Optimal exposure of the proximal abdominal aorta: A critical appraisal of transabdominal medial visceral rotation

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Purpose: Adequate exposure of the upper abdominal aorta and its branches is a necessary prelude to safe and durable reconstruction of this aortic segment. Although a variety of approaches to this exposure have been described, few outcome data are available to assess the benefits and limitations of the different exposure options. In this series we report the results of the transabdominal medial visceral rotation (MVR) approach to exposure of the paramesenteric and pararenal aorta.
Methods: One hundred eight operations were performed in 104 patients, representing 19.5% of all aortic reconstructions during a 5.5 year interval. Most patients had hypertension (*n* = 77, 71.3%) or a history of smoking (*n* = 83, 76.9%). Heart disease was present in one third of patients (*n* = 33), and a similar proportion had abnormal renal function (elevated creatinine level) before operation (*n* = 40, 37.0%). One third of patients (*n* = 34) had undergone previous aortic or aortic branch reconstruction. Eighty percent of procedures were elective (*n* = 87). Seventy-one patients (65.7%) required renal revascularization, usually for hypertension or elevated creatinine levels, whereas 37 patients (34.3%) underwent visceral reconstruction, most often for symptoms of chronic mesenteric ischemia. Only 22 patients required isolated infrarenal aortic repair. Most of the aortic lesions were aneurysmal (*n* = 42). Eighty percent of procedures (*n* = 88) required suprarenal or more proximal aortic clamping. The most frequently used reconstruction techniques were bypass (*n* = 39, 36.1%), endarterectomy (*n* = 18, 16.7%), or both (*n* = 23, 21.3%).
Results: There were four intraoperative deaths (3.7%) and 15 postoperative deaths (13.9%). All intraoperative deaths and four postoperative deaths were related to hemorrhage and its complications. Visceral infarction was the most frequent cause of postoperative death. The intraoperative complications that were determined to be related to the medial visceral rotation approach included splenic injury (*n* = 23, 21.3%), one aortic injury, and one adrenal injury. The aortic injury was associated with substantial intraoperative bleeding and subsequent death. The postoperative complications resulting from MVR included pancreatitis (*n* = 5), which contributed to death in two patients, and possibly some of the cases of visceral infarction not associated with visceral reconstruction. The other common postoperative complications, cardiac (*n* = 25, 24.0%), pulmonary (*n* = 32, 30.8%), renal (*n* = 20, 19.2%), and infectious (*n* = 17, 16.3%), were attributed to the procedures performed.
Conclusions: Transabdominal MVR exposure of the upper abdominal aorta provides unrestricted access to the visceral branch–bearing segment of the aorta and places no limitations on the choice of arterial reconstruction technique. The associated morbidity and mortality rates are typical of patients undergoing these complex vascular repairs, but the frequency of splenic injury and postoperative pancreatitis is increased. (J VASC SURG 1994;19:375-90.)

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Table I. Patient profile

	No.	*%*
Risk factors		
Diabetes	7	6.5
Hypertension	77	71.3
Hypercholesterolemia on treatment	4	3.7
History of smoking	83	76.9
Associated illnesses		
Heart related	33	30.6
Lung disease requiring treatment	6	5.6
Elevated liver enzymes	7	6.5
Elevated creatinine level	40	37.0
Prior surgery		
Aortic/aortic branch	34	31.5
Nonvascular intraabdominal	21	19.4

The operative management of vascular disease affecting the proximal abdominal aorta and its major branches presents a dual challenge to the surgeon: adequate exposure and optimal reconstruction. The difficulty of exposing the paravisceral and pararenal aorta is well known and has actually lead to the development of indirect operative strategies designed specifically to avoid direct exposure of this segment of the aorta.[1,2] We initially used a thoracoretroperitoneal approach to allow unrestricted access to the distal thoracic and proximal abdominal aorta.[3] Although the resulting exposure is extensive, the additional perioperative morbidity of a two-body cavity approach was significant. Recently, we began using an entirely intraabdominal approach, with medial rotation of the viscera, to expose these aortic segments. This report summarizes the application of this technique to the first 104 patients and emphasizes patient selection, the operative technique, and perioperative outcome.

MATERIALS AND METHODS

Between July 1987 and November 1992, 555 aortic or aortic branch reconstructions were performed at the University of California, San Francisco. Of this group, 108 procedures (19.5%) that were performed in 104 patients used the transabdominal medial visceral rotation (MVR) approach for aortic exposure. During this time interval, prospectively collected data included the operative indication, operative technique, arteries repaired, level of urgency of the operation, intraoperative complications, level of aortic cross-clamp, and length of any associated renal or visceral ischemia. The rest of the data used in this analysis were obtained by review of the hospital record, the office records, and the records provided by the referring physicians. Only one record was not available for complete review.

The study group included 56 women and 48 men, mean age 63.4 ± 14.9 years. Most patients had hypertension and a history of smoking (Table I), whereas diabetes and treated hypercholesterolemia were rare. One third of patients had a documented cardiac history, with angina (n = 14) and arrhythmias (n = 14) the most frequent diagnoses. Valvular heart disease was present in nine patients (8.3%), a history of congestive heart failure was present in eight (7.4%), and previous myocardial infarction (MI) was documented in only six (5.6%). Lung disease severe enough to require treatment was uncommon. Before operation only seven patients (6.5%) had abnormal liver enzymes, whereas more than one third of patients already had evidence of impaired renal function as indicated by an elevated serum creatinine level (Table I). Almost half of the patients (n = 49, 45.4%) had previously undergone either aortic or aortic branch reconstruction (n = 34, 31.5%) or other major, nonvascular, intraabdominal surgery (n = 21, 19.4%).

Eighty-seven procedures were elective (80.6%), 15 were urgent (13.9%), and six were emergency procedures (5.6%). Thirty-seven patients (34.3%) underwent visceral revascularization, either alone (n = 13), or in combination with aortic (n = 2), renal (n = 7), or aortorenal (n = 15) reconstruction (Table II). Most patients undergoing visceral reconstruction had chronic symptoms (n = 17, 15.7%), whereas four (3.7%) were admitted with acute visceral ischemia (Table III). One patient with chronic symptoms had acute symptoms while in the hospital awaiting elective visceral revascularization. Another seven patients (6.5%) had entirely asymptomatic visceral artery occlusive lesions. In the final eight cases the visceral arteries were repaired during removal of an infected aortic graft (n = 1) or during correction of aortic aneurysmal disease (n = 7).

