Management and Long-term Outcome of Aortic Dissection

DONALD D. GLOWER, M.D., RUDIGER H. SPEIER, M.D., WILLIAM D. WHITE, M.P.H., L. RICHARD SMITH, M.D., J. SCOTT RANKIN, M.D., and WALTER G. WOLFE, M.D.

All 163 patients admitted to one institution between 1975 and 1988 with aortic dissection were reviewed. Type I and type II patients received grafting of the ascending aorta, with an intraoperative mortality rate of 11%. For type III dissection, management was medical in 53 patients, while 19 required surgery for aortic rupture or expansion, with an intraoperative mortality rate of 11%. The 9- or 10-year survival rates were 29%, 46%, and 29% for types I, II, and III respectively. Of 135 patients with primary aortic dissection, 17 (13%) required subsequent aortic surgery. Cause of late death was other cardiovascular disease in 38%, rupture of another aortic segment in 18%, sudden death in 24%, and other medical conditions in 21%. Although operative therapy for types I and II dissections and reserving operation for selected type III dissections provides acceptable long-term survival, careful follow-up is necessary due to concurrent cardiovascular disease and residual aortic disease.

ALTHOUGH THE LONG-TERM survival rate with aortic dissection has improved since the reports of Hirst[1] and Anagnostopoulos,[2] aortic dissection remains a morbid event, with hospital mortality rates as high as 40%.[3] Furthermore controversy still persists after two decades of debate regarding therapy for descending or DeBakey type III aortic dissection.

Based on many reports suggesting that medical management has survival rates equivalent to or better than surgical therapy for type III dissection,[2,4-11] conventional management for type III dissection has been to reserve operation for those patients with complications of aortic dissection. Recently, however, several authors reported large numbers of patients with type III dissection treated surgically with remarkably low mortality rates.[3,12-18] This has reawakened interest in aggressive surgical therapy and left doubts as to the optimal management therapy for patients with type III dissection.

Address reprints to Donald D. Glower, M.D., Box 3851, Duke University Medical Center, Durham, NC 27710.

Accepted for publication August 29, 1990.

From the Department of Surgery, Duke University Medical Center, Durham, North Carolina

For types I and II aortic dissection, operative therapy has been the standard of care since the report of Daily.[5] Debate has persisted, however, as to the relative merits of aortic valve replacement *versus* resuspension for aortic valve insufficiency,[3,19] the management of aortic arch involvement with aortic dissection,[20-22] primary aortic repair *versus* aortic grafting,[19,23] and the choice of the inclusion *versus* exclusion techniques of aortic grafting.[24-25] To clarify these issues better, a retrospective study was undertaken of all patients admitted to Duke University Medical Center with the diagnosis of aortic dissection.

Methods

Patient Population

The records of all 163 patients admitted to Duke University Medical Center from 1975 through 1988 with the diagnosis of aortic dissection were examined. Based on the extent of dissection as classified by DeBakey,[3] 68 patients had type I dissection, 23 had type II dissection, and 72 had type III. During the 14-year period examined, most patients were seen by the authors. The diagnosis of aortic dissection was confirmed in all patients by either aortography (135 patients), computed tomography (46 patients), magnetic resonance imaging (8 patients), operative exploration (4 patients), or autopsy (3 patients).

To concentrate on treatment for primary aortic dissection, 28 patients were excluded from further analysis because of previous cardiac or thoracic aortic operation, intraoperative aortic dissection, or death occurring before any therapy was instituted. Nine type I and 1 type II patients presented moribund and expired shortly after admission, either before therapy could be instituted (8 pa-

tients) or before the diagnosis of dissection was apparent (2 patients). Seven type I, five type II, and three type III patients had undergone previous cardiac or thoracic aortic procedures. Nine of these 15 patients with previous operation underwent surgical repair of their dissection with five intraoperative deaths (56%). Four of the six medically managed patients with previous operation were discharged alive, with survival up to 106 months. Two type I and one type II patients developed aortic dissection intraoperatively during other cardiac procedures. Two of these patients died during operation from cardiac failure and one died 18 days after operation from sepsis and complications of cardiac failure.

After discharge patients were followed with serial chest films and with arteriogram, computed tomography, or magnetic resonance imaging as needed to confirm the extent or size of aortic disease. Follow-up was obtained in 131 of 135 patients (97%) and was complete to 1988 in 118 of 135 patients (87%).

Statistical analysis of survival and reoperation outcomes was performed using the Cox–Mantel test to compare Kaplan–Meier curves. Prognostic variables with significant effect on survival were determined from the Cox proportional hazards regression model using both univariate and multivariate analysis. Only those variables significant at the 0.1 level by univariate analysis were examined with multivariate models and stepwise backward elimination of insignificant variables. Because of the small number of patients and deaths in this study, no attempt was made to include all variables of possible prognostic significance in the multivariate analysis. Unless otherwise stated, all results are listed as mean ± standard error of the mean.

Management Technique

Patients with significant hypertension were admitted to the intensive care unit for monitoring and for blood pressure control with beta blockers and vasodilators. All patients managed medically or surgically received long-term treatment with beta blockers and additional antihypertensive agents as needed for blood pressure control.

Surgical candidates with ascending aortic dissection underwent median sternotomy. Patients were cooled to 28 C on cardiopulmonary bypass and the heart was arrested with cold potassium cardioplegia. The ascending aorta was opened longitudinally after clamping the aorta just below the innominate artery, and aortic intima and adventitia were reattached with sutures.[26] In all but 10 patients, a woven Dacron graft then was sutured proximally just above the coronary ostia, and the distal suture line was completed using 3-0 polypropylene. Eight patients underwent primary aortic repair with obliteration of the false lumen[23] and two patients had an intraluminal prosthesis inserted into the ascending aorta.[27] In four patients with intimal tears of the aortic arch, circulatory arrest was used to extend the distal anastomosis up under the arch. Two patients with known arch tears were managed successfully with grafting of the ascending aorta alone, and one patient with an arch tear died from hemorrhage before grafting could be attempted. In patients with type I or type II dissection, aortic valve resuspension was performed in 22 of 66 patients (33%) for acute dissection involving a previously normal aortic valve. Nine patients (14%) required aortic valve replacement for underlying aortic stenosis (four patients), annuloaortic ectasia (two patients), or chronic dissection (three patients). The two patients with annuloaortic ectasia each required Bentall[28] procedures due to aortic root enlargement.

Since 1975 patients with type III dissection were managed selectively, *i.e.*, surgery was offered only to those of acceptable operative risk and with aortic expansion or complications of aortic dissection.[29] Fifty-one patients were managed medically, while 18 type III patients required surgical intervention. Indications for operation were aortic rupture in eight and aortic expansion in 10.

Patients with type III dissection were explored by posterolateral thoracotomy through the left fourth or fifth intercostal space. The distal circulation was supported with left femoral vein to left femoral artery cardiopulmonary bypass in eight patients (44%). A heparinized Gott shunt from the proximal aorta or left ventricular apex to the left femoral artery was used in seven patients (39%). Three patients (17%) were managed without additional perfusion of the distal circulation, due to either life-threatening hemorrhage or inadequate access to the distal circulation. The aorta was opened longitudinally into the true lumen and the tear was identified. A straight woven Dacron graft was secured within the aortic lumen with proximal and distal anastomoses of 3-0 polypropylene, incorporating a strip of Teflon felt wrapped externally around the native aorta. When possible the aortic wall was closed over the graft.

