Carotid Endarterectomy Without Temporary Intraluminal Shunt

Study of 309 Consecutive Operations

DAVID A. OTT, M.D., DENTON A. COOLEY, M.D., F.A.C.S., LIBERATO CHAPA, M.D., ALDEMIR COELHO, M.D.

A prospective study was undertaken to determine the efficacy of performing carotid endarterectomy without an intraluminal shunt. During a two-year period, 240 patients, ranging in age from 36 to 89 years, underwent 309 consecutive carotid endarterectomies. The indication for operation was transient ischemic attacks in 151 (63%) patients, asymptomatic carotid bruit in 67 (28%), and previous stroke in 22 (9%). Internal shunts were not used in any patients and all arteriotomies were patched with a preclotted knitted Dacron® velor patch. Systemic heparinization was used during the procedure. The early postoperative mortality was 0.64% (2/309). Both deaths were caused by myocardial infarction. The incidence of stroke after operation was 1.29% (4/309). Neither carotid clamp time nor the presence of contralateral disease correlated with the occurrence of postoperative stroke. According to results of angiography, 22 patients had total occlusion of the contralateral internal carotid artery with satisfactory intracranial circulation. No postoperative strokes occurred in this subgroup. Results of this study revealed that equally good or superior results may be obtained without a temporary shunt in performing carotid endarterectomy.

From the Division of Surgery of the Texas Heart Institute of St. Luke's Episcopal and Texas Children's Hospitals, Houston, Texas

TWENTY-FIVE YEARS AFTER the advent of carotid endarterectomy (CEA), controversy continues regarding the necessity of intraluminal shunting during the procedure. Excellent results, both with and without shunts, have been reported in numerous series.[2,3,8,9,18,21,24,25,30,33] Our results of CEA without temporary shunting are equally good or superior; and we have noted that shunting does not prevent postoperative stroke even in patients in whom shunting theoretically should be indicated, *i.e.* those with contralateral stenosis or total occlusion.[4,7,16,17,20,21,23,24,27,30] Accordingly, an analysis was undertaken of our results with patients who underwent CEA without an intraluminal shunt, regardless of anatomical or other considerations, during a two-year period. The data are presented in this report.

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Reprint requests: Denton A. Cooley, M.D., Texas Heart Institute, P.O. Box 20345, Houston, Texas 77025.

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Materials and Methods

From 1977–1978, 309 consecutive CEAs were performed in 240 patients who ranged in age from 36 to 89 years. The age distribution of these patients revealed that 72% of them were in the range of 50 to 70 years (Fig. 1). Among the patients, 157 (65.4%) were men and 83 (34.6%) were women.

Evidence of generalized atherosclerotic disease elsewhere in the cardiovascular system was present in 181 (75%) patients in this series—with 59 (24%) having various types of atherosclerotic peripheral vascular occlusive disease; 18 (7.5%), aneurysms of the abdominal aorta; and 104 (43%), some manifestation of cardiac abnormality according to history or results of radiographic, electrocardiographic or physical examination.

Indications for operation are summarized in Figure 2 and include transient attacks of ischemia, asymptomatic carotid stenosis, and previous stroke. Preoperative angiographic studies were performed in all patients, using the Seldinger technique in most, with views recorded of the aortic arch as well as the intracranial and extracranial carotid and vertebral arterial systems. Unilateral stenosis of the carotid artery with or without ulceration was present in 138 (57.5%) of the patients who required surgery (Fig. 3). Bilateral stenotic lesions occurred in 80 (33.3%) patients. Total occlusion of the contralateral internal common carotid artery was

