Juxtarenal Infrarenal Abdominal Aortic Aneurysm

Special Diagnostic and Therapeutic Considerations

E. STANLEY CRAWFORD, M.D. W. CLARK BECKETT, M.D. MICHAEL S. GREER, M.D.

From the Department of Surgery, Baylor College of Medicine, and the Surgical Service of The Methodist Hospital, Houston, Texas

Juxtarenal infrarenal abdominal aortic aneurysms are defined as those aneurysms that involve the infrarenal abdominal aorta adjacent to or including the lower margin of renal artery origins. The misinterpretation of findings at exploratory operation or special studies may suggest renal artery involvement and result in abandonment of operation and/or referral to distant centers, thus delaying treatment. This report is concerned with 101 patients with a median age of 68 who had such aneurysms, all referred with a diagnosis of renal or visceral arterial involvement either after exploratory operation (32), because of aneurysmal size (12), or due to misinterpretation of special studies (57). Computed tomographic (CT) scans, ultrasounds, and aortograms in the anterio-posterior projection frequently suggested renal artery involvement due to the fact that the upper end of aneurysm frequently lay over the renal artery origins due to infrarenal aortic elongation and buckling of the aorta at the renal artery level. The true nature of the lesion was best demonstrated by aortography performed in the lateral position. The operation producing the best results was one performed through a midline abdominal incision. The aorta is cross-clamped at the diaphragm and the proximal anastomosis is performed from inside the aneurysm at the renal artery level. The graft then is clamped and the other clamp removed to restore flow in the visceral vessels while the distal anastomosis is completed. Early survival occurred in 93% of patients employing the operation, despite the fact that other conditions frequently were present: renal insufficiency in 19, rupture in seven, renal artery occlusive disease in 20, chronic obstructive pulmonary disease in 34, and hypertension in 77.

JUXTARENAL INFRARENAL ABDOMINAL AORTIC ANEURYSMS are defined as aneurysms that involve the infrarenal abdominal aortic segment that extends up to and sometimes includes the lower margins of the renal artery origins. These lesions are unique and deserve special consideration. Aneurysms in this location require suprarenal aortic clamping for total replacement, which is necessary to prevent recurrence or progression of residual disease. Accurate diagnosis is difficult without special studies that need proper interpretation. Exploration and palpation based on physical examination alone may suggest visceral arterial involvement. Clarification at operation frequently requires tedious dissection for exposure of the visceral vessels, particularly the renal arteries. Such dissection may cause injury to these vessels and adjacent structures, be difficult to accomplish, or be inadequate and cause the operator to abandon operation unless he is prepared to undertake a more extensive procedure requiring visceral artery reattachment. Finally, the involved infrarenal aortic segment may be elongated. This may produce upward buckling or bowing of the renal segment of aorta and over-riding of the latter segment by anterior and upward extension of the aneurysm. These anatomic dearrangements may suggest suprarenal extension by ultrasonography, computed tomographic (CT) scanning, and aortography when viewed in the anterio-posterior plane (Fig. 1).

The unique features of aneurysm at this level may cause abandonment at exploration, incomplete aneurysmal replacement, or referral by the otherwise competent aortic surgeon and undesirable delay of treatment, particularly in the patient with rupture or impending rupture. This report is concerned with a review of a consecutive series of patients observed over a 22-year period in order to present the authors' concepts, which have evolved to permit reasonably accurate diagnosis and relatively simple and safe operation.