Patient Presentation

The mean age for patients with ascending dissection (types I or II) was 56 ± 12 (standard deviation [SD]) years, with 74% of patients being male. Presentation was acute (less than 2 weeks of symptoms) in 90% of type I patients, as opposed to 38% of type II patients ($p < 0.001$) (Table 1). Type I patients were also more likely to present with rupture (32% *versus* 0%, $p < 0.05$) or tamponade (25% *versus* 0%, $p = 0.05$) than type II patients (Table 2). Aortic insufficiency was clinically evident in 30% of ascending aortic dissections, and 13% of patients with ascending dissection presented in shock. Type I dissection was associated with pulse loss in 48% of patients and dissection

TABLE 1. *Patient Characteristics in Types I, II, or III Aortic Dissection with Medical or Surgical Therapy*

Characteristic	Type I	Type II	Type III	
			Medical	Surgical
Number	50	16	51	18
Age	56 ± 2	55 ± 2	67 ± 1	62 ± 2
Male	39 (78%)	10 (63%)	36 (71%)	12 (67%)
Acute	45 (90%)	6 (38%)*	37 (73%)	9 (50%)
Thoracoabdominal	30 (60%)	—	28 (55%)	11 (61%)
No. medical illnesses	0.6 ± .1	1.0 ± .1*	1.4 ± 0.2	0.5 ± 0.3†

* $p < 0.05$ *vs.* type I.
† $p < 0.05$ *vs.* medical.

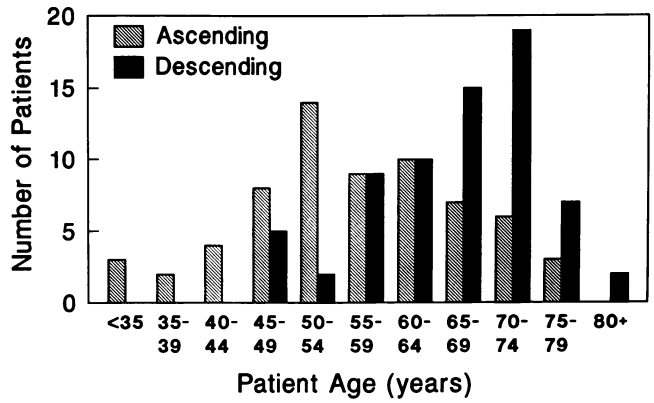

FIG. 1. Age distribution of patients with ascending (type I or II) or descending (type III) aortic dissection.

below the diaphragm in 60% of patients. Type II patients were more likely than type I to have cardiac disease (75% *versus* 24%, $p < 0.001$) with 56% of type II patients having previous aortic valve disease. Marfan's syndrome also was slightly more common in type II dissection, occurring in 4% of type I and 13% of type II dissections. Renal or visceral ischemia, stroke, and myocardial infarction were relatively uncommon, with myocardial infarction in 2% of ascending dissections and stroke or renal or visceral ischemia each occurring in 6% of ascending dissections.

In 69 patients dissection originated in the descending thoracic aorta. Of these 69 type III patients, 10 patients had dissection extending proximally into the aortic arch, while 59 dissections were strictly distal to the left subclavian artery. Thirty type III dissections were limited to the thoracic aorta, while 39 extended into the abdominal aorta. Age ranged from 47 to 83 years, with a mean of 66 ± 9 (SD) years, which is somewhat older than types I and II dissections ($p < 0.05$) (Fig. 1). There were 48 men and 21 women, with 46 type III patients presenting acutely, while 23 patients had chronic dissections. Compared to medical patients, surgical type III patients were younger, had a higher incidence of rupture on admission, and had fewer major medical illnesses. The number of major medical illnesses was computed as a count of the following organ systems involved with significant disease: cardiac, pulmonary, renal, cerebrovascular, peripheral vascular, and gastrointestinal/biliary. Medical and surgical patients did not differ significantly in sex, distal extent of dissection, or chronicity (Tables 1 and 2).

TABLE 2. *Presenting Complications in Types I, II, or III Aortic Dissection with Medical or Surgical Therapy*

Complication	Type I	Type II	Type III	
			Medical	Surgical
Number	40	12	51	18
Rupture	14 (35%)	0*	2 (4%)	8 (44%)†
Tamponade	10 (25%)	0	0	0
Shock	7 (18%)	1 (8%)	2 (4%)	0
Aortic insufficiency	13 (32%)	3 (25%)	0	0
Pulse loss	19 (48%)	0*	2 (4%)	0
Renal or visc ischemia	3 (8%)	0	2 (4%)	1 (6%)
Stroke	2 (5%)	1 (8%)	0	0
Myocardial infarction	0	1 (8%)	2 (4%)	0

* $p < 0.05$ *vs.* type I.
† $p < 0.05$ *vs.* medical.

Results

Types I and II Aortic Dissection

The intraoperative mortality rate was 11% (5 of 47 patients) for type I patients and 14% (2 of 14 patients) for type II patients. The 30-day mortality rates were 26% (12 of 47 patients) and 14% (2 of 14 patients for types I and II dissections, respectively, with 5-year survival rates of 56% ± 9% and 87% ± 8% (Fig. 2). The cause of death with types I or II dissection was cardiovascular disease in 38%, intraoperative in 27%, rupture in 12%, sudden or unexplained in 8%, and other unrelated caused in 15% (Fig. 3).

Subsequent to their original operation, nine patients (17%) with types I or II dissection underwent further surgical procedures for aortic dissection (Table 3). Freedom from dissection-related death or complication requiring operation was 55% ± 8% at 5 years and 39% ± 11% at 9 years for patients with type I dissection and 80% ± 6% and 46% ± 21% for patients with type II dissection at 5 and 10 years, respectively (Fig. 2). Despite the significant incidence of late dissection-related death or reoperation, freedom from late thoracic aortic operation was 87% ± 6% and 60% ± 15% at 5 and 10 years, respectively, for types I or II aortic dissection (Fig. 4). Long-term results for 17 patients receiving aortic valve resuspension were good, with no patient requiring a subsequent aortic valve procedure. Patients with types I or II dissections undergoing aortic valve replacement or no aortic valve procedure had a 30% probability of needing subsequent aortic valve replacement at 10 years (Fig. 5). Of eight patients undergoing

