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A Prospective Study of Internal Carotid Artery Plication During Carotid Endarterectomy: Early Clinical and Duplex Outcome

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Objective: *internal carotid artery (ICA) plication prevents kinking and secures the distal intimal step following carotid endarterectomy (CEA). The aims of this prospective study were to quantify the proportion of patients in whom plication might be beneficial and determine whether plication is associated with an increased incidence of early restenosis and a reduction in postoperative thromboembolic complications.*
Methods: *analysis of a prospectively gathered computerised database.*
Results: *between 1 November 1992 and 31 December 1997, 228 consecutive CEAs were performed in 213 patients, of which 84 (37%) in 79 patients were plicated. Sixty endarterectomy sites have been examined by duplex ultrasonography at a median of 5 (range 1–44) months postoperatively. No abnormality was detected in 52 (87%), six (10%) had restenosis of <50% and two (3%) restenosis of 50–75%. All were asymptomatic. Three patients (3.6%), one of whom died, had an intraoperative neurological event and one patient (1.2%) had a postoperative cerebral haemorrhage. No patient suffered ICA thromboembolism. During the same time period 144 non-plicated CEAs were performed in 134 patients. Of these, one (0.7%) had an intraoperative and five (3.5%) had a postoperative neurological event. Five of these six complications were due to ICA thromboembolism. There was no mortality in the non-plicated group.*
Conclusion: *ICA plication can be used to prevent kinking, secure the distal intimal step, has not, to date, been associated with increased early restenosis rate and has avoided postoperative ICA thromboembolism.*

Key Words: Carotid endarterectomy; Kinking; Intimal step; Plication; Thromboembolism.

Introduction

Atherosclerosis is associated with elongation of the affected artery. An internal carotid artery (ICA) which is tortuous prior to carotid endarterectomy (CEA) tends to become even more redundant postoperatively. In this situation, completion angiography often reveals kinking of the ICA,[1] particularly where the endarterectomised surface meets the distal intima, a phenomenon we have frequently also observed during long term postoperative follow-up.[2] In the long term, kinking may contribute to restenosis due to increased turbulence. In the immediate postoperative period, kinking is haemodynamically unfavourable and may increase the risk of ICA thromboembolism and stroke.[3–5] Most of the shortening procedures described to date involve resection and re-anastomosis of either the internal or common carotid artery,[6–10] this includes eversion endarterectomy. The advantage of this technique over others is the shorter time taken to perform this procedure, but a relative disadvantage is its inability to control the distal intimal step.[11] In November 1992, the senior author (CVR) first devised a posterior plication technique which simultaneously straightens the ICA and completely excludes the distal intimal step from the vessel lumen. A similar technique was independently described by Riles in 1995.[12] The aims of this prospective study were to quantify the proportion of patients in whom plication might be applicable and to determine whether plication is associated with an increased incidence of early restenosis and/or a reduction in postoperative thromboembolic complications.

Material and Methods

Interrogation of a prospectively gathered carotid database identified a consecutive series of 228 CEAs performed in 213 patients between 1 November 1992 and

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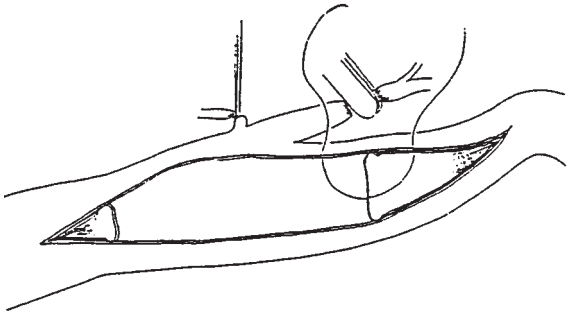

Fig. 1. First suture is placed on the medial side of the artery to begin the plication.

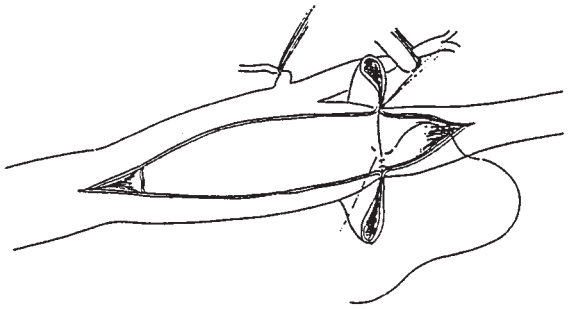

Fig. 2. Second suture is placed on the opposite side and is run continuously across the posterior wall.