Seventy-one patients (65.7%) underwent renal revascularization, either alone (n = 18) or in combination with aortic (n = 31), visceral (n = 7), or aortovisceral (n = 15) revascularization (Table II). Most renal artery procedures were performed for hypertension (n = 21), 19.4%), elevated serum creatinine levels (n = 2, 1.9%), or both (n = 14, 13.0%). However, 12 patients (11.1%) had renal artery stenoses that were asymptomatic. One patient with visceral ischemia had such extensive calcific disease of the visceral and renal arteries and aorta that endarterectomy of the entire abdominal aorta and its branches was the only feasible method of revascular-

Table II. Operative details

	No.	*%*
Technique		
Bypass	39	36.1
Bypass + endarterectomy	23	21.3
Endarterectomy	18	16.7
Bypass + reimplantation	9	8.3
Bypass + endarterectomy + reimplantation	7	6.5
Dilation	1	0.9
Bypass + dilation	1	0.9
Bypass + excision/primary reanastomosis	1	0.9
Reimplantation + excision/primary reanastomosis	1	0.9
Transposition + reimplantation	1	0.9
Angioplasty + excision/primary reanastomosis	1	0.9
Bypass + angioplasty + transposition	1	0.9
Bypass + endarterectomy + transposition	1	0.9
Bypass + excision/primary reanastomosis + reimplantation	1	0.9
Other	3	2.8
Arteries repaired		
Aorta only	22	20.4
Renal only	18	16.7
Visceral only	13	12.0
Aorta + renal	31	28.7
Aorta + visceral	2	1.9
Renal + visceral	7	6.5
Aorta + renal + visceral	15	13.9
Aortic cross-clamp level		
Supraceliac	54	50.0
Supra-SMA	20	18.5
Suprarenal	14	13.0
Intrarenal	6	5.6
Partial occlusion	4	3.7
None*	10	9.3

*Aortic branch clamped only.

izing the mesenteric circulation. Five patients underwent renal arterial reconstruction for complex renal aneurysmal disease, usually caused by fibromuscular dysplasia. Fifteen patients had renal artery involvement by aortic aneurysmal disease, and one had renal artery involvement by an infected aortic graft. Thirty-seven patients (34.3%) required no renal artery reconstruction (Table III).

Seventy aortic reconstructions (64.8%) were performed for aortic aneurysmal disease (n = 42), occlusive disease (n = 19), combined aneurysmal and occlusive disease (n = 3), infected aortic grafts (n = 4), or to allow indicated renal or visceral artery repair (n = 2) (Table III), one example of which is described above. Among the aortic aneurysms, 24 were infrarenal, 11 were suprarenal, and 7 were thoracoabdominal (distal thoracic aorta). Eleven of the infrarenal aneurysms had associated renal or visceral artery occlusive disease. Twenty-eight aneurysms were asymptomatic, two were ruptured, and five had the acute onset of symptoms but were not ruptured. Seven patients had chronic symptoms of varying duration, including one patient with an inflammatory aneurysm, one with a primary aortoenteric fistula, and one with a mycotic aneurysm. Nineteen patients had aortic occlusive disease, either alone (n = 6) or in combination with visceral or renal occlusive disease (n = 13). Fifteen of these patients had lower extremity claudication, whereas four had rest pain. The three patients with combined occlusive and aneurysmal aortic disease had asymptomatic aneurysms and claudication. Thirty-eight patients had only renal or visceral revascularization that did not require aortic reconstruction.

The techniques used for aortic or aortic branch reconstruction are summarized in Table II. Bypass was the most common technique (n = 39, 36.1%), followed by bypass plus endarterectomy (n = 23, 21.3%) and by endarterectomy alone (n = 18, 16.7%). The other techniques – reimplantation, transposition, excision and primary reanastomosis, angioplasty, dilation – were usually used in combination with either bypass or endarterectomy. Aortic bypasses originated from all levels of the aorta: supraceliac, 6; supra–superior mesenteric artery (SMA), 2; suprarenal, 12; and infrarenal, 43. There

Table III. Indication for operation

For aortic procedures			70
Aneurysmal disease		42	
Ruptured	2		
Symptomatic	12		
Asymptomatic	28		
Occlusive disease		19	
Rest pain	4		
Claudication	15		
Aneurysmal + occlusive disease		3	
Asymptomatic + claudication	3		
Graft infection		4	
Incidental		2	
For renal artery procedures			71
Hypertension		21	
Elevated creatinine		2	
Hypertension + elevated creatinine		14	
Asymptomatic		12	
Renal artery aneurysms		5	
Involved by aortic aneurysm		15	
Involved by infected aortic graft		1	
Incidental		1	
For visceral artery procedures			37
Acute symptoms		4	
Chronic symptoms		17	
Chronic + acute symptoms		1	
Asymptomatic		7	
Involved by aortic aneurysm		7	
Involved by aortic graft infection		1	

were 25 aortic tube grafts, 18 aortoiliac grafts, and 20 aortofemoral grafts. Among the renal artery reconstructions, nine were performed in eight patients with the ex vivo technique.

OPERATIVE TECHNIQUE

Left medial visceral rotation

We currently prefer a standard, full-length midline transabdominal incision, although initially a modified left subcostal incision was used ($n = 7$). After exploratory laparotomy the small bowel is enclosed in an intestinal bag and displaced to the right. Mobilization of the descending and sigmoid colon is begun in the standard manner by incising the lateral peritoneal reflection. This peritoneal incision is carried cephalad through the phrenocolic and lienorenal ligaments. With gentle blunt and occasional sharp dissection, a plane is developed between the pancreas and Gerota's fascia. The descending colon, pancreas, spleen, and stomach are then rotated anteriorly and medially, leaving the gonadal vein, ureter, left kidney, and adrenal gland in situ. Maintaining the correct plane during this mobilization will avoid bleeding, pancreatic injury, and adrenal or renal injury (Fig. 1). The spleen and pancreas are protected with moistened pads, and a self-retaining retractor system is positioned to hold all of the anteriorly mobilized viscera to the right. The peritoneum is reflected from the left crus of the diaphragm and the triangular ligament and left lobe of the liver are freed. The esophagophrenic ligament is left intact to protect the anterior and posterior trunks of the vagus nerve. The aorta is now clearly in view, crossed by the left renal vein, the autonomic ganglia tissue, and the left crus of the diaphragm (Fig. 2).

