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Analysis of Complications in Digital Vein Grafts

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Summary. Between 1975 and 1978, 49 interpositional vein grafts were used for vascular repair in replantations and compound hand injuries as well as for toe-to-thumb transfer (1 case). Of these, 34 were employed on primary management. Indications and operative techniques are discussed. Cases with incidents causing cessation of blood flow and requiring re-operation are analyzed.

Key words: Microvascular surgery – Replantation surgery – Vein grafts – Hand injury – Haemodynamics.

Excellent suture technique, undamaged vessel ends and absence of tension at the suture site are of capital importance for the patency of microvascular anastomoses.

Crush or avulsion injuries generate traction and shearing forces which cause extensive damage to the severed vessel proximal and distal to the site of rupture. When attempts are made to re-unite such vessels, thrombosis usually develops either intra-operatively or in the immediate postoperative period. Satisfactory anastomosis after adequate debridement of the vessel is only obtained by bone shortening or autologous interpositional vein grafts.

In extensive vascular injuries of the hand bone shortening is limited by functional considerations. Bridging of defects with a neurovascular pedicle from an other digit [8] is confined to exceptional cases, i.e. to single-digit injuries.

Interpositional vein grafts are beneficial both on primary management of crush or avulsion injuries and on secondary intervention for restoring the patency of thrombosed vessels by microvascular surgery [6]. In free tissue grafting interpositional vein grafts are rarely indicated.

At the Plastic and Reconstructive Surgery Service, Department of Surgery I, University of Vienna Medical School, 20 patients underwent interposition of autologous vein grafts between 1975 and 1978. We shall discuss and analyze clinical material, operative technique, the results, the complications, and the corrective measures required.

Clinical Material

Of the 130 patients referred to the replantation service since 1974, 19 received interpositional vein grafts. In one case a toe-to-thumb transfer was performed for thumb repair. 10 Patients required

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replantation of 11 amputated parts. Vein grafts were placed in 2 cases when secondary surgery was required for thrombosed primary repairs. Severe compound injuries of the hand or imcomplete amputation were present in 7 cases. Autologous veins were used to bridge arterial defects in 27 cases (19 on primary management, 8 on secondary surgery) and venous defects in 22 (15 on primary management, 7 on secondary surgery), (Table 1).

Patient age was 8 to 60 years (mean age: 22 years). Of our material 16 were males and 4 females. Circular saw injuries were most common, accounting for 13 cases. These were followed by avulsion injuries [4]. Smooth or tidy amputations due to chopping and punching injuries required bridging of vascular defects in 3 cases.

The localization of the injuries and the amputation levels are shown in Table 2.

On primary management, interpositional vein grafts had a length of 5 to 40 mm (mean, 23 mm) and 10 to 60 mm (mean, 31 mm) for arterial and venous repair, respectively. On secondary surgery considerably longer vein grafts were required, i.e. 18 to 100 mm (mean, 58 mm) for arterial and 20 to 80 mm (mean, 45 mm) for venous defects.

Operative Technique

The vessels are liberally dissected in the amputated part and the residual stump or the severely damaged hand and inspected. Adventitial bleeding or intramural hematomas at sites distant from the rupture are due to shearing or traction forces. Since there are generally associated intimal lesions, vascular segments thus affected are resected.

Once the bone has been stabilized and the severed tendons have been sutured, the vascular defect is measured. Veins with a diameter of 1 to 2 mm are available both on the volar aspect of the forearm and on the dorsum of the foot. For bridging venous defects the interpositional vein graft should have approximately the same diameter as the vessel to be repaired. In arterial defects the vein graft diameter should be two-thirds that of the arterial diameter, as some dilatation is likely to occur on account of intra-arterial pressure.

Venous grafts are taken under normal blood flow conditions. A skin incision is made over the entire length of vein required. Multiple transverse incisions were not found to be helpful, as the veins are quite easily damaged on subcutaneous dissection. Lateral branches are ligated close to the graft and bisected. Bipolar coagulation may be used for this purpose in interpositional grafts designed for venous repair.