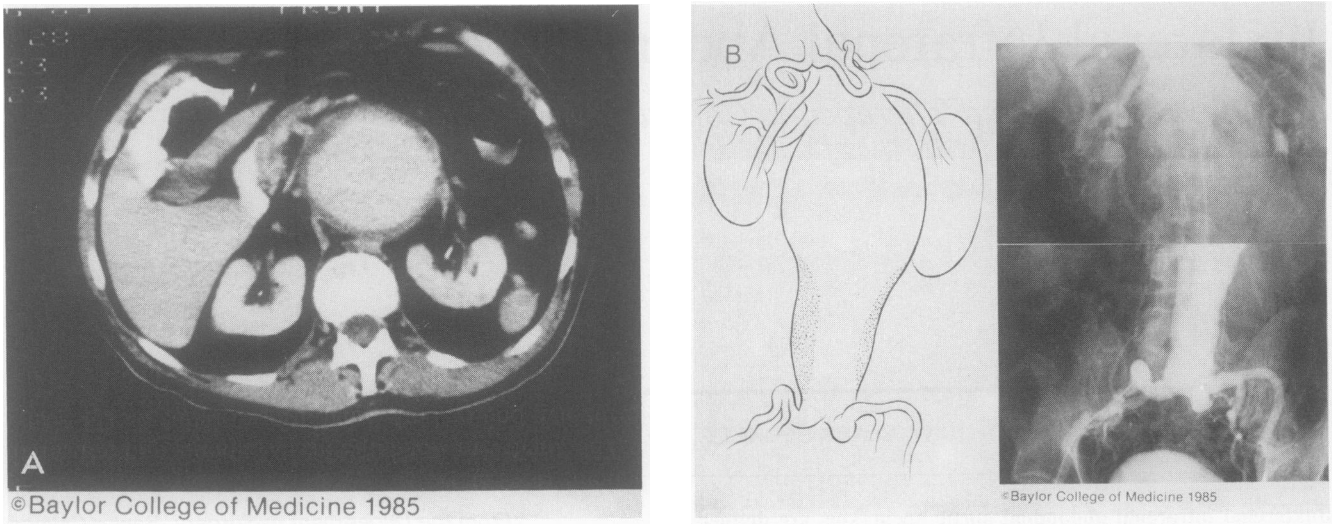
Clinical Material

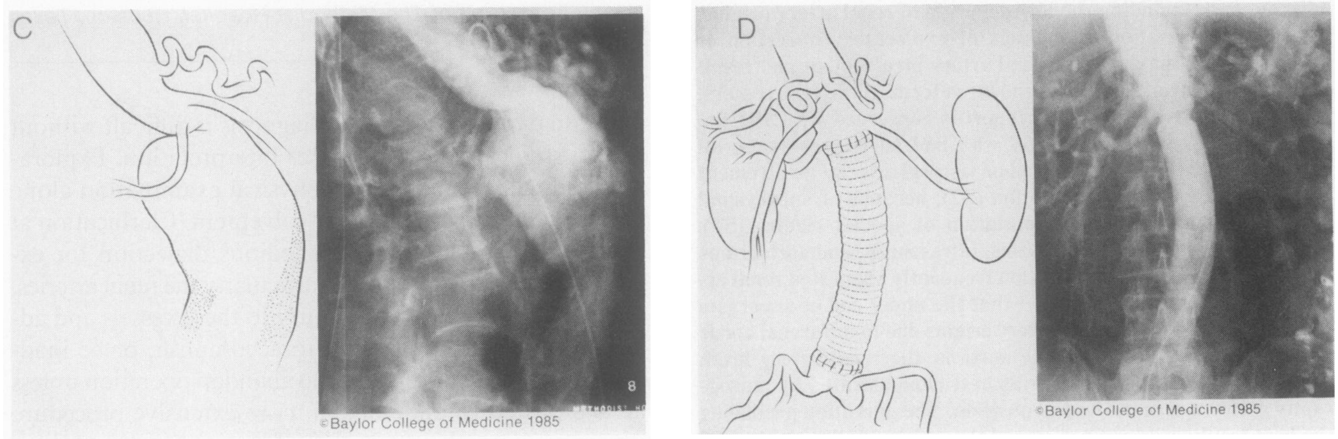
During the period extending from March 6, 1963, to April 3, 1985, 101 patients had graft replacement therapy

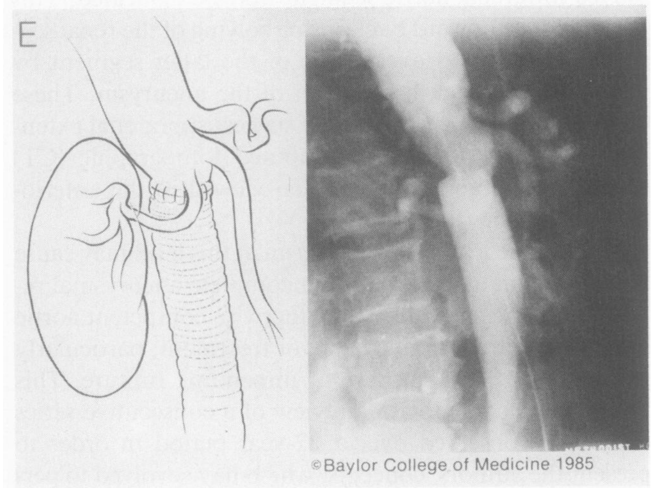
Presented at the 97th Annual Meeting of the Southern Surgical Association, Hot Springs, Virginia, December 1–4, 1985.

Address for correspondence: E. Stanley Crawford, M.D., 6535 Fannin Street MS B-405, Houston, TX 77030.

Submitted for publication: December 12, 1985.

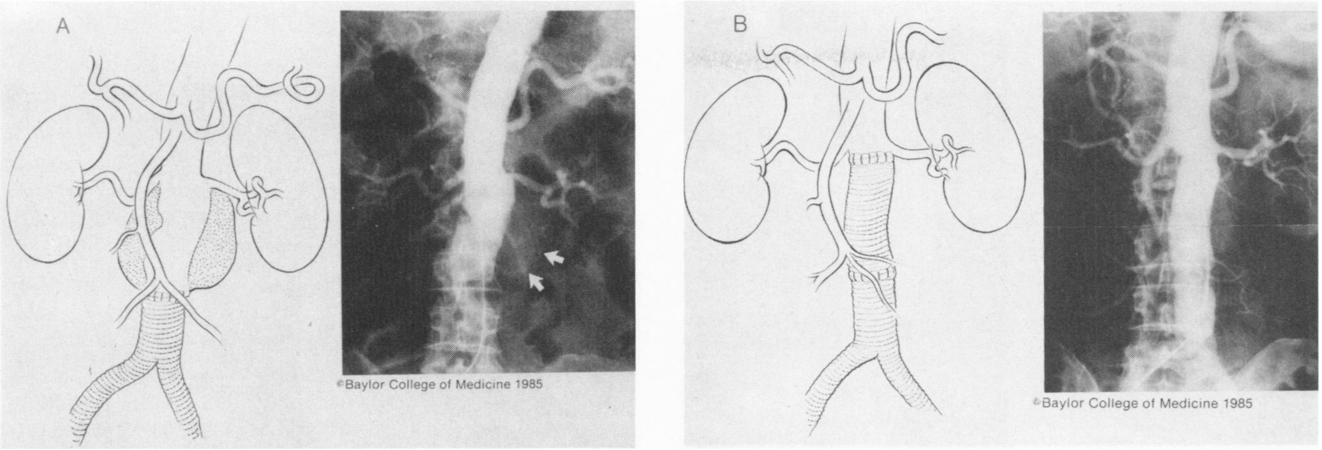






FIGS. 1A–E. Studies made before and after operation in a patient with juxtarenal infrarenal aortic aneurysm. *A.* Computerized axial tomogram made before operation showing renal pedical at level of aneurysm suggesting renal artery involvement. *B.* Drawing and aortogram (AP) made before operation suggest juxtarenal position of aneurysm on right and renal artery involvement on left. *C.* Drawing and aortogram (lateral) made before operation show juxtarenal location of aneurysm on right. Left renal artery is not visualized. The "aortic kink" located below superior mesenteric artery and normal aorta above kink is characteristic of juxtarenal, infrarenal location of large aneurysm. *D* and *E.* Drawing and aortogram made after operation showing graft in place in the anterioposterior view (*D*) and in the lateral view (*E*).

