Thromboendarterectomy is sometimes performed in association with coronary artery bypass graft surgery (CABG). Right coronary arteries and severely narrowed coronary arteries mainly undergo thromboendarterectomy, but perioperative acute myocardial infarctions (AMI) are possible complications. One hundred seventy-six consecutive patients with rest and stress thallium-201 scintigraphy and angiography were studied before and after surgery. To compare patients with and without thromboendarterectomy, 48 patients who had undergone thromboendarterectomy and whose characteristics matched closely those of patients who had not were selected. Twenty patients had previous AMI before CABG in each group. Analysis accounted for the severity of vessel lesion (complete or incomplete) and for the patency of the graft and of the native coronary artery. In these 98 patients, graft patency was lower than in the overall group and similar among patients with and without thromboendarterectomy among the 56 patients without previous AMI. In patients with previous AMI and thromboendarterectomy, however, reperfusion was achieved more often through the native vessel than through the graft. New AMI or residual ischemia occurred in 32% of the areas undergoing thromboendarterectomy and in only 5% of the standard grafts (p < 0.001). Best results were obtained in patients with incomplete occlusion after AMI. Patients without previous AMI had worse results. Thus, thromboendarterectomy can yield 64 to 75% good results in selected subgroups when CABG is otherwise impossible, but should be avoided in mildly or moderately stenotic arteries perfusing noninfarcted myocardium.

Methods

Patients: One hundred seventy-six consecutive patients undergoing CABG form the basis of this study. Patients who had undergone multiple cardiac surgery (bypass combined with valve replacement or aneurysm resection) or who were advanced in age (older than 75 years) were excluded. All patients included underwent angiography both before surgery and after 6 months for bypass and native vessel control. Patients were also studied by pre- and postoperative thallium myocardial scans within 1 month before and 6 months after surgery. To compare patients with and without thromboendarterectomy, 48 patients treated with thromboendarterectomy were matched closely with other patients who were not selected. The following criteria were used for matching: location and severity (complete occlusion or incomplete stenosis) of the lesion under study, presence or absence of previous AMI in the vessel area under study or elsewhere, number of coronary arteries significantly narrowed and number of grafts.
We achieved perfect matching for the first 2 criteria but only very close matching for the latter 2. We thus had 96 patients separated into 2 groups: 48 patients with and 48 without thromboendarterectomy. In both groups, 18 patients had total occlusion and 24 subtotal occlusion of the right coronary artery; 2 patients had total occlusion and 8 patients subtotal occlusion of the left circumflex artery, and 4 patients had subtotal occlusion of the left anterior descending coronary artery that was either treated with thromboendarterectomy or matched with a thromboendarterectomy-treated lesion. Fifty-six lesions were analyzed in each group. Severity of stenosis in the arteries with subtotal occlusion averaged 82% in the group with and 81% in the group without thromboendarterectomy (difference not significant). In each group, 20 patients had previous AMI and 28 had no previous AMI before CABG. There were slight differences between the number of arteries narrowed and between the number of grafts in the 2 groups.

**Surgery:** Patients underwent surgery on hypothermic cardiopulmonary bypass (esophageal temperature 28°C). The left ventricle was vented through the right superior pulmonary vein, and St Thomas' cardioplegic solution was used in all patients except for 7 who underwent single bypass. We performed endarterectomy on many thrombosed or severely stenosed right coronary arteries by incising them at the crux and separately pulling the atheromatous core from the posterior or descending coronary artery and from the distal right coronary artery. Care was taken to ascertain that the ends of the core were smoothly tapered. If the core was broken, the artery was incised at the presumed site of atheroma fracture and the procedure was repeated. Less frequently, manual endarterectomy was performed on diffusely involved left circumflex or left anterior descending arteries. After thromboendarterectomy, the lumen of the vessel was lavaged to remove any particulate matter before the graft was performed.

**Angiography:** The preoperative angiographic investigation was performed by standard intracoronary arteriography using the Judkins technique. The postoperative control was carried out using digital subtraction angiography and aortic supravalvular injections. Each aortocoronary bypass and native vessel that did not appear patent or was poorly visualized by the supravalvular injections using the previously described technique was further investigated by selective catheterization.