Unlike Büchler [3] we strip the vein of adjacent fatty and connective tissue. The adventitia is left in place, since Wyatt [17] showed the vasa vasorum ensure early revascularization of interpositional vein grafts. Once the vein has been stripped, it is clamped distally and irrigated centripetally with Ringer's solution containing 10% heparin to remove the blood. Then the requisite graft length is delineated. Before removing the graft the proximal and distal ends are tagged anteriorly with sutures of different color to prevent twisting of the graft and to indicate the direction of flow through the graft.

On arterial reconstruction vein grafts are oriented with the valves facing in the direction of flow. Rotation of grafts with the valves facing in the counterflow direction, as recommended by Miller in 1976 [14], did not give satisfactory results in our hands. In extensive defects the central and peripheral stumps generally are of different caliber. This can be compensated by end-to-side anastomosis or by "graft splitting" (Fig. 1).

In severe compound injuries of the hand more than one volar digital artery may be severed. These multiple defects may be bridged by a single vein graft

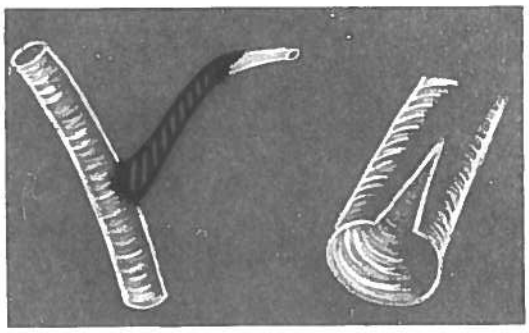

Fig. 1. "Splitting of graft" to compensate for caliber difference

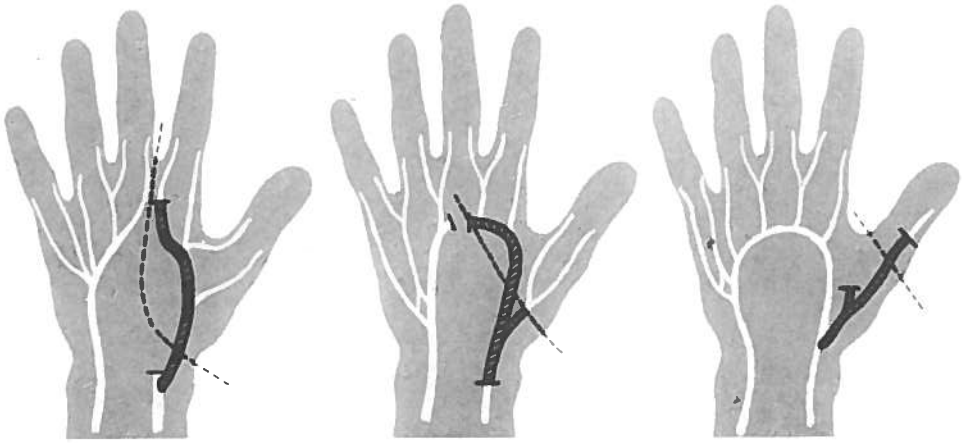

Fig. 2. Examples of long vein graft (---- amputation level)

(Fig. 2) with the distal arterial stumps anastomosed end-to-side to the interpositional graft or the lateral venous branches anastomosed end-to-end to the digital artery stumps.

Postoperatively, patients are given low molecular weight dextran up to a maximum dose of 500 ml b.i.d. for 7 days, depending on their age and body weight.

Results of Autologous Vein Grafting

Table 1. *Occlusion Rates*

Total material:	49:10=20%	
	27 veno-arterial anastomoses	7=26%
	22 veno-venous anastomoses	3=14%
Primary management:		
	19 veno-arterial anastomoses	5=26%
	15 veno-venous anastomoses	3=20%
Secondary surgery:		
	8 veno-arterial anastomoses	2=25%
	7 veno-venous anastomoses	0= 0%
Re-Amputations	One of 22 cases	= 4,5%

Cases requiring secondary surgery after venous grafting merit a detailed analysis.