Exposure of the upper abdominal aorta requires circumferential dissection of the left renal vein to its junction with the inferior vena cava so that it can be widely displaced as needed. Caudal retraction of the left renal vein facilitates the exposure of the origin of the renal arteries. The left renal artery can easily be freed from its origin to the renal hilum. Right lateral retraction of the inferior vena cava allows exposure of the proximal 2 to 3 cm of the right renal artery. The SMA and celiac axis are exposed by incising the dense autonomic ganglia on the left lateral surface of the aorta and the crus of the diaphragm. As this neural and muscular tissue are mobilized to the right in the plane of Leriche, the supraceliac aorta becomes visible. Resection of the median arcuate ligament and separation of the muscle fibers of the diaphragm expose the distal thoracic aorta within the lower mediastinum. Mobilization of the lower abdominal aorta proceeds by incising the loose areolar tissue along its left lateral surface. Reflection of this tissue to the right reveals the origin of the inferior

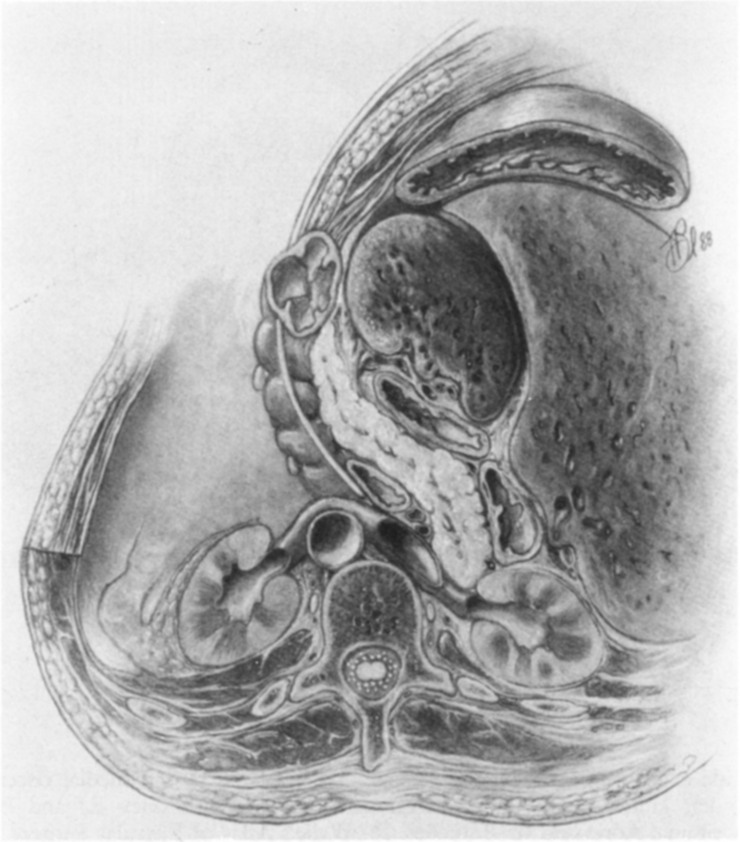

Fig. 1. Preferred retroperitoneal plane behind pancreas and in front of left kidney. Cross section is viewed from cephalad projection at level of pararenal aorta. Left renal vein is seen crossing aorta. Distortion resulting from retraction displaces stomach anterior to liver and compresses spleen against liver medially. (Reproduced with permission from Stoney RJ and Effeney DJ. Thoracoabdominal Aorta and Its Branches. In: Wylie's Atlas of Vascular Surgery, p. 52. J.B. Lippincott Company, Philadelphia, Pennsylvania, 1992)

mesenteric artery, with the course of the vessel now vertical as a result of the colon displacement. The aortic bifurcation and the iliac arteries are easily accessible for mobilization if necessary. This complete form of left medial visceral rotation was performed in 81 procedures (75.0%) in this series.

Modified left medial visceral rotation

The technique of left medial visceral rotation may be modified according to the required level of aortic exposure and the planned revascularization technique. If required to replace a large upper abdominal aortic aneurysm, the mobilization plane is developed posterior to the left kidney (Fig. 3). When the proximal extent of aortic exposure is below the SMA, the visceral rotation may be confined to the colon, leaving the pancreas, spleen and stomach in situ—a partial or limited left MVR (*n* = 9, 8.3%). In this case the incision in the lateral peritoneal reflection is extended only up to the splenic flexure, dividing the phrenocolic ligament but leaving the lienorenal ligament intact. Instead the lienocolic ligament is then incised, allowing the splenic flexure and descending colon segments to be rotated anteriorly and medially. The pararenal and infrarenal aorta can then be exposed as described above.

Right medial visceral rotation

Finally a partial or limited rotation of the viscera from the right can be performed (*n* = 12, 11.1%). An incision is made in the lateral peritoneal reflection along the ascending colon and is carried cephalad to the hepatocolic ligament, which is then transected. This enables the hepatic flexure and ascending colon segments to be rotated anteriorly and medially. The second portion of the duodenum is then in view and can be mobilized along with the head of the pancreas with a traditional Kocher maneuver. This exposes the

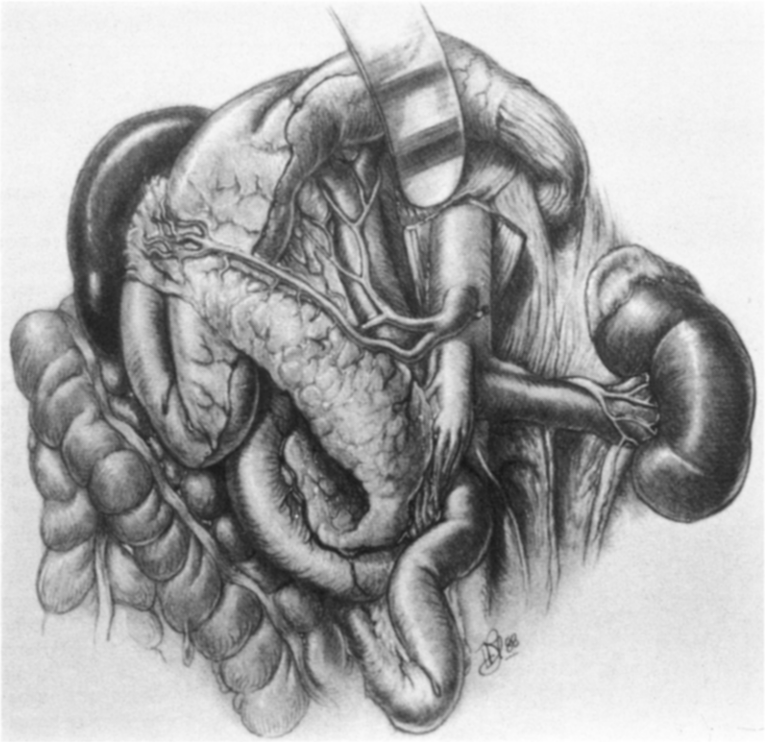

Fig. 2. Wide exposure of thoracoabdominal aorta provided by left medial visceral rotation anterior to left kidney. (Reproduced with permission from Stoney RJ and Effeney DJ. Thoracoabdominal Aorta and Its Branches. In: Wylie's Atlas of Vascular Surgery, p. 54. J.B. Lippincott Company, Philadelphia, Pennsylvania, 1992.)

inferior vena cava and the pararenal aorta (Fig. 4). Circumferential dissection of the inferior vena cava and the right and left renal veins allows for safe retraction of these vessels as necessary. Retraction of the inferior vena cava to the left and of the right renal vein caudally exposes the origin of the right renal artery, which can be mobilized from the aorta to the hilum of the kidney. However, this approach does limit exposure of the left renal artery to the proximal 2 to 3 cm. The distal aorta can then be exposed as previously described.

