British Heart Journal, 1973, 35, 1080–1084.

Iatrogenic brachial artery injuries

A. P. Barabas, J. Bouhoutsos, and Peter Martin

From the Department of Surgery, Royal Postgraduate Medical School, Hammersmith Hospital, Du Cane Road, London

During a 7-year period approximately 700 left heart cardiac catheterizations were carried out via open brachial arteriotomy. Of these, 25 patients with a missing or weak radial pulse after catheterization were referred for operation. Despite minimal early ischaemic symptoms and signs, all 25 patients had a complete occlusion of the brachial artery at the site of the arteriotomy. Commonest causes for occlusion were circumferential intimal tears or excessive suturing.

Technical details of the repair of the damaged artery – débridement, venous patch graft, and no anticoagulation after operation – were found to be important and led to long-term patency in 16 of the 17 'early' cases.

Eight 'late' patients, who escaped early detection, were operated on 1 week to 16 years after brachial artery occlusion. Of the 8, 7 were successfully relieved of their symptoms.

Brachial artery catheterization not infrequently leads to a narrowed or occluded artery. In two recent prospective studies 24 per cent of 204, and 12·2 per cent of 328 patients, respectively, had this complication (Machleder, Sweeney, and Barker, 1972; Campion *et al.*, 1971). On long-term follow-up of those with an untreated brachial artery occlusion considerable functional impairment was found in 68 per cent (Campion *et al.*, 1971). In addition in a few cases, reported by Hall (1971), severe acute ischaemia and acute amputation of the arm resulted.

We report here 25 cases with brachial artery injury following left heart cardiac catheterization. In 17, reconstructive surgery was carried out within 24 hours of catheterization ('early' cases) and in 8 after more than 24 hours ('late' cases).

Patients and incidence of complication

The age and sex distribution of the 25 patients are summarized in Tables 1 and 2. They were all referred for operation between the years 1965 and 1972. Approximately 700 left heart cardiac catheterizations were carried out by means of open brachial arteriotomy in Hammersmith Hospital during these 7 years, giving an incidence of this complication of just over 3·5 per cent.

'Early' cases

Symptoms Seventeen of the 25 cases were treated within 24 hours of catheterization (Table 1). Only 5 of the 17 had severe symptoms such as pain and numbness of the hand. A further 9 experienced coldness and minor paraesthesiae only, and the remainder were completely free from symptoms.

Received 24 April 1973.

Clinical signs Fourteen of the 17 had absent and 3 had weak pulses at the wrist; all 17 had objective coldness of the affected hand compared to the opposite side.

Findings at operation The time of surgical exploration varied from 3 to 20 hours after cardiac catheterization. In all cases there was a complete occlusion of the artery at the site of the previous arteriotomy (this includes those 3 cases where a weak pulse had been felt at the wrist).

In all an organic narrowing of the lumen of the artery was present, which led, in turn, to secondary thrombosis and complete occlusion. In 10 cases the narrowing was due to a circumferential tear and curling up of the intima (Fig. 1a); in 4 the sutures closing the arteriotomy were mainly at fault, and in the remaining 3 pressure from a periarterial haematoma accounted for the narrowing.

Surgical procedure In all patients the artery was opened at least 0·5 cm above and below the arteriotomy site. Local thrombectomy was carried out and an embolectomy catheter was passed up the brachial and down the radial and ulnar arteries, to

TABLE 1 *'Early' repairs (first 24 hours) of brachial artery injury after cardiac catheterization*

Case No.	*Sex*	*Age (yr)*	*Symptoms*	*Findings (apart from thrombosis)*	*Procedure*	*Follow-up*		
						Duration	*Symptoms*	*Radial pulse*
1	M	19	Mild	1) Intimal tear + thrombus	Thrombectomy alone			
				2) Rethrombosis	Rethrombectomy, débridement, patch graft	6 mth	o	+
2	F	45	Severe	Intimal tear + thrombus	Thrombectomy, débridement, patch graft	8 mth	o	+
3	F	40	Mild	" " "	" " " "	4 yr	o	+
4	F	49	Severe	" " "	" " " "	6 yr	o	+
5	M	40	Mild	" " "	" " " "	2 yr	o	+
6	M	26	Severe	" " "	" " " "	4 yr	o	+
7	F	45	Mild	" " "	" " " "	18 mth	o	+
8	F	6	Nil	" " "	" " " "	3 yr	o	o (failed)
9	F	40	Mild	" " "	Venous patch graft	4 mth	o	+
10	F	25	Nil	" " "	" " "	3 mth	o	+
11	F	55	Severe	Haematoma	Evacuation thrombectomy	6 mth	o	+
12	M	60	Mild	"	" "	18 mth	o	+
13	F	18	Mild	"	" "	2 yr	o	+
14	M	56	Mild	Faulty sutures	Resuture only	1 yr	o	+
15	M	32	Nil	" "	Resuture and vein patch graft	Nil	o	+
16	M	40	Severe	" "	" " " " "	5 yr	o	+
17	M	16	Mild	" "	" " " " "	6 mth	o	+