for juxtarenal infrarenal abdominal aortic aneurysms. These patients' records and follow-up treatments were analyzed retrospectively as previously reported.[1] There were 86 men and 15 women, whose ages ranged from 28 to 85, with a median of 68 years. Associated diseases or conditions included hypertension in 77, atherosclerotic heart disease in 48, chronic obstructive pulmonary disease in 34, peptic ulcer in 15, cerebrovascular disease in 14, and gallstones in ten. Patients on hemodialysis or whose serum creatinine levels were 2 mg/dl or higher after max-



FIGS. 2A and B. Illustrations of a patient who had partial removal of a juxtarenal infrarenal abdominal aortic aneurysm who developed progressive enlargement and rupture of residual aneurysm 2 years later, successfully treated by graft replacement. *A.* Diagram and aortogram made before last operation showing persistent juxtarenal infrarenal abdominal aortic aneurysm. *B.* Diagram and aortogram made after second operation showing functioning graft in place.

imum rehydration and treatment following admission were considered to have impaired renal function. One patient was being treated by chronic hemodialysis, and 18 had elevated creatinine levels. Thus, 19 patients were considered to have impaired renal function. Two of the latter patients had had nephrectomy for renal artery obstruction and had occlusive disease in the remaining renal artery. Associated occlusive lesions involved the renal arteries in 20, iliac arteries in 13, femoral arteries in five, and brachiocephalic arteries in seven patients. Fifty-four aneurysms, one ascending aorta, one transverse arch, 18 descending thoracic aorta, 29 iliac artery, two femoral artery, and three other sites, were present in 45 patients.

Etiology and Symptoms

The etiology of aneurysmal disease was atherosclerosis in 93, inflammatory in seven, and medial degenerative disease (Marfan's) in one. Five patients had had previous infrarenal aortic aneurysmal replacement in which the proximal segment of aneurysm had not been removed because aortic clamping was performed below the renal arteries. These short segments of residual aneurysm increased in size and reoperation was necessary for progression in all and rupture of the residual disease in two patients (Fig. 2).

Symptoms were present in 52 patients and included abdominal, flank, and back pain in 38 and intermittent claudication of the legs in 14. Rupture had occurred in seven patients (Fig. 3).