**Sctngigraphy:** Myocardial scans were performed at rest and stress 6 months after CABG. Although rest scans were performed in all patients preoperatively, exercise tests were not always possible at that time because of patients' symptoms. Stress testing was carried out on a bicycle ergometer at a progressively increasing load using a standard submaximal heart rate protocol. Thallium (2 mCi administered intravenously) was injected 1 minute before discontinuation of exercise. The rest and stress thallium scans were evaluated comparatively, using a segmental approach, for evidence of fixed or reversible defects in the myocardial distribution of the various arteries. This information was related to the distribution of the lesions, position of the graft and results of preoperative scintigrams to assess the presence or absence of new myocardial infarction or residual ischemia in the grafted areas. In a few patients, tomographic myocardial scintigraphy was performed concomitantly and used for evaluation whenever comparative rest and stress pre- and postoperative data were available.

**Statistical methods:** Statistical analysis was performed using the chi-square method with Yate's correction or Fisher's exact test whenever appropriate.

**Results**

**Mortality:** Early and late postoperative mortality was similar in patients with and without thromboendarterectomy. Five of 176 patients died during follow-up. One patient without thromboendarterectomy died within 1 month of intervention. Two patients with and 2 patients without thromboendarterectomy died during the first postoperative year. In 1 patient in each group, death was of a noncardiac origin.

**Graft patency:** Graft patency in the overall population (176 patients, 391 grafts) was 89% at 6-month follow-up (44 occluded grafts). Patency of the grafts to the matched narrowed arteries selected in this study (56 arteries with and without thromboendarterectomy) was lower in the group with (34 of 56, 61%) than in the group without (44 of 56, 79%; p <0.05) thromboendarterectomy, but both groups appear to differ from the overall population (p <0.05). Native vessel patency, in contrast, was higher in the group with thromboendarterectomy (19 of 56 [34% with] vs 2 + 7 = 9 of 56 [16% without]) (p <0.05). Therefore, the frequency of combined graft and native vessel occlusions (G + NV.O) was similar in both groups.

![FIGURE 1. Graft (G.P.) and native vessel patency (NV.P) in patients with and without thromboendarterectomy (T.E.A.). Patency of the graft to the matched narrowed arteries was lower in the group with thromboendarterectomy (10 + 25 = 34 of 56, 61%) than in the group without thromboendarterectomy (7 + 37 = 44 of 56, 79%) (p <0.05). Native vessel patency, in contrast, was higher in the group with thromboendarterectomy (10 + 9 = 19 of 56 [34% with] vs 2 + 7 = 9 of 56 [16% without]) (p <0.05). Therefore, the frequency of combined graft and native vessel occlusions (G + NV.O) was similar in both groups.](image-url)
creased graft patency rate in the group with thromboendarterectomy appeared to result from the subgroup of patients with thromboendarterectomy in a vessel perfusing a previously infarcted myocardium (Figure 2). In this subgroup, the incidence of graft patency was lower (9 of 20, 45%) but the native vessel more often remained patent (12 of 20, 60%). This perfusion pattern may reflect decreased flow and metabolic demand of the infarcted myocardium. In contrast, in patients without thromboendarterectomy, successful grafting frequently coincided with occlusion of the native vessel. In patients without previous AMI, the pattern of myocardial perfusion was not influenced by thromboendarterectomy (Figure 2).

Scintigraphic results: Results of scintigraphy are shown in Figure 3. Patients are again divided according to the presence or absence of a previous AMI in the analyzed vessel territory. New scintigraphic defects, mostly new myocardial infarction (11 cases) but also residual ischemia (7 cases), are more frequent in patients with than in those without thromboendarterectomy. This difference is highly significant. Patients with thromboendarterectomy but without previous AMI are at highest risk, because 13 of 36 such patients (36%) had new scintigraphic defects (9 AMI, 4 residual ischemia) after bypass surgery. Electrocardiographic changes indicative of a new AMI (new Q waves) were described in 5 of the patients with scintigraphic defects suggestive of a new AMI. In 2 other patients, other electrocardiographic changes (ST depression or T-wave inversion) were observed.

When data from the angiographic perfusion pattern analysis and myocardial scintigrams were combined, 3 groups of patients were defined: good cases—the segment was perfused without new AMI or residual ischemia; bad cases—segments with new AMI or residual ischemia irrespective of the perfusion pattern; and equivocal cases—the segment appeared not perfused by the graft or the native vessel (collateral perfusion is, however, possible) but no new AMI or residual ischemia was seen on the thallium scintigram.