Table 2

Amputations – Replantations

No.	Pat.	Age	Sex	Injury by	Amput. level	Vein graft art. [mm]	Vein graft vein [mm]	Thrombosis
Primary management with autologous vein grafts								
1	H.K.	48	♂	circular saw	U.E.r./II/PIP		25	
2	K.R.	66	♂	circular saw	l./I/MCP		30	
3	K.J.	16	♂	circular saw	r./III/Ph2	18 25	20 15	×
4	H.K.	34	♂	circular saw	r./III/Ph2	20	35	
5	D.R.	18	♂	circular saw	r./III/Ph1	8 18	10	
6	H.H.	40	♂	circular saw	r./FA/3/3		30 40 40	
7	M.K.	20	♂	cutting-off wheel	r./II/PIP	22	18	
8	S.O.	13	♂	gear shaft avulsion	r./I/Ph1	30		×
9	K.D.	29	♀	reigus avulsion	r./I/MCP		28	
10	S.M.	19	♂	punching tool	r./wrist	40	30 50 60	
					l./wrist	35	40	×
Primary management with direct repair (vessel-suture)								
11	H.M.	16	♂	circular saw	l./I/IP			×
12	M.J.	20	♂	circular saw	l./III/PIP			×
Severe compound hand injuries or incomplete amputations								
Primary management with autologous vein grafts								
13	U.M.	16	♀	meat tenderizer	r./I/Ph1	30 35		
14	K.R.	60	♀	circular saw	l./II/Ph1	35		
15	M.F.	42	♂	circular saw	l./I/MCP	20		
					l./IV/MCP	20		
16	W.H.	26	♂	circular saw	l./III/Ph1	40		
17	G.H.	18	♂	circular saw	r./II/PIP	5		
18	S.E.	38	♂	ax	l./I/MCP	10		
19	R.R.	8	♀	spade	L.E.l./I/MCP	8		
Free tissue grafting – toe-to-thumb transfer								
Primary management with autologous vein grafts								
20	H.K.	20	♂	circular saw	U.E.r./I/MCP 2nd toe left	20		×

Re-operation with autologous vein graft								
1st re-operation, time after prim. management	Interpos. vein graft v-a, [mm]	Interpos. vein graft v-v, [mm]	Thrombosis	2nd re-operation	v-a / v-v [mm]		Thrombectomy	Re-amputation
24 h	30	30						
16 h	80	35	×/a	7 days			×	×
stat.	70 50	60 70 80						
24 h 24 h	18	20	×/v	24 h	20	25		
stat.	100		×/a	stat.	100			

Incidents and Pertinent Corrective Measures

Case 3. A 16-year-old high school student sustained injuries to the right hand while using a circular saw. These consisted of incomplete amputation of the index and complete amputation of the middle fingers. After primary management of the index finger the middle finger, which was severely crushed, was replanted on express request of the patient. After debriding the vessels back to normal-appearing vascular tissue 2 arteries and 2 veins were bridged with autologous vein grafts. Eighteen hours after surgery massive bleeding developed on the volar aspect of the middle finger which necessitated prompt re-exploration. This revealed a hematoma extending dorsally and a defect in the interpositional graft bridging the radial digital artery at the site of thrombosis. Apparently the thrombosed graft site failed to withstand the intra-arterial pressure so that bleeding ensued. The heamtoma was evacuated, all of the 4 vein grafts were resected and a vein and artery were bridged with new autologous vein grafts. The postoperative course was uneventful (Fig. 3).