Although it is unusual to need simultaneous extensive bilateral exposure, it is nonetheless feasible to perform left and right MVRs at the same operation. This was required in six of our patients (5.5%), four of whom had left complete and right partial MVR, whereas the remaining two patients had left partial and right partial MVR.

The extensive exposure of the aorta provided by MVR is reflected in the varied levels of the aortic cross-clamp in this series (Table III). In half of the patients, this was the supraceliac aorta, and in three patients the distal thoracic aorta was the clamp site. Overall more than 80% of these procedures required aortic clamping at some level above the renal arteries. The resulting interval of visceral ischemia averaged 38.6 ± 18.0 minutes and renal ischemia averaged 38.6 ± 22.0 minutes. Methods of spinal cord protection, such as cerebrospinal fluid drainage, were not used in this series of operations. Cold perfusion of the kidneys was used selectively in cases where a prolonged period of renal ischemia was anticipated, particularly for the left kidney, and routinely during ex vivo reconstructions. The mean operative time for this extensive exposure and the subsequent complex repairs was 8.2 ± 2.8 hours. Coincident with this longer operative time was an average administered crystalloid volume of 7.6 ± 3.4 liters and a mean transfusion requirement of 1.7 ± 2.2 L. Most patients (n = 92, 85.2%) did receive intraoperative red cell transfusions, although autotransfusion of shed blood (Cell Saver Autotransfusion Device; Haemonetics Corp., Braintree, Mass.) was frequently used (n = 83), as was predonated autologous blood. Administration of other blood products was less common, with 33 (30.6%) patients receiving platelets, fresh-frozen plasma, or cryoprecipitate. Heparin was administered in only 56 cases (51.9%), reflecting

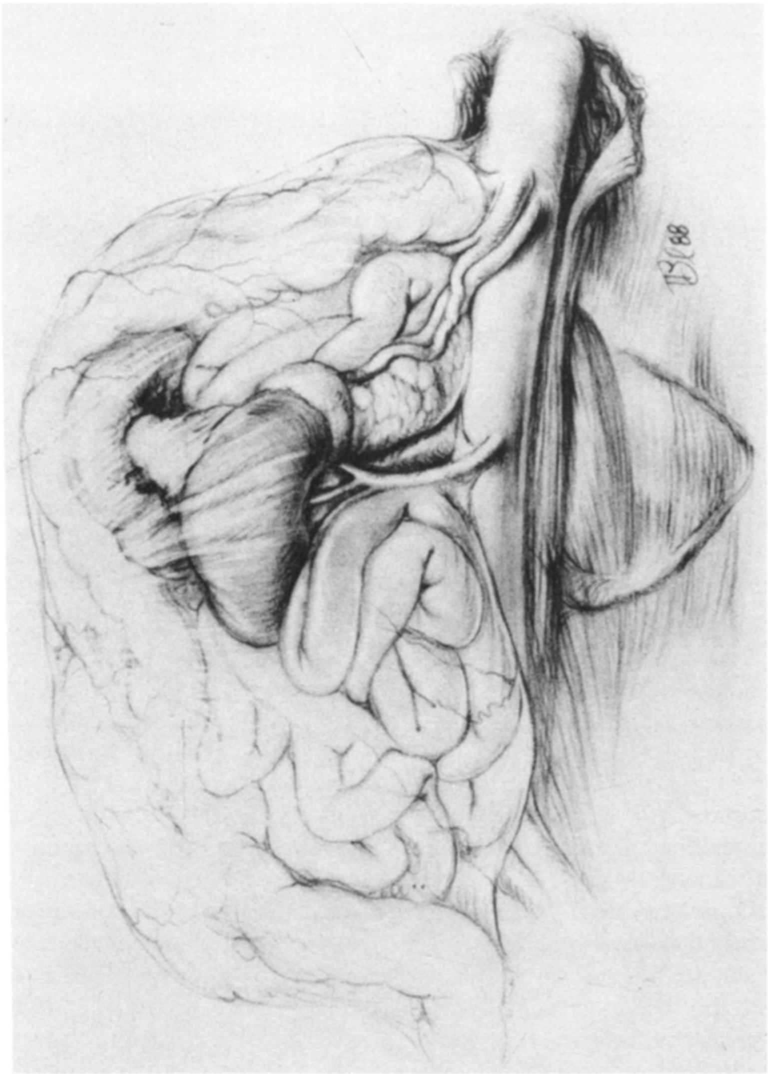

Fig. 3. Exposure that results when plane of dissection and mobilization is carried posterior to left kidney.

the current approach of the senior author, who uses no systemic anticoagulation during any aortic reconstruction. The mean postoperative weight gain was 9.0 ± 5.0 kg.

RESULTS

Intraoperative mortality. Four patients died during operation (3.7%): one during attempted repair of a ruptured aortic aneurysm; three during elective procedures, two of which involved visceral revascularization. All intraoperative deaths were caused by hemorrhage as a result of a diffuse coagulopathy affecting the entire area of dissection. In one case coagulopathy was caused by massive bleeding from a ruptured aneurysm. All patients were treated with coagulation factors (platelets, fresh frozen plasma, cryoprecipitate) and topical coagulants, but the bleeding could not be controlled.

Postoperative mortality rate. Postoperative mortality rate was 13.9% (*n* = 15) and was least among patients undergoing elective operations and greatest in the emergency setting (Table IV). Elective primary procedures involving only aortic, renal, or visceral reconstruction were associated with a perioperative mortality rate of 3.8%, whereas reoperative procedures had a mortality rate of 16.7%, and combined aortic and branch repairs had a similar mortality rate of 18.4%.

The leading cause of death after operation was visceral infarction with sepsis, occurring in seven

Fig. 4. Right-to-left medial visceral rotation to expose structures of right retroperitoneum, including kidney. (Reproduced with permission from Stoney RJ and Effeney DJ. Thoracoabdominal Aorta and Its Branches. In: Wylie's Atlas of Vascular Surgery, p. 4. J.B. Lippincott Company, Philadelphia, Pennsylvania, 1992.)

patients (Table V). Of interest, only two of these patients had undergone visceral revascularization. Both repairs were successful and remained patent. However, one patient did not recover from the extensive acute visceral ischemia that was present at the time of the emergency visceral revascularization. Diffuse colon and small bowel ischemia developed with no obvious explanation in the other patient. The other five patients had either diffuse ischemia of the colon or small bowel ($n = 3$) or patchy involvement of small bowel or small bowel/colon/gall bladder ($n = 2$). Four of these five patients underwent cross-clamping above the SMA ($n = 3$) or celiac artery ($n = 1$) and all underwent aortic and renal reconstruction. The one remaining patient in this subgroup had removal of an infected aortic graft, with infrarenal aortic control and right MVR. She had diffuse small bowel and colonic ischemia and also had a perioperative MI.

