Aortic and Renal Vascular Disease

Factors Affecting the Value of Combined Procedures

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Assessment of the predictive value of preoperative factors in the determination of operative risk in 50 patients who underwent simultaneous aortic and renovascular procedures over a 10-year period is reported. There were six operative mortalities (12%). Factors associated with increased mortal risk were azotemia (43% *vs.* 7%), associated complex renal or visceral procedures (31% *vs.* 5%), treatment of aortic aneurysm *vs.* occlusive disease (17% *vs.* 5%), positive EKG (19% *vs.* 4%), age over 60 years (20% *vs.* 4%), and a history of diffuse peripheral vascular disease (18% *vs.* 7%). None of these differences, by themselves, had statistical significance. Through discriminate analysis with assignment of weighted scores to the five most powerful predictors of operative death (complex procedure—4, azotemia—4, aortic aneurysm repair—3, positive electrocardiogram—2, history of diffuse vascular disease—2), a weighted score of ≥10 predicted operative death with an 83% sensitivity and 93% specificity ($p = 0.003$). Although advanced age, diabetes, severity of hypertension, and history of heart disease were associated with increased operative risk, they contributed minimal discriminate value to that provided by the preceding five variables. This was because these weaker risk factors were usually found in association with the predictors in the discriminant score. This study suggests that in patients with high weighted discriminant scores (≥10), consideration of operative risk is particularly important in evaluation of the proposed value of combined procedures.

MANAGEMENT OF THE diffusely atherosclerotic patient frequently requires assessment of occlusive disease at multiple sites and determination of the clinical significance of angiographically identified disease. Similarly, simultaneous correction is often considered for atheromatous involvement of adjacent arterial segments. In this regard, simultaneous correction is commonly advocated for patients with disease involving both the abdominal aorta and the renal arteries. Unfortunately, the decision to perform combined simultaneous correction is frequently based on the mere presence of anatomic disease in these two sites without concern for the clinical significance of the disease at each site, the risk of simultaneous correction in respective clinical settings, or the subsequent course in patients with disease left uncorrected.

Clearly, aortic aneurysms that extend proximally to involve the renal artery origins require simultaneous reconstruction of both sites. Likewise, patients with uncontrolled renovascular hypertension secondary to correctable renovascular disease who also have aortic occlusion (Fig. 1) or an aortic aneurysm (Fig. 2) may require simultaneous repair of both lesions. In contrast, the criteria for simultaneous correction of either functionally insignificant renal artery stenosis or clinically silent aortoiliac disease require further definition. Since intervention at either site implies that there is an associated improvement in morbid event-free survival or quality of life, identification of factors important in determining the operative risk and outcome in patients undergoing combined correction of such disease is pertinent to their management.

This report summarizes experience with the management of patients with both renovascular and aortic occlusive or aneurysmal disease and the use of combined aortic and renovascular procedures in the Specialized Center for Research in Hypertension at Vanderbilt University Medical Center for the past 10 years.

Patient Population

During the 10-year period, January 1, 1973 through December 31, 1983, 50 patients have undergone com-

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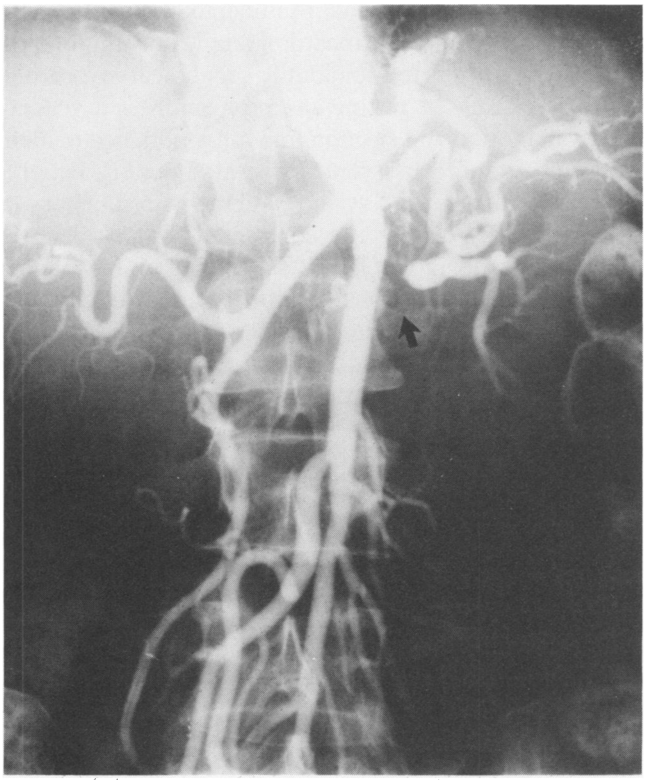

FIG. 1. Arteriogram showing total occlusion of infrarenal aorta and severe bilateral renal artery occlusions.