Case 8. A 13-year-old male sustained an avulsion injury of the right thumb, which was caught in the gear shaft of a truck. Replantation was done by using a 3 cm interpositional vein graft for bridging the arterial defect. Initially pulsations and capillary filling were adequate, but deteriorated gradually to the point of complete arterial occlusion. On re-operation 16 h later the princeps pollicis artery was found to be thrombosed. Minor intimal lesions due to the avulsion injury had presumably given rise to appositional thrombus formation in the postoperative period. As the proximal end of the damage was not unequivocally identifiable, an 8 cm interpositional vein graft was anastomosed side-to-end with the radial artery at the wrist. Distally the graft was "split" and sutured end-to-end to the princeps pollicis artery. Arterial flow was excellent, but drainage through the vein repaired on primary management was inadequate so that interposition of a graft proved to be necessary. The postoperative course was initially uneventful. But on day 7 after re-operation the patient developed acute thrombosis in the arterial vessel. The day before, the plaster splint had been removed when changing the dressing, and the following night the hand had inadvertantly been left without immobilization so that, while the patient slept, the thumb was compressed by the head with resultant occlusion of the vessel. Thrombectomy which was attempted in the morning proved to be unsuccessful and the thumb had to be re-amputated (Fig. 4).

Case 10. A 19-year-old male sustained amputation of both hands at the level of the wrist while working with a punching tool. While the right hand was successfully replanted, the left had to be immediately re-explored because interposition of venous grafts for repairing the superficial palmar arch and a dorsal vein failed to produce adequate blood flow. The underlying cause apparently was incomplete thrombectomy in the proximal stump. The graft was resected, thrombectomy was carried far towards proximal and the radial and ulnar arteries were re-united with the 2 palmar arches by interposing a 50 mm and a 70 mm vein graft. In addition, 3 dorsal veins were reconstructed. The postoperative course was uncomplicated.

Case 12. A 20-year-old male sustained an amputation of the left middle finger. Replantation was done by direct vascular repair. 24 h after surgery capillary filling ceased. On exploration the arterial repair which had been sutured with slight tension was found to have thrombosed and the anastomotic site was resected. The defect left by the resection was bridged by an autologous vein graft. Another 24 h later there was suddenly evidence of considerable venous stasis, which failed to improve on exteme elevation of the left arm. On re-operation the venous anastomosis was found to be thrombosed so that it had to be resected; the resultant defect was repaired by interposing a vein graft. The second digital artery was reconstructed at the same time. The cause underlying the late venous thrombosis such as was present in this case was unidentified.

Case 20. A 20-year-old male lost his left thumb at the proximal third of the metacarpal bone while working with a circular saw. Primary management of the stump was done elsewhere and the patient was referred to us for reconstruction of the thumb. The second toe of the left foot was used for thumb reconstruction and the missing metacarpal bone was replaced by an iliac crest graft. Since arterial revascularization was established with a plantar phalangeal artery which was distal to the perforating dorsal branch, primary vein grafting was required for adequate length. Despite fully patent anastomoses phalangeal blood flow was inadequate. This prompted resection

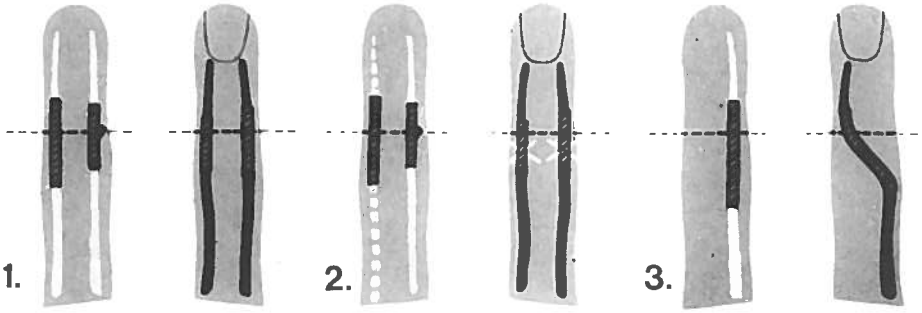

Fig. 3. 16-year-old male, r. 3rd finger – amputation level, 2nd phalanx. 1. Replantation, 2. Complication: thrombosis and bleeding. 3. Re-operation

Replantation – Primary Management:

Vein graft (30 mm) — A.

