Aortic Reconstruction in High-Risk Pulmonary Patients

JACOB G. ROBISON,* M.D., F.A.C.S., W. CLARK BECKETT, JR., M.D.,† JOSEPH L. MILLS, M.D.,† BRUCE M. ELLIOTT,* M.D., F.A.C.S., and RICHARD ROETTGER, M.D.

From the Division of Vascular Surgery, Department of Surgery, Medical University of South Carolina, Charleston, South Carolina and Vascular Surgery Service, Wilford Hall USAF Medical Center, Lackland AFB, San Antonio, Texas†*

Seventeen patients with clinical chronic obstructive pulmonary disease (COPD) who required aortic reconstruction underwent preoperative pulmonary function testing that categorized them as extremely high risk for pulmonary complications. Ten patients (Group 1) received perioperative steroids and seven patients (Group 2) received no perioperative adjunctive steroids. The mean forced expiratory volume (FEV 1) was 45% of the predicted value in Group 1 patients and 47% in Group 2 patients. The forced expiratory flow (25% to 75%) was severely restricted in both groups: 0.47 liters per second in Group 1 (16% ± 6% predicted value) and 0.53 liters per second (20% ± 7% predicted value) in Group 2 patients.

Using a regimen consisting of preoperative pulmonary physiotherapy, optimization of theophylline levels, and early postoperative extubation with initiation of postoperative physiotherapy resulted in survival in all cases. There did not appear to be a clear advantage to the use of adjunctive perioperative steroids. The overall incidence of pulmonary complications was 22%. Four patients died during the follow-up interval. The remaining 13 patients were alive at a mean follow-up interval of 35 months. Using a number of adjunctive techniques, successful aortic reconstruction can be accomplished in many patients with severe COPD, and the majority will survive for extended periods after operation despite their impaired pulmonary function.

PULMONARY COMPLICATIONS AND RESPIRATORY FAILURE are leading causes of postoperative morbidity in the elderly patient, and several authors have confirmed that patients with impaired pulmonary function documented by pulmonary function testing are at greatest risk for pulmonary complications after operation.[1,2,3,4]

Avoidance of pulmonary complications presents a special challenge in patients with severely impaired pulmonary function who require abdominal aortic reconstruction. The risks of respiratory complication in patients with severe chronic obstructive pulmonary disease (COPD) undergoing thoracic, cardiac, or upper abdominal surgery have been previously considered, and specific management options to reduce these complications have been described.[5,6] However, recent experience assessing the relative risks of major vascular reconstruction and detailing optimal management of patients with severe COPD requiring major aortic surgery is limited.[7,8]

We undertook this review of our recent experience with patients requiring intra-abdominal aortic reconstruction and with concomitant severe COPD to determine (1) what methods contribute to optimal perioperative management (2), the utility of perioperative adjunctive steroids, and (3) the factors that could be identified in our patients that might indicate a prohibitive surgical risk.

Patients and Methods

Patient Profile

From 1980 through 1987 441 patients underwent major elective aortic reconstruction at Wilford Hall United States Air Force Medical Center. All of the patients who were considered candidates for elective procedures based on clinical evaluation underwent routine pulmonary function testing. In this way 18 (4% of total group) patients who were candidates for aortic surgery were identified as especially vulnerable from a pulmonary standpoint and were prospectively identified for an aggressive therapeutic protocol.

Sixteen patients were male and two were female. All 18 patients had a history of heavy tobacco use. Docu-

The views expressed herein represent those of the authors and not those of the United States Air Force or Department of Defense.

Correspondence and reprint requests to: Jacob G. Robison, M.D., Division of Vascular Surgery, CSB 420, Medical University of South Carolina, Charleston, SC 29425

Accepted for publication: November 3, 1988.

mented clinical coronary artery disease was present in two patients. Four patients had associated hypertension. None were diabetic, and no patients required prophylactic cardiac revascularization in this group.

Indications for aortic reconstruction included aneurysmal disease of the abdominal aorta in 13 patients and severely symptomatic or progressive aortoiliac occlusive disease in five patients. One patient with fever, back pain, and multiple anastomotic aneurysms underwent aortic graft resection and extra-anatomic axillofemoral bypass for suspected graft sepsis. The five patients with occlusive disease were impaired by their lower-extremity ischemic symptoms significantly more than by pulmonary symptoms.