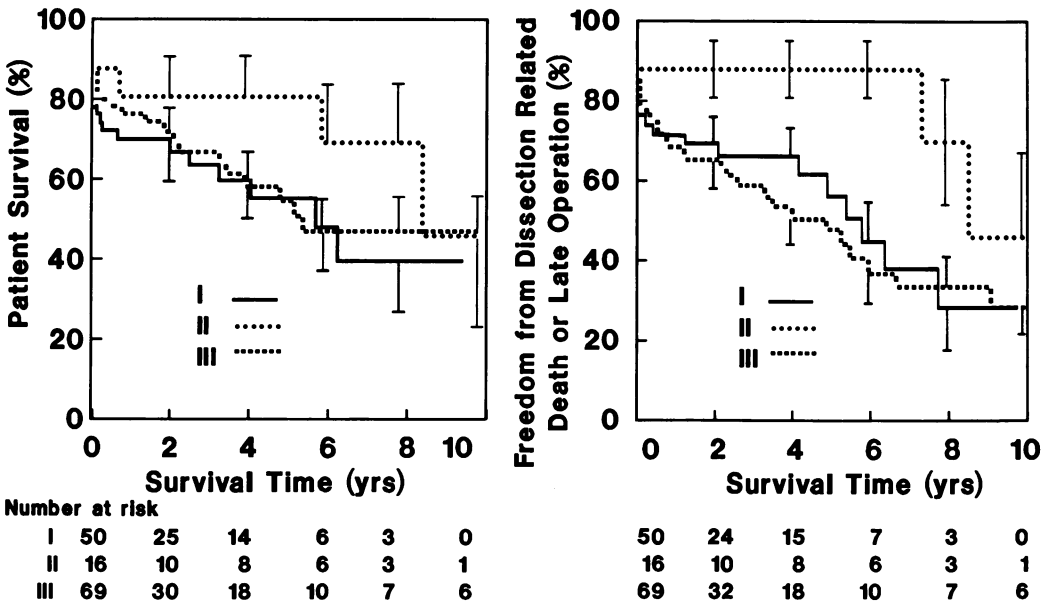

FIG. 2. Patient survival (left panel) and freedom from dissection-related death or late operation (right panel) for type I, type II, and type III aortic dissections.

primary repair of aortic dissection without grafting, two subsequently required Bentall procedures for aortic insufficiency and ascending aortic aneurysm at 8 and 71 months after operation.

For patients with types I or II dissection, only thoracoabdominal dissection (extension of the dissection below the diaphragm) or the presence of a tear in the aortic arch were significantly related to long-term mortality (Table 4, Fig. 6). In this population of 66 patients with types I or II dissection treated surgically, patient age, aortic rupture, complications of dissection at presentation (defined as shock, acute renal failure, visceral ischemia, pulse loss, acute myocardial infarction, or acute stroke), gender, acute presentation, admission date, emergent operation, and the number of medical illnesses all failed to reach significance as independent predictors of death. The 6-month mortality rate did, however, increase from 10%–20% to 40%–60% as age exceeded 60 years (Fig. 7).

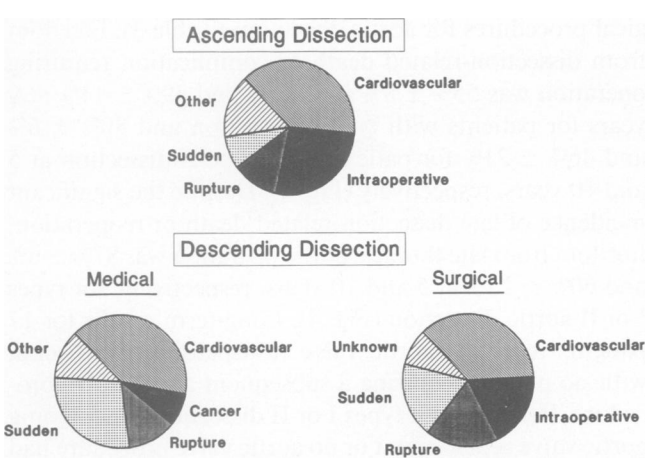

FIG. 3. Cause of death for patients with ascending dissection (top panel) or descending dissection with medical or surgical therapy (bottom panel).

An additional predictor of 30-day mortality rate in patients with acute types I or II dissection appeared to be the experience of the operating surgeon. For acute types I or II dissections during the time period examined, three surgeons each performed nine or more operations for aortic dissection, with a 30-day operative mortality rate of 18% (7 of 39 patients). This mortality rate was significantly better than the pooled 30-day mortality rate of 72% (13 of 18 patients; $p = 0.0001$) for the seven remaining surgeons who each repaired seven or fewer dissections during the 14-year period examined.

Type III Aortic Dissection

With type III dissection, hospital stay was 14 ± 2 days for surgical patients and 9 ± 1 days for medical patients ($p < 0.05$). The intraoperative mortality rate was 25% (two of eight patients) in patients presenting with rupture, with death resulting from hemorrhage in each patient. No intraoperative deaths occurred when operation was performed electively for aortic expansion. The 30-day hospital mortality rate was 62% (five of eight patients) in patients undergoing operation for rupture, with the three additional hospital deaths resulting from cardiac failure, myocardial infarction, and cardiac arrhythmias in one patient each. All patients repaired surgically for aortic expansion were discharged alive, and no patient developed paraplegia. The 30-day mortality rate was 18% (9 of 51 patients) for patients treated medically, with the cause of death being rupture in two, myocardial infarction in two, and heart failure, renal failure, arrhythmia, sudden death, and hemorrhage at delayed operation in one patient each

TABLE 3. *Subsequent Operations for Complications of Aortic Dissection in Patients Managed Surgically*

Type	Initial Operation	Reoperation	Interval to Reoperation	Reoperation Indication
I	AscAo, Resus	AscAo	69 months	Recurrent dissection
I	AscAo, AVR	AscAo	38 months	False aneurysm
I	AscAo	AscAo	3 months	Mediastinitis, anast dehiscence
II	Primary	AVR, AscAo	8 months	Aortic insuff
II	AscAo, AVR	AVR, AscAo	102 months	Aortic insuff
II	Primary	Bentall	71 months	Aortic insuff, aortic expansion
I	Bentall	DescAo, Arch, ThorabdAo	30 months 55 months 91 months	Distal dissection, Marfan's syndrome
I	AscAo, Resus	DescAo, AxFem	3 months	Distal ischemia
I	AscAo	FemFem	1 day	Distal ischemia
III	DescAo	DescAo	65 months	Distal dissection
III	DescAo	DescAo	2 months	False aneurysm

Arch = arch graft, AscAo = ascending aortic graft, AVR = aortic valve replacement, DescAo = descending aortic graft, Primary = ascending aortic primary repair, Resus = aortic valve resuspension.

(Fig. 3). One medical patient dying of rupture was moribund at admission, and a second medical patient died of rupture acutely after an otherwise stable course. For all 69 type III patients, 5- and 10-year survival rates were 48% ± 7% and 29% ± 8%, respectively (Fig. 2). Late aortic rupture was confirmed in one medical patient after 58 months and in two surgical patients after 5 and 47 months.