End-to-end anastomosis/vein

Re-exploration:

16 h after replantation
for thrombosis

rad. art.: side-to-end
uln. thumb art.: end-to-end

"Long" interpositional vein graft (80 mm)

rad. thumb vein: end-to-end
uln. thumb vein graft (35 mm)
and transposition of 2nd digital vein

Fig. 4. 13-year-old male, r. thumb – amputation level, 1st phalanx

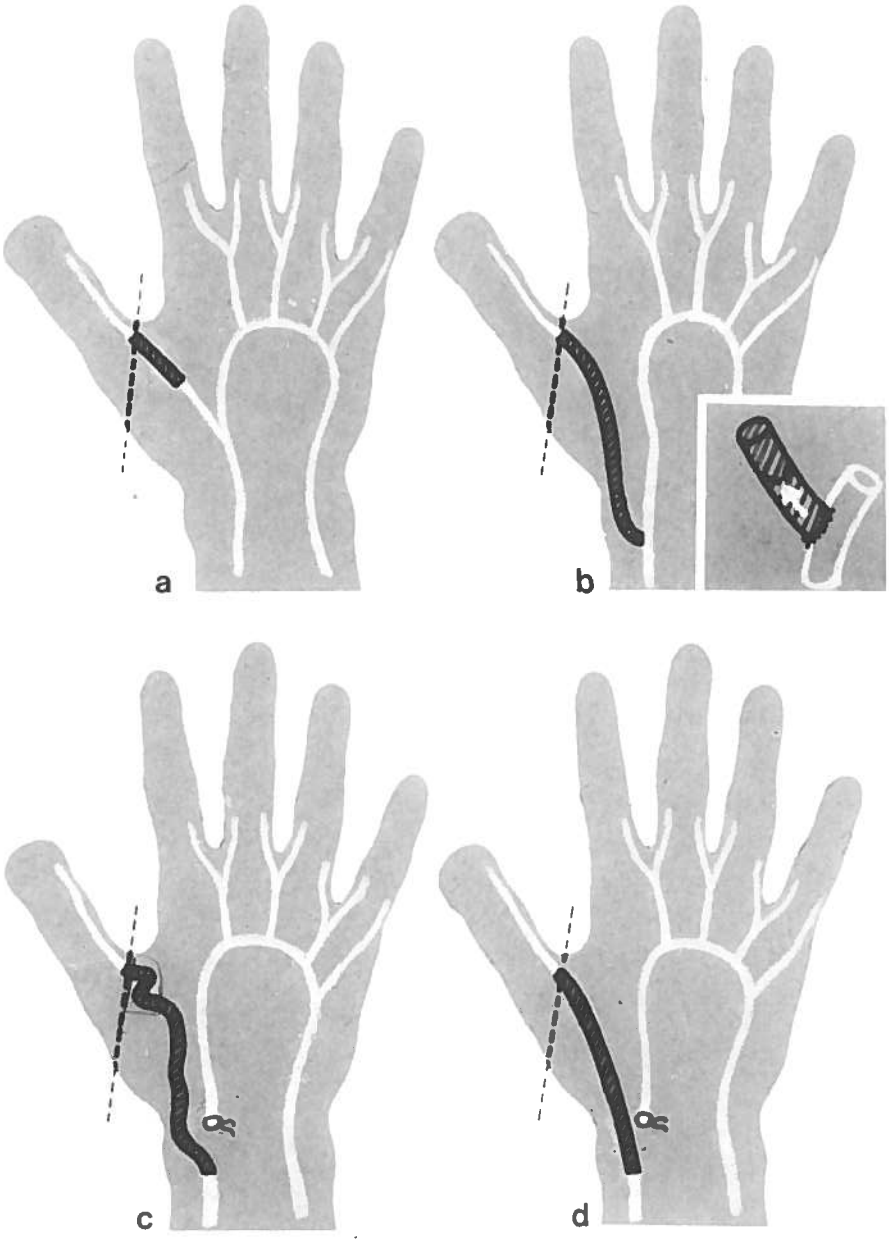

Fig. 5a–d. 20-year-old male, toe-to-thumb transfer, left 2nd toe to repair thumb. **a** 20 mm interposed vein graft poor flow. **b** 1st Reexploration – Stat.: "long" vein graft between rad. art. (side-to-end) "orthograde". **c** 2nd Re-exploration – Stat.: redundant vein — "kinking". **d** 3rd Re-exploration: ultimate condition 100 mm interpositional vein graft

of the interposed vein graft and retrograde catheterization. As satisfactory flow from the proximal stump was consistently absent, extensive damage to the princeps pollicis artery at the time of the primary injury was thought to be the underlying factor. For this reason the radial artery was exposed at the wrist and a 10 cm vein graft was put in place to bridge the defect. Orientation of the graft with the valves facing in the reverse direction and failure to force the valves open necessitated sacrificing of the graft and another intra-operative exploration. Circulation was reconstituted with a new vein graft which proved to be redundant when removing the clamps so that kinking occurred. The kinked segment was resected and a new anastomosis was made distally. The postoperative course was uneventful (Fig. 5).

Discussion

Autologous vein grafts were first successfully used for vessel repair by Ćarrel and Ǵuthrie in 1906 [5]. In spite of excellent long-term results [12] the technique was rarely used for a considerable time. Not before alloplastic vessel grafts in peripheral arteries of the limbs were found to be associated with an extremely high failure rate [7, 13] did autologous vein grafting gain general acceptance. The major break-through was made between 1959 and 1962. With the advent of microvascular surgery the scope of vein grafting was extended to include small vessels [4, 9, 11, 18]. With the use of elegant microsurgical techniques the patency rates of interpositional vein grafts obtained in rabbit and rat experiments were quite outstanding.

