The Impact of Coronary Artery Disease on Carotid Endarterectomy

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In a series of 531 CENDX, preoperative cardiac risk was categorized by clinical criteria. Patients with CAD (history of previous MI, angina, congestive heart failure, and/or electrocardiographic evidence of CAD were selected for more invasive studies based on clinical criteria. The overall incidence of postoperative myocardial infarction was 2.5% and increased slightly to 4% in patients with symptomatic cardiac disease. More importantly, the overall mortality was 0.9% and only 3 of 13 (23%) postoperative myocardial infarctions were fatal. Neurologic complications averaged 1.4% and approximately 70% were related to preceding cardiac events. Twenty-two patients or 4% of the entire series underwent carotid endarterectomy combined with coronary artery bypass graft and this approach was associated with one death and one stroke. Therefore, we conclude that a selective approach to coronary arteriography and subsequent CABG based on clinical criteria is associated with an acceptably low mortality and cardiac morbidity.

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DUE TO THE SYSTEMIC NATURE of atherosclerosis, symptomatic coronary artery disease (CAD) occurs in approximately 40% of patients undergoing carotid endarterectomy.[1-3] It is not surprising that the major nonneurologic complications of carotid endarterectomy are cardiac. Myocardial infarction (MI) is responsible for 25–50% of all perioperative deaths following carotid endarterectomy.[4,5] In patients with symptomatic CAD, undergoing carotid endarterectomy, cardiac-related mortality increased to 75% of the total mortality.[6] The surgeon must balance the probability of perioperative stroke or fatal cardiac event (cost) against the prevention of stroke by the procedure (gain or benefit) in patients considered for carotid endarterectomy (CENDX). Unfortunately, the latter is much more difficult to quantify and significant benefit may not be apparent for several years, a time during which CAD can further raise costs. Given the high prevalence of symptomatic CAD in patients considered for CENDX, the surgeon cannot reject every patient with cardiac symptoms.

There are several approaches to lowering cardiac morbidity and mortality in patients undergoing CENDX. Based on their experience with patients undergoing aortic aneurysm surgery in which 55% of patients symptomatic for CAD and 17% of patients asymptomatic for CAD had surgically correctable lesions of the coronary arteries,[7] Hertzer and his associates at the Cleveland Clinic have advocated routine coronary cinearteriography for all patients undergoing CENDX.[4] They performed myocardial revascularization either as a staged procedure or combined in 27% of patients undergoing CENDX. This approach assumes that routine coronary cinearteriography for all patients undergoing CENDX is predictive of operative risk for a cardiac event, but the latter supposition has not been well substantiated. Ennix et al.[6] advocated a more liberal use of coronary arteriography and concomitant coronary revascularization. Based on a review of their experience with a group of 77 patients with symptomatic coronary artery disease undergoing CENDX in which there was a disturbingly high mortality of 18.2% (11/14 (80%) deaths due to acute MI), they recommended CABG combined with CENDX for all patients undergoing CENDX who had symptomatic CAD. We have used an alternative approach to routine coronary arteriography in patients undergoing CENDX and have relied on a clinical grading system to select patients for these more invasive studies. This grading system was derived from the Goldman classification of preoperative risks.[8] It is the purpose of this paper to review cardiac mortality and morbidity in 386 patients undergoing 531 CENDX using clinical criteria for prediction of cardiac risk.

Methods

The carotid registry of the Vascular Service at Tufts-New England Medical Center, Boston, was reviewed for the 5-year period, 1974–1979. Patients were selected for CENDX based on standard clinical criteria: (1) history of transient ischemic attacks (TIA), (2) completed stroke