The second most common cause of postoperative

Table IV. Mortality

		Intraoperative		*Postoperative*		*Overall*	
	No.	*No.*	*%*	*No.*	*%*	*No.*	*%*
Elective	87	3	3.4	10	11.5	13	14.9
Urgent	15	0	0.0	3	20.0	3	20.0
Emergency	6	1	16.7	2	33.3	3	50.0
Total	108	4	3.7	15	13.9	19	17.6

MSOF, Multisystem organ failure.

Table V. Causes of death

Intraoperative bleeding			4
Bleeding		4	
Postoperative			15
Hemorrhage and its complications		4	
Liver rupture	1		
Massive intraoperative	3		
Visceral infarction/sepsis		7	
s/p visceral reconstruction	2		
No visceral reconstruction	5		
Sepsis		3	
Intraabdominal abscess/MSOF	2		
Unknown cause	1		
Miscellaneous		1	
MI/pancreatitis	1		

MSOF, Multisystem organ failure.

death was hemorrhage. In three cases massive hemorrhage caused by coagulopathy occurred during operation, and these patients succumbed to the subsequent complications of multisystem organ failure. The fourth patient bled from a spontaneous hepatic rupture one day after antegrade aortovisceral bypass to both the SMA and celiac artery. This patient succumbed despite multiple reexplorations and even ligation of the celiac graft limb. The cause of the liver bleeding was never established. Of all patients who died of bleeding and its sequelae (n = 8), either during or after operation, six had supraceliac clamping, whereas two never underwent aortic cross-clamping. The mean interval of visceral ischemia in these six patients was 40.1 minutes. Furthermore, five had not received systemic heparin during operation.

Sepsis was responsible for three postoperative deaths, one associated with a retroperitoneal abscess, and one with an intraabdominal abscess. Although in the remaining patient a source of sepsis was not clearly identified, autopsy did show pancreatitis. Pancreatitis and acute MI were the major etiologic factors in the final death (Table V).

Intraoperative morbidity rates. The most frequent intraoperative complication was splenic injury, which necessitated splenectomy in all but one instance (Table VI). It occurred in 19.0% of patients undergoing elective operations, compared with 60.0% of the patients undergoing emergency procedures. In 17 cases splenic injury was the only intraoperative complication. Other injuries that occurred during dissection occurred in the left adrenal gland, the left renal vein, the celiac axis, and the aorta—which occurred on the right side of the paravisceral aorta while placing the aortic clamp.

Postoperative morbidity rates. Although most patients (n = 74, 71.2%) were extubated within 24 hours of surgery, the most common postoperative complications still were lung related (Table VII). Although no patient died as a direct consequence of a pulmonary complication, eight initially extubated patients (10.8%) did require reintubation. All were successfully reextubated, except one patient (mentioned above) who died of visceral infarction after right MVR and in-line autogenous aortic reconstruction for an infected aortofemoral graft. Sixteen patients were treated for pneumonia, and two patients required drainage of pleural effusions that were not associated with a concurrent pulmonary or intraabdominal process.

Cardiac complications occurred in 25 patients (24%), but most of these were atrial arrhythmias (n = 13). Although these arrhythmias required treatment, they generally had little associated morbidity. Six patients had postoperative MI (5.6%).

Table VI. Intraoperative complications

Splenic injury			23
Splenectomy		22	
Splenorraphy		1	
Hemorrhage			8
Technical			7
Intimal flaps		2	
Celiac/SMA	1		
Renal	1		
Injuries		5	
Celiac axis	2		
Aorta	1		
Adrenal	1		
Renal vein	1		
Thrombosis/embolization			5
Aorta		1	
Renal		1	
Small bowel		1	
Femoral		2	
Miscellaneous			1
Gall bladder perforation		1	

Table VII. Postoperative complications

Cardiac			25
Arrhythmia requiring treatment		19	
Myocardial infarction		6	
Pulmonary			32
Pneumonia		16	
Respiratory failure		13	
Pleural effusion		2	
Pulmonary edema		1	
Renal			20
New onset dialysis		9	
Among survivors	3		
Among nonsurvivors	6		
Elevated creatinine at discharge (survivors only)		11	
Neurologic			4
Cerebrovascular accident		3	
Lower extremity paralysis		1	
Gastrointestinal			14
Bowel ischemia/infarction		8	
Pancreatitis		5	
Hemorrhage		1	
Infection (nonpulmonary)			17
Urinary tract		5	
Gastrointestinal		4	
Intravascular catheter		3	
Intraabdominal/retroperitoneal		2	
Wound		2	
Unknown source		1	
Limb ischemia			5
Requiring fasciotomy		3	
Wound			3
Dehiscence		2	
Hematoma requiring drainage		1	
Hemorrhage			2

One occurred after massive intraoperative hemorrhage in a patient who later died of multisystem organ failure. One MI was ultimately fatal, in spite of coronary artery grafting. This patient also had severe pancreatitis, which contributed to her death. One MI occurred after removal of an infected graft and in-line aortic reconstruction (mentioned above). This patient later had extensive visceral infarction of unclear cause, but which may have been related to the MI. The remaining 3 MIs were well tolerated.

Of the surviving patients (n = 89), 74 (83.1%) were discharged with creatinine levels equal to or less than their admission creatinine level. Only one of these patients required transient dialysis during the hospitalization. Thirteen patients had elevated creatinine levels at the time of discharge, and two of these patients had dialysis instituted after operation and continued to undergo dialysis at the time of discharge. Dialysis was anticipated in one of these patients, because his preoperative creatinine level measured 5.6 mg/dl. Among the 15 postoperative deaths, six patients required the institution of dialysis, three after massive bleeding, two after the postoperative development of intestinal ischemia/infarction, and one after an urgent operation for acute intestinal ischemia and peritonitis.