Due to the different clotting parameters of these experimental species, the results can not be extrapolated to man.

Both experimentally and in clinical follow-up studies arterial repairs were found to be associated with a higher patency rate than reconstruction of venous defects [2, 9]. While this may be due to the higher flow rates in arteries versus veins, veno-venous anastomoses require greater operative skills on account of the delicacy of the vessel walls which tend to tear easily. In the author's experience careful, non-traumatizing dissection of vein material for grafting is capital [15].

In amputations with extensive crushing, interposition of autologous vein grafts constitutes a true alternative to bone shortening. In avulsion amputations it is the only promising treatment [16], as we have shown in 3 cases. Similarly, severe compound injuries of the hand or incomplete amputations with extensive vascular damage should be repaired by interpositional vein grafts on primary management [1]. Some tension can, at times, not be avoided when reuniting severed vessels in incomplete digital amputations.

To obviate time-consuming vessel grafting we transsected the residual skin, shortened the bone and united vessels without tension in some of these cases. Functional flow measurements [10] showed the spontaneous adaptability of vessels in completely amputated digits to be significantly poorer than in incomplete digital amputations. This would appear to imply that tissue bridges and their innervating fibers play an important role in the normal regulation of blood flow. Consequently, vessel repair should be done by vein grafting, despite the longer time required, rather than by completely severing what originally was an incompletely amputated digit. Re-operations can be minimized by routine interposition of vein grafts in experimental microvascular surgery

and by paying close attention to technical factors, i.e. non-traumatic excision of grafting material, tagging of long grafts to prevent rotation, correct orientation of valves and meticulous postoperative monitoring. If re-operations are unavoidable, they should be done as soon and as radically as possible. Successful revascularization may, at times, require grafts of considerable length.

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