Chronic Visceral Ischemia

Three Decades of Progress

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Symptomatic visceral atherosclerosis is a major surgical challenge because of its life-threatening course and the complexity of its definitive operative treatment. Evolution in the operative approach to the visceral aorta and progress in the intraoperative management of patients undergoing complex vascular reconstructions prompted a review of the authors' cumulative experience in the surgical management of chronic visceral ischemia. Among all patients undergoing visceral revascularization at the University of California, San Francisco during the past three decades, 74 patients were identified whose primary reconstruction used transaortic endarterectomy (TA TEA) (n = 48) or antegrade bypass (AB) (n = 26), the authors' preferred revascularization techniques. The two treatment groups were comparable in gender distribution, age, presenting symptoms, and physical findings, although the amount of preoperative weight loss was greater in the AB group (35.8 ± 19.5 *versus* 22.4 ± 12.0, p = 0.003). The groups were also comparable in the prevalence of atherosclerosis risk factors, symptomatic vascular disease at other sites, and previous vascular operations. However associated renal artery atherosclerosis was slightly greater in the TA TEA group (58.3% *versus* 23.1%, p = 0.07) when compared to the AB group. Antegrade bypass was usually performed transabdominally (88.5%), while TA TEA was approached thoracoretroperitoneally (75.0%). Celiac revascularization was almost universal in both treatment groups, but the TA TEA group underwent significantly more frequent superior mesenteric artery (SMA) revascularization (93.8% *versus* 46.2%, p = 0.0001) and slightly more frequent inferior mesenteric repair (18.8% *versus* 3.8%, p = 0.07) than the AB group. In addition the frequency of combined renal and visceral repair (25.0% *versus* 0.0%, p = 0.01) as well as combined aortic, renal, and visceral repair (22.9% *versus* 3.8%, p = 0.03) was significantly greater in the TA TEA group. The obligatory interval of renal and visceral ischemia did not differ between the two approaches. The perioperative mortality rate was 12.2% and was the same for TA TEA (14.6%) and AB (7.7%). Overall the incidence of complications was the same with either operative approach, although patients in the TA TEA group tended to have multiple complications (17.1% *versus* 0.0, p = 0.03) and all significant pulmonary complications occurred in this group. Two patients were lost to follow-up. The cumulative percentage of patients who remained asymptomatic following AB or TA TEA was (respectively) 95.8% and 97.3% at 1 year and 86.5% and 86.1% at 5 years. Both of these operative approaches provide durable symptom relief with acceptable operative morbidity and mortality rates. These results are attributed to intraoperative transesophageal echocardiography, to intraoperative assessment of the visceral reconstruction with Duplex ultrasonography, and to the increasing use of the transabdominal approach, with medial visceral rotation, to provide aortic exposure for both AB and TA TEA techniques.

ATHEROSCLEROSIS IS the most common cause of obstruction of the orifices of the celiac and mesenteric (visceral) branches of the aorta.[1-4] The resulting reduction in splanchnic blood flow produces clinical symptomatology, which typically begins as postprandial ischemic pain, called 'intestinal angina' by Mikklesen.[5] Chronic, symptomatic visceral ischemia is a progressive, nutritionally disabling precursor to fatal intestinal infarction, although the exact proportion of patients who will eventually develop this is unknown.[1,6-8] Surgeons pioneered the understanding of chronic visceral ischemia and introduced the first operations for revascularization of the visceral aortic branches more than three decades ago.[2,3,8-14]

Evolution in the operative approaches to the visceral segment of the abdominal aorta and progress in the intraoperative assessment and management of patients undergoing complex vascular reconstructions prompted us to review our 30-year cumulative experience in the surgical management of symptomatic chronic visceral ischemia.

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This study investigates the safety and efficacy of visceral revascularization by transaortic endarterectomy or antegrade bypass, the two preferred techniques in our institution. We evaluated those adjunctive measures that might lessen the incidence of operative morbidity and improve the technical quality of the reconstructions, thereby contributing to long-term survival and durable relief of symptoms.

Methods

The records of all patients who underwent visceral revascularization at the University of California, San Francisco during the past the three decades were identified. The patients chosen for this study consisted of those who had chronic symptoms of intestinal ischemia and who underwent their primary visceral reconstruction at our institution. Specifically excluded from the study were those patients with acute visceral ischemia, those who had their initial visceral reconstruction at other institutions, those with median arcuate ligament syndrome, and those patients whose surgeon had performed less than ten visceral revascularizations at UCSF. The resulting study group of 85 patients (16 men and 69 women; mean age, 60.7 ± 10.5 years) consisted of 48 patients who underwent transaortic visceral endarterectomy (TEA), 26 patients who underwent antegrade visceral bypass, and 11 patients whose vascular reconstruction was performed using a variety of other techniques. The focus of the study was a comparison of the antegrade bypass and the transaortic endarterectomy treatment groups. Data were accumulated by review of inpatient, outpatient, and referring physician records. Follow-up data were accumulated by interview of the patients, their families, and the referring or primary care physician. Data were analyzed using the unpaired Student's *t* test, chi square contingency analysis and Fisher's exact test (one tailed), where appropriate. Follow-up data were analyzed in life table format, with the two specific endpoints being recurrence of intestinal ischemia symptoms (long-term relief of symptoms) and death from any cause (long-term survival). Life table curves were terminated when the standard error exceeded 10%.