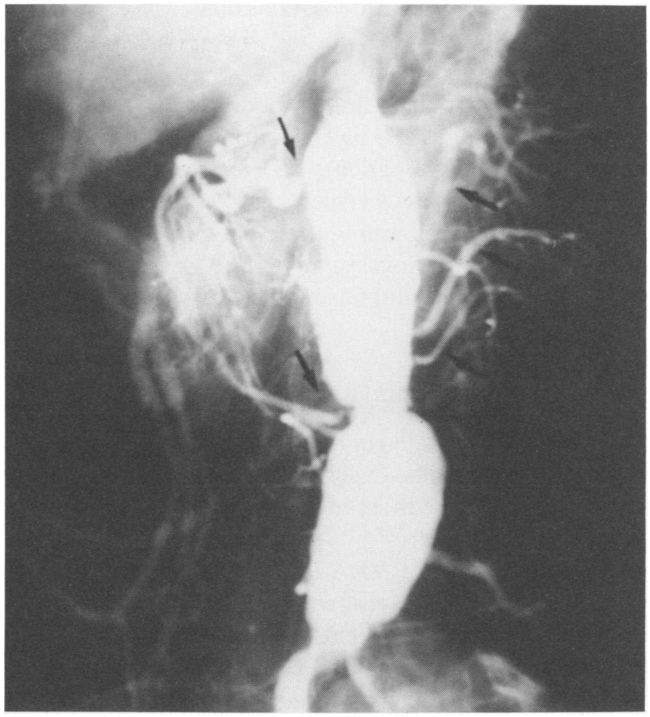

FIG. 2. Arteriogram demonstrating combined problem of abdominal aortic aneurysm and multiple severe renal artery occlusions.

bined aortic and renovascular procedures at Vanderbilt University Medical Center. For comparison, 321 patients underwent renovascular procedures alone and 269 patients were submitted to aortic procedures for occlusive or aneurysmal disease without associated visceral or renal reconstruction during this period. Not included in these groups are patients requiring renal revascularization during management of suprarenal or thoracoabdominal aortic aneurysms and patients only undergoing nephrectomy in conjunction with an aortic procedure.

Forty-nine of the 50 patients in the study group were hypertensive. Forty-six of these patients were evaluated through the Specialized Center for Research in Hypertension. Three patients underwent urgent operation without evaluation of hypertension before surgery. Clinical characteristics of the 50 patients are as follows: ages ranged from 44 to 73 years (mean: 59.4 years). There were 32 men and 18 women. Forty-three patients abused tobacco. Three patients had diabetes mellitus. Twenty-two patients had a history of heart disease that included previous myocardial infarction (9 patients), active angina pectoris (13 patients), congestive heart failure (6 patients) and previous coronary artery bypass (4 patients). Preoperative electrocardiography demonstrated previous myocardial infarction, ischemia, or left ventricular hypertrophy (with or without strain) in 27 patients. Hyperlipoproteinemia was present in 25 patients. Severity of hypertension ranged from 180/90 to 280/165 (Fig. 3). Significant azotemia (serum creatinine ≥ 3 mgdl) was present in seven patients and ranged from 3.2 mgdl to 8.5 mgdl at the time of admission of these patients. Three patients required hemodialysis before surgery.

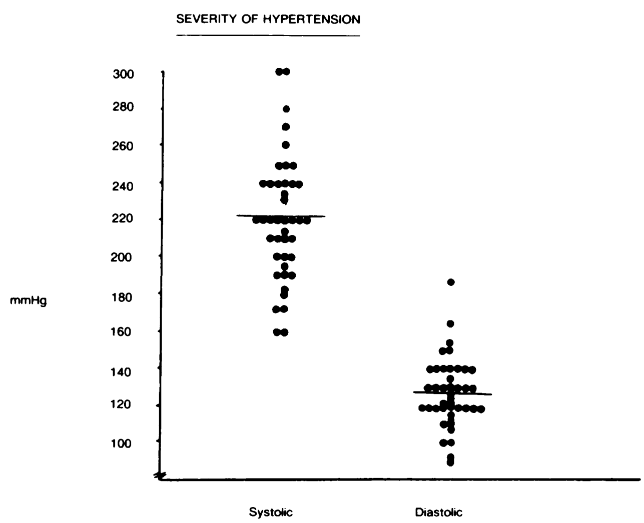

FIG. 3. Chart showing severity of hypertension present in study population.