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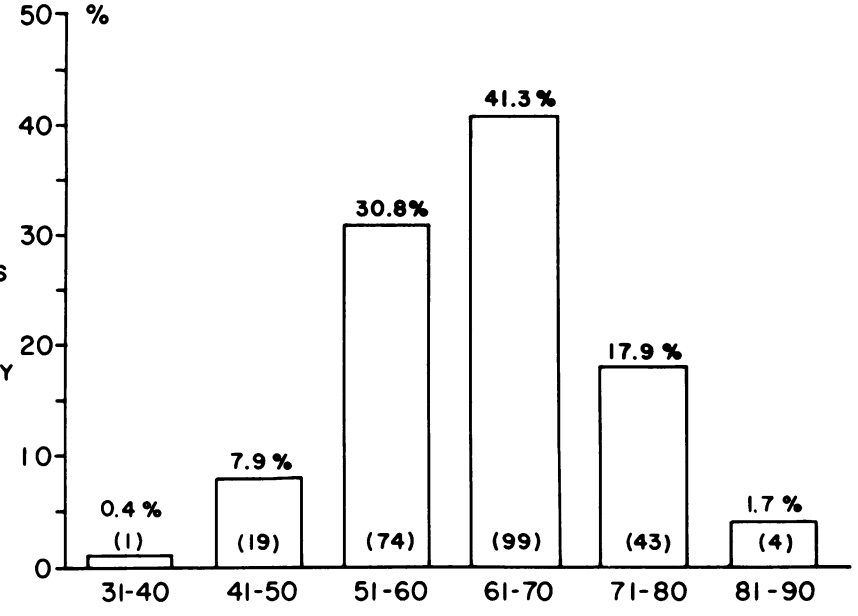

FIG. 1. Age distribution of 240 patients who had 309 carotid artery endarterectomies.

present in 22 (9.2%) patients, and none developed postoperative neurologic complications.

Fifty-seven patients who underwent major concomitant procedures at the time of CEA were analyzed separately and divided into two groups. Group I included 29 patients who had CEA performed concomitantly with a procedure requiring cardiopulmonary bypass (CPB)—myocardial revascularization in most. Group II was comprised of 28 patients who had CEA with a procedure involving the abdominal aorta, including resection of an aneurysm of the abdominal aorta, aortofemoral bypass, or revascularization of the renal or mesenteric artery.

Surgical Technique

The basic principles used in performing CEA at the Texas Heart Institute have been described previously (Table I) (Figs. 4a and b).[13] To slow cerebral metab-

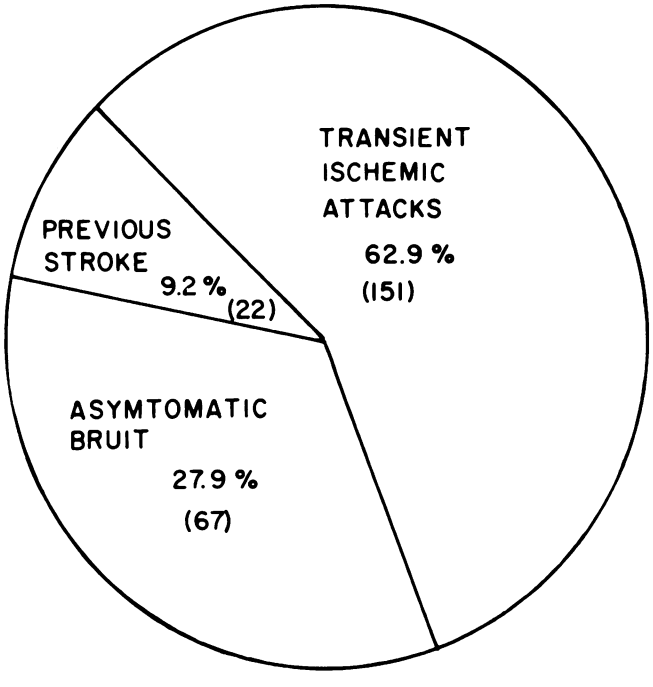

FIG. 2. Indications for carotid endarterectomy.