Eight patients (12%) with type III aortic dissection underwent aortic operations subsequent to initial therapy. Two medical patients required grafting of the descending aorta for rupture or expansion after 9 days and 17 months of medical therapy, respectively. Three medical patients underwent grafting of abdominal aortic aneurysms after 2, 6, and 43 months. One medical patient required grafting of the ascending aorta after 22 months for ascending aortic aneurysm. Two surgical patients required reoperation 2 and 65 months after operation, one for false aneurysm of the proximal anastomosis and one for progression of descending thoracic dissection (Table 3). For patients with type III aortic dissection, freedom from dissection-related death or complication requiring operation were 54% ± 8% at 5 years and 46% ± 8% at 10 years (Fig. 2). Freedom from late thoracic aortic operation was 92% ± 10% and 73% ± 22% at 5 and 10 years, respectively (Fig. 4)

By univariate analysis for type III dissection, the only factors significantly associated with impaired long-term survival were the presence of complications of dissection at presentation, increasing patient age, aortic rupture at presentation, admission date, and acute presentation (Table 5). By multivariate analysis, only the presence of complications of dissection on admission, increasing patient

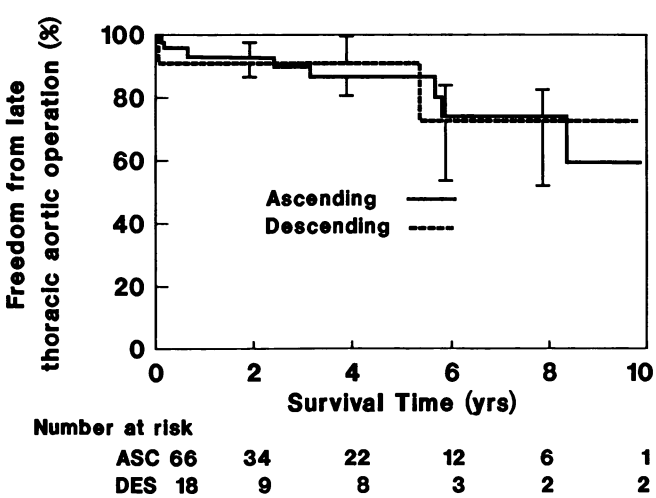

FIG. 4. Freedom from thoracic aortic reoperation after grafting of the ascending or descending aorta for aortic dissection.

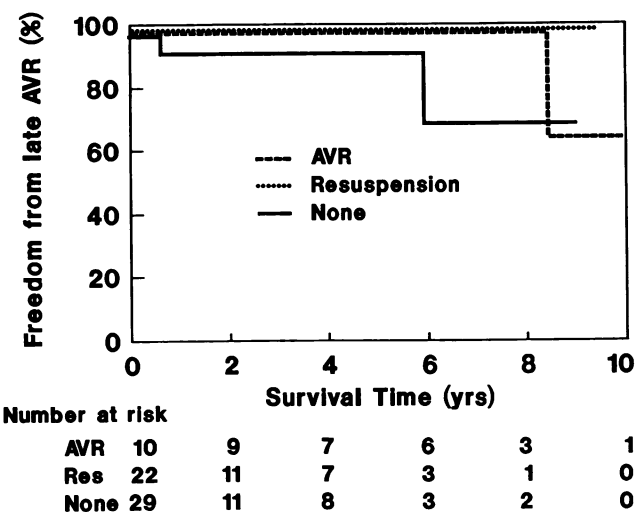

FIG. 5. Freedom subsequent aortic valve replacement in patients with ascending dissection receiving initial aortic valve replacement (AVR), resuspension, or no aortic valve procedure.

TABLE 4. *Univariate and Multivariate Analysis of Variables Significantly (Univariate p < 0.1) Predictive of Death for Ascending Aortic Dissection*

	Univariate		Multivariate	
Variable	Chi^2	p	Chi^2	p
Arch tear	3.94	0.047	2.54	0.11
Thoracoabdominal dissection	3.60	0.058	2.82	0.09

age, and aortic rupture were independent predictors of death (Figs. 7 and 8). Among the complications of dissection present at admission, shock, acute renal failure, visceral ischemia, acute myocardial infarction, and pulse loss were each associated with no survival more than 5 months in type III dissections. Six-month mortality rate increased dramatically from less than 20% to 60% as age approached 70 years in descending dissections (Fig. 7). Proximal or distal extent of dissection, gender, the presence of an arch tear, and concurrent medical illness all failed to reach significance as independent predictors of survival in patients with type III aortic dissection. Of particular importance in type III dissections, no significant difference in survival was noted between patients treated medically and those treated surgically (p = 0.5) (Fig. 9). Estimates of maximal aortic size by computed tomography or aortography were significantly related to subsequent risk of rupture or need for operation (Fig. 10). Dissections larger than 5.5 cm to 6.0 cm in diameter had greater than a 50% probability of rupture or operation.

Discussion

The earliest descriptions of aortic dissection were those by Morgagni in 1761[30] and by Nicholls in his autopsy of King George II in 1760.[31] Clear distinction between dissections involving different portions of the aorta was not made until 1955, when DeBakey described nine different subgroups of dissections along with the first large series of surgical results.[32] In 1964 and again in 1982, DeBakey revised the classification of aortic dissection into three types based on the location of the aortic tear[33] or the extent of aortic involvement.[3] In 1970 Daily et al.[5] noted that descending dissections generally had better survival with medical therapy than with surgical therapy, unless complications of dissection or increase in aortic size mandated surgical intervention. Based on these observations, the Hume,[34] Stanford,[5] Reul,[12] Najafi,[35] Alabama,[7] Inoue,[36] and MGH[10] classifications have all distinguished dissections involving the ascending aorta from those that do not.

Since the reports of Daily[5] and others, standard treatment of descending or type III dissection has reserved surgical therapy for patients with complications or aortic enlargement. Yet, despite many published studies of type III aortic dissection, debate as to the optimal therapy for type III dissection has persisted due to lack of controlled data and due to improved results with surgical therapy. Systematic analysis of prognostic variables in type III dissection has been reported from only a small number of institutions.[18,37,38] Similarly data including 10-year follow-up and series of at least 150 patients are scanty, coming from four institutions: Baylor University,[3,18] Stanford University,[13,37] the Mayo Clinic,[17,19] and the Massachusetts General Hospital.[10]

In the present series, surgical management for selected high-risk type III patients produced results similar to those of other recent surgical series. The 30-day mortality rate of 28% for surgical type III patients correlates with that

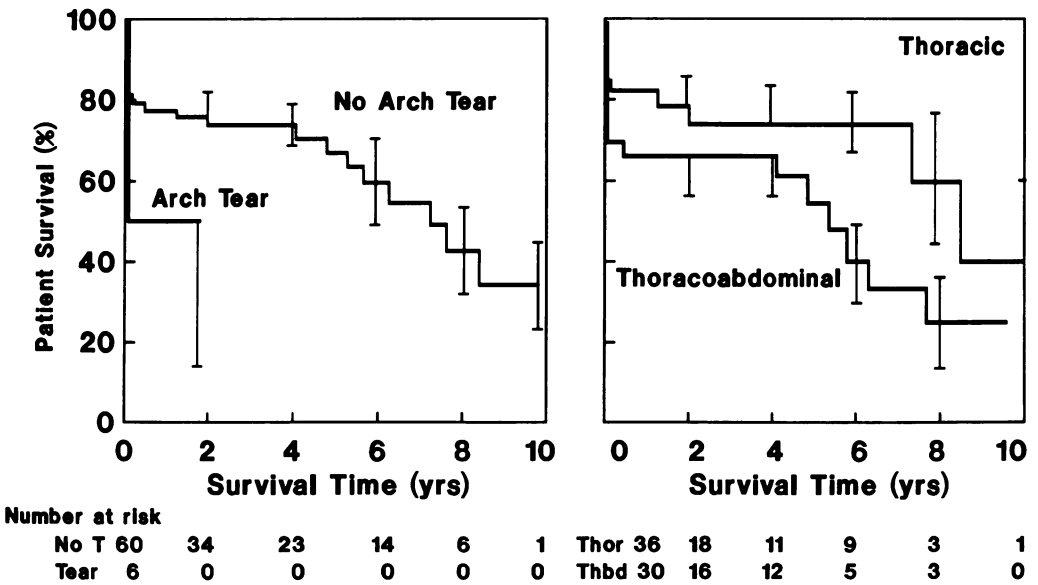

FIG. 6. Survival with or without an arch tear (left panel) and with thoracic or thoracoabdominal dissection (right panel) in patients with ascending aortic dissection.