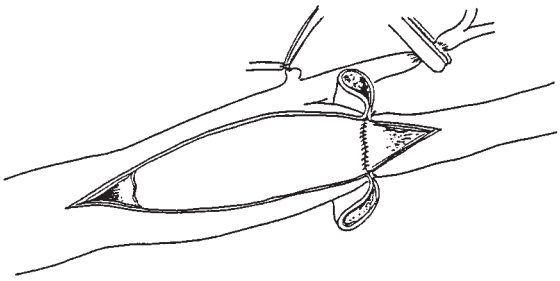

Fig. 3. On complication of plication.

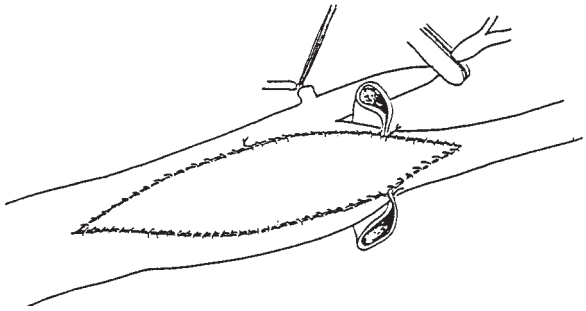

Fig. 4. Patch angioplasty performed after plication.

31 December 1997 under the care of two consultant surgeons (CVR and AWB). In 84 CEAs (37%), performed in 79 patients, the plication technique was used, because after endarterectomy the ICA became redundant and redundancy was enough to exclude at least 5 mm or more of the posterior wall from the vessel lumen. In the view of authors' previous experience it was felt that failure to shorten the ICA leads to postoperative kinking and haemodynamically unfavourable results.

Endarterectomy is carried out in standard fashion. A 6/0 polypropylene suture is used to perform the plication. The first suture is placed on the medial edge of the artery (Fig. 1). Tying the suture outside the artery leads to evagination of the redundant posterior wall and exclusion of the distal intimal step from the new luminal surface (Fig. 2). A second suture is placed on the opposite (lateral) edge in the same fashion and tied. One or other suture, depending on the preference and hand dominance of the operator, is then run continuously across the posterior wall of the ICA (Fig. 2). At least eight, and often as many as 12, sutures are placed to prevent a pursestring effect which might narrow the artery at this point. On reaching the distal edge, the suture is taken to the outside of the artery, passed through the pleat and tied to one end of the original suture. This leaves a straight carotid artery, a buried distal intimal step, a smooth continuous internal surface and a shortened arteriotomy (Fig. 3). The arteriotomy is closed by means of a patch angioplasty (Fig. 4). All operations were conducted under general anaesthesia. All patients were monitored by means of near infra-red cerebral oximetry. The indications for shunting were the presence of one or more of the following. Stump pressure <50 mmHg, a fall in the cerebral oximetry of >5% and non-pulsatile ICA backflow.

Results

Of the 79 patients (84 CEAs) who underwent plication, 48 were men and 31 were women. The median age was 69 years (range 49–85 years) and median total hospital stay was 5 days (range 3–28 days). The indications for surgery were amaurosis fugax 14 (17%), transient ischaemic attacks (TIA) 44 (52%), previous stroke 12 (14%), TIA and amaurosis eight (10%). Six CEAs (7%) were performed for asymptomatic disease. A shunt was used in 30 (36%) operations and patch angioplasty in all but one. A vein patch was used in two cases (2.4%), expanded polytetrafluoroethylene (ePTFE) in six (7.2%) and Dacron in 75 (90.4%). As part of the study, it was decided that all patients undergoing plication should be examined at least once postoperatively, by means of duplex ultrasonography.

Table 1. Neurological complications in patients undergoing CEA.

	Plication ($n=84$)	No plication ($n=144$)
TIA or CVA with complete recovery*	3	5
CVA with residual deficit*	–	1
Fatal CVA	1	–

* At time of discharge from vascular surgical ward.

Table 2. Diagnosis and cause of neurological events.

