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Acute Intraoperative Arterial Elongation: an Experimental Study

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Objectives: *small arterial defects resulting from either trauma or resection of an aneurysm often present difficult problems to the vascular surgeon.*
Design: *to demonstrate that certain arterial gaps as a result of traumatic injury or aneurysm resection could be closed with acute intraoperative arterial elongation.*
Materials: *fifteen mongrel dogs underwent acute intraoperative arterial elongation of the right superficial femoral artery, with the left side used for a control vessel.*
Methods: *arterial defects created surgically (median 50 (range 25 to 60 mm) mm). Appropriate length of artery was then undermined. A Foley catheter was placed proximally and distally directly beneath this undermined portion of vessel. The vessel is lengthened following 3 expansion/relaxation cycle of Foley catheter. Arterial gaps were closed by end to end anastomosis. Arterial pressure study was performed in all vessels.*
Results: *acutely, arterial pressure differences proximal and distal to the anastomosis were seen only when arterial gaps were exceeded 55 mm. There was no occlusion either acutely or after 4 weeks follow-up period. Light microscopic examination of arterial specimens revealed partial disruption of internal elastic lamina. At the end of the follow-up period, formation of neointima with regeneration of the internal elastic lamina was demonstrated. Scanning electron microscopy revealed minimal endothelial denudation.*
Conclusions: *we believe that, acute intraoperative elongation can be used as an alternative technique to vein grafting for the repair of small traumatic arterial defects in selected cases.*

Key Words: Arterial trauma; Arterial defect; Arterial elongation.

Introduction

Arterial defects occur most commonly because of either trauma or resection of an aneurysm. They often present difficult problems to the vascular surgeon. Performing a tension-free direct anastomosis is often difficult as injured arteries tend to retract. Despite mobilising the artery by dividing branches, a tension-free anastomosis cannot always be achieved. With extensive (5 cm) mobilisation, we were able to overcome defects up to 2 cm in a canine model. Autologous lower extremity vein represents the best option.[1] But, vein grafts demand a second incision for their harvest and the performance of two anastomose. Also some technical problems must be addressed; such as lumen size discrepancy, vein length and the possible presence of venous valves. Moreover in some patients, focal or diffuse hyperplastic lesions of saphenous vein grafts result graft failure.[2] Tissue expansion, primarily used on skin and subcutaneous tissues, plays a major role in reconstructive plastic surgery. It has been shown that blood vessels can also be elongated over a period of weeks using this same basic approach.[3] Also, some plastic surgeons successfully performed the acute intraoperative arterial elongation (AIAE) by using special miniature tissue expanders.[4]

In this study we wanted to show the feasibility of AIAE as an adjunctive method to overcome large defects and to demonstrate that a simple Foley catheter can be used for AIAE.

Materials and Methods

Acute intraoperative arterial elongation of the right superficial femoral artery has been performed in 15 mongrel dogs (20–30 kg) and the left side was used as a control. The investigation conforms to the principles outlined in the Declaration of Helsinki.[5] Ege University Medical Faculty Ethic Committee approved the procedure.

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Fig. 1. A Foley catheter is placed beneath the undermined segment of artery and inflated to stretch the vessel.

The dogs were sedated with IM 1.1 mg/kg of xylazine and 10 mg/kg ketamine hydrochloride. The dose of 15 mg/kg thiopental sodium was given through the IV route as a drip in 0.9% NaCl during the operations. ECG, oxygen saturation and arterial pressure were continuously monitored. Antibiotic prophylaxis was performed with 100 mg/kg cephalexin. All dogs were heparinised in a dose of 100 U/kg before the AIAE. After the AIAE, heparin was neutralised in the ratio of 1/1.3 with protamine.

Surgical technique

Approximately 12–15 cm of femoral artery was exposed. Arterial resections were performed surgically ranging from 25 to 60 mm (median 50 mm). A short segment of artery was left attached to the underlying connective tissue both proximally and distally, to anchor the vessel during expansion. An appropriate length of artery was undermined. All collaterals were divided. A 16 Ch Foley catheter was placed directly beneath this undermined portion of the artery. Foley catheter was inflated until the vessel was tightly stretched across it. This expansion was maintained for 2 min. The catheter was deflated for 1 min. Two additional stretch-relaxation cycles were performed. The aim was to stretch the artery maximally without tearing it. Expansion time was 4 and 6 min respectively and relaxation time was 1 min. With each subsequent cycle, the expansion volume of the Foley catheter was increased ((1) cycle 20 cc, (2) cycle 30 cc, (3) cycle 40 cc). This method was applied to the both sides of the arterial defects (Fig. 1). Following elongation, the attached short segment was then freed. Tension-free end to end anastomosis was performed by using two separate 7/0 polypropylene suture materials. Arterial pressure recordings were done in elongated vessels at both proximal and distal to the anastomosis in acute and long term, controlateral femoral artery blood pressure was used as reference. Doppler examination was performed, immediately after surgery, first postoperative day and subsequently every week until the end of the follow-up period. All dogs were reoperated after 4 weeks.

