aneurysm (a pulsating haematoma due to a leak from the anastomosis or the puncture site) (Figs 5a & 5b), total removal of the graft is undertaken as an

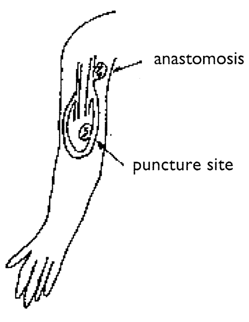
Table IV – Blocked grafts and outcome after intervention

Patient	Graft patency	Cause of blockage	Operation	Secondary patency	Outcome
1	3 yrs 10 mths	---	Nil		
2	1 yr 10 mths	---	Nil		
3	1 yr 11 mths	---	Nil		
4	0 yrs 7 mths	Innominate stenosis	Nil		
5	0 yrs 2 mths	---	Nil		
6	2 yrs 1 mth	Venous stenosis	Nil		
7	2 yrs 7 mths	---	Nil		
8	2 yrs 5 mths	---	Nil		
9	1 yr 3 mths	---	Nil		
10	0 yrs 1 mth	Venous thrombosis	Nil		
11	3 yrs 0 mths	Innominate stenosis	Nil		
12	0 yrs 9 mths	Venous stenosis	Thrombectomy/Vein patch	Failed	
13	0 yrs 3 mths	---	Thrombectomy	Failed	
14	2 yrs 3 mths	Venous stenosis	Thrombectomy/Vein patch	Failed	
15	1 yr 5 mths	Venous stenosis	Thrombectomy/Vein patch	Failed	
16	0 yrs 1 mth	Poor vein	Thrombectomy	Failed	
17	1 yr 6 mths	Venous stenosis	Thrombectomy/Vein patch	0 yrs 9 mths	Infection – removed
18	0 yrs 1 mth	---	Thrombectomy	0 yrs 1mth	Infection – removed
19	0 yrs 2 mths	---	Thrombectomy	3 yrs 0 mths	Blocked
20	1 yr 2 mths	---	Thrombectomy x 3	0 yrs 2 mths	Infection – removed
21	0 yrs 2 mths	---	Thrombectomy	1 yr 11 mths	Blocked
22	0 yrs 9 mths	---	Thrombectomy	0 yrs 4 mths	Blocked
23	2 days	---	Thrombectomy	0 yrs 11 mths	Blocked
24	0 yrs 7 mths	Venous stenosis	Thrombectomy/Interposition graft	0 yrs 1 mth	Blocked

Patient numbers 6, 8 and 9 had renal transplantation done

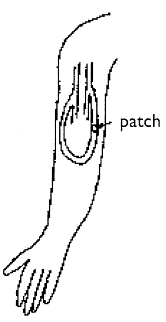
--- Information not available

Fig 5a – False aneurysm.



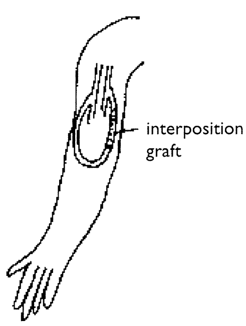
False aneurysm at anastomosis and puncture site

Fig 5b



Patch repair of false aneurysm

Fig 5c



Interposition graft repair of false aneurysm

Fig 5d

emergency procedure as the infected pseudoaneurysms can rupture, as it did occur in one patient (Fig 2). The anastomotic leak is usually caused by infection weakening the suture lines while the puncture site pseudoaneurysm usually starts off as a defect in the graft already weakened from multiple punctures which eventually becomes infected.

Diabetics tend to have more infective complications (Table III) though this is not statistically significant when compared with non-diabetics and other authors also report similar results. Our patients on steroids were not more predisposed to infection though the numbers involved may be small.

Meticulous attention to aseptic cannulation with rotation of the puncture sites is important to prevent graft infections. Of the 17 infected grafts which had to be removed, all were functioning except one, which is an important cause of loss of serviceability of AVGs (Fig 4).

Pseudoaneurysms without infection were mainly those with defects in the grafts from same-spot cannulation punctures. If the skin is not stretched thin and blue, it is sometimes possible to continue to use the graft taking care to avoid puncturing the pseudoaneurysm though close monitoring is required. One patient was left alone for this reason. Patch grafting and interposition graft with PTFE were done in 4 cases with one failure (Fig 3 and Figs 5c, 5d).

Steal syndrome occurs when AVGs are placed in patients who already have diseased arteries with compromised inflow. The shunting of blood through the AVG results in inadequate perfusion to the extremity which is manifested by coolness, numbness, weakness and ischaemic pain especially on dialysis. Therefore a limb with poorly felt peripheral pulses should not be grafted. In our one patient presenting with a steal syndrome, clip narrowing of the graft lumen failed to resolve his symptoms and his graft had to be removed.

Venous congestion after AVG creation occurs when there is an undetected stenosis or occlusion of the proximal veins. These lesions are usually caused by previous placement of temporary dialysis catheters into the subclavian vein. The proximal venous obstruction result in decreased venous return causing arm swelling, pain and skin changes much like that of venous insufficiency of the leg. Angioplasty with or without stenting the procedure of choice. Surgical subclavian to subclavian venous bypass is necessary when angioplasty fails. One of our patients developed severe venous congestion which required removal of the AVG. Some authors have recommended pre-operative imaging of the proximal veins to exclude venous stenosis especially if there is a history of insertion of dialysis catheters into the subclavian vein in order to avoid this complication[17].