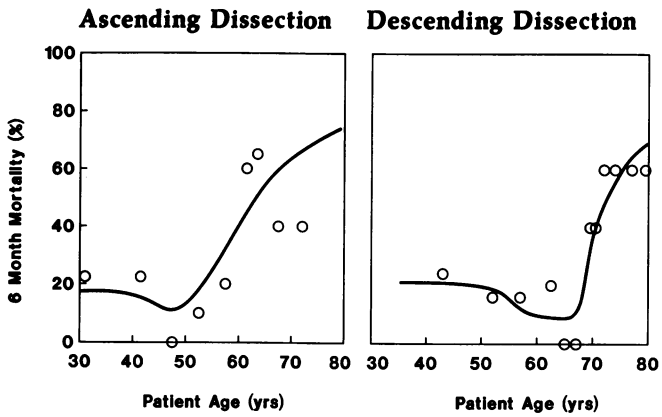

FIG. 7. Influence of patient age on 6-month mortality rates in patients with ascending or descending aortic dissection.

of other series (Table 6), and the long-term survival rate shown in Figure 2 also parallels that reported by Crawford,[18] Rizzoli,[39] and Sutton.[8] Differing patient selection criteria between series may account for some of the differences in mortality rates. The increased likelihood of rupture or operation with aortic diameter greater than 5.5 cm to 6 cm in type III dissection (Fig. 10) compared well with the 5.5-cm criterion for operation proposed by Crawford et al.[18]

Data from the current study (Fig. 9) imply that selective management of type III dissection, as practiced at this institution, can provide acceptable results with comparable survival between medical and surgical groups. Figure 9 does not, however, imply that surgical and medical treatment were equivalent because all surgical patients had aortic rupture or aortic expansion and should have had worse survival if surgical intervention had been ineffective. For patients with uncomplicated descending aortic

TABLE 5. *Univariate and Multivariate Analysis of Variables Significantly ($p < 0.1$) Predictive of Death for Descending Aortic Dissection*

	Univariate		Multivariate	
Variable	Chi^2	p	Chi^2	p
Presenting complication of dissection	57.80	0.0001	25.76	0.0001
Age	12.98	0.0003	11.96	0.0005
Rupture	7.43	0.006	6.24	0.01
Recent admission data	6.73	0.01	2.09	0.15
Acute presentation	3.87	0.049	1.91	0.17

dissection, a retrospective, multivariate analysis of patients from two institutions similarly found no difference in survival or incidence of late operation between medical and surgical therapy.[38]

Type I dissection is known to be associated with a particularly poor prognosis without surgical intervention.[5] The number of type I patients arriving at this institution sufficiently ill to die before therapy could be instituted emphasizes the urgency with which acute type I dissection must be managed. Other than the current report, very few surgical series have provided data on the incidence and outcome in patients not receiving operation for type I or II dissection due to death occurring before operation or due to other severe medical disorders.[18]

Intraoperative aortic dissection was rare at this institution but was highly morbid with all three patients dying of cardiac failure, perhaps due to severity of underlying cardiac disease and origin of the dissection in the ascending aorta. Murphy et al.[40] reported a 40% (6 of 15 patients) mortality rate with intraoperative dissection, while Carey[41] reported survival in six of seven patients in whom intraoperative dissection originated at the femoral artery can-

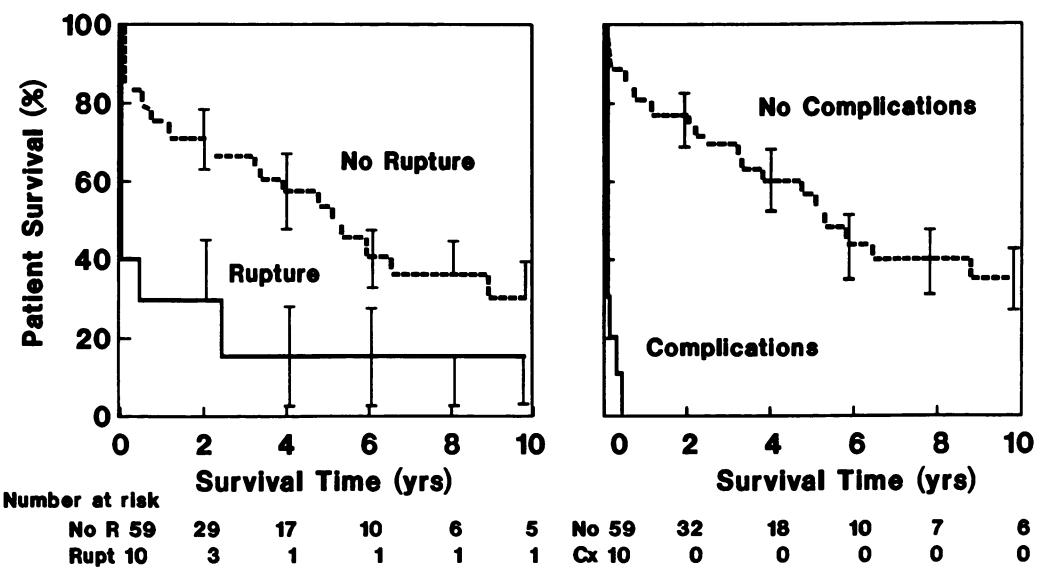

FIG. 8. Survival with or without rupture (left panel) and with or without other presenting complications of dissection (right panel) in patients with descending aortic dissection.

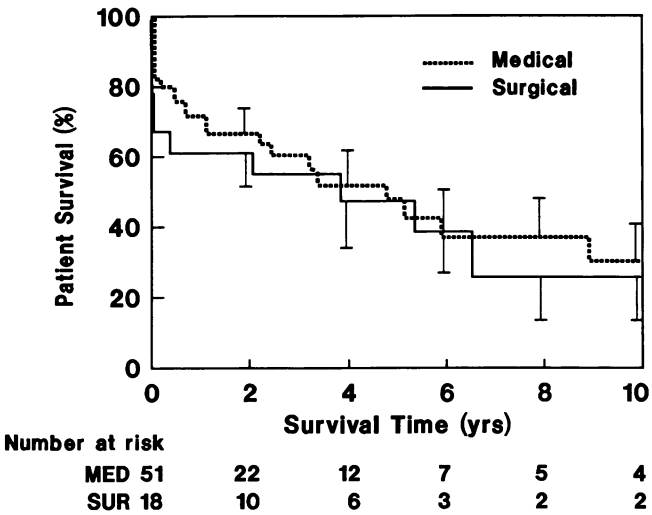

FIG. 9. Patient survival with medical or surgical therapy in descending aortic dissection.