More bad cases and fewer good cases were defined among patients with thromboendarterectomy than in patients without (χ² = 3.85, p <0.05). This was most evident in the group without previous AMI (Figure 4) because this group was larger than the group with previous AMI (Figure 5) (χ² = 3.58, p <0.01).

Functional significance: To evaluate the functional importance of these scintigraphic abnormalities we analyzed the performance of patients postoperatively as measured by the workload achieved in a standardized protocol. Patients with good surgical results exercised up to 123 ± 37 W. This represented a 42-W improvement over preoperative performance (in 35 patients in whom pre- and postoperative values were available, 84 to 126 W). In contrast, patients with poor or equivocal results only reached 107 ± 4 W (p <0.05), corresponding to only a 25-W improvement (17 cases with both pre- and postoperative studies; 89 to 114 W). The workload achieved postoperatively by patients without thromboendarterectomy was slightly higher than that achieved by patients with thromboendarter-
octomy (123 vs 113 W). This difference does not reach statistical significance but it likely reflects the increased incidence of bad results in the group of patients with thromboendarterectomy.

Discussion

Coronary endarterectomy was first reported by Bailey in 1967. It was initially performed without bypass grafting, but this approach was not found to be rewarding and was therefore abandoned. In particular, gas endarterectomy was found to be the cause of perioperative AMI. Endarterectomy is now used in combination with CABG, especially in patients with diffuse distal disease in whom bypass is otherwise difficult or impossible. There is still no agreement, however, on the role of this procedure in the management of patients with coronary artery disease.

Few studies have analyzed in detail the results of thromboendarterectomy. Although as in our study, the early mortality rate appears unaffected by performance of endarterectomy, the frequency of perioperative AMI is higher in patients undergoing combined thromboendarterectomy and CABG than in those undergoing CABG alone (15 vs 6% in the study of Hallim et al). Pre- and postoperative myocardial scintigraphies in our study provide a more detailed functional evaluation. Furthermore, comparative analysis of patients with and without thromboendarterectomy is facilitated by our matching procedure, enabling us to compare patients with similar lesion severity, incidence of previous AMI and number of grafts. However, despite matching, those patients differed in that surgeons were comfortable performing bypass surgery without thromboendarterectomy in 50% of them.

Our data indicate a similar incidence of reperfusion in both groups. However, the incidence is lower than in the overall population. As also indicated by Kay et al, graft patency is somewhat lower in the group with thromboendarterectomy, but this difference is almost compensated for by the higher native vessel patency in that group. Because this pattern of perfusion predominates in patients with thromboendarterectomy on a vessel supplying a previously infarcted region, it could reflect diminished flow and metabolic demand in this region or retrograde reperfusion leading to flow competition favoring the native vessel.

Scintigraphic abnormalities, new AMI and residual ischemia (despite similar perfusion rates) occurred more frequently in the thromboendarterectomy group and especially in patients without previous AMI. This significantly diminished the potential benefits of revascularization, and patients with equivocal or poor scintigraphic results had a lower functional capacity 6 months after surgery.

We therefore recommend that in patients without previous AMI, the indication for thromboendarterectomy be limited as much as possible and performed only when obstruction is severe or complete and bypass is otherwise impossible. Milder lesions (70% or less) are probably best left alone when, for technical reasons, conventional bypass is impossible. In patients with previous AMI, both the risks and potential benefits of thromboendarterectomy and CABG are likely to

![Graph](attachment://graph.png)

**FIGURE 4.** In patients without previous myocardial infarction, objective evaluation of the reperfusion results through angiography and scintigraphy defines good, bad and equivocal cases. Bad cases predominate in the group with thromboendarterectomy ($\chi^2 = 3.85; \mu <0.05$). Abbreviations as in Figure 3.

![Graph](attachment://graph2.png)

**FIGURE 5.** In patients with previous myocardial infarction who had undergone thromboendarterectomy, bad cases again predominate. However, this difference doesn't reach the significant level, possibly because of the small number of patients ($\chi^2 = 3.58; \mu <0.1$). Abbreviations as in Figure 3.
be less. Indication for bypass should not be underestimated, however, because the infarct rarely involves the whole jeopardized area and the artery to the infarct area can still be the origin of collaterals to other vessels.

References