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(CS), and (3) prophylactic carotid endarterectomy (P-ENDX), either for carotid bruit or as a second side following CENDX for symptomatic disease. Medical histories were examined to identify those who had major preoperative cardiac risk factors: history of myocardial infarction (MI), angina, congestive heart failure, hypertension, or major arrhythmia. Based on both clinical and electrocardiographic evidence, the patients who underwent CENDX were divided into four groups (Fig. 1): (The first three groups underwent CENDX alone) Group 1—no symptoms, physical findings or electrocardiographic signs of coronary artery disease (CAD), Group 2—absence of both symptoms and physical findings for CAD, but electrocardiographic evidence of CAD (criteria for previous MI), and finally, Group 3—symptomatic CAD, *e.g.* angina, history of MI or CHF as well as electrocardiographic evidence of CAD. The fourth group with severe CAD and carotid disease underwent simultaneous carotid endarterectomy and coronary artery bypass graft (CENDX + CABG).

Surgical Technique

Details of our technique have been extensively described before[9] and will be summarized here. Anesthesia was induced with intravenous synthetic narcotic agents with careful attention paid to minimizing hypertension. The conduct of anesthesia was exactly the same as used in coronary artery bypass surgery. All patients had radial artery lines to monitor intra-arterial pressure, while those with a history of CAD had left ventricular function monitored by Swan-Ganz catheter. The carotid was exposed through a neck incision made parallel to the course of the sternocleidomastoid muscle. Careful dissection of the tissues away from the carotid was performed in order to avoid embolization of luminal contents. The carotid sinus was not routinely injected with local anesthetic, but only when bradycardia (less than 60 beats/min) developed. Following administration of 5000 units of heparin intravenously the patients underwent test clamping to determine cerebral perfusion. Patients were selectively shunted based on previously established EEG criteria.[10] A generous endarterectomy was carried out so that the internal carotid portion measured approximately 2–3 in order for it to be smoothly tapered. Tacking of the distal site of the enderterectomy was employed very infrequently. The endarterectomy site was carefully flushed and the arteriotomy closed with a running 6–0 multifilament suture. Heparin was not routinely reversed with protamine. Light anesthesia was maintained throughout the procedure so that the patients could be awakened in the operating room at the end of the procedure.

Combined Carotid and Coronary Artery Bypass (CENDX + CABG)

Anesthesia was induced with intravenous synthetic narcotic agents and with attention paid to minimizing the rate pressure product. A sternotomy was performed in a pericardial well. The heart was not manipulated. Completion of the sternotomy allowed rapid institution of bypass, should any hemodynamic deterioration occur. Simultaneous with sternotomy, the saphenous vein was harvested. After sternotomy, the CENDX was performed according to the technique previously described above. Following closure of the endarterectomy, the neck wound was lightly packed with a gauze sponge and left open for later closure. Cardiopulmonary bypass was then instituted with an aortic cannula in either a two stage single venous cannula or with bicaval cannulation. The left ventricle was vented through the superior pulmonary vein. Potassium cardioplegia solution was instilled through the aortic route and was utilized to maintain a temperature between 12–15 C, as monitored through a needle thermister in the left ventricular apex. All distal and proximal anastomoses were performed during a single aortic cross-clamp period. After clamp removal, the heart was defibrillated. The proximal anastomoses were performed using a partially occluding aortic clamp while the heart beat in a vented state. Throughout the period of cardiopulmonary bypass, systemic temperature was kept between 25 and 28 C and arterial perfusion pressure was maintained over 80 mmHg to assure adequate cerebral flow.

Postoperative Complications

Cardiac. Cardiac complications were defined as: (1) cardiac death—the patient died from a documented myocardial infarction, arrhythmia, or from a refractory low cardiac output state that was not part of an inexorably downhill course, primarily caused by some noncardiac conditions such as sepsis, (2) myocardial infarction—proven by characteristic EKG changes and myocardial isoenzyme elevations (in certain cases this condition was further substantiated by a pyrotechnetium scan), (3) electrocardiographic changes—ST segment depression or T wave changes which were new and were not present prior to surgery and were unaccompanied by elevation of myocardial isoenzymes or positive pyrotechnetium scan, (4) congestive heart failure—defined by clinical findings or rales on auscultation, characteristic x-ray findings, and in the majority of cases by elevated pulmonary-capillary wedge pressure as determined by Swan-Ganz catheter monitoring, and (5) major cardiac arrhythmia—an atrial or ventricular rhythm which required intervention by intravenous drugs.