TABLE 2 *Late repairs of brachial artery occlusion after cardiac catheterization*

No.	*Age (yr), sex*	*Time of operation after catheterization*	*Procedure*	*Follow-up*		
				Duration	*Symptoms*	*Radial pulse*
1	29 M	1 wk	Vein bypass	1 yr	o	+
2	32 M	2 wk	" "	18 mth	o	+
3	48 F	4 wk	" " (failed)	3 yr	+	o
4	25 M	4 wk	" "	2 yr	o	+
5	66 F	6 wk	Thrombectomy and on-lay vein graft	8 yr	o	+
6	42 M	1 yr	Vein bypass	3 yr	o	+
7	25 F	2 yr	" "	1 yr	o	+
8	36 M	16 yr	" "	2 yr	o	+

remove propagating thrombi. After dealing with the cause of the narrowing, the arteriotomy was closed with a venous patch graft in all but 4 cases. In the 10 patients with circumferential tear of the intima a venous patch graft was used in every case, though in one case (Case 1) only after the failure of the first operation. Local arm veins (brachial or cephalic) were used in 11 and the saphenous vein in 4 cases.

Anticoagulation Intravenous heparin (10,000 units 6 hours) was started as soon as possible after detecting a weak or absent wrist pulse. This was continued all through the operation and was stopped after.

Results Sixteen of the 17 patients had return of wrist pulses and are free of any symptoms on follow-up from 3 months to 6 years. One patient's brachial artery (a child of 6) was technically difficult to repair and was left occluded, but she has no symptoms 2 years later.

'Late' cases

Eight of the 25 patients had operation for brachial artery occlusion more than 24 hours after cardiac catheterization (Table 2). They first noticed ischaemic symptoms on return to normal activities after discharge from hospital. No patient had rest pain, but pain in the arm developed on such simple every-

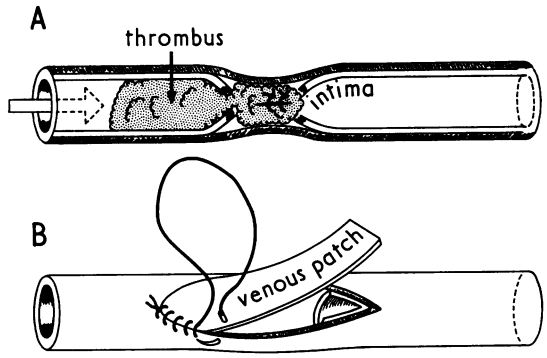

FIG. 1 *(A) Schematic drawing of typical findings at the site of arterial injury. (B) Recommended repair: trimming of intima and venous patch graft.*

day tasks as combing the hair, shaving, washing up, or even writing. Two patients (Table 2, Cases 7 and 8) complained of this only after successful heart surgery had abolished other symptoms (i.e. severe breathlessness) and had restored full activity.

Signs The radial pulse was absent in 6 of the 8 and could be felt only on occasions and with difficulty (when warm and at rest) in 2. Blanching of the affected hand on lifting was more pronounced compared to the normal side; pain in the forearm stopped clenching and unclenching of the hand within 5 minutes.

Radiology All patients had an arteriogram either before operation (selective aortic arch aortogram) or, preferably, an open operative brachial arteriogram just before the arterial operation. Complete occlusion of the segment of the brachial artery was shown in every case. Rich collateral channels were present in those (Cases 6, 7, and 8) who had a long-standing occlusion (Fig. 2). The radial and ulnar arteries were patent in all 8 cases.

Surgical procedure Seven of the 8 had end-to-end vein bypass, using the cephalic vein in 2 and the saphenous in 5. One case had a thrombectomy and long (6–7 cm) on-lay vein patch graft. Heparin was only used locally by injection into distal arteries during operations.

No anticoagulants were given before or after operation.

Results Seven of the 8 patients had a return of pulses and became symptom free and remained so for periods between 1 and 8 years. In one patient the graft failed and she continues with ischaemic symptoms.

FIG. 2 *Brachial arteriogram 16 years after cardiac catheterization via the brachial artery. Despite rich collaterals this patient had ischaemic symptoms of the hand. A vein graft was inserted. He remains free from symptoms 2 years later.*

Discussion

The incidence of brachial artery occlusion in this series (3·5%) is lower than reported by others (Machleder *et al.*, 1972; Campion *et al.*, 1971). Our study was retrospective and this may partly account for the low apparent incidence. The fact that open brachial arteriotomy was used in preference to percutaneous puncture, in our view, also contributed to this low complication rate. In any case, as surgeons, we were not involved in the catheterizations, and are unable to comment on how this low incidence was achieved. The discussion will be con-

fined, therefore, to the management of brachial artery occlusion after cardiac catheterization, once it has occurred.

Absent or weak distal pulses on return to the ward after brachial artery catheterization should be regarded as indicative of arterial injury. Arterial spasm should not be considered as an alternative, as it is rare and we have never seen it on exploring the brachial artery. Furthermore, it does not last long in an undamaged vessel.