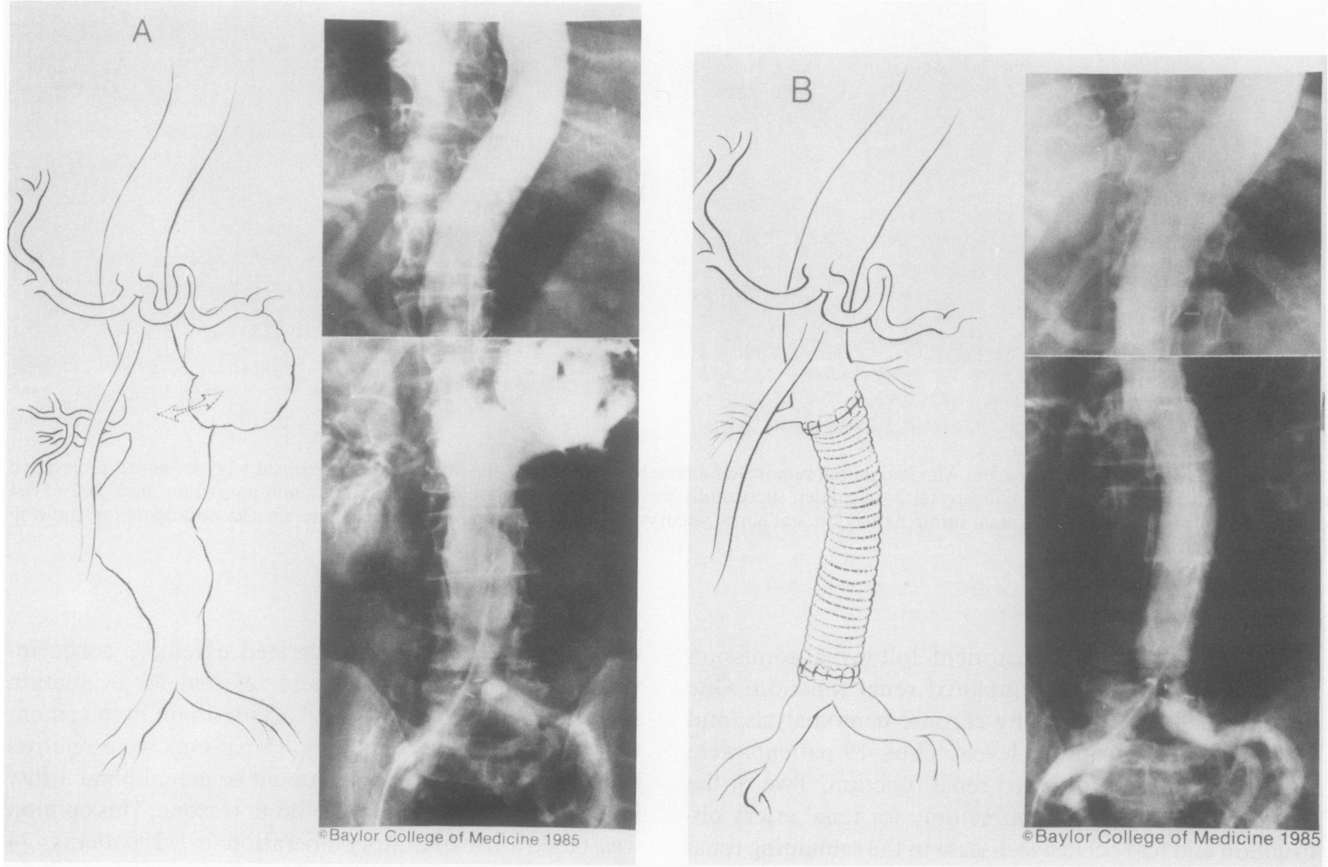
Basis for Referral

A pulsatile abdominal mass was detected by physical examination in 12 patients. The aneurysms in these cases were large and their size suggested extensive aortic involvement. These patients were referred for evaluation and treatment because visceral artery origin involvement was suspected. The remaining 89 patients were referred because renal artery encroachment or actual renal artery involvement was suspected for other reasons. This opinion was based on exploratory operation in 32 patients, 24 who had not had special studies performed before exploratory operation and eight who had had such studies: aortography in five, CT in one, and ultrasonography in two. Renal artery or more diffuse visceral vessel involvement was suspected in the remaining 57 patients based on special studies alone: aortograms alone in 18, aortography and CT scans in 11, CT scans alone in 13, ultrasonography alone in 13, and both CT scans and ultrasonography in two patients.

Basis for Definitive Diagnosis

Biplane aortography was performed for the first time in 49 patients and repeated in 18 patients. This examination was performed in ten of the 12 patients referred initially with the simple diagnosis of abdominal aortic aneurysm for evaluation and treatment. The remaining 57 examinations were in patients who previously had been admitted elsewhere, explored, or who had studies that were inadequate to determine the level of renal artery origin. Thus, satisfactory aortography (biplane) was available in 83 patients. CT scans and/or ultrasonograms were available in the other patients. These techniques clearly showed the aneurysm to be located below the renal arteries in 42 patients (Fig. 2).

The aneurysm was large in 59 patients and appeared to involve one or both renal artery origins by CT scan,



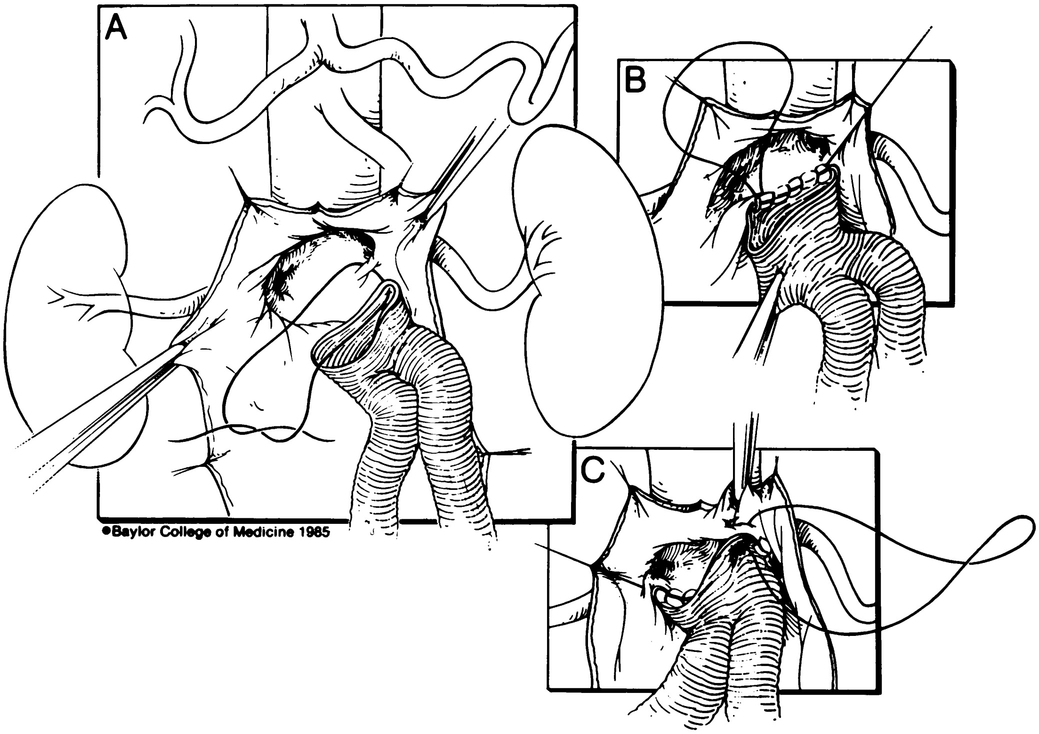
FIGS. 3A and B. Illustrations of a patient with contained rupture of a juxtarenal infrarenal abdominal aortic aneurysm who had a nonfunctioning left kidney treated by infrarenal graft replacement. *A*. Diagram and aortogram made before operation that show rupture of aneurysm and nonvisualization of left renal artery and kidney. *B*. Diagram and aortogram made after operation showing juxtarenal position of graft and nonvisualization of left renal artery and kidney, neither of which could be identified at operation.

ultrasonography, and aortography performed in the anterio-posterior projection (Fig. 1A). Aortography in the lateral projection in these cases revealed elongation of the aneurysmal segment, upward and cephalad kinking, or buckling of the uninvolved proximal aortic segment (Fig. 1C). Renal arteries appeared either to arise from this uninvolved segment of the aorta or the sites of their origins were not discernable. Exploration in earlier cases of this type revealed the aneurysm to be juxtarenal infrarenal in location. Thus, this type of aortic kinking became recognized as an aortographic sign of infrarenal aortic involvement and, to date, has proven incorrect in only one case in which the left renal artery arose abnormally low and from the aneurysm. The left renal artery in this case required reattachment to the graft, placed below the right renal artery.