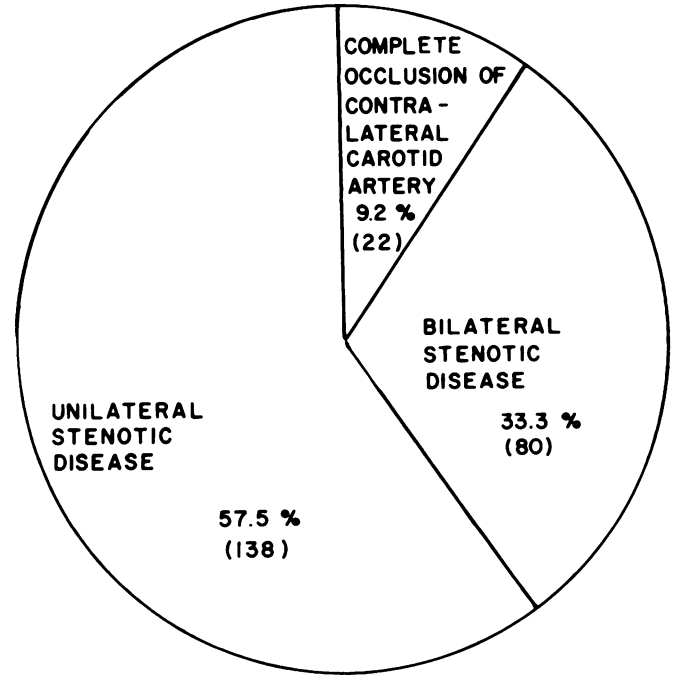

FIG. 3. Results of preoperative angiographic study in patients requiring carotid endarterectomy.

TABLE 1. *Technique of Carotid Endarterectomy Used at the Texas Heart Institute*

Deep general endotrachial anesthesia
Normothermia
Normocarbia
Normal or slightly elevated blood pressure
Careful positioning of patient
Avoid peripheral nerve injury (hypoglossal, facial, vagus)
Gentle manipulation of carotid artery
Systemic heparinization
No shunt
Adequate endarterectomy under direct vision
Dacron velour patch angioplasty (most patients)
Avoid emboli (air or atheromatous debris)
Avoid hypotension in the postoperative period

olism, relatively deep general anesthesia was induced, using inhalation anesthetics and a large dose of thiopental administered intravenously. Body temperature and the pressure of carbon dioxide were maintained in the normal range. Mean blood pressure was adjusted to a normal or slightly elevated level for each patient, both during and after the procedure. When the patient was positioned for operation, special care was taken to avoid undue manipulation or hyperextension of the neck. The carotid artery and its branches were handled gently with only enough of the vessel dissected to allow satisfactory placement of the clamps proximally and distally. Systemic heparinization and reversal with protamine sulfate was used in all patients.

Under direct vision, meticulous CEA without a shunt was performed, and the artery was closed with a preclotted knitted Dacron® velour patch in all patients (Fig. 4). Care was taken to avoid embolization of air or entry of atheromatous debris into the internal carotid system.

Results

The early postoperative outcome of 309 consecutive CEAs without intraluminal shunting is summarized in Table 2. All patients who awoke from surgery with, or who developed, a neurologic deficit during the postoperative period without adequate explanation are included in the results. Four (1.3%) patients suffered permanent neurlogic deficits following surgery; six (1.9%) others demonstrated mild and transient deficits which were reversed completely within a few days of operation. No permanent neurologic deficits occurred in the 102 patients who had either complete occlusion or significant stenosis of the contralateral artery at the time of surgery, although two (1.9%) of these patients demonstrated transient deficits.

Operative mortality (within 30 days postoperatively) for the entire group was 0.64% (two patients). Both deaths occurred because of a myocardial infarction on the second and third postoperative days, respectively.