Neurologic Complications

Stroke was defined as any neurologic damage that did not clear within 24 hours and left the patient with a prolonged neurologic deficit. Neurologic events were described in regard to their vascular supply and the relationship to vessel operated upon.

Results

Three hundred and eighty-six patients underwent 531 CENDX. The majority (96%) of patients underwent CENDX alone (CENDX group)—364 patients undergoing 509 CENDX, but 22 patients underwent CENDX combined with coronary artery bypass (CENDX + CABG).

Preoperative Cardiac Status (Fig. 1)

The patients were divided by cardiac risk criteria into four groups: Group 1—no clinical evidence (history and physical exam) or electrocardiographic signs of CAD included 132 patients who underwent 178 CENDX (34%), Group 2—no history of CAD, but electrocardiographic evidence of CAD (an old MI) was composed of 43 patients undergoing 57 carotid endarterectomies (10%), and Group 3—with clinical and electrocardiographic evidence of CAD consisted of 189 patients undergoing 274 CENDX (52%). A fourth group underwent simultaneous CENDX with CABG and consisted of 22 patients (4%). This latter group by process of selection was probably the "sickest" group.

Preoperative atherosclerotic risk factors were compared for the three groups undergoing CENDX alone. Although the incidence of hypertension and lower extremity arterial disease was approximately 50% and comparable among the three groups, both the incidence of diabetes mellitus (26%) and all three factors simultaneously were two-fold greater in Group III (CAD+, EKG+).

Preoperative Neurologic Indications for Carotid Endarterectomy (CENDX alone groups) (Table 1)

TIA was the most frequent indication (61%) for the 364 patients undergoing 509 carotid endarterectomies alone. Completed stroke and prophylactic CENDX were relatively comparable as an indication for surgery. The presence or absence of clinical and/or electrocardiographic evidence of CAD did not appear to affect the neurologic indications for CENDX, because TIA was two to three times more frequent a reason for endarterectomy than completed stroke or prophylaxis in all three groups. The same number of prophylactic carotid endarterectomies were carried out in those with no evidence of CAD (Group 1) as in those with clinical and EKG evidence of CAD (Group 3).

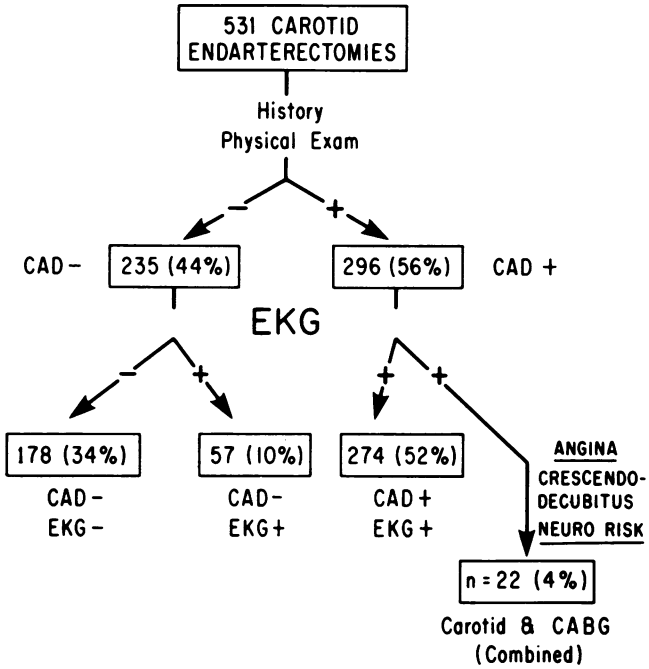

FIG. 1. Protocol for determining preoperative cardiac risk. The incidence of coronary artery disease (CAD) was determined by clinical and electrocardiographic criteria. The majority of our patients, 66%, had evidence of CAD, but only 4% required concomitant carotid endarterectomy and coronary artery bypass.