Visceral Revascularization Techniques

Transaortic Endarterectomy

Initially transaortic endarterectomy of the visceral vessels was performed through a thoracoretroperitoneal approach (n = 36). Recently, however, we have obtained the same extensive aortic exposure through a transabdominal approach with medial rotation of the viscera (MVR) from the left (n = 7). In this technique, the left kidney remains in its anatomic position, while the plane behind the left colon, spleen, pancreas, and stomach is developed to allow displacement of these structures toward the midline (Fig. 1). The entire aorta, from the distal thoracic level inferiorly, can be completely exposed in this manner (Fig. 2). During complete aortic occlusion and with control of any intervening intercostal branches, a 'trap door' aortotomy is placed to circumscribe the orifices of the celiac and superior mesenteric arteries (SMA) (Fig. 3A) and an endarterectomy is performed, removing the aortic wall lesion and its extensions into the visceral orifices (Fig. 3B). In many cases in this series (n = 23, 47.9%), the significant aortic atheroma was confined to the ventral surface of the aorta immediately around the celiac and SMA orifices and the aortic endarterectomy was limited to the trap door segment itself. However more diffuse aortic disease, frequently in the setting of associated renal artery occlusive lesions, required extension of the aortotomy caudally to allow sleeve aortic endarterectomy and bilateral (n = 17) or unilateral (n = 6) renal artery TEA (Fig. 4). Following completion of the endarterectomy, the

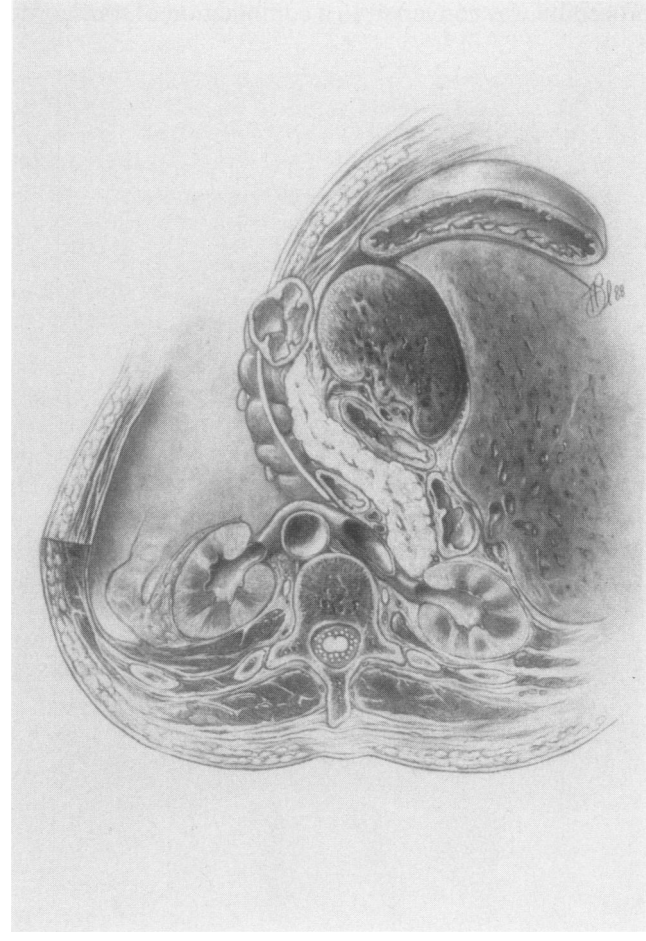


FIG. 1. Illustration of medial visceral rotation (MVR) approach to the aorta. Note that the kidney remains in its anatomic location, while the other abdominal viscera are displaced medially after mobilization from the left.