Carotid artery clamp time was less than 20 minutes in 216 patients (70%) and greater than 20 minutes in 93 patients (30%). No correlation was noted between carotid clamp time and the incidence of stroke after endarterectomy in any of the subgroups in this series, although the low incidence of stroke in all groups probably makes statistical comparison invalid. This finding has been noted previously.[4,12,28] Among these patients who underwent concomitant procedures, in group I (CEA with CPB) one (3.4%) stroke occurred, and one (3.4%) patient died. The cause of the single death was related to the cardiac disease, namely sudden cardiac arrest caused by myocardial infarction on the fifth day after operation.

In group II, (CEA with associated procedure of the abdominal aorta), three postoperative neurologic deficits occurred—two (10.7%) of which were directly responsible for the death of the patient (Table 3). Two other deaths occurred in this group because of mesenteric infarction.

Discussion

In our series of patients who underwent CEA without shunting, the 1.3% incidence of permanent neurologic deficit compares favorably with other reported series, both with and without shunting.[2-12,14-18,21,23-25,27,29,30,33] Noteworthy is the absence of a postoperative deficit in the 102 patients who had either complete or partial

TABLE 2. *Early Postoperative Results of Carotid Endarterectomy Without A Shunt in 309 Procedures*

Angiographic Data	No. of Operations	Postoperative Neurologic Deficit				Operative Mortality	
		Permanent		Temporary			
		No.	%	No.	%	No.	%
Unilateral disease	207	4	1.9	4	1.9	2	1.0
Contralateral disease							
Stenotic lesion	80	—		1	1.2	—	
Complete occlusion	22	—		1	4.5	—	
Total	309	4	1.3	6	1.9	2	0.64