Indications for Surgery in the CENDX and CABG Group

The CENDX + CABG Group was selected for simultaneous surgery based on a history of severe angina (at rest or crescendo) coupled with either symptomatic carotid disease in 14 (60%) of the patients or with angiographic high risk for a neurologic event during cardiopulmonary bypass (Table 2). This table correlates the findings on carotid arteriography with the neurologic indication for surgery in the CENDX + CABG Group and shows that nearly 75% of the patients had hemodynamically significant stenoses, of which 50% were bilateral. CENDX + CABG was carried out for ulcerative plaque disease

TABLE 1. *Neurological Indications for Carotid Endarterectomy*

Group	TIA	CS	PCE
CENDX			
(1) CAD−EKG− (n=178)	110	36	32
(2) CAD−EKG+ (n=57)	26	20	11
(3) CAD+EKG+ (n=274)	174	49	51
(4) Combined CENDX and CABG (n=22)	11	3	8
Total	321	108	102

TABLE 2. *Correlation of Neurological Indication for Carotid Endarterectomy and Carotid Arteriogram in Combined Carotid Endarterectomy and Coronary Artery Bypass Group*

Neurological Indication	Unilateral Stenosis >60%	Bilateral Stenoses >60%	Ulcerated Plaque	Contralateral Occlusion or >60% Stenosis
TIA (n=11)	3	4	3	1
CS (n=3)	0	1	1	1
PCE (n=8)	4	2	0	2
Total (n=22)	7	7	4	4

alone only in patients with symptomatic carotid disease. Concern for diminished cerebral perfusion during cardiopulmonary bypass prompted CENDX + CABG in eight patients (36%) who were asymptomatic for carotid disease, but who had hemodynamically significant stenoses by carotid arteriography. These stenoses had been detected initially as a cervical bruit and a subsequent noninvasive study showed them to be hemodynamically significant. In addition to a history of severe angina in all 22 patients, six patients had a history of congestive heart failure and eight had a previous history of myocardial infarction. Coronary arteriography revealed extensive three and four vessel disease in all patients. Seven patients had reduced left ventricular function as determined by systolic ejection fractions less than 40%.

Postoperative Cardiac Complications (Table 3)

Myocardial Infarctions. A total of 13 acute myocardial infarctions occurred in 509 CENDX alone group (1–3) for an overall incidence of 2.5%, of which three were fatal (23%). None occurred in patients without symptomatic and/or electrocardiographic evidence of CAD. The incidence of MI was comparable in these latter two groups: Group 2 (3.5%), Group 3 (4%). Two MIs developed in the CENDX + CABG Group.

TABLE 3. *Cardiac Complications*

Complication	Group 1 (n=178) CAD− EKG−	Group 2 (n=57) CAD− EKG+	Group 3 (n=274) CAD+ EKG+	Group 4 (n=22) Simultaneous Carotid/CABG
Myocardial infarction	0	2 (3.5%)	11 (4%)	2 (9%)
Minor				
Congestive heart failure	2 (1.1%)	0	12 (4.4%)	2
Arrhythmia	2	5	10	6
Ischemic EKG changes	2	0	4	0
Total minor	6 (3.4%)	5 (8.8%)	26 (9.5%)	8 (36%)

Minor cardiac morbidity is summarized in Table 3 and averaged 7.3% for the CENDX alone groups. Minor cardiac complications were lowest in Group 1 and were evenly distributed among CHF, arrhythmia, and ischemic EKG changes. Although Group 2 had an incidence of minor cardiac complications similar to Group 3 (8.8%), this incidence was entirely due to arrythmias. The 274 CENDX in Group 3 were further subdivided into those performed either in patients with a history of angina pectoris alone—188 procedures, or patients with a history of both angina pectoris and previous myocardial infarction—64 procedures. The incidence of both myocardial infarction (4.3%) and congestive heart failure (4.3%) was comparable between these two subgroups.