All patients had clinically symptomatic COPD requiring chronic administration of oral theophylline preparations, and two patients had also been maintained on chronic oral steroid therapy. Eight patients used nebulized bronchodilators regularly (usually metaproterenol), and three additional patients required inhalational steroid agents (beclomethasone) before admission. Two patients required intermittent home oxygen therapy.

Preoperative Evaluation

Preoperative evaluation included chest x-ray, EKG, pulmonary function tests to include forced vital capacity, forced expiratory volume in one second (FEV-1), forced mid-expiratory flow (FEF 25–75), and room air arterial blood gases. Actual measured values and relative values to those predicted for each patient were recorded. All patients were specifically counseled to stop smoking when they were initially evaluated before elective admission, although compliance was variable. All patients ceased or significantly reduced smoking on admission. Although most patients had clinical cardiology evaluations before operation, routine noninvasive cardiac evaluation was not undertaken during the interval of this study.

All patients in this group met one or more criteria on the basis of pulmonary function tests indicating "high risk" (Table 1) and underwent an intensive therapeutic regimen. On admission, instructions in chest physiotherapy and incentive spirometry were given and serum theophylline levels were optimized. In selected patients, pulmonary medicine and anesthesia consultation were obtained before operation. Nebulized bronchodilator treatments of alupent or terbutaline were begun three to four days before surgery. In addition to the oral steroids given to two patients for maintenance, adjunctive parenteral steroids were administered immediately before surgery to eight additional patients on the basis of consultant recommendations or preference of the senior surgeons; the administration of these steroids was tapered over 72 to 96 hours after operation.

Intraoperative Management

All patients underwent a general endotracheal intubation and received an inhalation anesthetic. In more recent cases the choice has been isoflurane. In addition, five patients had placement of an epidural catheter in conjunction with a light general inhalation anesthetic. Hemodynamic monitoring using peripheral arterial catheters and pulmonary arterial catheters was routinely performed. Intravenous fluid management and pressor agents were administered to optimize cardiac index before, during, and after aortic cross clamping. All patients received intravenous mannitol before aortic cross clamping. Because of the bronchodilation associated with inhalation agents and the propensity for theophylline preparations to cause cardiac irritability in conjunction with inhalation anesthetics, intravenous aminophylline was generally avoided during the procedure.

The surgical approach in 16 patients was through a standard midline incision, while a left retroperitoneal approach was used in two patients. Aortic reconstruction was performed using standard techniques and Dacron grafts. One extra anatomic axillofemoral reconstruction was performed in the patient with suspected graft sepsis. A Witzel gastrostomy was performed in nine of 18 patients.

Postoperative Management

All patients were admitted to the Intensive Care Unit immediately after operation, where continuous hemodynamic monitoring was performed for 48 to 72 hours. Therapeutic theophylline levels were maintained using intravenous infusion of aminophylline to maintain levels between 10 and 20 micrograms per ml. When gastrointestinal tract function resumed, theophylline preparations were administered orally or *via* the gastrostomy tube. Adequate pain control was administered with intravenous morphine intermittently during the first 24 hours and subsequently with intramuscular injections every 4 to 6 hours. Patients with epidural catheters were given epidural morphine for 24 to 48 hours. Patients were weaned from ventilatory support using standard extubation parameters (vital capacity greater than 15 cc per kilogram and negative inspiratory force greater than 25 to 30 cm H_2O) and arterial blood gas sampling. Pulse oximetry and continuous mixed venous O_2 sampling were monitored in selected patients later in the series. An attempt to aggressively wean these patients with a goal of early extubation was initially achieved in all but one case. Chest physiotherapy including incentive spirometry, was begun immediately after extubation. Patients were maintained at bed rest and were encouraged to perform footboard exercises for the first three to five days after operation. Ambulation was begun

TABLE 1. *Risk Factors for Postoperative Pulmonary Complications Following Abdominal Surgery*

1. Maximal breathing capacity <50% of normal
2. Forced expiratory volume in one second (FEV_1)
   <1.2 liter or
   <65% of predicted
3. Vital capacity <1.8 L
   <70% predicted
4. Pa O_2 <50 mmHG
   Pa CO_2 >45 mmHG
5. Forced Mid-expiratory flow (FEF 25–75%)
   <600 cc/sec
   <50% predicted

after mobilization of third-space fluid accumulation, usually on the third to fifth postoperative day.