Diagnostic Evaluations

Angiography

Aortography demonstrated abdominal aortic aneurysms in 29 patients and severe aortoiliac occlusive disease in 21 patients. Five patients had total aortic occlusion. Renovascular disease was secondary to atherosclerosis in 47 patients. The remaining three patients had fibromuscular dysplasia. Renovascular disease was present bilaterally in 44 patients and bilaterally severe (≥75% stenosis) in 20 patients.

Renal Vein Renin Assays

Preoperative renal vein renin assays (RVRA) were performed in 40 patients. Lateralization of activity (≥1.5:1.0) to the side with the most severe renovascular disease occurred in 28 patients (70%). The technique of preparation and performance of RVRA in our center have been previously described.[1,2] Reasons for not performing RVRA before surgery in nine patients included previous unilateral nephrectomy (2 patients), need for urgent operation (3 patients), and technical considerations (3 patients).

Split Renal Function Studies

Urologically performed split renal function studies (SRFS) were performed in 36 patients, according to previously published methods.[1,2] Five studies were uninterpretable due to lack of urine flow from one of the two kidneys. Reasons for not performing SRFS in 13 patients included previous unilateral nephrectomy (2 patients), need for urgent operation (3 patients), dialysis-dependent renal failure (3 patients), and technical considerations (5 patients). Results were positive in 2 patients (65%). Either RVRA or SRFS were positive for RVH in 85% of the 31 patients who underwent both of these studies.

Operative Management

Perioperative Management

In brief review, current preoperative evaluation and perioperative management of this diffusely atherosclerotic group of patients include reducing high dose beta-adrenergic blockers and converting enzyme inhibitors to low doses by introduction of methyldopa therapy. Similarly, clonidine antihypertensive therapy is gradually tapered and discontinued. This is done to remove rebound hypertension in surgery or immediately after surgery secondary to their abrupt withdrawal. If blood pressure control is not achieved by methyldopa, oral vasodilator therapy, and diuretics, the patient is administered intravenous nitroprusside therapy with constant intra-arterial monitoring of blood pressure in an intensive care unit.

All patients who are able to undergo stress testing are submitted to an electrocardiographically monitored, standardized stress test to identify subclinical myocardial ischemia. Likewise, resting and postexercise left ventricular wall motion and ejection fraction is obtained to identify stress-induced left ventricular dysfunction. Patients with a positive stress test and patients with a history of ischemic heart disease are considered for preoperative coronary arteriography. Patients identified in this manner to have clinically significant coronary artery disease and in whom the aortic disease does not require emergent operation are submitted to myocardial revascularization prior to performance of the combined aortic and renovascular procedures.

In addition, patients with poor myocardial performance (defined as a resting ejection fraction of less than 35% or an ejection fraction that drops with exercise) are placed in the intensive care unit 24 hours before operation and have a radial artery catheter and a Swan-Ganz catheter inserted to collect baseline information regarding optimal left ventricular filling pressures and cardiac output under conditions of volume loading and afterload-reducing vasodilators (nitroglycerine or nitroprusside). In this manner, optimal myocardial performance for the individual patient can be identified prior to induction of anesthesia and operation. Likewise, all other patients not requiring preoperative pulmonary artery pressure measurements have similar catheterization immediately prior to induction of anesthesia to provide intraoperative and postoperative data regarding myocardial performance.

All patients receive mannitol (12.5 g intravenously) in the period prior to aortic or renal artery cross-clamping and intravenous heparin (1 mg/kg) immediately prior to cross-clamping. Frequently, protamine (25–50 mg) is given at the end of the procedure to partially counteract the residual anticoagulant effect of heparin.

Operative Procedure

Operative procedures performed in the 50 patients are summarized in Table 1. Aortic procedures consisted of replacement of aortic aneurysm with Dacron grafts in 27 patients and aortoiliac or femoral bifurcation grafts in 21 patients for occlusive disease. Renovascular procedures included renal artery thromboendarterectomy (6 patients), reimplantation of six renal arteries, and 47 bypass grafts with either saphenous vein (33 grafts) or synthetic material (14 grafts). Three patients had contralateral nephrectomy in conjunction with renal revascularization, nine patients had bilateral renal artery reconstruction, and four patients also underwent superior mesenteric artery reconstruction. In all instances, aortic grafts were attached "end-to-end" to the proximal aorta. Similarly, most renal artery grafts were attached "end-to-end" to the distal renal artery.