Correlation of Cardiac Morbidity to Neurologic Indication

When the incidence of perioperative cardiac morbidity was related to the preoperative neurologic indication for CENDX in Groups 1–3, there was no significant difference in the incidence of myocardial infarction or minor cardiac complications among the three neurologic indications for carotid endarterectomy.

Mortality (Table 4)

Five of the 364 patients undergoing CENDX alone died for a patient mortality of 1.4% (procedure mortality of 0.9%), and all had a clinical history of CAD (Group 3). Two patients died following an acute MI without associated neurologic changes, while two additional patients had neurologic alterations subsequent to a major cardiac event: MI, 1, arrhythmia, 1. One patient eventually died of pulmonary complications following a stroke. Thus, 80% of deaths were cardiac-related.

Neurologic Complications (Table 4)

Of the 509 patients undergoing CENDX alone, seven patients (1.3%) developed a prolonged neurologic deficit. Five of the seven strokes (70%) were associated with a major cardiac event: three acute MIs and two instances of pronounced and prolonged hypotension, but without permanent EKG changes or elevation of myocardial isoenzymes. Six of seven strokes developed within 24 hours of surgery. Two strokes occurred in the territory of the nonoperated carotid.

Combined CENDX and CABG Group

Neurologic events. One patient developed sudden changes in the EEG during dissection of the carotid. Following surgery, the patient had weakness of the right upper extremity and expressive aphasia consistent with a left cortical embolus.

Mortality. One patient who underwent an urgent carotid endarterectomy combined with CABG died of right ventricular failure unresponsive to pharmacologic and mechanical support.

Staged CENDX and CABG Surgery

Thirteen patients from Group 3 underwent subsequent coronary artery bypass following the initial carotid endarterectomy. The cardiac procedure was carried out as a subsequent staged procedure for progressive angina. One of 13 patients developed a subendocardial MI (CPK isoenzyme elevation, nonspecific ST-T wave changes but negative myocardial scan following his carotid endarterectomy). There were no other neurologic or cardiac complications following the 13 staged coronary artery bypass procedures.

Discussion

Our study shows that carotid endarterectomy alone can be carried out with a low overall mortality (0.9%) and cardiac morbidity (incidence of MI 2.5%), despite a high prevalence (66%) of CAD in our patients. This study supports not only a selective approach to invasive assessment of CAD, but also a restricted use of CABG combined with carotid endarterectomy. The prevalence of CAD in our patient population (66%) was somewhat greater than other series such as Ennix (49%)[6] or Hertzer (50%).[4] Atherosclerotic risk factors, such as hypertension and diabetes mellitus, were comparable among the patients undergoing CENDX alone (Group 1–3) and almost identical in incidence to Hertzer's patients.[4] Not only was our overall mortality (0.9%) slightly less than many other large series as shown in Table 5, but also the proportion of MIs which were fatal (23%) was relatively low. Furthermore, the percentage of patients with known CAD (Group 3) who developed an MI was extremely small (4.5%), being approximately one-third the 12.9% incidence described in Ennix's and his associates' series.[6]

The low mortality and cardiac morbidity rates can be attributed to several factors: (1) preoperative selection of patients, (2) reduction of cardiac risks before surgery, and (3) the type of anesthetic management in the operative and perioperative period.