Complications involving the gastrointestinal tract resulted in a high rate of repeat operation (n = 9) and death (n = 8). Visceral ischemia involving the small or large bowel occurred in eight patients and was the cause of death in seven of these. These patients have already been discussed. Clinically evident pancreatitis occurred in five patients and required operative debridement in one patient, percutaneous drainage to control a pancreaticocutaneous fistula in another and pancreatic resection and internal drainage in a third patient, who later died. Additionally, peripancreatic inflammation was found at autopsy in a sixth patient. Among these six patients, five had combined aortorenal reconstruction and only one had aortorenovisceral reconstruction. There was one thoracic level cross-clamp, one supraceliac clamp, three supra-SMA clamps, and one suprarenal clamp. Of note, although serum amylase measurements were not routinely obtained after operation, in the 50 patients where amylase determinations were available, 29 were elevated. The final patient with a gastrointestinal complication had recurrent upper gastrointestinal hemorrhage after operation, which required two reexplorations, each requiring jejunal resection. The cause of the "ulcerations" found in the jejunum was never established.

Most of the nonpulmonary infections were minor. These included urinary tract infection (n = 5), *Clostridium difficile* enterocolitis (n = 4), central venous catheter infection (n = 3), and wound infection (n = 2). However, one wound infection did necessitate repeat operation for debridement of the abdominal wall. The two major infections were an intraabdominal abscess and a retroperitoneal abscess; both required operative drainage, and both were ultimately fatal (see above).

Five patients underwent reexploration for bleeding. In two of these cases this was a planned reexploration to remove packs left to control bleeding at the time of the initial operation. One patient died and one survived. In one patient coagulopathy developed after operation, which required reexploration. The bleeding was controlled with packs, which were removed 48 hours later, and the patient ultimately recovered. The two remaining patients (one with postoperative hepatic rupture and one with jejunal bleeding) have already been discussed.

Five patients manifested limb ischemia after operation. Two patients underwent femoral thromboembolectomy, and one required a fasciotomy. Two patients had negative femoral exploration results for thrombus or embolus. One of these two required placement of an axillofemoral graft followed by fasciotomy, whereas the other underwent fasciotomy. One patient required a fasciotomy only, presumably for a long period of ischemia during operation.

DISCUSSION

Exposure of the upper abdominal aorta and its branches with the traditional midline transperitoneal approach is limited by the overlying viscera, which substantially restrict visibility of this aortic segment. The hazards of proximal aortic or aortic branch reconstruction with marginal exposure led some surgeons to adopt indirect revascularization techniques to treat lesions in this region.[1,2] However, others recognized that these indirect methods limited the options for reconstruction and cumulative experience raised questions about the durability of the indirect techniques.[4,5] DeBakey, Creech, and Morris[6] were the first to report that unrestricted exposure of the distal thoracic and entire abdominal aorta could be achieved by a thoracoabdominal approach, with rotation of the viscera from left to right in a plane anterior to the left kidney. A few years later Shirkey et al.[7] described the technique of transabdominal medial visceral rotation in a plane anterior to the left kidney to provide exposure of an injury to the proximal SMA. Two years later Buscaglia, Blaisdell, and Lim[8] reported their experience in treating 33 patients with penetrating abdominal vascular injuries involving the aorta, its major visceral branches, and the vena cava. They advocated the use of left-to-right medial rotation of the viscera to approach the aorta and its branches and the use of right-to-left medial rotation of the viscera to approach the inferior vena cava. They also described modifications to augment the exposure: rotation of the left kidney anteriorly and medially to access the posterolateral aorta and the extension of the incision into the thorax to expose the distal thoracic aorta. It is not entirely clear from the study how many of their patients were approached transabdominally and how many had a thoracoabdominal approach. Subsequently this exposure became very popular for the treatment of traumatic injuries to this proximal aortic segment, varying only in whether the plane was developed anterior or posterior to the kidney.[9-12] During this time the only published description of this approach in the elective setting came from Crawford,[13] who used it to expose complex aneurysms involving the proximal abdominal aorta.

Our search for the optimal method of exposure for this segment of the aorta began with the thoracoretroperitoneal technique,[3] which was actually a combination of DeBakey's thoracoabdominal approach and the retroperitoneal approach first used in the repair of abdominal aortic aneurysms.[14] This method provides unrestricted access to the full length of the aorta, but at the cost of a two-body cavity incision. An analysis of our own patients undergoing visceral reconstruction for chronic mesenteric ischemia demonstrated a substantially greater morbidity rate (especially pulmonary) in the thoracoretroperitoneal group, when compared with the transabdominal group.[15] This prompted us to determine whether we could obtain adequate aortic exposure without the thoracic portion of the incision. At this time interest in the retroperitoneal approach to the aorta was revitalized,[16-18] with several retrospective studies suggesting that it was less morbid than the standard transabdominal approach.[19-24] Therefore we first designed this technique to be a subchondral modification of the retroperitoneal approach, directed towards the more proximal abdominal aorta. After a brief experience with this approach, and with the failure of prospective studies[25] to clearly establish the superiority of retroperitoneal aortic exposure over transperitoneal exposure, we returned to a traditional transabdominal incision, with medial rotation of the viscera. A detailed outcome analysis of the patients who underwent this approach allows us to identify its advantages and disadvantages.

The advantages associated with the use of medial visceral rotation are the resulting unlimited exposure and the lack of any constraint on the choice of arterial reconstruction technique. As indicated by the frequency of supraceliac and thoracic aortic cross-clamping in this series of operations and the diversity in the type of reconstruction techniques used, this exposure provides the surgeon with the maximum operative options to manage complex arterial lesions of the upper abdominal aorta and its branches, regardless of extent. This approach is particularly appealing when the patient has previously undergone aortic surgery or other major intraabdominal procedures, as was the case in 31.5% and 19.4% of our patients, respectively. It is not the technique of choice for transient proximal aortic control to allow infrarenal aortic reconstruction. This approach avoids the thoracic incision, which we previously used in the thoracoretroperitoneal exposure, while providing essentially the same extent of aortic mobilization. Only true thoracoabdominal aneurysms, which involve a substantial segment of the descending thoracic aorta, still require the two-body cavity exposure. Unlimited aortic exposure also expedites the revascularization, which is reflected in our mean visceral ischemia times of only 38 minutes.

In analyzing the outcome of this series of operations, we have attempted to identify those deaths and complications that are related to the medial visceral rotation exposure versus those that are related to the arterial reconstructions that were performed. Without a comparable group of patients who underwent the same mixture of operations with a different method of aortic exposure, this is difficult and speculative. Nonetheless, our discussion will focus on those complications that we believe are consequences of the dissection and those that are consequences of the required retraction.