Postoperative Complications

Postoperative complications occurred in 17 patients. Six of these patients died in the perioperative period (Table 2). Acceleration of excretory renal dysfunction occurred in seven patients. This occurred as a subsequent additional problem in four of the five patients dying of other lethal complications in the postoperative period. Two of the remaining three patients had return of adequate function and the other patient required long-term hemodialysis. Lethal myocardial infarctions occurred in two patients. One of these occurred in surgery and the other occurred after surgery. The latter was a lethal myocardial infarction 7 days after an uneventful operation.

Five patients required re-exploration for either bleeding (3 patients), left colonic infarction (1 patient), or ureteral obstruction (1 patient). Two patients developed lethal diffuse intravascular coagulation. One patient had a stroke in the anterior cerebral artery distribution. Other less severe complications included postoperative pancreatitis (2 patients), cholesterol emboli to the lower extremities (1 patient), groin lymphocele (1 patient), and groin wound infection (1 patient).

TABLE 1. *Operative Procedures*

		Number
Aortic procedure		
Aneurysm resection		29
Y-graft for occlusive disease		21
Renal procedure		
Aorto-renal bypass grafts		47
Material: Vein	33	
PTFE	12	
Dacron	2	
Thromboendarterectomy		6
Renal reimplantation		6
Bilateral revascularization	9	
Contralateral nephrectomy	3	
Visceral revascularization	4	

Follow-up Evaluations

Follow-up evaluations to date of death or within 1 month of this report are available in 43 of the 44 surviving patients. Subsequent operations during the follow-up period in the surviving patients include: cerebral revascularizations (3 patients), repair of occluded limbs of aortobilateral femoral grafts (1 patient), femoropopliteal bypasses (5 patients), mesenteric revascularization (1 patient), hypogastric artery bypass (1 patient), correction of femoral artery false aneurysm (2 patients), contralateral renal revascularization (3 patients), and nephrectomy after graft occlusion (1 patient).

Response to Operation

Patients were classified as cured, improved, or failed on the basis of postoperative blood pressure and medication requirements and the change in these parameters from preoperative levels. Patients were considered cured if they were normotensive (diastolic blood pressure < 95 mmHg) on no medication. In contrast, patients were considered failures if there was neither a substantial reduction in diastolic blood pressure (>20 mmHg) nor medication requirements from preoperative levels. All other patients were considered improved. Using these criteria, 44 patients were classified according to blood pressure response to operation.

TABLE 2. *Operative Mortalities*

Age (yrs)	Serum Creatinine (mg/l)	Highest Blood Pressure	Operation	Cause of Death
70	4	300/140	Aneurysm resection, renal artery bypass, contralateral nephrectomy	Large colon infarction, renal failure
73	1.9	230/190	Aneurysm resection, renal artery bypass, contralateral nephrectomy	Myocardial infarction
66	2.3	210/140	Aneurysm resection, renal artery bypass	Diffuse intravascular coagulation, renal failure
65	1.8	220/92	Aneurysm resection, renal artery bypass, mesenteric and celiac bypass	Reoperation for bleeding, renal failure
51	8.5	200/115	Y-graft for occlusion, bilateral renal revascularization	Diffuse intravascular coagulation, renal failure
61	3.7	210/140	Aneurysm resection, *ex vivo* renal artery bypass	Myocardial infarction

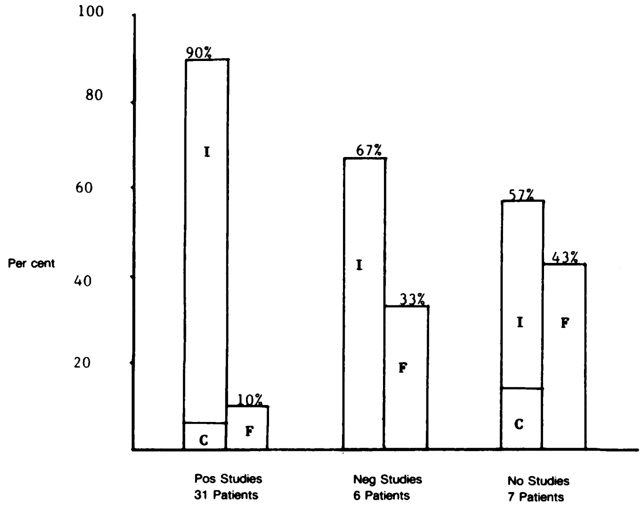

FIG. 4. Comparison of results of preoperative functional studies and blood pressure response to operation. C = cure; I = improved; and F = no response. See text for definitions.