TABLE 4. *Mortality and Stroke Rate in 531 Carotid Endarterectomies*

	Mortality		Stroke	
Group	Overall	Cardiac-Related	Overall	Cardiac-Related
(1) CAD−EKG− (n=178)	0	0	2 (1%)	0
(2) CAD−EKG+ (n=57)	0	0	1 (1.7%)	1
(3) CAD+EKG+ (n=274)	5 (1.8%)	4 (80%)	4 (1.4%)	4
Total carotid alone	5 (0.9%)	4 (80%)	7 (1.4%)	5 (71%)
(4) Combined	1 (4.5%)	1	1 (4.5%)	0

Preoperative Selection

Due to the systemic nature of atherosclerosis, between 40–50% of patients undergoing CENDX have symptoms of coronary artery disease.[1,3,12] As with other peripheral vascular surgical procedures, the surgeon must be able to select that patient in whom the cardiac risk of surgery justifies the benefits of the procedure. Does the concomitant presence of both CAD and carotid occlusive disease dictate a different approach than with clinically overt coronary or carotid artery disease alone? One approach has been to use evidence of atherosclerotic disease in one system, carotid disease, as a marker of disease in another, CAD, and perform coronary arteriography on all candidates for CENDX.[12]

In a series of 144 patients undergoing carotid endarterectomy at the Cleveland Clinic, coronary arteriography revealed severe (>70%) luminal obstruction in 75/85 (89%) of patients with suspected CAD and in 25/59 (39%)

TABLE 5. *Operative Mortality and Acute Fatal Myocardial Infarction Associated with Carotid Endarterectomy*

Series	Year	Number of Procedures	Operative Mortality (%)	Cardiac-Related Mortality (No. Cardiac Deaths/Total Deaths) (%)
DeWeese[3]	1973	103	1	100
Nunn[1]	1975	234	5	25
Rich[12]	1975	209	2.6	17
Ennix[6]	1979	1391	2.1	45
Thompson[13]	1979	1286	2.1	—
Hertzer[4]	1981	335	3	60
Sundt[5]	1981	1145	1.5	50
Compilation total		4703	2.5	42
Present series		509	0.9	80

TABLE 6. *Combined Carotid Endarterectomy and Coronary Artery Bypass Surgery*

Series	Year	Number of Patients	Operative Mortality (%)	M.I. (%)	Stroke (%)
Bernhard[21]	1972	15	0	0	6.6
Mehigan[22]	1977	25	4	8	8
Okies[23]	1977	16	6.3	6.3	6.3
Hertzer[12]	1978	115	4.3	10	4.3
Morris[24]	1978	44	4.5	0	2
Rice[25]	1980	54	0	0	1.9
Compilation total		269	3.9	4.1	4.9
Present series		22	4.5	4.5	4.5

of patients not suspected clinically of having CAD, so that nearly 70% of that overall series had severe luminal obstruction.[14] This method of screening for cardiac risk assumes that coronary arteriography predicts operative risk for carotid endarterectomy, a causal relationship that is attractive but unproven. While coronary arteriography may demonstrate disease in the majority of patients with cardiac symptoms, 60 out of 100 asymptomatic patients would be subjected to an invasive and costly coronary arteriogram to no benefit. What is even more striking is that CABG was carried out in only one half of the 75 patients with symptoms and severe coronary obstruction in the Cleveland Clinic experience. Coronary arteriography in another series of 100 patients who were asymptomatic for CAD, but who were undergoing peripheral vascular procedures, showed a similar incidence of anatomically significant coronary artery lesions, but also a low subsequent rate of CABG.[15] The low benefit to cost ratio of routine coronary arteriography argues against its use as a screening method prior to CENDX.

While CABG appears to lower markedly the cardiac risks of subsequent surgery such as aortic aneurysmectomy, aortic and femoral-popliteal reconstruction,[16,17] the timing of CABG is different for patients with carotid disease. Most surgeons prefer to precede cardiac surgery with carotid endarterectomy so that the risk of stroke is lessened during cardio-pulmonary bypass. As shown in Table 6, the relatively high stroke rate of CENDX combined with CABG (21–25) argues against a liberalization of its use for all patients with symptomatic cardiac disease undergoing carotid endarterectomy, as has been recommended by Ennix and associates.[6] They experienced with CENDX a high cardiac mortality in patients with CAD and felt that concomitant CABG would lower this mortality. In our series, combined CENDX and CABG was reserved for patients with unstable angina (crescendo or decubitus) and: (1) symptomatic carotid disease—TIA, completed stroke or (2) asymptomatic carotid disease with angiographic high risk—ipsilateral stenosis and contralateral occlusion, bilateral stenoses, or unilateral high grade stenosis. Our combined CENDX + CABG Group, therefore, was highly selected and represents in general our sickest patients. The majority of our patients who presented with CAD and carotid disease had CENDX alone or CABG staged to follow CENDX. It is interesting to note that our indications for combined surgery are similar to those of the Cleveland Clinic,[4,12] so that our major point of difference lies in the use of coronary arteriography as a routine screening method for CAD. We are in concordance that CABG plays an important role in the long-term survival of the patient with peripheral vascular disease.