nulation site. The high mortality rate of intraoperative dissection in the current series and that of Murphy may reflect the more serious nature of dissection originating in the ascending aorta as opposed to the femoral artery.[41]

In the present series, the mortality rate was also significant when patients with previous cardiac or thoracic aortic procedures required acute surgical intervention. Similarly Murphy reported only two of nine survivors with operation for acute ascending aortic dissection occurring after a previous cardiac surgical procedure, and these two survivors had the dissection repaired within hours of the original cardiac procedure.[40] Early diagnosis and operative intervention therefore would appear to be important in managing acute types I or II dissection after other cardiac

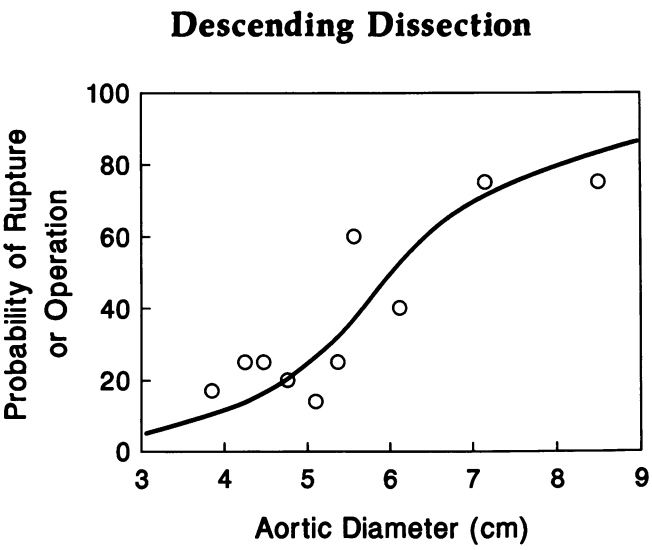

FIG. 10. Effect of maximal aortic diameter on probability of aortic rupture or aortic operation in descending aortic dissection.

TABLE 6. *Medical and Surgical Deaths (*30-day, Hospital, or Operative) from Larger Studies of Type III Aortic Dissection*

Institution	Author	Medical	Surgical
Baylor	Crawford 1988		41/317
Lyon, France	Kirkorian 1988	15/42	
Mayo	Jex 1986		18/64*
MGH/Yale	Cambria 1989	13/90	27/58
Milan, Italy	Ruberti 1988		11/29*
Stanford	Miller 1984		15/54*
Texas Heart Institute	Reul 1975		19/91*
U Alabama	Appelbaum 1976	7/27	8/21
U British Columbia	Fradet 1988	4/27	6/20
U Virginia	Mills 1979	10/17	5/14
Uppsala, Sweden	Bergholm 1984	5/22	12/13
Zurich, Switzerland	Von Segesser 1988		8/31
Total		53/225 (24%)	170/712 (24%)

procedures. On the other hand, patients presenting with chronic ascending aortic dissection after previous cardiac operations may fare better, with five of six such patients reported by Orszulak[42] surviving repair of aortic dissection.

Increased deaths in types I or II dissection with aortic involvement below the diaphragm (Fig. 6, Table 4) has been reported by Cambria[43] and DeBakey.[3] These additional deaths may have resulted from increased risk of distal organ ischemia and distal aortic rupture. Indeed the occurrence of peripheral pulse loss or visceral ischemia as presenting complications of descending dissection was associated with a significant mortality rate in the current study (Table 5). Crawford et al.[18] have reported large numbers of patients in whom both the thoracic and the abdominal aorta were grafted. The morbidity of extensive aortic grafting still leaves doubt as to the role for such procedures.

The association between native aortic valve disease and dissection, including chronic type II dissections, was noted by McKusick in 1957.[44] Type II dissection may be more likely when previous aortic disease is limited to the ascending aorta (as with ascending aortic aneurysm associated with aortic valve disease), while type I dissection may more often result from chronic hypertension and diffuse aortic disease.

Spencer and Blake[45] first described successful resuspension of the aortic valve for regurgitation produced by aortic dissection in 1962. While several authors have favored aortic valve replacement for aortic valve insufficiency due to dissection,[3,46-48] many institutions have reported good short-term results for aortic valve resuspension.[7,19,25,49-52] Long-term results after aortic valve resuspension have been limited to the report of Miller et al.[13] with two reoperations in 134 patient-years of follow-up[49] and the report of Jex et al.[19] with 1 of 18 patients ultimately requiring reoperation. Data from the current study (Fig. 5) demonstrate that the failure rate of aortic

valve resuspension with up to 9 years of follow-up can be low in patients with acute dissection, a previously normal valve, and absence of annuloaortic ectasia. Previous dissatisfaction with aortic valve resuspension may have resulted from suboptimal patient selection.

Primary repair of aortic dissection was described by DeBakey in 1955 for type III dissections[32] and in 1964 for ascending aortic dissection.[33] Olinger[23] recently reported a series of 14 patients undergoing primary repair of ascending aortic dissection, with one patient requiring subsequent aortic valve replacement and repair of a sinus of valsalva aneurysm. In the present series, however, a significant 25% incidence of late ascending aortic aneurysm and aortic insufficiency requiring operative correction was noted. Three of five patients with primary aortorrhaphy reported by Appelbaum et al.[7] died from redissection. Jex et al.[19] also noted recurrent aortic dissection in 4 of 13 patients treated with primary aortorrhaphy as opposed to 3 of 59 patients treated with an aortic graft ($p = 0.005$). Although the patient numbers are small, these results suggest that interposition grafting of ascending aortic dissection should be the procedure of choice for repair of aortic dissection.

Just as the merits of primary aortic repair have been debated, the choice of the inclusion[26] *versus* exclusion[13] of the native aortic wall around the aortic graft has been controversial. Massimo et al.[53] reported that the incidence of late death due to persistent distal dissection was higher with the inclusion technique than with aortic exclusion. Similarly Kouchoukos et al.[24] reported a higher incidence of late reoperation on the ascending aorta or aortic valve using the inclusion *versus* the exclusion technique (23% ± 5% *versus* 10% ± 7% at 5 years). Borst,[25] on the other hand, argued that the inclusion technique should better obliterate the false channel and decrease secondary rupture. Data from the current study indicate that the inclusion technique can provide a low incidence of reoperation at 5 years (13% ± 6%) (Fig. 10) quite comparable to the 13% ± 4% incidence of dissection-related reoperation at 5 years reported by Haverich et al.[37] with the exclusion technique. Although the reoperation rate at 10 years was somewhat higher in the current study with the inclusion technique (40% ± 15%) than that reported by Haverich et al.[37] with aortic exclusion (23% ± 6%), these results do not differ significantly due to small patient numbers.