Blood pressure responses in the evaluated group are summarized in Figure 4. Gross examination of results shows that 35 of the surviving patients (84%) had a beneficial blood pressure response. Four patients (9%) were cured of hypertension, 31 patients (72%) had significant improvement in severity of hypertension and medication requirements, and eight patients (19%) demonstrated no beneficial blood pressure response. Included in this group of nonresponders are two patients who had uncorrected severe residual contralateral renal artery stenosis, two patients who were technical failures of renal revascularization, and one patient who maintained dialysis-dependent renal failure after operation. Evaluation of blood pressure response in regard to the results of preoperative functional assessment by RVRA and SRFS is more revealing. Twenty-eight of the 31 patients (90%) with either positive RVRA or SRFS exhibited a beneficial blood pressure response. In contrast, when studies were negative (6 patients), only four (67%) had a beneficial response. Finally, seven patients underwent renovascular procedures without preoperative RVRA or SRFS. Four of these patients (57%) had a beneficial response.

Statistical Analysis of Risk Factors

Evaluation of preoperative status and recordable variables was undertaken to identify parameters that might be useful in determining operative risk in such patients considered for combined aortic and renal procedures. For purposes of analysis, the risk factors that were evaluated were defined to be positive as follows: 1) age: over 60 years; 2) azotemia: serum creatinine $\geq$ 3 mgdl; 3) history of heart disease: previous myocardial infarction, congestive heart failure, previous myocardial revascularization, or active anginapectoris; 4) positive electrocardiogram: electrocardiographic evidence of previous myocardial infarction, ST-T wave changes of ischemia or left ventricular hypertrophy; 5) type of aortic disease: aortic aneurysm *vs.* occlusive disease; 6) complex procedure: bilateral renal, *ex vivo* renal, or mesenteric artery revascularization; 7) history of peripheral vascular disease: previous aortic or distal vascular procedures or evidence of clinical occlusive disease below the aortoiliac segment; 8) tobacco abuse; and 9) diabetes.

The statistical analysis of each individual risk factor on operative mortality was assessed using Fisher's exact test. The two-sided alternative hypothesis was tested in all cases by doubling the p value associated with the one-tailed test.[3] A stepwise discriminant analysis was performed to assess the risk associated with different constellations of risk factors.[4,5] It was necessary to drop aortoiliac occlusive disease as a risk factor in this analysis since it was perfectly correlated with abdominal aortic aneurysms. That is to say, classification as an aneurysm excluded classification as occlusive disease. Also, the magnitude of variability of recorded blood pressures in each individual patient, and in regard to the variabilities of associated antihypertensive medication therapies, provided such a heterogeneous data base that accurate analysis of this variable in the study population was not undertaken. Both backwards and forwards selection procedures produced identical discriminant rules. Wilk's lambda statistic was used to assess the statistical significance of this analysis.[6] In order to facilitate the interpretation of the discriminant function, the constant term was discarded and the magnitudes of the coefficients were adjusted in order to make the largest coefficients equal 100.

Results of Statistical Analysis

Table 3 summarizes operative risk in relation to the variables analyzed in this study and their associated statistical significance. Of these variables, only azotemia and complex procedures approached statistical significance.

Since the presence of multiple risk factors in the same patient can have a cumulative effect on operative mortality, we assessed this cumulative risk by means of a discriminant analysis. This procedure assigns each patient a risk score derived from the patient's risk factors. This score is a weighted sum of the risk factors present in the patient. The coefficients are selected to optimize the predictive value of these scores with respect to operative mortality. Then, the discriminant rule based on these scores assigns all patients with scores above a selected threshold value as being at increased risk of operative death.

TABLE 3. *Risk Factors Evaluated for Operative Mortality*

Risk Factor	Patients	Operative Deaths (number)	Operative Deaths (per cent)	p Value
All patients	50	6	12	
Age ≥ 60	25	5	20	0.19
Tobacco abuse	43	6	14	0.77
Diabetes	1	3	33	0.80
Hx heart disease	22	4	18	0.45
Hx peripheral vascular disease	22	4	18	0.45
+EKG	27	5	19	0.27
Serum creatinine ≥ 3 mg/dl	7	3	43	0.059
Abdominal aortic aneurysm	29	5	17	0.37
Complex procedure	13	4	31	0.066

Such a discriminant analysis based on all of the variables given in Table 3 yielded a rule with a 100% sensitivity and 88% specificity (p = 0.04). A stepwise selection algorithm, however, identified five variables as having greatest utility for predicting operative death. These were azotemia, complex procedure, a positive electrocardiogram (+EKG), operation for aortic aneurysm (AAA), and diffuse peripheral vascular disease (PVD). The discriminant score based on these variables was obtained by assigning the strongest variable, azotemia, 100 points and each of the remaining variables the proportionate score when compared to azotemia. In this manner, the other variables were assigned numbers as follows: complex procedures = 98 points, AAA = 74 points, PVD = 66 points, and +EKG = 56 points.