Results

All patients underwent preoperative pulmonary function testing, usually in conjunction with room air arterial blood gas analysis as listed in Table 2. Group 1 (11 patients) received perioperative intravenous steroids in the form of hydrocortisone 300 to 400 mg or methyl prednisolone 120 mg on the day of surgery. Group 2 consisted of seven patients who received no perioperative adjunctive steroids.

The mean FVC, FEV 1, and FEF (25% to 75%) were not significantly different between these two groups although Group 1 tended toward lower values. The mean FEV 1 was 43% of the predicted value in the Group 1 patients and 47% in Group 2 patients. The FEF (25% to 75%) was severely restricted in both groups: 0.44 L/sec in Group 1 (16% ± 6% predicted value) and 0.53 L/sec (20% ± 7% predicted value) in Group 2 patients. The mean preoperative room air pO_2 was slightly better in in the nonsteroid group (83.8± 7.2mmHG) *versus* the steroid group (68 ± 6.6 mmHG).

All but one patient were extubated within 18 hours. Two patients required reintubation and mechanical ventilation for respiratory insufficiency. One patient was a 62-year-old white woman with a 30 pack-year history of cigarette smoking, history of hypertension, myocardial infarction, and congestive heart failure who underwent abdominal aortic aneurysm repair for an expanding aneurysm. She was extubated on the first postoperative day, but required reintubation and mechanical ventilation on both the third postoperative day and again on the sixth postoperative day for respiratory insufficiency. Following extubation on the 12th postoperative day, she was discharged nine days later. The second patient was undergoing evaluation for possible postoperative MI on the third postoperative day in the Cardiac Intensive Care Unit when he suffered respiratory arrest due to inspissated secretions requiring intubation. Myocardial infarction was ruled out, he recovered, and was discharged on the 12th postoperative day.

TABLE 2. *Results of Pulmonary Function Testing in Patients Requiring Aortic Surgery*

Patient Number	FVC (liters)	%PRED	FEV-1 (L/sec)	%PRED	FEF 25%–75% (L/sec)	%PRED	pO2 (mm Hg)	pCO2 (mm Hg)	pH
Group. 1. Patients Receiving Perioperative Steroids									
1	3.01	59	0.67	20	0.19	7	69	44	7.45
2	2.98	65	1.51	48	0.59	21	58	46	7.45
3	3.87	80	1.02	31	0.26	9	74	42	7.46
4	5.30	106	2.74	77	0.94	28	81	36	7.41
5	3.51	73	1.56	47	0.52	17	74	37	7.44
6	3.15	82	1.27	41	0.39	15	68	38	7.38
7	3.81	80	1.37	42	0.40	14	65	38	7.46
8	3.01	105	1.63	77	0.58	23	66	40	7.44
9	2.51	53	0.78	25	0.26	10	67	48	7.36
10	2.19	63	1.18	46	0.52	19	—	—	—
11	1.68	40	0.50	16	0.20	5	59	42	7.42
Mean	3.18	73	1.29	43	0.44	15	68.1	41.1	7.42
Standard Deviation	0.92	19	0.58	19	0.21	7	6.6	3.8	0.03
Group 2. Patients Without Perioperative Steroids									
11	2.06	50	1.01	35	0.45	17	90	37	7.46
12	3.07	69	1.04	35	0.30	11	94	38	7.39
13	3.14	60	1.66	47	0.52	17	88	41	7.48
14	4.29	86	1.46	42	0.45	14	—	—	—
15	3.77	82	1.63	52	0.65	23	79	42	7.42
16	2.32	60	1.48	59	0.71	32	78	38	7.43
17	1.99	71	1.24	62	0.65	28	74	34	7.46
Mean	2.95	68	1.36	47	0.53	20	83.4	38.3	7.44
Standard Deviation	0.81	12	0.25	10	0.13	7	7.2	2.6	0.03

Other respiratory complications included a clinical pneumonia in one Group 1 patient and pulmonary embolus in one Group 2 patient. The overall incidence of significant clinical pulmonary complications was 22%. There were five other infectious complications; four of these were related to the urinary tract. There was one wound infection in a Group 1 patient. Although a postoperative cardiac complication occurred in each group (2 patients) there were no postoperative deaths. Aside from the exceptions noted above, no patient required prolonged ventilatory assistance greater than 48 hours. The overall outcome was not significantly different between Group 1 and Group 2.