The complications that may be related to the dissection include injuries to structures in the field and possibly the development of coagulopathy. Among the recorded injuries, those that seem to be clearly related to the MVR technique are splenic injury, left adrenal injury, and clamp injury to the right lateral aortic wall. The splenic injuries almost always occurred during the early phase of mobilization of the spleen itself or during mobilization of the splenic flexure of the colon. The injury leading to splenectomy was frequently a tear of the lower pole splenic capsule, a tear of the splenic hilum, or a degloving of the capsule on the posterior surface of the spleen. This suggests that greater care in placing traction on the splenic flexure and in pulling the spleen up out of the splenic fossa during incision of the posterior peritoneum could reduce the number of these injuries. Although we have not yet encountered any sequelae of splenectomy in these patients, the frequency of splenectomy (21.2%) is clearly higher than that encountered in other approaches to the aorta. Left adrenal injury will occur if one does not stay in the same plane anterior to the kidney from the level of the left renal vein all the way up to the aortic hiatus in the crus of the diaphragm. We learned this point while accumulating experience with the thoracoretroperitoneal approach, which has the same potential for left adrenal injury. Consequently the incidence of such injuries in this MVR group is low. Finally, the injury to the aortic wall occurred during an attempt to place a clamp around an inadequately mobilized paravisceral aorta. The MVR approach allows only restricted exposure of the right side of the aorta and therefore care must always be taken to be sure that the crus and median arcuate ligament tissue are completely divided and retracted to allow sufficient mobilization of the right side of the aorta to safely place a clamp. Failure to adequately mobilize the paramesenteric aorta increases the risk that the aorta will be injured during placement of the occluding clamp.

In seven of the eight patients who died as a result of hemorrhage, a coagulopathy developed during operation in the setting of an emergency operation (n = 1), reoperative aortic surgery (n = 2) or complex visceral revascularization (n = 4). The liver ruptured in the eighth patient after a visceral revascularization. We believe this spontaneous rupture resulted from massive reperfusion edema of the liver. This has previously been reported involving the spleen, but not the liver.[15] Although all of the patients were aggressively treated with blood and component replacement and topical coagulants, the coagulopathy either could not be reversed at all or resulted in such extensive blood loss before it was controlled that the patient ultimately succumbed to its consequences. The cause of the coagulopathy in these cases has never been defined, and therefore it is difficult to determine exactly what the contribution of the method of exposure is, as opposed to the contribution of the procedure itself. Proposed mechanisms include prolonged hepatic/visceral ischemia, hypothermia, and hemodilution, none of which are specific to any one method of exposure. Six of the eight patients required supraceliac aortic clamping, but the period of visceral ischemia was not prolonged (40.1 mins). To minimize the risk of development of coagulopathy, we prefer to maintain some visceral perfusion by placing the aortic clamp at the lowest level that allows safe performance of the indicated repair. Thus we do not routinely place a supraceliac clamp, even though it is often technically easier, if a lower level clamp is adequate. We also try to maintain core temperature throughout the operation and have minimized or eliminated the use of heparin. In fact, only three of the patients in whom coagulopathy developed received heparin during operation. Of course, transient visceral/hepatic ischemia, hypothermia, and heparin-related bleeding are by no means specific to the MVR approach but are really a consequence of the indicated arterial reconstruction. Without a control group of patients we cannot assess the independent contribution of the method of exposure to the frequency of coagulopathy. Thus the only case where it seems clear that MVR contributed significantly to the hemorrhage that led to the patient's death was the case of injury to the right paravisceral aorta, which has already been discussed above.

Complications that might be related to retraction of the viscera include pancreatitis and visceral ischemia/infarction. During mobilization of the viscera, progressively more medial retraction is placed on the pancreas until finally, when the viscera are fully mobilized to the midline, retractors are placed on the pancreas at about the level of the neck. During this mobilization increasing traction is exerted on the visceral vessels, until the proximal vessels have been exposed over an adequate length to allow reconstruction. This retraction and traction has the potential for injury to the pancreas and the visceral vessels or may create a low-flow state in the viscera by compressing or occluding the SMA and to a lesser extent the celiac axis. Only two of the five episodes of pancreatitis occurred in patients who had undergone splenectomy, so pancreatic injury during splenectomy cannot explain all of these episodes. Although most of the patients who had pancreatitis had a supravisceral aortic cross-clamp (supra-SMA, supraceliac or thoracic), there was in fact no correlation between aortic clamp level and pancreatitis. Therefore we believe retraction injury was the mechanism responsible for at least some of the cases of pancreatitis which occurred. Pancreatitis proved to be a substantially morbid complication, with two of the affected patients requiring reoperation and one requiring percutaneous drain placement. Pancreatitis also clearly contributed to one, and possibly two postoperative deaths. In the second case, death was officially attributed to sepsis. However at autopsy, no clear focus of sepsis was found, but there was peripancreatic inflammation. In addition we discovered a high rate of postoperative hyperamylasemia in patients who had the MVR exposure. However, we are unsure of the significance of this finding because there are no data on the frequency of hyperamylasemia after aortic surgery with other exposures.

Of the two cases of visceral infarction after visceral revascularization, one represented an inability to reverse acute visceral ischemia. The other patient had diffuse colon and small bowel ischemia of unknown cause, which may have represented the consequences

Table VIII. Outcome according to type of exposure

*Exposure**	*N*	*Deaths*	*Pulmonary complications*	*Cardiac complications*	*Bleeding complications*	*Pancreatitis*
Complete left	81	15	27	22	11	3
Partial left	9	2	1	0	2	0
Partial right	12	1	2	1	0	1
Bilateral	6	1	2	2	1	1

*No significant differences between groups.

of a low-flow state. The five patients who had visceral ischemia without visceral repair showed both patterns of diffuse visceral involvement and patchy involvement. The former is consistent with a low-flow state or visceral thrombosis, whereas the latter is consistent with embolization. One of these patients also had a perioperative MI, which may have caused or contributed to the low-flow state and subsequent mesenteric infarction. The pattern of visceral infarction seen in these patients is not consistent with injury to the sigmoid or left mesocolon, which can occur if the plane anterior to the kidney is not properly developed. It is possible that manipulation of the paravisceral aorta or retraction on the visceral vessels resulted in embolization of atheroma or thrombus that was not initially apparent during operation. However, because four of these five patients required supravisceral clamping (even though no visceral reconstruction was performed), it is also possible that the intestinal ischemia resulted from embolization of thrombus that formed proximal to the aortic clamp or from low flow during the period of interrupted visceral perfusion. Either of these two mechanisms might also have occurred with a traditional midline exposure of the aorta; but the possibility remains that the retraction needed in the MVR approach may have resulted in as many as five deaths caused by intestinal ischemia/infarction.

Both of these two complications, pancreatitis and visceral infarction, emphasize the necessity for appropriate handling of the viscera during mobilization and retraction. Mobilization should be complete to allow the viscera to be uniformly retracted without being scissored against remaining fixed points. Furthermore, retractors should be well padded, and if mechanical retraction is used the retractors should be released intermittently. Finally the appearance of the retracted viscera should be assessed at regular intervals to be sure that adequate perfusion is maintained during all phases of the exposure.