Through division of each of these coefficients by 25 and rounding to the nearest integer, discriminant analysis is greatly simplified with no loss of discriminating power. This process yields the discriminant weights given in Table 4. We assigned 2 points each for PVD and +EKG, 4 points each for azotemia and complex procedures, and 3 points for AAA. Each patient's discriminant score is obtained by summing his total number of risk factor points. To illustrate this rule, a patient with azotemia, AAA and +EKG has a score of 4 + 3 + 2 = 9; a patient with AAA, a complex procedure, PVD and +EKG has a score of 3 + 4 + 2 + 2 = 11.

The ability of this discriminant analysis to predict operative death is illustrated in Figure 5. No deaths occurred in the group of patients with discriminant scores less than 5. Five of the six operative deaths had a discriminant score greater than 10. If one classifies patients with a score ≥ 10 as being at high risk, then this rule has a sensitivity of 83% and specificity of 93%. The discriminating power of the five variables used in the analysis is statistically significant (p = 0.003).

TABLE 4. *Operative Risk* Versus *Discriminant Analysis*

Variable	Discriminant Weight	No. Patients with Variable	Number of Deaths
PVD	2	22	4
+EKG	2	27	5
Azotemia ≥ 3 mg/dl	4	7	3
AAA	3	29	5
Complex procedure	4	13	4

Discussion

The risk of correction of either renovascular disease or aortic disease alone is significantly less than simultaneous correction of both. In our center, renovascular reconstruction, when done alone, is associated with a risk of less than one per cent. Similarly, elective repair of infrarenal abdominal aortic aneurysm and aortoiliac occlusive disease alone has had an associated operative mortality rate of less than three per cent. These risks are in contrast to the 12% risk of combined procedures in our center. One might argue from these data that the mere addition of renal revascularization or, conversely, aortic replacement dramatically increases the operative risk, irrespective of the clinical setting. To the contrary, however, discriminant analysis of the data demonstrates that operative risk of combined procedures can be negligible and that risk is primarily dictated by the preoperative status and magnitude of the operative intervention. In this regard, each of the powerful discriminating variables seen in our analysis simply is a marker of end-stage atherosclerosis and a descriptor of severe end-organ dam-

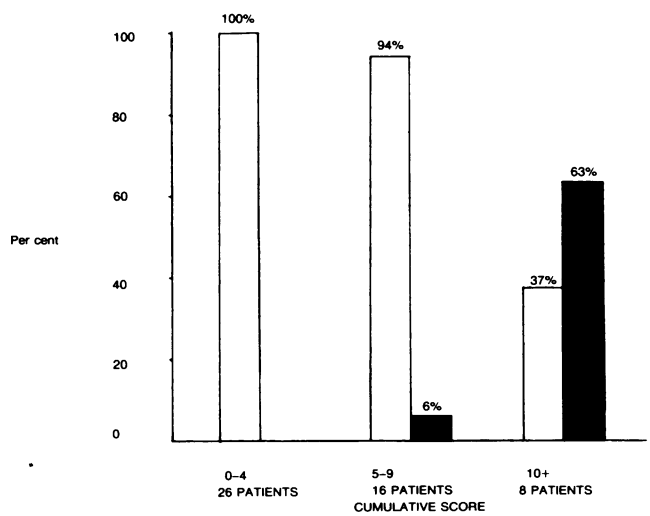

FIG. 5. Display of operative risk using weighted scores as derived through discriminant analysis. □ = Operative survival, ■ = Operative mortaltiy.

age. In the absence of such descriptors, operative risk for combined procedures was negligible. Interestingly, although age greater than 60 years was associated with a 20% operative risk, it was of no predictive value ($p = 0.19$). Clearly, risk is increased in older patients; yet this factor, like hypertension severity, is most appropriately looked upon as a marker associated with more advanced atherosclerosis and end-organ damage. In the absence of the other discriminating variables identified in this analysis, combined procedures similarly can be undertaken in the elderly and/or severely hypertensive patient without significantly increased operative risk.

The actual variables identified in our analysis as having discriminating power in predicting operative risk were significant azotemia, electrocardiographic evidence of left ventricular hypertrophy or ischemia, management of aortic aneurysm *versus* occlusive disease, presence of diffuse peripheral vascular disease, and procedures requiring simultaneous complex or bilateral renal or mesenteric artery reconstructions. When considered alone, none of these variables was statistically significant. On the other hand, the presence of multiple risk factors in the same patient had an impressive impact on operative mortality, and their cumulative effect, as demonstrated by stepwise discriminant analysis, was dramatic. In this regard, the presence of up to two of these factors did not imply unreasonable operative risk. In contrast, when the discriminant score was greater than 10, the patient's outlook became grim (83% operative mortality).