	Plication ($n=84$)	No plication ($n=144$)
Intraoperative neurological events	3	1
Postoperative neurological events	1	5
Diagnosis by CT brain and duplex scan	3	1
Diagnosis by re-exploration	1	5
Neurological events due to:		
thrombosis of the endarterectomy site	–	5
cerebral haemorrhage	1	–
others	3*	1**

* No evidence of haemorrhage and thrombosis was found.
** Admitted to another hospital, new infarct on CT brain, carotid duplex was not performed.

Six patients were lost from the follow-up. Two died from myocardial infarction 5 weeks and 14 months postoperatively, having been discharged after an uneventful CEA. A further four were referred from other parts of Scotland and were followed up locally. Of the remaining 78 endarterectomy sites (73 patients), 60 (77%) have been examined at least once by duplex at a median interval of 5 (range 1–44) months postoperatively. The remaining 18 CEAs have been performed too recently to have yet been scanned. Of the scans performed, 52 (87%) showed no haemodynamic abnormality, six (10%) showed a stenosis <50% and two (3%) revealed a stenosis of 50–75%. No kinking or tortuosity was detected. All patients have remained asymptomatic. During the same period a further 144 CEAs were performed without plication in 134 patients. In this group, a shunt was used in 23% and patch angioplasty in 80%. Postoperative duplex scans were performed in 84 (58%) at a median of two months (range 1–55 months) and showed no haemodynamic abnormality in 71 (85%), a stenosis of <50% in six (7%), a stenosis of 50–75% in six (7%) and complete occlusion in one patient. All patients were asymptomatic.

Neurological complications in the plicated and non-plicated groups are summarised in Table 1. In the plicated group, three (3.6%) patients awoke from anaesthesia with new deficits. One underwent an immediate re-exploration of the artery, a further two had computed tomogram (CT) of the head and duplex scan of the carotid arteries. No cause of the neurological event was found in any of these patients. There was one postoperative neurological complication in a man who developed cerebral haemorrhage on the fifth postoperative day diagnosed on CT scanning (Table 2).

In the non-plicated group, one patient (0.7%) awoke with a deficit and a further five patients (3.5%) developed postoperative complications. All but one underwent re-exploration, and thrombus was found at the endarterectomy site in all. The sixth patient was admitted to another hospital on the tenth postoperative day, having had an uneventful operation (Table 2).

Discussion

The clinical and cost-effectiveness of CEA depend crucially upon the operation being performed with a low level of neurological complications. Thromboembolism arising from the endarterectomised surface, perhaps as the result of technical error, is an important cause of stroke following CEA. Elevation of the distal intimal step to form a flap is a well-recognised hazard and many surgeons routinely "tack-down" this edge.[13–15] Kinking of the ICA following endarterectomy may be equally dangerous,[1–2] but is less well appreciated. Having observed kinking of the ICA on follow-up imaging in a significant number of cases,[2] the senior author sought to develop a technique that would simultaneously straighten the ICA and also bury completely the distal intimal ridge. The plication method described here achieves both those aims and is easy to perform. Initial concerns that the plication might lead to early restenosis have proved to be unfounded, as determined by the early follow-up duplex scans.

The main reason for carrying out the plication is to straighten the ICA. Several techniques have been described[6–9] including the eversion endarterectomy,[10] but all of these involve resection and re-anastomosis of either the internal or common carotid artery. One potential disadvantage of the eversion technique is its inability to secure the distal end-point of the endarterectomy,[11] although the preliminary results of the EVERsion carotid Endarterectomy versus Standard Trial (EVEREST),[16] does not suggest that this is a major problem. The advantage of plication technique is that it not only straightens but also buries the distal intimal step.

Although this is not a controlled study, and there was no statistically significant difference between the plicated and non-plicated groups with regard to the total incidence of neurological complications (4.8% vs.

4.2%), it is striking that no patient in the plicated group developed a complication as a result of ICA thrombosis whereas five of six patients in the non-plicated group did have proven ICA thrombosis and the sixth had an infarct. It is also notable that, although five patients in this group were re-explored for thrombosis, in none of the cases was an obvious technical error at the endarterectomy site identified. Every modification of surgical technique cannot be tested by randomised trials; however, from prior knowledge of haemodynamic principles this shortening procedure has obvious theoretical advantages when performed on selected patients.

Although it is difficult to prove the benefits of this procedure, this series provided clinical and duplex evidence that ICA shortening by plication can be done safely with no added morbidity in the group of patients who develop ICA redundancy after CEA. In addition, it excludes the distal intimal step from the vessel lumen, thus removing one of the proven causes of thromboembolism.

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