Histopathologic analysis

Arterial specimens were obtained immediately after elongation and at the termination of the follow-up period for light and scanning electron microscopy. For light microscopic examination, the specimens were fixed with buffered 10% formalin, embedded in paraffin, cut into 5-μm-thick sections, and stained with haematoxylin-eosin and Verhoeff–Van Gieson. Samples were examined and photomicrographs made with a Olympus BH2 light microscopy.

Arterial rings for scanning electron microscopy were washed in PSS and fixed with 5% glutaraldehyde in 0.2 mol/L sodium cacodylate-buffered saline solution, dehydrated in a graded series of ethyl alcohol, and dried in CO_2 at the critical point. Then they were fixed by means of Leit C, coated with gold. Samples were examined and photomicrographs made with a JEOL JSM 5200 scanning electron microscopy.

Results

We progressively resected longer lengths of vessel until we ascertained the maximum gap that could overcome with the vessel elongation. Vessel resections up to 60 mm still allowed comfortable direct end-to-end anastomosis. The arterial gaps were closed using end to end anastomosis. Arterial pressure differences were seen in four dogs in the acute term. In these dogs (nos 8, 9, 10 and 12, Table 1), resected arterial segments were too long and recoil of the vessels also lengthened the gaps. An anastomosis was performed under minimal tension in these dogs. These pressure differences disappeared at the end of the follow-up period (Table 1).

The patency rate in the elongated vessel was 100% in the short term and over a 4 week period. There was no luminal narrowing at the anastomotic size, even in the dogs which exhibited pressure differences in the short term. No aneurysms or other complications were noted. Under light microscopic examination, elongated segments harvested immediately after expansion

Table 1. Summary of experimental study.

Dogs	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Arterial resection (mm)	25	30	45	35	40	45	50	55	60	60	50	55	50	50	50
A	93	85	96	98	97	78	89	55	60	64	79	58	87	79	96
B	94	85	97	98	96	78	87	78	99	85	79	84	87	78	96
A1	88	90	88	76	68	89	78	76	80	76	94	75	86	84	82
B1	88	89	88	78	70	88	78	77	83	76	94	73	84	88	84
Immediate patency	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Follow-up patency	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Technical difficulty	No	No	No	No	No	No	No	Yes	Yes	Yes	No	Yes	No	No	No

A: Arterial pressure in elongated vessels after AIAE (mmHg); B: arterial pressure in control vessels after AIAE (mmHg); A1: arterial pressure in elongated vessels after end of the follow-up period (mmHg); B1: arterial pressure in control vessels after end of the follow-up period (mmHg).

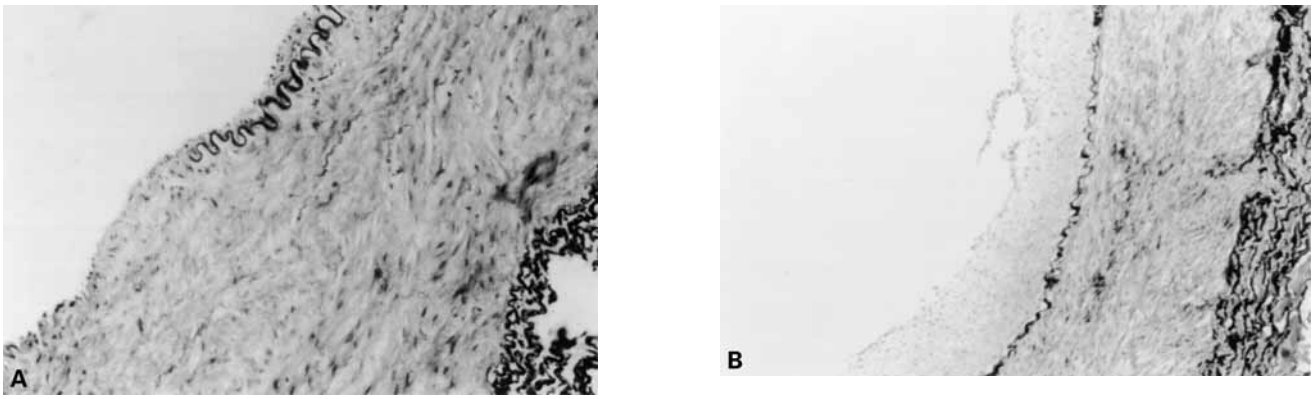

Fig. 2. (a) Some disruption of the internal elastic lamina in acute term (Verhoeff–Van Gieson; ×20); (b) healing of the internal elastic lamina via intimal proliferation at the end of the follow-up period (Verhoeff–Van Gieson; ×10).