Treatment

Treatment consisted of infrarenal aortic replacement with Dacron® graft. Application was dependent on the period of treatment. Early in the experience, the aorta was cross-clamped above the renal arteries and below the superior mesenteric artery in eight patients. Subsequently, the aorta was cross clamped routinely at the diaphragm. Early, when the "aortic kink sign" was being evaluated, large aneurysms in eight patients were exposed through a thoracoabdominal incision to permit exploration and visceral artery reattachment if these vessels proved to be involved. Subsequently, long midline incisions were employed routinely for exposure, except in seven patients who had simultaneous replacement of aneurysms of the descending thoracic aorta. Thus, the following technique, as employed in 78 patients since 1979, has evolved as the standard procedure for the treatment of these lesions.

The abdomen is entered through a long midline incision and the region of aneurysm explored only by evisceration of large and small bowel. The aorta is isolated and clamped in the aortic hiatus of the diaphragm as previously described.[2,3] The aneurysm is entered, the walls retracted with stay sutures, and the contained clot removed. Lumbar arteries and the inferior mesenteric artery are ligated



FIGS. 4A–C. Technique of exposure and proximal graft insertion in the treatment of juxtarenal infrarenal abdominal aortic aneurysm. *A.* The proximal uninvolved aorta at the origin of the renal arteries is identified. A suture is placed through the graft and the uninvolved aorta or lower margin of the renal artery. *B.* The suture is tied and, using continuous suture technique, the posterior anastomosis is made from the inside. *C.* The anterior portion of the anastomosis is performed from the outside. The location of the renal arteries is identified intermittently during the anastomosis using right angle clamps to avoid obstruction during suturing.

with sutures. Iliac artery back flow is controlled with balloon catheters or clamps. The back flow in the proximal aortic segment between proximal clamp and renal arteries is collected by a cell saver device and returned to the patient after washing. The distal end of the uninvolved proximal aortic segment is exposed from inside the aneurysm using retractors (Fig. 4). The renal artery origins are identified and probed with right angle clamps. A woven Dacron graft then is inserted by attaching it to the uninvolved proximal aortic segment with continuous #000 polypropylene suture. This suture line is located either just below the origin of the renal arteries or it may include the lower circumference of renal artery origin. To avoid obstruction of the latter, suturing may be performed with a right angle clamp in the renal artery. After completing the proximal anastomosis, the graft and proximal aorta are flushed by temporary removal of the aortic clamp at the diaphragm. The graft then is cross clamped below the anastomosis and the aortic clamp at the diaphragm is removed to restore circulation into the visceral vessels while graft insertion is completed distally in the usual manner. Reconstruction is completed by closing the aneurysmal wall and retroperitoneal tissues around the graft.

Aortic or renal artery occlusion times affecting renal artery blood flow varied from 7 to 69 minutes, with a median occlusion time of 19 minutes. The longer periods were in seven patients submitted to simultaneous replacement of descending thoracic aortic aneurysms and 13 patients who had simultaneous renal artery reconstruction for occlusive disease. The latter patients were treated by endarterectomy in 12 and graft bypass in one case. Routine cholecystectomy was performed in four patients.

The type of graft employed in these cases depended on the presence of iliac arterial disease. The latter arteries were uninvolved in 63 patients and the aortic aneurysm was simply replaced using a woven Dacron tube extending from the renal arteries to the aortic bifurcation. The aortic and iliac artery aneurysms were replaced in 25 patients using bifurcation woven Dacron grafts that extended from the renal arteries to the bifurcation of the iliac arteries. The 13 patients with associated occlusion of the iliac arteries were treated by graft replacement of abdominal aortic aneurysm and aortobilateral femoral artery bypass grafting using bifurcation knitted Dacron grafts.

Results

The major complications of operation included renal insufficiency (as previously defined) in 16, cardiac in ten, pulmonary in nine, hemorrhage in three, sepsis in two, and pulmonary embolus in two patients. Of the 16 patients whose blood creatinine levels were above 2 mg/dl after operation, eight required hemodialysis.

There were eight (7%) early deaths from multiple causes in most cases (Table 1). These were renal failure in five, myocardial infarction in four, pulmonary insufficiency in two, pulmonary embolus in one, and sepsis in one patient.

TABLE 1. *Juxtarenal Abdominal Aortic Aneurysm: Causes of Death*

		30-Day Death		Late Deaths	
Causes of Death	Total No. of Cases	No. of Cases	Per Cent of 8	No. of Cases	Per Cent of 12
Cardiac	11	4	50	7	58
Renal	6	5	62	1	8
Cancer	3	1	12	2	17
Pulmonary	2	2	25	0	0
Stroke	1	0	0	1	8
Sepsis	1	1	12	0	0
Suicide	1	0	0	1	8
Pulmonary embolus	1	1	12	0	0
Other	3	1	12	2	17

The incidence of early death was clinically dependent on a number of factors, including sex of the patient, the presence of symptoms, rupture of aneurysm, the presence of associated diseases (including renal artery occlusive disease, cerebrovascular disease, chronic obstructive pulmonary disease, and hypertension), renal insufficiency present either before or after operation, abdominal and aneurysmal exploration prior to admission, level of aortic clamping, and the period of treatment. However, when the statistical significance of each of these factors was determined by univariate analysis using Fisher's exact 2-tailed test, only two of the variables emerged as significant predictors of early death, probably because of the small number of patients in the various subgroups (Tables 2 and 3).

The significant predictors of early death by this method were the presence of renal artery occlusive disease and the period of treatment. For example, the mortality of those patients with associated renal artery occlusive disease was 20% (4/20, 2/13 submitted to reconstruction and 2/7 not reconstructed) compared to 5% (4/81) in patients who had normal renal arteries, and 29% (4/14) in patients treated before 1979 compared to 5% (4/87) treated later (Table 2). The latter variable retained significance in the multivariate analysis (calculated by the stepwise logistic regression analysis method) and, thus, became the strongest predictor of risk from dying early after operation (Table 3).