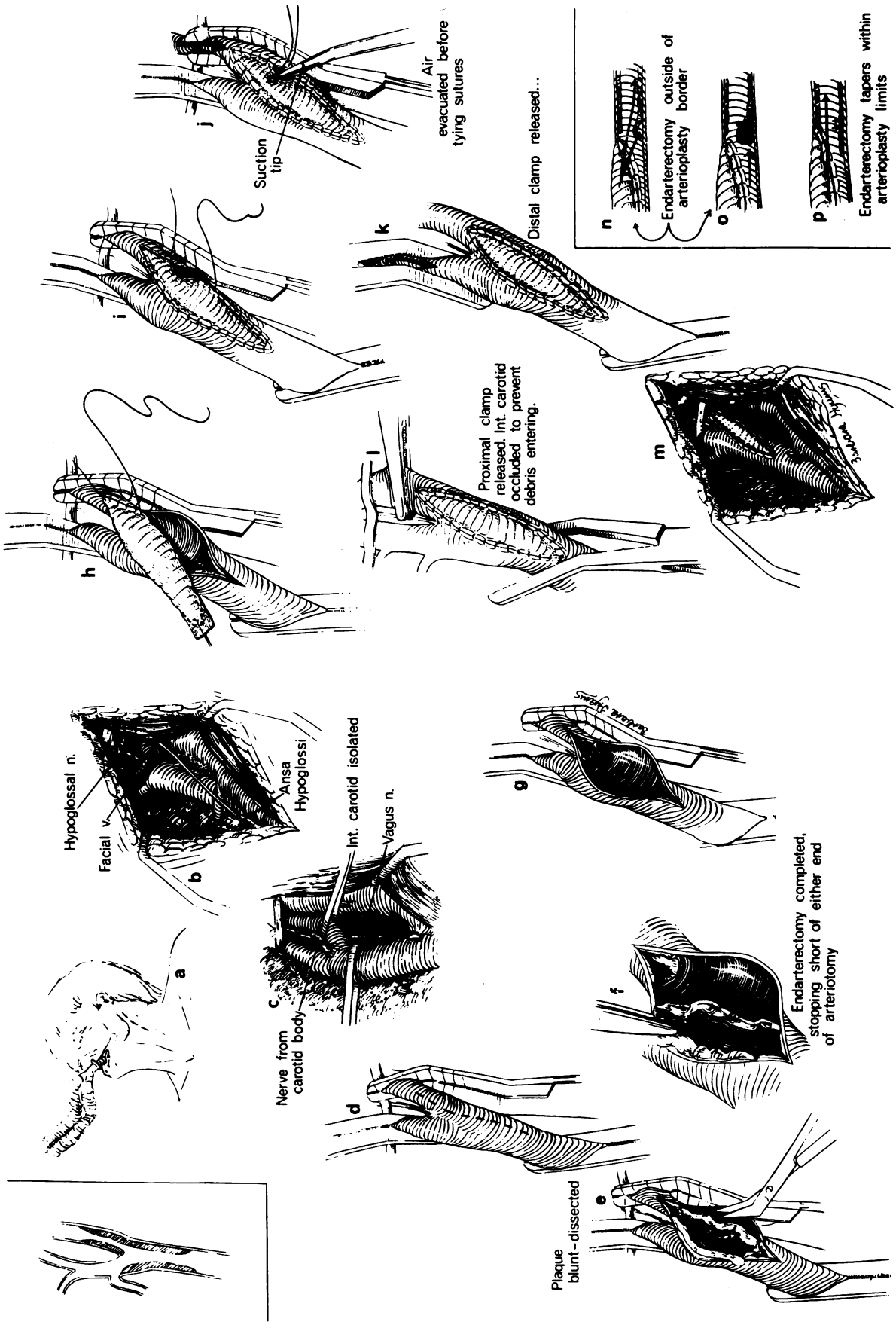

FIG. 4. Drawings showing the surgical techniques used for carotid endarterectomy. Prevention of intramural dissection or thombosis distal to the endarterectomy is shown (n and o) (From Cooley DA, Wukasch DC: *Techniques in Vascular Surgery*. Philadelphia, W. B. Saunders, 1979, pp 22–23).

TABLE 3. *Carotid Endarterectomy With Concomitant Procedures*

Procedure	No. of Operations	Postoperative Stroke		Operative Mortality	
		No.	%	No.	%
Cardiac (requiring cardiopulmonary bypass)	29	1	3.4	1	3.4
Abdominal aorta (aneurysm of ascending aorta, aortofemoral bypass, mesenteric and renal revascularization, etc.)	28	3	10.7	4 [2 strokes & 2 mesenteric infarctions]	14.2

occlusion of the contralateral carotid artery at the time of surgery. These results provide clinical evidence that cross circulation from the opposite internal carotid artery is not necessary for maintaining cerebral integrity during CEA. Collateral circulation from the vertebral system apparently provides adequate perfusion to sustain cerebral viability during carotid clamping in these patients.[4,26,28,32] For this reason, careful anteriographic interpretation of the intracranial circulation may be important to ensure that adequate circulation through the circle of Willis exists, although no significant anatomic abnormalities were noted in our series.

These findings also serve to suggest why the rate of stroke is virtually the same regardless of whether a shunt is used, *i.e.* most strokes after CEA probably are caused by emboli that occur either spontaneously or secondary to positioning of the patient, manipulation of the artery, or insertion of a shunt.[3,20,29] Unrecognized intimal dissection during insertion of a shunt after closure of the artery may account for other instances of operative stroke (Fig. 4).[13] The presence of the intraluminal shunt often interferes with the technical performance of the distal dissection and repair of the arteriotomy particularly when the lesion or bifurcation is in an unusually cephalad location.

Some may question our use of a fabric patch graft as an arterioplasty in all patients. In patients with an unusually small caliber internal carotid artery a direct repair patch graft can compromise the lumen leading to early stenosis and thrombosis. Moreover, late cicatricial stenosis may occur when the arteriotomy is closed directly. We have never encountered this complication in our patients in whom the patch graft technique was used.