The greatest source of death in the current study was associated cardiovascular disease (Fig. 3). The fact that known pre-existing cardiac, renal, or cerebrovascular disease were not of prognostic significance suggests that cardiovascular disease was more pervasive in this patient population than was clinically evident. The significant long-term mortality rate and the prominence of cardiovascular, sudden, and rupture-related death suggests that careful follow-up is needed, both for cardiovascular disease and for complications of aortic dissection. The significance of residual aortic disease also was demonstrated by Heinemann et al.,[54] who found that 17% of 86 patients with acute ascending aortic dissection developed significant dilation of the distal aorta after repair of the ascending aorta. These results parallel those observed for all patients with Marfan's syndrome, with which 48% of deaths are due to aortic dissection or rupture and 36% are due to sudden death or other cardiovascular disease.[55]

The influence of the surgeon's experience on operative mortality rates in aortic dissection has not been documented previously. Several factors that might contribute to the association between the surgeon's experience and operative mortality rate include the relative infrequency of aortic dissection in most thoracic surgical practices, the acuity with which most patients present, the technical demands of operations for aortic dissection, especially when exposure is difficult and tissues are suboptimal, and the judgment required in technical aspects such as the handling of distal perfusion during aortic clamping. The implication is that, even in a large medical center, mortality rates might be improved through management of aortic dissection by a few individuals.

One potential weakness of this study was the number of patients dying suddenly, especially in the type III group, without being able to distinguish sudden death by aortic rupture from death by other causes, such as stroke or myocardial infarction. These sudden deaths generally occurred at home or in outlying hospitals and again emphasize the need for long-term follow-up, both for associated cardiovascular disease and for aortic disease.

Remaining issues include whether surgical therapy might benefit type III patients other than those with rupture or expansion. The low surgical mortality rate in the group operated on electively for expansion suggests that a relatively low operative mortality rate could be achieved under elective conditions for other patients. Patients with acute dissection and those with retrograde dissection potentially could benefit more frequently from operation more than currently thought. Although retrograde aortic dissection is not uncommon, few data are available regarding outcome of aortic dissections originating in the descending aorta but extending retrograde into the aortic arch or ascending aorta. Pinet[56] found 4 of 32 patients (13%) with dissection originating in the descending aorta to have involvement of the ascending aorta, not unlike the aortic arch involvement seen in 10 of 69 patients (14%) with type III dissection in the present study. Cipriano[57] reported deaths in three of six patients with retrograde extension of dissection into the ascending aorta. The three retrograde patients managed surgically in the current series gave mixed results, with one operative death, one long-term survivor, and one patient dying suddenly at home 1 month after operation. While patients with acute or

retrograde type III dissection may be at increased risk for death, extent of this risk and the optimal management of these patients awaits further data.

A related issue is whether those patients with ascending dissection and increased risk due to an intimal tear in the aortic arch might also benefit from a more aggressive approach. Several authors[18,20,21,53,58] have grafted the aortic arch when involved, particularly with an intimal tear in the aortic arch or compromise of brachiocephalic vessels. Nonetheless the 20% to 34% mortality rate of arch replacement has tended to discourage its use. Furthermore Miller et al.[13] were unable to show any significant relationship between resection of the primary intimal tear and subsequent risk of late valvular or aortic operation, although the reoperation rate was lower in patients with tear resection.

Operation remains the therapy of choice in patients with type I or II aortic dissection. Particularly in type I patients in whom presentation is often acute, operation should be performed on an urgent basis because the risk of death from rupture is otherwise significant. Type II patients more often present with chronic dissection and with previous aortic valve disease. Aortic valve resuspension in patients without native aortic valve disease has resulted in excellent freedom from long-term valve failure. The practice of reserving surgical intervention for type III patients with rupture or expansion has produced acceptable outcome at this institution during the last 14 years. The late incidence of aortic complications such as rupture, further dissection, or expansion often requiring surgery was a small but significant contributor to late death. Careful and aggressive follow-up with chest film, computed tomography, or angiography is essential in minimizing late morbidity and mortality rates due to residual aortic disease and concurrent cardiovascular disease in patients with aortic dissection.

Acknowledgments

The authors thank Louise Leighton for secretarial assistance in preparing the manuscript and Juanita Wrenn and Susan Hellenbrand for assistance in preparing the illustrations.

References

1. Hirst AE Jr, Johns VJ Jr, Kime SW Jr. Dissecting aneurysm of the aorta: a review of 505 cases. Medicine (Baltimore) 1958; 37:217–279.
2. Anagnostopoulos CE, Prabhakar MJS, Kittle CF. Aortic dissections and dissecting aneurysms. Am J Cardiol 1972; 30:263–273.
3. DeBakey ME, McCollum CH, Crawford ES, et al. Dissection and dissecting aneurysms of the aorta: twenty-year follow-up of five hundred twenty-seven patients treated surgically. Surgery 1982; 92:1118–1134.
4. Wheat MW Jr. Acute dissection of the aorta. Cardiovasc Clin 1987; 17:241–262.
5. Daily PO, Trueblood HW, Stinson EB, et al. Management of acute aortic dissections. Ann Thorac Surg 1970; 10:237–47.
6. Dalen JE, Alpert JS, Cohn LH, et al. Dissection of the aorta: Medical or surgical therapy? Am J Cardiol 1974; 34:803–808.
7. Appelbaum A, Karp RB, Kirklin JW. Ascending vs descending aortic dissections. Ann Surg 1976; 183:296–300.
8. Sutton MSJ, Oldershaw PJ, Miller GAH, et al. Dissection of the thoracic aorta. A comparison between medical and surgical treatment. J Cardiovasc Surg (Torino) 1981; 22:195–202.
9. Bergholm U, Hallen A. Dissecting aneurysm of the descending thoracic aorta. Surgical or medical treatment? Scand J Thorac Cardiovasc Surg 1984; 18:45–47.
10. Doroghazi RM, Slater EE, DeSanctis RW, et al. Long term survival of patients with treated aortic dissection. J Am Coll Cardiol 1984; 3:1026–1034.
11. Kirkorian G, Hochmann B, Kassis A, et al. Long-term prognosis of patients with acute type B aortic dissection treated medically. J Am Coll Cardiol 1988; 11:162A.
12. Reul GJ, Cooley DA, Hallman GL, et al. Dissecting aneurysm of the descending aorta. Improved surgical results in 91 patients. Arch Surg 1975; 110:632–640.
13. Miller DC. Replacement of the transverse aortic arch during emergency operations for type A acute aortic dissection [letter]. J Thorac Cardiovasc Surg 1989; 98:310–313.
14. Mills SE, Teja K, Crosby IK, Sturgill BC. Aortic dissection: surgical and nonsurgical treatments compared. An analysis of seventy-four cases at the University of Virginia. Am J Surg 1979; 137: 240–243.
15. Carlson DE, Karp RB, Kouchoukos NT. Surgical treatment of aneurysms of the descending analysis of 85 patients. Ann Thorac Surg 1983; 35:58–69.
16. Miller DC, Mitchell RS, Oyer PE, et al. Independent determinants of operative mortality for patients with aortic dissections. Circulation 1984; 70(Suppl I):153–164.
17. Jex RK, Schaff HV, Piehler JM, et al. Early and late results following repair of dissections of the descending thoracic aorta. Surg 1986; 3:226–237.
18. Crawford ES, Svensson LG, Coselli JS, et al. Aortic dissection and dissecting aortic aneurysms. Ann Surg 1988; 208:254–273.
19. Jex RK, Schaff HV, Piehler JM, et al. Repair of ascending aortic dissection. Influence of associated aortic valve insufficiency on early and late results. J Thorac Cardiovasc Surg 1987; 93:375–384.
20. Bachet J, Teodori G, Goudot B, et al. Replacement of the transverse aortic arch during emergency operations for type A acute aortic dissection. J Thorac Cardiovasc Surg 1988; 96:878–886.
21. Lansman SL, Raissi S, Ergin MA, Griepp RB. Urgent operation for acute transverse aortic arch dissection. J Thorac Cardiovasc Surg 1989; 97:334–341.
22. Miller DC, Stinson EB, Oyer PE, et al. Operative treatment of aortic dissections. Experience with 125 patients over a sixteen-year period. J Thorac Cardiovasc Surg 1979; 78:365–382.
23. Olinger GN, Schweiger JA, Galbraith TA. Primary repair of acute ascending aortic dissection. Ann Thorac Surg 1987; 44:389–393.
24. Kouchoukos NT, Marshall WG Jr, Wedige-Stecher TA. Eleven-year experience with composite graft replacement of the ascending aorta and aortic valve. J Thorac Cardiovasc Surg 1986; 92:691–705.
25. Borst HG, Laas J, Frank G, Haverich A. Surgical decision making in acute aortic dissection type A. Thorac Cardiovasc Surg 1987; 35:134–135.
26. Wolfe WG. Acute ascending aortic dissection. Ann Surg 1980; 192: 658–666.
27. Lemole GM, Strong MD, Spagna PM, Karmilowicz NP. Improved results for dissecting aneurysms. Intraluminal sutureless prosthesis. J Thorac Cardiovasc Surg 1982; 83:249–255.
28. Bentall H, DeBono A. A technique for complete replacement of the ascending aorta. Thorax 1968; 23:338–339.
29. Wolfe WG, Moran JF. The evolution of medical and surgical treatment of acute aortic dissection. Circulation 1977; 56:503–504.
30. Morgagni GB. De Sedibus et Causis Morborum per Anatomen Indagitis. Translated by Alexander A. The Seats and Causes of Diseases Investigated by Anatomy. Vol 1. London: 1769:802–808.