Renal failure was the most common complication and the most common factor in the cause of early death, accounting for 62% (5/8) of the deaths. This problem was clinically related to a number of factors, but univariate analysis employing the same technique indicated that renal clamp time was a statistically significant predictor of early renal failure after operation (Table 2). For example, this complication occurred in 13% (6/47) of the patients in whom the clamp time was over 19 minutes compared to 2% (1/54) of those in whom the clamp time was less than 20 minutes. Although rupture of the aneurysm was of borderline significance as a univariate variable, it emerged as a strong predictor of postoperative renal failure by multivariate analysis (Table 4).

Long-term Results

Follow-up information was obtained for all of the 93 patients who survived 30 days. Twelve of these patients died during the follow-up period from multiple causes (Table 1). Follow-up for the remaining 81 patients was obtained during the period extending from March 2, 1984, to October 26, 1985. The length of follow-up in these cases was less than 6 months in 15, more than 6 months but less than 1 year in 6, more than 1 year but less than 5 years in 51, and more than 5 years in nine cases. Using this survival data, a Kaplan–Meier curve of survival probability was constructed with number of survivors and standard error at each interval for a period of 5 years (Fig. 5). On the basis of this method of calculation, survival at 5 years is expected to be 75 ± 10%, despite median age of 68 years at the time of operation.

Discussion

Proximal extension of infrarenal abdominal aortic aneurysm up to renal artery origin, increasing the difficulty of graft replacement, generally has been recognized since introduction of graft replacement therapy for abdominal aortic aneurysm. The term "juxtarenal infrarenal" was applied to these lesions very early in the development of this field of surgery. Unfortunately, the authors cannot determine the first to describe, name the lesion, or successfully treat it by replacement therapy. However, the senior author first became acquainted with the condition by personally observing an operation in 1955 in which

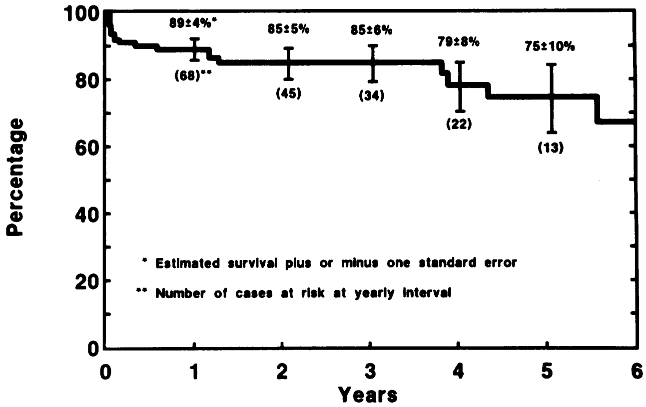


FIG. 5. Kaplan-Meier probability survival curve for 101 patients submitted to graft replacement for juxtarenal infrarenal abdominal aortic aneurysm.

TABLE 2. *Univariate Relations Between Patient Clinical Variables and Early Death and Renal Failure (101 Patients)*

Variable	No. of Cases	30-Day Death No.	30-Day Death Per Cent	p Value	Dialysis No.	Dialysis Per Cent	p Value
Age 28–68	52	4	8	1.0000	4	8	1.0000
69–85	49	4	8		3	6	
Male	86	8	9	0.6012	7	8	0.5900
Female	15	0	0		0	0	
Symptomatic	51	6	12	0.2691	6	12	0.1120
Asymptomatic	50	2	4		1	2	
Rupture	7	1	14	0.4492	2	29	0.0735
Nonrupture	94	7	7		5	5	
Renal artery occlusive disease	20	4	20	0.0471	3	15	0.1374
None	81	4	5		4	5	
ASHD	48	4	8	1.0000	3	6	1.0000
None	53	4	8		4	8	
CERE	14	2	14	0.3061	1	7	1.0000
None	87	6	7		6	7	
COPD	34	1	3	0.2611	2	6	1.0000
None	67	7	10		5	8	
HBP	77	8	10	0.1927	6	8	1.0000
None	24	0	0		1	4	
Previous aneurysm repair	8	0	0	1.0000	0	0	1.0000
None	93	8	9		7	8	
Renal dysfunction	19	2	11	0.6426	2	11	0.6132
None	82	6	7		5	6	
Referring technique							
Exploration	32	4	13	0.2591	4	12	0.2036
Other	69	4	6		3	4	
Midline incision	86	7	8	1.0000	5	6	0.2776
Thoraco–abdominal incision	15	1	7		2	13	
Level of clamp							
At diaphragm	93	8	9	1.0000	7	8	1.0000
Below diaphragm	8	0	0		0	0	
Renal clamp time							
7–19	54	3	6	0.4671	1	2	0.0477
20–125	47	5	11		6	13	
Concurrent aneurysm repair	7	1	14	0.4492	1	14	0.4049
None	94	7	8		6	6	
Surgery before 1979	14	4	29	0.0121	2	14	0.2492
Surgery 1979 and after	87	4	5		5	6	

* Test = Fisher's exact 2-tailed test.
ASHD = atherosclerotic heart disease.
CERE = cerebrovascular disease.
COPD = chronic obstructive pulmonary disease.
HBP = high blood pressure.

Dr. Denton A. Cooley replaced such an aneurysm using a graft. The aorta was clamped in this case at the level of the superior mesenteric artery, the aneurysm was totally excised, and the proximal end of the aortic homograft was sutured to the proximal aorta and incisions made in the lower circumference of both renal arteries. This operation was successful and a more modern method of treatment was illustrated by the same individual in a surgical atlas published in 1979.[2] The current authors have employed the latter techniques as described here and elsewhere, with minor modification, and consider the method to be the current procedure of choice.[3] Others who have presented their experience in recent years include Perry, Robb, and Stoney and associates.[4–6]

The application of the surgical techniques described here are simple and in the range of any vascular surgeon competent in the management of infrarenal abdominal aortic aneurysms. Thus, they may be applied and treat-

TABLE 3. *Risk Factors Predictive of Early Death*

Variable	Univariate Analysis (p Value)	Multivariate Analysis (p Value)
Renal artery occlusion	0.0471	NS
Treatment before 1979	0.0121	0.0068

ment not delayed or complicated by exploration and later referral.