Since patients undergoing CENDX must live for a sufficient time after surgery to accrue the benefits of stroke or TIA prevention, concomitant prevention and correction of CAD becomes the major determinant of the benefits from CENDX. Like DeWeese's earlier study,[3] 60% of late deaths were cardiac in our series of 70 prophylactic CENDX who were followed for 5 years.[2] Since treatment of CAD by CABG has been clearly shown to improve survival in certain subsets of patients with CAD, *e.g.*, left main disease,[23] the survival of both ours and DeWeese's patients might have been prolonged by CABG. Little is accomplished for the patient with both coronary and carotid disease, if the risk of stroke has been eliminated by CENDX, but the quality of life and chance for survival are impaired by the progress of coronary artery disease.

We have used clinical criteria to predict cardiac risk and to select patients for more invasive cardiac studies. Selection was guided by the risk factor index developed by Goldman and his associates.[8] Several of these risk factors, such as arrythmia or CHF, can be reduced by medical treatment. Following a course of maximal therapy, left ventricular function should be assessed objectively by radionuclide ejection fraction both at rest and with cold pressor stress. Although angina was not a statistically significant risk factor in Goldman's study, in our patients, careful scrutiny of the anginal pattern combined with selective use of exercise or cold pressor stress testing and myocardial scans helped to define "high risk" patients. Patients with unstable angina, crescendo or decubitus angina, markedly positive stress test, anterior wall ischemia by scan or a systolic ejection fraction less than 40%, in general, were referred for coronary arteriography prior to CENDX (Fig. 2).

In addition to preoperative selection and modification of cardiac risk, the type of anesthesia and form of cardiovascular monitoring during surgery influence greatly the incidence of cardiac complications. During the last 4 years, we have adopted for all patients undergoing CENDX the cardiac method of anesthesia—slow induction, atraumatic intubation, and balanced narcotic maintenance during anesthesia, which avoids myocardial depression. Monitoring by Swan-Ganz catheter permits assessment of left ventricular function in response to both fluid requirements and changes in systemic vascular resistance. This form of cardiovascular monitoring results in a rational pharmacological control of the patient during anesthesia and in the perioperative period. The importance of monitoring left ventricular function is supported by Cooperman's study, in which approximately 50% of postoperative patients who developed pulmonary edema had inappropriate fluid administration.[24]

Although induced hypertension may theoretically improve cerebral perfusion, the afterload challenge to the patient with CAD may actually decrease cardiac output and thereby increase both left ventricular stroke work and myocardial demands (Fig. 3). Hypertension places the patient at risk for a cardiac event. Continuous monitoring of cerebral perfusion with EEG allows the surgeon and anesthetist to gauge the effect of their pharmacologic maneuvers.[10] Postoperative alterations in baroreceptor tone may lead to hyper- or hypo-tension in nearly 50% of patients undergoing carotid endarterectomy.[25] Hypertension is associated with not only an increased demand on the myocardium, but also with an increased risk for a neurologic event.