31. Nicholls F. Observations concerning the Body of his late Majesty, October 26, 1760. Philos Trans Roy Soc London 1761; 52:574–579.
32. DeBakey ME, Cooley DA, Creech O Jr. Surgical considerations of dissecting aneurysm of the aorta. Ann Surg 1955; 142:586–612.
33. DeBakey ME, Henly WS, Cooley DA, et al. Surgical management of dissecting aneurysm involving the ascending aorta. J Cardiovasc Surg (Torino) 1964; 5:200–211.
34. Hume DM, Porter RR. Acute dissecting aortic aneurysms. Surgery 1963; 53:122–154.
35. Najafi H, Dye WS, Javid H, et al. Proceedings: aortic insufficiency secondary to aortic root aneurysm and/or dissection. J Cardiovasc Surg 1976; 17:91.
36. Inoue T. Dissecting aneurysm of the aorta—classification and proposal of surgical procedures. Jpn Circ J 1982; 46:201–204.
37. Haverich A, Miller DC, Scott WC, et al. Acute and chronic aortic dissections—determinants of long-term outcome for operative survivors. Circulation 1985; 72(Suppl II):22–34.
38. Glower DD, Fann JI, Speier RH, et al. Comparison of medical and surgical therapy for uncomplicated descending aortic dissection. Circulation 1989; 80(Suppl II):24.
39. Rizzoli G, Gregio L, Mazzucco A, et al. Determinants of late survival of 105 patients operated for dissection of the aorta. Eur J Cardiothorac Surg 1988; 2:18–24.
40. Murphy DC, Carver JM, Jones EL. Recognition and management of ascending aortic dissection complicating cardiac surgical operations. J Thorac Cardiovasc Surg 1983; 85:247–256.
41. Carey JS, Skow JR, Scott C. Retrograde aortic dissection during cardiopulmonary bypass:"nonoperative" management. Ann Thorac Surg 1977; 24:44–48.
42. Orszulak TA, Pluth JR, Schaff HV, et al. Results of surgical treatment of ascending aortic dissections occurring late after cardiac operation. J Thorac Cardiovasc Surg 1982; 83:538–545.
43. Cambria RP, Brewster DC, Gertler J, et al. Vascular complications associated with spontaneous aortic dissection. J Vasc Surg 1988; 7:199–209.
44. McKusick VA, Logue RB, Bahnson HT. Association of aortic valvular disease and cystic medial necrosis of the ascending aorta. Report of four instances. Circulation 1957; 16:188–194.
45. Spencer FC, Blake H. A report of the successful surgical treatment of aortic regurgitation from a dissecting aortic aneurysm in a patient with the Marfan syndrome. J Thorac Cardiovasc Surg 1962; 44:238–245.
46. Pate JW, Richardson RL, Eastridge CE. Acute aortic dissections. Am Surg 1976; 42:395–404.
47. Kidd JN, Reul GJ Jr, Cooley DA, et al. Surgical treatment of aneurysms of the ascending aorta. Circulation 1976; 54(Suppl III): 118–122.
48. Seybold-Epting W, Meyer J, Hallman GL, Cooley DA. Surgical treatment of acute dissecting aneurysm of the ascending aorta. J Cardiovasc Surg (Torino) 1977; 18:43–48.
49. Meng RL, Najafi H, Javid H, et al. Acute ascending aortic dissection: surgical management. Circulation 1981; 64(Suppl II):231–234.
50. Cachera JP, Vouhe PR, Loisance DY, et al. Surgical management of acute dissections involving the ascending aorta. Early and late results in 38 patients. J Thorac Cardiovasc Surg 1981; 82:576–584.
51. Wolfe WG, Oldham HN, Rankin JS, Moran JF. Surgical treatment of acute ascending aortic dissection. Ann Surg 1983; 197:738–742.
52. Murday AJ, Pillai R, Magee PG, et al. Results of surgical repair for dissection of the ascending aorta. Br Heart J 1987; 57:548–551.
53. Massimo CG, Presenti LF, Marranci P, et al. Extended and total aortic resection in the surgical treatment of acute type A aortic dissection: experience with 54 patients. Ann Thorac Surg 1988; 46:420–424.
54. Heinemann M, Laas J, Karck M, Borst HG. Thoracic aortic aneurysms after acute type A aortic dissection: necessity for follow-up. Ann Thorac Surg 1990:49; 580–584.
55. Marsalese DL, Moodie DS, Vacante M, et al. Marfan's syndrome: natural history and long-term follow-up of cardiovascular involvement. J Am Coll Cardiol 1989; 14:422–428.
56. Pinet F, Froment JC, Guillot M, et al. Prognostic factors and indications for surgical treatment of acute aortic dissections: a report based on 191 observations. Cardiovasc Intervent Radiol 1984; 7:257–266.
57. Cipriano PR, Griepp RB. Acute retrograde dissection of the ascending thoracic aorta. Am J Cardiol 1979; 43:520–528.
58. Ergin MA, O'Connor J, Guinto R, Griepp RB. Experience with profound hypothermia and circulatory arrest in the treatment of aneurysms of the aortic arch. Aortic arch replacement for acute arch dissections. J Thorac Cardiovasc Surg 1982; 84:649–655.