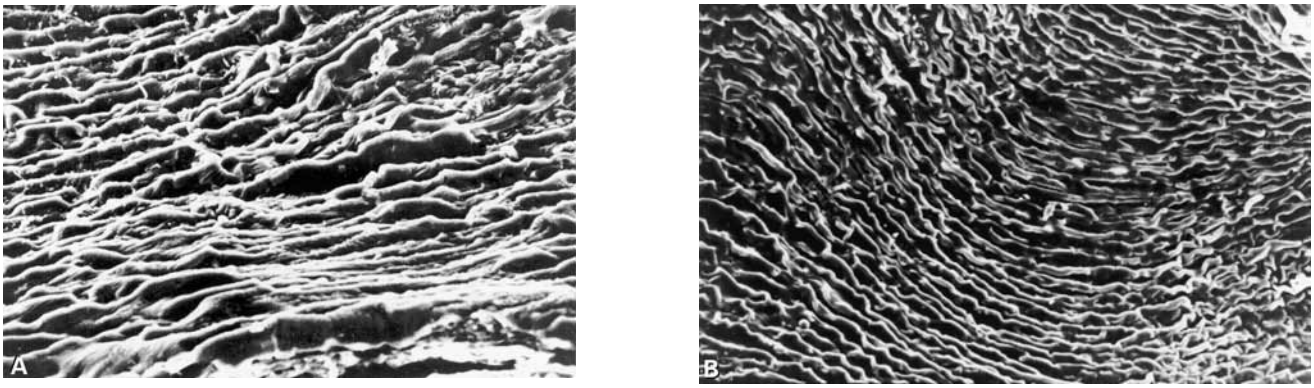

Fig. 3. (a) Scanning electron microscopy showed minimal denudation and flattening of endothelium in elongated vessels after AIAE (×350); (b) endothelium was in good condition at the end of the follow-up period (×200).

showed minimal disruption of the internal elastic lamina (Fig. 2a). Specimens obtained at the end of the follow-up period demonstrated the formation of neointima with the regeneration of the internal elastic lamina (Fig. 2b). Scanning electron microscopy showed small areas of denuded endothelium in elongated vessels after AIAE (Fig. 3a). Endothelium was in good condition at the end of the follow-up period (Fig. 3b).

Discussion

Peripheral arterial gaps are most frequently encountered after traumatic arterial damage and resection of an aneurysm. When an arterial gap is too large to overcome by vessel mobilisation, an autologous vein graft is used to bridge the gap, since no artificial graft has proven to be as reliable.[6]

We tried to show the feasibility of intraoperative arterial elongation in an experimental model. In a dog femoral artery model, a Foley catheter was used as a modified vessel expander. The expanded segment should be undermined to allow placement of the catheter. Our elongation procedure consist of a series of external expansion and relaxation cycles. Three stretch-relaxation cycles were used to elongate the vessel. All vessels were successfully elongated by using Foley catheter. To be able to anchor the vessel during the expansion, a small segment of artery should be left attached to the underlying tissue between the defect and the segment to be elongated. In a series of experiments, we progressively resected longer lengths of vessel until we ascertained the maximum gap that could overcome with vessel elongation. If the defect is short, only one expansion site could be enough, in either proximal or distal. We found that arterial gaps longer than 55 mm were not good candidates for AIAE. However blood pressure examination results which were recorded at the end of the follow-up period were acceptable even in dogs with gaps longer than 55 mm. We believe that the disappearance of pressure differences at the end of the follow-up period was mainly due to vessel remodelling, because there was no luminal narrowing at the anastomotic size even the vessels in the dogs which had pressure differences in the acute term. No evidence of thrombosis, aneurysm or pseudoaneurysm was found in any of the elongated vessels. Cohen *et al*. reported successful repair following arterial excision up to 70 mm in dogs.[7] But they did not perform any pressure studies. The degree of disruption to the internal elastic lamina was associated with the expansion volume, length of the arterial gap and tension. Internal elastic lamina disruption could be prevented by avoiding over inflation of Foley catheter. The vascular reactivity and organ chamber studies demonstrated intact contractile functions of elongated arteries within 1 h and 24 h after expansion.[8] It is well known that, even after implanting synthetic grafts in dogs, these will show re-endothelialisation. In canine model Shi *et al*. showed that all the patent endarterectomised arteries were partially re-endothelialised at both the 4- and 8-week intervals.[9]

In another study, the distribution of re-endothelialisation and the development of intimal thickening were investigated electron microscopically and immunohistochemically using saphenous vein grafts implanted into the femoral artery in dogs. Small islands of surviving endothelial cells were occasionally observed away from the valves at 1 day. By 1 week, the re-endothelialisation extended to over 70% of the total luminal surface area.[10]

Our study has some drawbacks. First, planimetry could be done in order to measure the degree of disruption which was not performed in this study. Second, our follow-up period was limited within four weeks that relatively short period for development of maximal neointimal hyperplasia. Third, rapid and extensive re-endothelialisation which occured in canine model is not same in humans.

Conclusion

This study demonstrates the feasibility of AIAE in small arterial defects. Although these findings are no proof that same will happen in humans, our preliminary results have been encouraging. This technique could be recommended as a reliable alternative to vein grafting to repair small arterial defects that occurred in healthy arteries. This limits its applicability to other fields than trauma. Main indications for this technique are small arterial defects or pseudoaneurysms resulted by trauma.

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