Hypertension was a frequent antecedent event in those patients who developed cardiac complications in our series, so that careful control of postoperative hypertension is an important factor in lowering the rate of cardiac complications. The majority of our 13 myocardial infarctions occurred within the first 24 hours after surgery at a time when hypertensive events are most frequent. Control of postendarterectomy hypertension with intravenous nitroprusside can be more effectively managed by monitoring the central cardiac response *via* Swan-Ganz catheter. The 23% mortality rate for our patients who incurred an MI is approximately one half of that described in a collective review of surgical patients by Salem et al.[26] and is probably related to more aggressive cardiovascular monitoring and pharmacologic management. Thus, selection of the patients with CAD for CENDX based on clinical criteria coupled with the cardiac type of anesthesia and monitoring of left ventricular function can reduce perioperative cardiac complications.

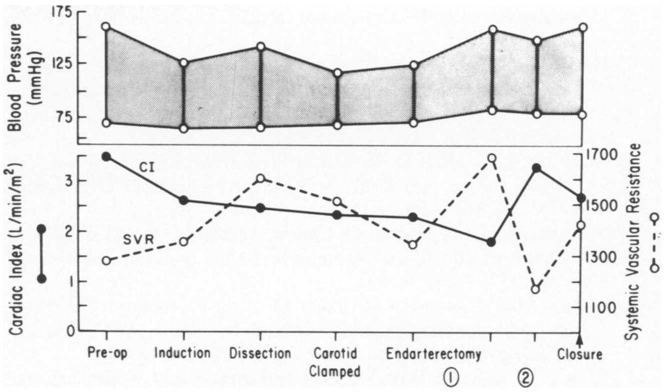

FIG. 3. Hemodynamic course of patient undergoing carotid endarterectomy. Systolic and diastolic pressures in the top panel are contrasted to cardiac index (CI) (closed circle) and systemic vascular resistance (open circle) in the bottom panel. During dissection of the carotid, systemic vascular resistance increased as cardiac index stabilizes at 2.5 L/min/m². During endarterectomy (right side) hypertension was induced because of EEG changes.[1] Concomitant with the elevated systolic blood pressure, systemic vascular resistance increased. Unfortunately, cardiac index dropped and ST segment changes were observed on EKG. At this point,[2] the patient was given an infusion of nitroprusside with an increase in cardiac output and a decrease in systemic vascular resistance. This case exemplifies the important relationship between hypertension (afterload) and the cardiac response during carotid endarterectomy.

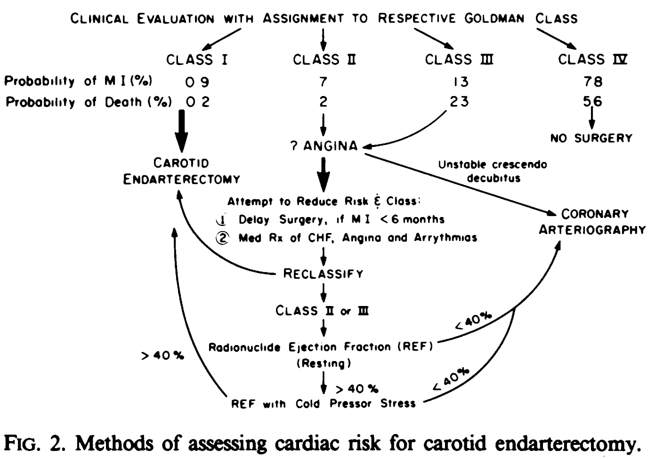

FIG. 2. Methods of assessing cardiac risk for carotid endarterectomy. Flow diagram for assessing cardiac risk in patients undergoing carotid endarterectomy. Initially, patients were assessed by clinical criteria and assigned to one of four Goldman categories. Patients in Class I underwent carotid endarterectomy without further cardiac evaluation, while those in Class IV usually were not offered surgery. Patients in Goldman Class II or Class III first underwent medical attempts to reduce their cardiac risk and to improve their classification. If neither of the latter two results were achieved, the patients underwent further evaluation with radionuclide ejection fraction both at rest and with cold pressor stress testing. Coronary arteriography was carried out if this test was, in general, less than 40% or if angina was unstable.

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