This series of patients includes several different forms of medial visceral rotation, which are clearly not equivalent to one another. The complete left MVR is a much more extensive exposure and is generally used when more extensive arterial reconstruction is required. Not surprisingly, most of the deaths and serious morbidity occurred in this group of patients (Table VIII). Although the outcome did not vary significantly between the four types of exposure used (whether compared as four separate groups or compared as complete left MVR versus all others combined), the small size of the right, partial left, and bilateral MVR groups makes us reluctant to conclude that these different forms of exposure all pose the same risk to the patient.

In reporting this series of patients who underwent aortic exposure with medial visceral rotation, we were attempting to determine whether this exposure per se places the patient at any increased risk of complications in general or introduces any specific complications that are not encountered with other exposures. Admittedly it is difficult to assess the impact of the exposure alone, independent of the risk of the type of reconstruction and the arteries repaired. However, from this series we conclude that the frequency of splenic injury leading to splenectomy is higher with this approach. Furthermore, the frequency of pancreatitis and intestinal infarction without visceral revascularization may be greater than with a standard transabdominal approach. It is also unclear whether the incidence of significant bleeding is higher with this approach. A definitive delineation of the MVR-specific morbidity and mortality rates awaits a comparison of equivalent groups of patients undergoing similar arterial reconstructions with a standard midline abdominal approach compared with medial visceral rotation.

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DISCUSSION

Dr. F. William Blaisdell (Sacramento, Calif.). The key to vascular surgery is adequate exposure, and this approach provides unlimited exposure to the entire abdominal aorta. As Dr. Ramos indicated, we have used this procedure in trauma initially because we could get at any part of the abdominal aorta. When one is treating a retroperitoneal hematoma whose source is not apparent, it is obvious that one wants to be able to control any aspect of the aorta; hence, its adoption initially for management of trauma. Subsequent to that, we have used it in cases such as visceral artery revascularization as described in this study.

In my opinion the approach from the right side is much simpler and much safer in that there is less anatomy to get out of the way. And when one is looking at the suprarenal portion of the aorta, it does not require exposure of the SMA or the celiac axis. The right-sided approach is the favorite approach.

Another issue in approaching from the left side, particularly under emergency circumstances, is whether to mobilize the kidney. There's a fascial envelope that surrounds the aorta that is removed from the field by mobilization of the kidney. Therefore under emergency circumstances, if you're in a hurry to get control of the aorta and get in the right plane of the aorta, it is appropriate to mobilize the kidney. Otherwise, extensive dissection is required to open that fascial envelope anterior to the kidney before one reaches and can obtain control of the aorta. Certainly under elective circumstances one has the option of going above or below the kidney.

Bleeding is a complication of this procedure. There's an extensive dissection plane, and coagulopathy developed in many of these patients after complex operations. And certainly in our experience, that is the most common serious complication that requires reintervention to drain or control the bleeding.

Another issue is that after prolonged operation, sometimes it's difficult to reduce all the viscera safely in the abdomen. And one can compromise respiratory function by trying to pack swollen abdominal contents back into the abdominal cavity. And when you use extensive retraction, as was shown here, very frequently large amounts of fluid are administered and are required during a 6- or 8-hour operation. Under these circumstances we leave the abdominal cavity open or close it temporarily with reintervention when that edema subsides.

Have you attempted to deal with that problem in that manner?

I am curious about the incidence of pancreatitis. When I saw the dissection that really mobilized the pancreas extensively, one can explain the high incidence of pancreatitis on that and perhaps the use of mechanical retractors, which certainly can produce ischemia of some of those organs when one is trying to work extremely high in the abdominal cavity.

Are there any complications relative to extensive exposure of the thoracic aorta? Sometimes you have very little left to approximate that diaphragm to retroperitoneal tissue. Often we favor two-cavity intervention under emergency circumstances rather than dissection of the diaphragm extensively. We make a limited opening in the chest and control the aorta there and then do the dissection below without extensively mobilizing the diaphragm.

Dr. Tammy K. Ramos. We agree that it is much easier and quicker to approach the upper abdominal aorta by rotating the left kidney anteriorly and medially along with the other viscera. We occasionally use this method to approach large aneurysms involving the upper abdominal aorta as was originally described by Dr. Crawford.[12] However, for most of the reconstructions in this study, and specifically when the upper abdominal aorta and its branches are involved by occlusive disease, it is necessary to approach the aorta anterior to the left kidney by entering the dense fascial plane that surrounds the aorta and runs anterior to the kidney.

As suggested by our mean operative time of more than 8 hours, the intestines were displaced and retained for extended periods of time during these procedures. However, we did not experience any difficulties returning the viscera to the abdominal cavity, and therefore we did not have to modify our routine midline, single-layer, fascial closure. In fact, in this series there were two patients who required packing (with planned reexploration) to control bleeding caused by coagulopathy. This was accomplished without changing our wound closure.

Pancreatitis seems to be an exposure-related complication. The complete left medial visceral rotation requires extensive mobilization, displacement, and retraction of the pancreas. We have noted a high rate of hyperamylasemia after operation in these patients. However, we are unsure of the significance of this finding because there are no data on the frequency of hyperamylasemia after aortic reconstruction with other approaches. Fortunately, only a small number of these patients had clinically significant pancreatitis.

Finally, the complete left MVR provides excellent exposure of the distal 8 to 10 cm of the thoracic aorta. When more proximal exposure of the descending thoracic aorta is required, we use a thoracoretroperitoneal or thoracoabdominal approach.

Dr. William J. Quiñones-Baldrich (Los Angeles, Calif.). In our experience, splenic injury is frequent. We see this with about the same frequency that you've reported. Coagulopathy is seen in some of these patients after such an extensive procedure, probably related to liver and visceral ischemia. It is our policy that if we see a small subcapsular hematoma in the spleen, we would proceed with the splenectomy, rather than try to repair the spleen or observe the process. This is based on two cases that I have seen personally, where subcapsular hematomas have resulted in bleeding during the postoperative period.

What is your recommendation regarding the management of a small splenic injury after visceral rotation?

Dr. Ramos. There were 23 intraoperative splenic injuries in this series, of which 22 were treated with splenectomy and one was treated with splenorrhaphy. If we have any concerns about our ability to repair an injured spleen, then we remove it rather than risk ongoing intraoperative and postoperative hemorrhage. In our experience, splenectomy has been well tolerated in this population of older adult patients.

Dr. Albert E. Yellin (Los Angeles, Calif.). MVR has been used probably for about 15 years in trauma surgery for the high aortic injuries. The residents are familiar with it. It gives excellent exposure, and we thank Dr. Blaisdell for introducing it.