Graft thrombosis can be early (less than 30 days) or late (more than 30 days). Early thrombosis after surgery is due to poor technique or small veins. Late thrombosis during follow-up is due to stenosis in the vein proximal to the graft, excessive pressure on the puncture site after dialysis, hypotension after dialysis or intimal hyperplasia (narrowing of the venous anastomosis due to deposition of fibrous tissue and smooth muscle cells as a result of turbulent flow). Loss of "thrill" over the graft is the usual presenting feature.

No reasons were given for not attempting thrombectomy in eleven patients (Table IV, Patient number 1 to 11). Three patients had kidney transplants and perhaps unblocking of the grafts was deemed unnecessary. Thrombectomy is done with a Fogarty size 3 or 4 balloon catheter under local anaesthesia (Fig 6a) to try to unblock the graft. Thrombectomy alone may be sufficient but as the causative factor in late cases is usually stenosis of the venous anastomosis (Fig 6b), patching with PTFE (Fig 6c) or interposition grafting (Fig 6d) can be done. Salvage procedures failed in five patients (Table IV, patient number 12 to 16). Three had vein patching done which failed possibly from technical factors. Two had thrombectomy which failed. One may have an underlying cause as yet undetected and the other had a small vein which could not sustain adequate graft flow. Eight patients had successful salvage procedures (Table IV, patient number 17 to 24) Five more grafts blocked after a period ranging from 1 month to 3 years (Table IV, patient number 19, 21 to 24). Though nothing more was done, reports[18] indicate that repeated salvage procedures can prolong graft life and preserve other sites for future access. PTFE grafts are unique in that, unlike vein, they are very amenable to unblocking procedures.

When the venous anastomosis is stenosed due to intimal hyperplasia (Fig 6b), high venous pressure in the returning cannula during dialysis can be an early warning sign of impending graft thrombosis. Timely revision procedures like patch-grafting (Fig 6c) or interposition grafting (Fig 6d) can obviate a thrombotic episode as was done in 2 of our patients with success.

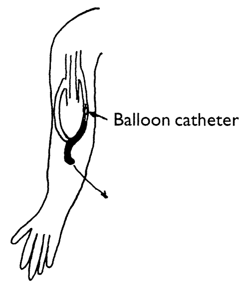


Fig 6a – Thrombectomy.

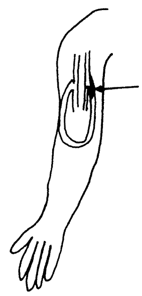


Fig 6b – Venous end stenosis.

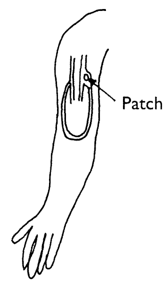


Fig 6c – Patch repair of venous end stenosis.

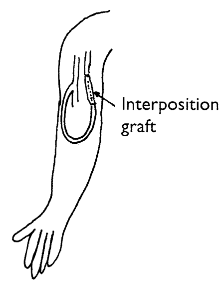


Fig 6d – Interposition graft repair of venous end stenosis.

Table V – Life table of cumulative patency over time

Interval (months)	No. at risk at the beginning of interval	No. falied during interval	No. withdrawn during interval	Interval failure rate	Cumulative patency rate	Standard error
0 – 6	92	5	11	0.0578	94.2%	2.51%
6 – 12	76	2	13	0.0288	91.5%	3.08%
12 – 18	61	6	11	0.1081	81.6%	4.7%
18 – 24	44	1	11	0.026	79.5%	5.0%
24 – 30	32	4	6	0.1379	68.5%	6.69%
30 – 36	22	2	5	0.1026	61.5%	7.63%
36 – 42	15	2	5	0.1600	51.6%	9.04%
42 – 48	8	0	3	0.000	51.6%	9.04%
48 – 54	5	0	2	0.000	51.6%	9.04%
54 – 60	3	0	2	0.000	51.6%	9.04%

Table VI – Life table of cumulative serviceability over time

Interval (months)	No. at risk at the beginning of interval	No. falied during interval	No. withdrawn during interval	Interval failure rate	Cumulative serviceability rate	Standard error
0 – 6	92	13	3	0.1436	85.6%	3.69%
6 – 12	76	5	10	0.0704	79.6%	4.3%
12 – 18	61	9	8	0.1579	67.0%	5.28%
18 – 24	44	3	9	0.0759	61.9%	5.64%
24 – 30	32	5	5	0.1695	51.5%	6.34%
30 – 36	22	2	5	0.1026	46.1%	6.7%
36 – 42	15	4	3	0.2963	32.5%	7.43%
42 – 48	8	1	2	0.1429	27.85%	7.68%
48 – 54	5	0	2	0.0000	27.85%	7.68%
54 – 60	1	0	1	0.0000	27.85%	7.68%

The cumulative primary patency of 77% at 2 years and 58% at 3 years (Table V, Fig 4) is comparable with other reported series[19,20,21]. No cumulative secondary patency rates (patency after procedures were done to salvage blocked grafts) were calculated as many of the blocked grafts were not salvaged.

CONCLUSION

AVG using PTFE offers vascular access with reasonable serviceability rates of 61% at 2 years and 38% at 3 years (Table VI, Fig 4). Graft failure is mainly due to infection and blockage.

We recommend meticulous care to prevent secondary infection during cannulation of the grafts. Constant vigilance by the dialysis staff and improved patient education may help to identify potential problems in the graft before it is blocked. Graft revision may then be undertaken accordingly. When thrombosis has occurred, the underlying cause should be established and rectified in order to maintain secondary patency and prolong the usage of the graft.

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