The discriminant rule that is proposed in this paper should prove to be of considerable value in selecting patients for surgical treatment. However, it is important to remember that the coefficients of this rule were derived from the patients reviewed in this series in such a way as to maximize the discriminating power of the rule. For this reason, we would expect this rule to have a somewhat lower sensitivity and specificity when applied prospectively to new patients.

The value of using any of the preceding markers of operative risk to dictate the appropriateness of operative intervention and the performance of combined renal and aortic procedures, however, is not absolute. Certainly, the lethal consequence of leaving a large abdominal aortic aneurysm uncorrected in a patient with severe, uncontrolled hypertension and azotemia secondary to renovascular disease is extremely high, and acceptance of an increased operative risk for its correction is justified. Nevertheless, the presence of each of these relative risk factors in patients with less extreme disease must be considered. This becomes most pertinent when one considers repair of angiographically significant but clinically mild aortoiliac occlusive disease in conjunction with renal revascularization for RVH. In such patients with multiple risk factors, we believe limitation of the procedure to renal revascularization and acceptance of the potential necessity of aortic reconstruction at a later time is superior to unnecessarily accepting the increased operative risk of aortic replacement when it is not clinically indicated.

At the other end of the spectrum of clinical presentations is the patient with clinically severe aortoiliac occlusive disease or aortic aneurysm who is found to have a unilateral renal artery stenosis on angiographic assessment. In such cases, controversy surrounds the necessity of functional assessment of the renovascular lesion before electing to combine renal reconstruction with the aortic procedure. Specifically, a frequently quoted reason for empiric renal reconstruction in such circumstances without preliminary evaluation is that it might improve renal function in the azotemic patient or protect that kidney from subsequently losing renal function. In contrast to this proclaimed value of empirically adding renal artery bypass, unilateral renal artery stenosis alone does not cause azotemia. Instead, significant bilateral disease (either intrarenal or extrarenal) must be present before overall renal function is adversely affected. Adding such a unilateral renovascular procedure without first proving its functional significance may unnecessarily risk further compromise to excretory function in a patient who may be azotemic predominately on the basis of bilateral arteriolar nephrosclerosis. For this reason, our policy is to assess the functional significance of such a renal artery lesion and proceed with its correction only when the studies (RVRA and/or SRFS) are positive. Nevertheless, if angiographically severe bilateral lesions are present and the patient has significant hypertension, we will add renal revascularization to aortic reconstruction regardless of the results of the functional studies that require lateralization for positive interpretation.

Finally, the ultimate value of any such risk factor assessment is to improve precision of gauging the relative significance of risk and benefit from a specific intervention. In this regard, the values found to be of cumulative predictive power should be transferable to patients undergoing aortic revascularization alone. Clearly, one can argue that if azotemia were present without renal artery stenosis, or if present in a patient with unilateral renal artery stenosis, that operative risk might even be greater in this subgroup, for in such a group the azotemia would represent even more advanced associated generalized atherosclerosis. Therefore, in such patients with high cumulative scores, consideration for conservative management or less extensive intervention is appropriate. To this end, we have found the use of percutaneous transluminal angioplasty and staged repairs of such disease in this high risk group of patients to have merit in overall patient management.

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Discussion

Dr. J. L. Villavicencio (Washington, D.C.): It gives me great pleasure to discuss this fine paper by Dr. Dean and collaborators. Keep your ears attuned to Southern accents, as my comments have to do with our experience in the last 20 years at Children's Hospital in Mexico City, with a very nasty disease that produces lesions in the thoracoabdominal aorta and its branches.

(Slide) With narrowing or occlusion of the aorta and the renal artery in the very young patient, the disease is called nonspecific obstructive arteritis, or Takayashu's disease, and hypertension is a prominent and ominous symptom. One of my former students, Dr. Lupi-Herrera, in 1977 reported 107 cases of this disease studied at the National Institute of Cardiology at Mexico City.

Seventy-two per cent of these patients have hypertension as the dominant symptom. My associate, Dr. Yonzalez-Cerna, and I operated on 22 such patients. (Slide) The ages were between 5 and 23 years, with 86 of them being children of less than 13 years of age. Females were two-thirds of our patients.