The current or persistent problem is one of diagnosis, and this study and others may clarify this. The diagnosis is made first on the basis of probabilities and second by special studies, both being employed in the evaluation of the patient. First, juxtarenal infrarenal abdominal aortic aneurysms are not rare and do not extend out onto the renal arteries. They occur in 2–7% of patients with infrarenal abdominal aortic aneurysm, depending on referral patterns. Abdominal aortic aneurysms that involve only the renal arteries are much more rare, being less than 1% when cases with involvement of aberrantly located renal arteries are excluded. Moreover, the renal arteries in cases of simultaneous involvement usually are involved by extension of aneurysm into renal artery. Thus, by deduction, one can conclude that the aneurysm is juxtarenal infrarenal in location if, one, the aortic segment from which the superior mesenteric and celiac axis is normal as determined by lateral aortography and, two, if the renal arteries are not themselves aneurysmal in nature.

Special Studies

Experience in the cases reported here further suggests that biplane aortography is indicated in all patients with abdominal aortic aneurysms, particularly those of large size. Although ultrasonography and CT scanning are valuable in diagnosis, these methods of examination are unreliable in determining renal artery involvement in patients with large aneurysms. The most common available method for this determination at the present time is biplane aortography. In patients with large aneurysms, the aorta at or near the renal artery level remains attached to the perispinal tissues anteriorly. The infrarenal aortic aneurysm not only produces widening of the infrarenal abdominal aorta, but elongation as well (Fig. 6). This elongation causes the superior aspect of the aneurysm to overlay the renal artery origins and kinking of the uninvolved aorta at the renal artery level.

TABLE 4. *Risk Factors Predictive of Renal Failure*

Variable	Univariate Analysis (p Value)	Multivariate Analysis (p Value)
Rupture	0.0735	0.0398
Clamp time	0.0477	NS

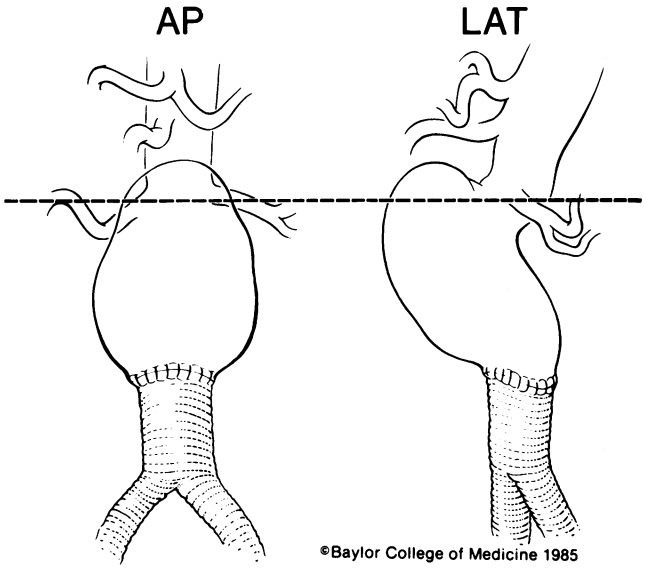


FIG. 6. Diagram of a large juxtarenal infrarenal abdominal aortic aneurysm showing elongation of segment involved by aneurysm and kinking of the uninvolved aorta at the renal artery level to demonstrate overlay of the aneurysm superiorly with the aortic segment from which the renal arteries arise.

Studies, ultrasonography, CT scanning, and aortography performed only in the anterio-posterior projection suggest renal artery involvement. Coronal ultrasonography and CT scanning are not reliable, but aortography in the lateral projection more clearly demonstrates this deformity and is indicative of juxtarenal infrarenal involvement, unless the renal arteries are aberrantly located low on the infrarenal abdominal aorta, which would not pose particular problems in the management.

Magnetic resonance imaging has just become available for clinical use, and it is hoped that this modality of noninvasive study will make juxtarenal infrarenal diagnosis clear, particularly when performed in the coronal and sagital positions as suggested by others.[7]

Acknowledgments

We gratefully acknowledge the computer programming, data retrieval, and statistical assistance of Mr. Kenneth Hess, the data collection and storage assistance by Ms. Barbara Brooks, the illustrations by Ms. Perri Smith, and preparation of the manuscript by Ms. Elizabeth Jones.

References

1. Crawford ES, Saleh SA, Babb JW III, et al. Infrarenal abdominal aortic aneurysm: factors influencing survival after operation performed over a 25-year period. Ann Surg 1981; 193:699–709.

2. Cooley DA, Wukasch DC. Techniques in Vascular Surgery. Philadelphia: W.B. Saunders Co., 1979: 62, 103.
3. Crawford ES, Crawford JL. Diseases of the Aorta, Including an Atlas of Angiographic Pathology and Surgical Technique. Baltimore: Williams & Wilkins, 1984: 144–147.
4. Perry MO, Silane MF. Management of renovascular problems during aortic operations. Arch Surg 1984; 119:681–685.
5. Robbs JV, Human RR, Rajaruthnam P. Management of abdominal aortic aneurysm extending above the renal arteries. Suid-Afrikaanse Tydskrif vir Chirurgie 1983; 21:234–242.
6. Stoney RJ, Skioldebrand CG, Quarfordt PG, et al. Juxtarenal aortic atherosclerosis, surgical experience and functional results. Ann Surg 1984; 200:345–354.
7. Amparo EG, Hoddick WK, Hricak H, et al. Comparison of magnetic resonance imaging and ultrasonography in the evaluation of abdominal aortic aneurysms. Radiology 1985; 154:451–456.