While lying in a warm bed, still dazed from the premedication, the patient will feel no ischaemic pain and complain of no symptoms. Clinical signs, other than a missing pulse, may also be absent.

On detecting an absent or weak radial pulse, intravenous heparin infusion (10,000 units 6 hours) should be started immediately to prevent the development or extension of local thrombosis, and arrangements should be made to take the patient to the operating theatre. These preparations will take at least an hour, and if there is no return of normal pulsation within this time all thoughts of transient arterial spasm should be discarded.

The technical details of the operations are important. General anaesthesia is not necessary and may be contraindicated because of the patient's cardiac condition. The brachial artery is widely exposed, down to the bifurcation into radial and ulnar arteries to ensure that the embolectomy catheter will be guided, if this is needed, into both arteries under direct vision and with the least trauma. Arteriotomy incision should start at the site of the puncture and should be at least 1 to 2 cm long. After local thrombectomy and the clearance of propagating thrombi, arterial clamps are applied. An attempt is now made to identify the cause for the thrombosis. In most cases (10 out of 17 in the present series), this will be a torn and curled up intima. This should be trimmed back to the points where it becomes normal. If the whole thickness of the artery is severely damaged, a portion may have to be excised and end-to-end anastomosed or grafted, but we have not found this necessary in 'early' cases. After débridement of the lumen of the artery, a venous patch graft is sutured to the arteriotomy and the sutures should include the cut ends of the intima to prevent it curling up again and causing recurrent thrombosis (Fig. 1b).

Faulty suturing (4 out of 17) was found to be the second commonest cause of obstruction at the site of arteriotomy. Narrowing of the lumen resulted from mistaken attempts to control all bleeding by immediate further suturing after the initial closure was found to leak. Slight pressure at the site and waiting for 5 to 10 minutes for the bleeding to stop spontaneously would have been advisable.

Once thrombosis follows removal of the faulty sutures, thrombectomy and resuturing are rarely sufficient. Trimming away the arterial wall, which is damaged by previous attempts at suturing, until an undamaged edge is obtained, and closure with venous patch graft are needed to prevent recurrence of thrombosis.

Once the mechanical cause for local thrombosis is removed, there is no need for further anticoagulation, and heparin infusion is discontinued. Postoperative anticoagulants are not only unnecessary but probably harmful as they may contribute to haematoma formation and infection. A suction drain is used and the wound closed by skin sutures.

Before closing the wound and after the arterial repair, we carry out routine operative radiography. This can show patency or otherwise at the site of repair, and also distinguishes between occlusion of the distal arteries by a clot, or narrowing by spasm. Arteriography thus often prevents unnecessary, harmful, and persistent attempts at passing embolectomy catheters as, unlike the brachial artery, the ulnar and radial are liable to prolonged spasm. After operation the arm is raised in a sling. Movements are encouraged straightaway to avoid contracture at the elbow.

All but one of our 'early' arterial repairs in adults were successful (Table 1, Case 1). At this operation the rules outlined above were not followed; the arteriotomy was closed after thrombectomy without débridement of the intima and without a venous patch graft. Rethrombosis followed despite continued anticoagulation and a second successful operation was carried out within 24 hours.

The consequences of not operating on brachial artery occlusion were pointed out by Machleder *et al.* (1972). Of their 49 patients with absent or weak radial pulse after catheterization, one lost an arm due to ischaemia and 68 per cent discharged from hospital had considerable functional impairment on long-term follow-up. These patients with chronic ischaemia of the arm may not complain of any symptoms because their severe cardiac disability overshadows them. Others complain but are not referred for operation, possibly because of improper understanding of the possibility of successful surgical relief.

All but 1 of the 8 patients with long-standing occlusion had successful repairs of their thrombosed brachial artery. The technique of end-to-end autogenous vein grafting is well established and in traumatic cases the long-term prognosis is excellent.

Patients who escape early detection and repair of brachial artery injury, therefore, should be given the benefit of surgical relief of their ischaemic arm symptoms.

We are grateful to Professor J. F. Goodwin and Dr. C. M. Oakley for referring their patients, and for advice on the preparation of this paper.

References

Campion, B. C., Frye, R. L., Pluth, J. R., Fairbairn, J. F., and Davis, G. D. (1971). Arterial complications of retrograde brachial arterial catheterization. *Mayo Clinic Proceedings*, **46**, 589.

Hall, R. (1971). Vascular injuries resulting from arterial puncture or catheterization. *British Journal of Surgery*, **58**, 513.

Machleder, H. I., Sweeney, J. P., and Barker, W. F. (1972). Pulseless arm after brachial artery catheterisation. *Lancet*, **1**, 407.

Requests for reprints to A. P. Barabas, Esq., F.R.C.S., Department of Surgery, Royal Postgraduate Medical School, Hammersmith Hospital, Du Cane Road, London W12 OHS.