The distribution of the lesions is of interest, (slide) since 18 of the 22 have lesions involving the aorta and the renal artery. The most important aspect of these cases is that the hypertension was refractory to medical management. Often the patients have to be operated on almost under desperate conditions, (slide) 68% of them having hypertensive encephalopathy and convulsions, and 32% of them presenting with congestive heart failure.

Surgery is challenging on these small scarred vessels, but is the only alternative. We lost three patients in our first 22 patients, and none in our last 11 patients, who have not been demonstrated in this slide. That gave us a mortality of 9%.

I would like to ask Dr. Dean what has been his experience with this disease, what his indications are, and the role of nephrectomy in renal vascular hypertension.

Dr. Victor M. Bernhard (Philadelphia, Pennsylvania): Dr. Ravitch, I have really enjoyed this presentation by Dr. Dean and his colleagues. We have heard a very careful and thoughtful analysis of a critical problem that has provided us with a discriminant rule for selecting patients who are at high risk from a variety of associated diseases. I concur with their conclusions, which I think many of us have applied without the benefit of their elegant statistical studies.

However, there are 50 patients and only six deaths. Therefore, it is a little difficult to clearly evaluate their analysis. I suspect the questionably significant factors would have been clearly significant if the series were twice as large. We will certainly be interested in the results of a prospective application of the discriminant algorithm that he has recommended. I commend to you his manuscript, which is extremely well written and thoroughly describes the elaborate statistical evaluation that he has presented.

I have the following three questions to ask the author. Coronary bypass patients are included in the high-risk category. How vigorously have you pursued angiographic evaluation of these patients and subsequent coronary bypass when indicated as a preliminary when you have had the luxury of time prior to doing the aortic and renal procedure? In the experience of many of us, the patient with severe coronary disease who has had aortocoronary bypass walks an iron bridge and is no longer in the high-risk group.

A second question relates to techniques. In that patient at high risk who requires revascularization and in whom the aortic lesion is neither life- nor limb-threatening, what procedure do you prefer, *i.e.*, a bypass from a distal artery when the aorta is not significantly compromised or when the aneurysm is minimal, bypass from the splenic and/or the hepatic vessels, or transaortic endarterectomy?

Finally, there is a group of patients discussed in his manuscript who were at normal risk for aortic surgery with an associated tight stenosis of the renal artery who did not have significant hypertension and did not have lateralization by renin studies or by split functions. Many of us would repair both the aorta and the renal arteries because the patient is at low risk, the abdomen is open for aortic repair, and the renal lesion is a potential problem. What has happened to those patients with this picture in your experience who did not have renal artery repair and how often have you had to do something about them subsequently?

Dr. G. Melville Williams (Baltimore, Maryland): Dr. Dean was kind enough to leave his manuscript with me, and I want to compliment him for his good results, and raise the following real issue.

The dilemma that we have is not, perhaps, so much sorting out who is at high risk to have an operation, but what the alternative is. Namely, what is the risk to that same individual of leaving him as he is?

Dr. Dean, I think, has provided us with as much information as we currently now have about what happens to kidneys that are fed by a very stenotic renal artery. We know that a lot of them die on the vine. When you combine that with the cumulative effects of hypertension promoting small vessel disease, which is the one thing we cannot do anything about surgically, it really means that the people that you are not operating on are consigned to a relatively early death.

So when you are stuck, even when you have these constellation of risk factors that would predict an 80% mortality, the question them comes up of: What are you going to do with this particular patient? Are there ways out of this box?

For example, how often have you considered balloon dilatation of the renal artery to fix one system, and then proceeding with the other one?

It is interesting, I think, in this paper and the one to follow, and in our own experience, where we have treated 66 of these complex patients and had six deaths, the mortality is amazingly constant at 10%, or thereabouts, and I agree it is too high, but at the same time I think this is a difficult group of patients, and I am very eagerly awaiting Dr. Stoney's presentation, to tell us: Is it worth doing all of this surgery for these complex patients? I would be interested in your views about that as well.

Dr. Jonathan E. Rhoads (Philadelphia, Pennsylvania): I think the previous discussants have really pointed out my question. I thought the problem was not so much one of predicting which patients were at high risk, as in comparing the combined procedure with a staged procedure with no procedure at all. And, I wondered if Dr. Dean could tell us what happened if the procedure was withheld, or divided into two parts.

Dr. Michael E. DeBakey (Houston, Texas): I was reluctant to approach, because I do not have a great deal to add to this discussion.

We have had experience with these problems. As those of you know who are familiar with the published reports on this subject, we have been writing about this problem for more than 25 years and have continuously tried to address some of the questions and issues that have been raised in the paper presented.