Carotid Endarterectomy and Concomitant Procedures

The patient undergoing carotid endarterectomy often must have concomitant major surgical procedures. We have not resolved the question of whether to combine CEA and intrathoracic, intra-abdominal, or major surgery on an extremity. For patients undergoing cardiopulmonary bypass (CPB) with hemodilution techniques, as customarily used in our hospital, the incidence of neurologic complications has been higher than when CEA is performed separately. The reason for this is unclear, but one can speculate that patients are more susceptible to cerebral edema when the hematocrit level is reduced to a range of 20–30 g/dl. Perhaps this is attributable to alterations in the so-called "blood brain barrier." Moreover, fluctuations in blood pressure during CPB may be responsible. When the combined procedures of CEA and CPB are performed, one might find theoretical justification for performing CEA before CPB or completing CPB before CEA. Based on results of limited experience with the combined procedure, we have concluded that the operations are more safely done separately even though two administrations of general anesthesia are necessary thus incurring the additional expense of time and money to the patient.

Another vexing problem is the finding in our series of a 10.7% incidence of neurologic complications among patients undergoing concomitant CEA and major vascular procedures such as resection of an aneurysm of the abdominal aorta or aortofemoral bypass for aortoiliac disease. Explanation for this may be found in the blood pressure changes with temporary occlusion and release of the abdominal aortic clamp, but in most patients the explanation has not been obvious. Perhaps the increased susceptibility is related to hematologic factors including the need for blood replacement in some of these patients. While these questions remain unsettled, the surgeon must approach the individual patient with the knowledge that some risk of neurologic complication exists regardless of whether CEA is done as a separate procedure or combined with other more extensive operative procedures.

Conclusion

Our purpose in this paper is to demonstrate the safe performance of carotid artery endarterectomy without an intraluminal shunt, not to condemn its use. The surgeon who obtains satisfactory results using the shunt should continue to do so. Our experience, however, reveals that equally good or superior results may be obtained without a shunt, and the surgeon who prefers the nonshunting technique could not be held liable for negligence if a neurologic complication develops after operation. The data presented herein confirm that excellent clinical results can be achieved predictably and safely without a temporary shunt, even in patients with contralateral partial, or total obstruction, of the carotid artery.

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Discussion

Dr. Jesse E. Thompson (Dallas, Texas): Dr. Cooley's results are excellent and they speak for his point of view; namely, endarterectomy without a shunt, but with routine patch grafting.

I don't think the patch graft is any real problem. I use it when the artery is small. There are no hard figures for comparison, but endarterectomy without a patch gives excellent long-term patency rates, of better than 95%.

I think the use of a shunt, however, is another matter, and there is a second prevailing point of view, held by the majority of vascular surgeons; and that is that carotid endarterectomy should be performed with a shunt, either routinely, which I personally prefer, or selectively, based on an estimation of the adequacy of cerebral collateral circulation.

Now there are cogent reasons for the existence of this point of view. Those patients with the most severe forms of cerebral vascular disease, who need revascularization the most, simply cannot tolerate carotid clamping without experiencing a neurologic deficit, unless cerebral protection is employed. The literature is replete with examples of such cases; and, in fact, Dr. Cooley alludes to this in his abstract with his last three words, "nearly every case."

William Baker in Chicago, the most avid nonshunter at present, reports a stroke incidence of 6.6% in those patients operated on whose opposite carotids were totally occluded, in contrast to our results of less than 1% with a shunt.

To date, the best reported mortality and morbidity results are those where routine shunting has been used, with selective shunting running a close second.

Thus how one performs carotid endarterectomy, as Dr. Cooley stated, comes down to a matter of personal preference based on experience. This is an acceptable position, provided the results are acceptable; and Dr. Cooley's results are certainly acceptable. But many other surgeons, at whatever level of training—residents, fellows, et cetera—whose past experiences, current volume, clamp time, and expertise differ from Dr. Cooley's, will not be able to duplicate his results, and would, therefore, be best advised to use shunts, whether routinely or selectively, based on stump pressure levels, EEG findings, or neurologic testing under local anesthesia.