All patients were followed for a minimum of 6 months; the longest follow-up was 54 months. Four patients died during the follow-up interval. One patient died 6 months after operation from unknown causes. One patient subsequently developed lung cancer and died 8 months after operation from progressive pulmonary insufficiency following radiotherapy. One additional patient succumbed to progressive respiratory insufficiency approximately 10 months after surgery, and one patient died following recurrent strokes 4 years after operation. The remaining 14 patients have been followed for a mean of 35 months (range, 6 to 54 months), indicating that many patients with COPD who undergo successful aortic reconstruction can survive for extended periods despite impaired pulmonary function.

Discussion

Surgeons must frequently balance the risks of an operative procedure against the results of the untreated underlying disease processes. This is certainly the case when the known risk of aortic aneurysm rupture exceeds the 5-year expected mortality rate of chronic obstructive pulmonary disease.[7] The correction of severe lifestyle-limiting or limb-threatening ischemia is also a significant consideration because the patency of direct aortic reconstruction is significantly superior to extra-anatomic bypass.[9] For patients with COPD and its consequent increased airway resistance, impaired gas exchange, and decreased efficiency of inspiratory muscles, any further impairment of tidal volume, vital capacity, or functional residual capacity by abdominal aortic surgery predisposes them to a high incidence of postoperative respiratory complications.[10] Such risks may deter the surgeon from an otherwise appropriate direct surgical approach.

Preoperative Management

Generally accepted criteria that appear to indicate the group at highest risk for postoperative pulmonary morbidity are listed in Table 1. Although a number of measured parameters appear to be useful, independent studies have confirmed that the forced mid-expiratory flow (FEF 25% to 75% or mid-FEF) in predicting respiratory insufficiency after operation appears to be the single-most reliable parameter predictive of postoperative complications following abdominal surgery, possibly because it represents a reduced capability to generate a cough and clear airways of secretions. Levels of mid-FEF less than 0.6 liters per second or less than 50% of predicted values are especially ominous and are identified as indicative of "high risk."[3,5,6]

Stein et al.[2] first suggested that the most predictive test for postoperative pulmonary complications was the mid-expiratory flow rate. Williams et al.,[11] however, reported several patients with mid-FEF rates of less than 500 cc per second with a successful outcome. With only a 19% overall pulmonary complication rate, they found that the so-called "prohibitive" range of function testing was not predictive of success or failure when an aggressive pre- and postoperative respiratory therapy program was maintained. Veith and Rocco[12] also stressed the importance of preoperative preparation of the surgical patient and the evaluation of respiratory function in reducing postoperative pulmonary complications. Gracey et al.[3] also found the mid-FEF of less than 50% predicted to be the most reliable test in predicting postoperative pulmonary complications. They again stressed the importance of preoperative preparation using an intensive 48-hour preoperative program and aggressive postoperative pulmonary toilet to decrease the respiratory complication rate to 19%.

The only previous report addressing the problem of severe COPD in patients requiring aortic reconstruction described respiratory complications in five of ten patients.[7] Three of these were easily managed, however, and there were no deaths. No patient was refused surgery on the basis of pulmonary risk alone, and this study emphasized the importance of attentive pulmonary care in obtaining a successful outcome.

Other risk factors for pulmonary complications following aortic surgery include smoking history, age, duration of anesthetic, and operative blood loss. Pulmonary insufficiency (either pneumonia or prolonged intubation greater than 72 hours), occurred in only 5.9% of 557 patients undergoing aortic reconstruction at the Cleveland Clinic.[8] No difference was seen among their patients with FEV 1 $>$ 60% of predicted *versus* those with an FEV 1 $<$ 60% of predicted in regards to either pulmonary insufficiency or mortality rate. While only nine patients with severe restrictions of FEV 1 less than 40% of predicted values were identified, only a fraction of the total patient group had undergone preoperative pulmonary function testing. The volume of intraoperative blood loss appeared to be associated more significantly with pulmonary complications than the preoperative pulmonary evaluation in this series.