Discussion

DR. ROBERT B. SMITH III (Atlanta, Georgia): Dr. Crawford and his colleagues have been the pacesetters in so many aspects of aortic surgery. Once again, they have demonstrated that the simplest and most direct surgical method produces superior results.

For those of us who are not equal to Dr. Crawford's masterly technical skill, it is reassuring to know that the kidneys will tolerate as much as twice his average normothermic ischemic time, or in the range of 35 to 40 minutes, before significant damage becomes recognizable. Our experience has convinced us that in the type of procedures just discussed, and also in the case of thoracoabdominal aneurysms repaired by the Crawford technique, one need not be bothered by elaborate renal artery perfusion arrangements or selective renal hypothermia, but simply cross-clamp the aorta and proceed to complete the visceral revascularization in a timely manner. We do use mannitol, for whatever protection that might provide, and exercise care to have the patient well hydrated at the time of the operation.

I have several technical questions related to management of concomitant renal and mesenteric artery lesions in association with the aneurysm repair:

How does Dr. Crawford handle coexisting asymptomatic stenosis or occlusion of one or both renal arteries and also of the superior mesenteric artery? Would you ordinarily do prophylactic revascularizations, and do you prefer endarterectomy or side limbs from the aortic prosthesis for this purpose? Additionally, how do you manage the inferior mesenteric artery, assuming that its orifice is patent at the aorta? Finally, you have reported favorable results with autotransfusion in aortic surgery. Have you observed significant complications with that technique in this present series?

Thank you.

DR. WILLIAM H. EDWARDS (Nashville, Tennessee): I want to compliment Dr. Crawford on his presentation this morning and thank him for allowing me to review his manuscript, which he actually got to me a couple of days ago, and to say that, as a bagman for the Nashville Mafia, I am pleased to be able to get up here again with leader, Secretary Sawyers, and the Godfather, Dr. Herrington.

Several years ago before this association, I made the statement that when Stanley Crawford speaks, people listen. I would repeat that this morning.

Dr. Crawford in his manuscript emphasizes that the diagnosis of juxtarenal abdominal aneurysm can be made many times on the basis of probabilities that this segment of the aorta may be involved in up to 10% of the patients, but that the renal arteries themselves will be involved in probably only about 1% of patients.

He has emphasized the role of aortography in the diagnosis of this lesion. The use of biplane aortography is essential, and we would agree 100% and have always felt that the use of an aortogram allows the surgeon to plan his operation and to see lesions such as these, so that he might better plan exactly what to do.

Adequate control of the proximal aorta is essential.

(Slide) For years we approached ruptured abdominal-aortic aneurysms by control of the aorta at the hiatus. However, one day I found this instrument at the St. Thomas Hospital, which is an aortic compressor that is an excellent instrument to apply at the esophageal hiatus to completely control the aorta, and this is what we currently use as long as we have a good strong, first year resident. We put him on several standing tools, and he is able to control that aorta without having to dissect it out and apply a clamp.

(Slide) Just a couple of arteriograms to re-emphasize exactly what Dr. Crawford has pointed out, that the aneurysm may extend right to the renals, that with lateral projection we can tell exactly what is involved, and that in addition to the aneurysm at the level of the renal arteries, we can also determine if there is any involvement of other visceral vessels that might need attention.

(Slide) In his manuscript, he comments on those aneurysms that might involve a renal artery, usually the left, and that with dissection of that left renal artery, it can be replanted onto the Dacron® graft, which can generally be placed below the right renal artery.

In closing, I would again like to compliment Dr. Crawford on his excellent presentation and to say that I am pleased that many of the techniques that he taught me 25 years ago still stand me in good stead.

Thank you.

DR. DANIEL B. NUNN (Jacksonville, Florida): It is indeed a privilege and honor to discuss Dr. Crawford's paper. Aside from being a reasonably experienced surgeon of some notoriety, Stanley Crawford enjoys the even greater distinction of being the only fellow Southerner that I know in whom I can recognize a Southern accent.

As is customary, Dr. Crawford's lucid and explicit presentation has left little room for disputation, and certainly it is impossible to match numbers with him. Nevertheless, I wish to make a few observations and also ask Dr. Crawford several questions.

The material presented underscores the need for adequate preoperative aortography in all nonemergent patients with aortic aneurysms and suspected renal involvement. In my judgment adequate aortography includes AP, lateral, and even possibly oblique views to evaluate not only the renal arteries but also the status of the mesenteric circulation.

I fully concur with Dr. Crawford's belief that one cannot depend on physical examination or CT scanning or ultrasonography to differentiate juxtarenal aortic aneurysms from those directly involving the renal arteries. Moreover, it should be emphasized that an accurate diagnosis on the basis of surgical exploration alone is frequently difficult.

The operative technique described by Dr. Crawford for the juxtarenal, infrarenal aortic aneurysms, that is, clamping the aorta at the diaphragmatic level and working within the aneurysm, is unquestionably technically easier, faster, and safer than alternative techniques utilizing suprarenal aortic occlusion. Diaphragmatic aortic occlusion as opposed to suprarenal occlusion avoids the danger of injury to the renal arteries and veins, the lumbar vessels, and the superior mesenteric artery.

I wish to pose the following questions to Dr. Crawford.

Number one, do you at times find it necessary to divide the left renal vein in dealing with juxtarenal aneurysm, and, if so, do you reanastomose the vein? Number two, I cannot help but ask whether you use systemic heparinization in this type of aneurysmectomy, and number three, do you employ routine use of Swan-Ganz monitoring both during the peri- and postoperative periods.

Finally, I wish to congratulate Dr. Crawford for still another significant contribution to vascular surgery, and also I want to thank you for the opportunity of reviewing your excellent manuscript.

DR. E. STANLEY CRAWFORD (Closing discussion): I want to thank Drs. Edwards and Nunn for their complimentary remarks and the knowledge that they have added to this subject and will address my discussion to their questions or the points that they have made.