Although pulmonary function testing in assessment of overall patient risk among patients with COPD provides essential guidelines, it should not overshadow the clinical importance of patient selection. In our study, no "high pulmonary risk" patients were identified on basis of pulmonary function testing alone; all had clinical COPD. Importantly, each of the patients in this group who was considered to be a surgical candidate passed the "steppensprechen" test; that is, none became severely short of breath with minimal activity while conversing. No patient was in obvious respiratory distress during examination at rest. In addition, patients with multi-system failure were not generally considered surgical candidates if cardiac, renal, or hepatic disease was judged critically significant in conjunction with severe COPD. This may account for the apparent low (10%) incidence of clinical coronary disease among patients selected for aortic reconstruction in our series.

Mendella et al.[13] suggested that certain nonsurgical patients with stable COPD may respond with a significantly improved FEV 1 after methylprednisolone therapy in a double-blind crossover trial. There was no clinical data that predicted this response to steroid treatment and the quantitative response was not clearly evident clinically. They noted that other studies suggested that between 15% and 30% of stable patients might benefit from steroid therapy and suggested that a steroid trial is the only method to assess response. In our experience with a small group of severe COPD patients undergoing aortic reconstruction, there does not appear to be any clear advantage of adjunctive perioperative steroid management in improving outcome among patients not previously on parenteral steroids.

In other attempts to mitigate pulmonary risks, a number of authors have suggested that cessation of smoking a minimum of 1 month before surgery is an important part of therapy,[7] while other authors have suggested a minimum of five to seven days. If this is accomplished immediately before surgery, however, increased bronchial secretions may result, and anesthesia may best be postponed until this resolves. Although our patients for elective procedures are strongly encouraged to stop smoking well in advance of surgery, such expectations are not always practical and can be extremely difficult for even highly motivated individuals.

While theophylline is beneficial in management, the mechanism of the theophylline preparations in improving pulmonary function in patients with COPD is not completely defined. The benefits may be not only due to their smooth muscle and bronchodilator capability, but to the stimulatory effect on the respiratory center with increased hypoxic ventilatory drive as well. There is also evidence to suggest that theophylline makes the diaphragm less susceptible to fatigue and improves its contractility.[14] These adjunctive effects may explain the benefit of theophylline preparations when no bronchodilator effect can be measured. The reason for such effects is unknown but may be related to elevated cyclic AMP levels at the cellular level. We do feel that maintenance of therapeutic theophylline levels as well as use of nebulized bronchodilator treatments can help maximize pulmonary reserve and contribute to improved outcome.

Patients who are considered candidates for elective aortic reconstruction who have clinical COPD should undergo pulmonary function testing to identify a high-risk group. Clinical judgment should not be neglected in selecting this group, however. All patients should be encouraged to cease smoking well in advance of elective procedures. Once the patient is identified as a high pulmonary risk, the most practical aspects of preoperative preparation appear to be instruction in inspiratory exercises and coughing, nebulized bronchodilator treatment, and adjustment of theophylline levels to the therapeutic range.

Intraoperative and Postoperative Management

The advantages of continuous epidural anesthesia in abdominal vascular surgery over general endotracheal anesthesia are not clear, because the incidence of postoperative atelectasis and pulmonary complications has not been shown to be significantly decreased.[15] The main advantage of epidural analgesia compared with parenteral narcotics may be in the early postoperative period when pain relief can be obtained with less suppression of normal physiologic pulmonary reflexes, such as cough and respiratory hypoxic drive.[16,17] The epidural technique appears to be well tolerated with few risks in abdominal vascular surgery that requires intraoperative heparinization.[18] Although only used in five patients in this series, we feel use of this technique should be considered in especially high-risk patients. Epidural technique may obviate general anesthesia altogether, especially if combined with a retroperitoneal approach.

The retroperitoneal approach (through a left lower quadrant incision extending toward the flank) has been advocated by some authors as advantageous for aortic reconstruction,[19] especially regarding postoperative pulmonary complications. We have used the retroperitoneal approach in two especially high-risk patients with accessible infrarenal aneurysms and have been gratified with the outcome. We have not found the technique as rapid and straightforward as suggested by others, which in part may reflect our unfamiliarity with it. In our experience, the direct midline approach seems more expeditious for most patients and provides easier access to iliac and renal arteries.

Intraoperative measurement of the pulmonary capillary wedge pressure (PCWP) and cardiac output *via* contin-

uous pulmonary artery catheterization is an important adjunct to maximize cardiac function with a minimum of fluid therapy. The PCWP is closely monitored in the postoperative period to guide therapy as well. Postoperative assessment of arterial blood gases or use of the pulse oximeter while weaning from mechanical ventilation is essential. Guidelines for extubation parameters are also useful. When feasible, early extubation obviates ventilator dependence and preserves respiratory muscle function and hypoxic drive. Early extubation allows early initiation of physiotherapy; coughing, deep breathing, and sighing facilitate return to patient's physiologic baseline.

Successful management of patients with clinical and laboratory parameters of severe COPD who require aortic reconstruction includes patient selection, preoperative instruction in chest physiotherapy, and maximization of theophylline levels. Although adjunctive perioperative steroids provide no clear advantage, other adjunctive intraoperative techniques and postoperative early extubation can also contribute to an acceptable incidence of postoperative pulmonary complications and morbidity. Severe COPD alone need not preclude appropriate surgical intervention when required for aortic reconstruction.

References

1. Tisi GM. Preoperative evaluation of pulmonary function. Amer Rev Resp Disease 1979; 119:293–310.
2. Stein M, Koota GM, Simon M, et al. Pulmonary evaluation of surgical patients. JAMA 1962; 181:103–108.
3. Gracey DR, Divertie MB, Didier EP. Pre-operative pulmonary preparation of patients with chronic obstructive pulmonary disease. Chest 1979;76:123–129.
4. Latimer RG, Dickman M, Day WC, et al. Ventilatory patterns and pulmonary complications after upper abdominal surgery determined by pre-operative and post-operative computerized spirometry and blood gas analysis. Am J Surg 1971;122:622–631.
5. Stein M, Cassara EL. Pre-operative pulmonary evaluation and therapy for surgery patients. JAMA 1970;211:787–790.
6. Hodgkin JE, Dines DE, Didier EP. Pre-operative evaluation of the patient with pulmonary disease. Mayo Clin Proc 1973;48:114–118.
7. Smith PK, Fuchs JCA, Sabiston DC. Surgical management of aortic abdominal aneurysms in patients with severe pulmonary insufficiency. Surg Gynecol Obstet 1980;151:407–411.
8. Diehl JT, Cali RF, Hertzer NR, Beven EG. Complications of abdominal aortic resection. Ann Surg 1983;197:49–55.
9. Rutherford RB, Patt A, Pearce WH. Extra-anatomic bypass: A closer view. J Vasc Surg 1987;6:437–446.
10. Alexander JA, Rodgers BM. Diagnosis and management of pulmonary insufficiency. Surg Clin North Am 1980;60:983–1000.
11. Williams CD, Brenowitz JB. "Prohibitive" lung function and major surgical procedures. Am J Surg 1976;132:763–766.
12. Veith FJ, Rocco AJ. Evaluation of respiratory function in surgical patients: importance of pre-operative preparation and in the prediction of pulmonary complications. Surgery 1959;45:905–911.
13. Mendella LA, Manfreda J, Warren PW, Anthonisen NR. Steroid response in stable chronic obstructive pulmonary disease. Ann Int Med 1982;96:17–21.
14. Aubier M, De Troyer AD, Sampson M, et al. Aminophylline improves diaphragmatic contractility. New Engl J Med 1981;305: 249–252.
15. Bromage PR. Epidural Analgesia. Philadelphia: W.B. Saunders, 1978: 399–420.
16. Egbert LD, Bendixen HH. Effect of morphine on breathing pattern. JAMA 1964;188:113–116.
17. Tomlin, PJ. Anesthesia for Vascular Surgery. London: Butterworth and Co., 1988.
18. Cunningham FO, Egan JM, Inahara T. Continuous epidural anesthesia in abdominal vascular surgery. Am J Surg 1980;139:624–627.
19. Sicard GA, Freeman M, VanderWoude JC, Anderson, CB. Comparison between the transabdominal and retroperitoneal approach for reconstruction of the infrarenal abdominal aorta. J Vasc Surg 1987;5:19–27.