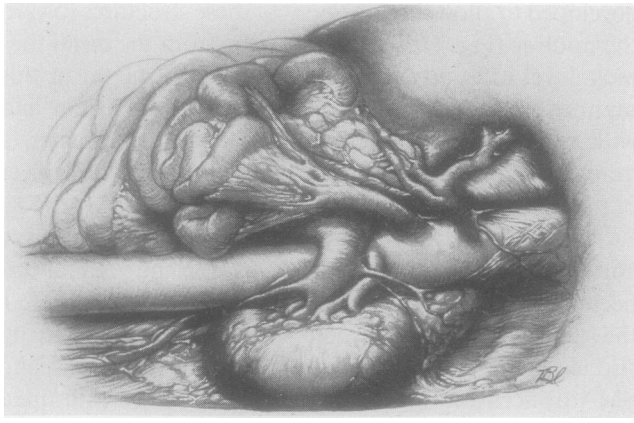
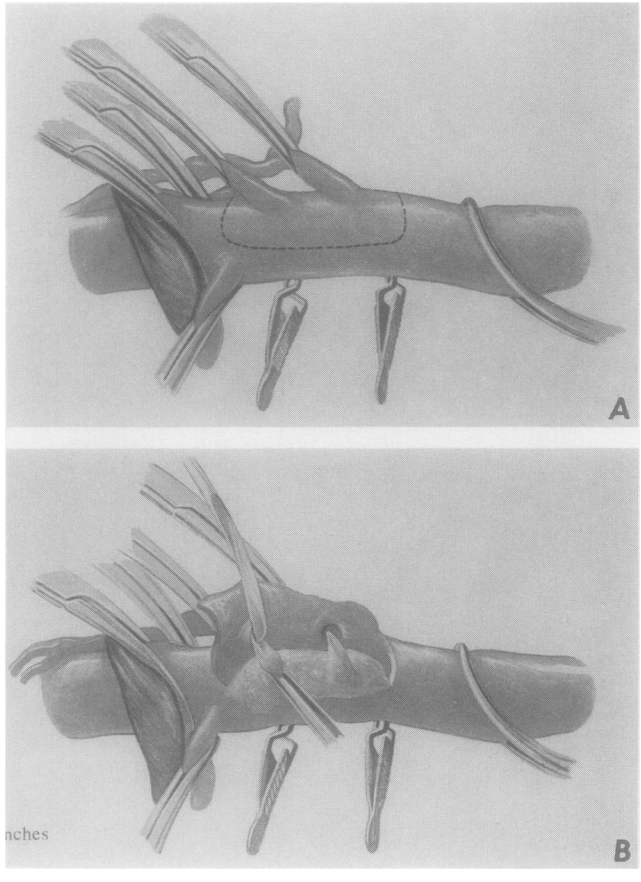


FIG. 2. The extent of the aorta that can be exposed easily after medial visceral rotation is shown. Note that the exposure is essentially the same as that provided by the thoracoretroperitoneal approach.

aortotomy is closed with a running suture (Fig. 5). In seven cases the planned orificial transaortic TEA could not be successfully completed due to transmural calcification or distal extension of the disease. In these cases the procedure was converted to a combination of transaortic TEA and other techniques, including antegrade bypass, interposition graft, transarterial TEA, and vein patch angioplasty.



FIGS. 3A and B. (A) Diagrammatic representation of trapdoor aortotomy circumscribing the visceral orifices. Note total proximal and distal aortic occlusion and control of individual intercostal arteries. (B) Trapdoor aortotomy has been opened and hinged on the right aortic wall. The endarterectomy is proceeding with removal of the SMA lesion.

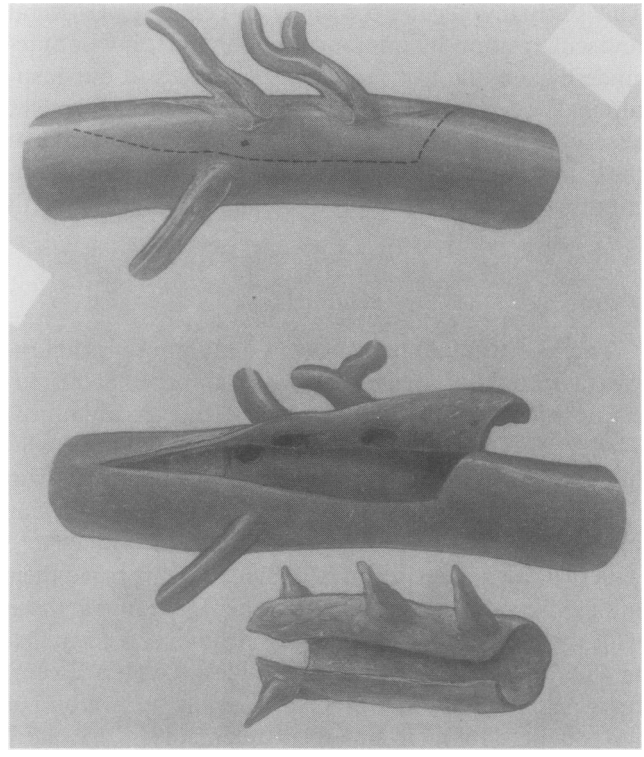


FIG. 4. Diagrammatic representation of the location of the modified trapdoor aortotomy used when associated renal artery disease requires combined visceral and renal endarterectomy.

Antegrade Visceral Bypass

Bypass grafts originating from the supraceliac, subdiaphragmatic aorta were initially performed using a transabdominal, transcrural approach to the aorta (n = 23), but medial visceral rotation has also been used in this patient group (n = 2). The proximal anastomosis, placed in the disease-free supraceliac aorta, requires temporary total aortic occlusion, However circumferential aortic mobilization is not routinely performed unless there is an intervening pair of intercostal arteries that need to be controlled. A small ellipse of aorta, oriented obliquely, is excised to facilitate the end-to-side anastomosis (Fig. 6). The celiac and SMA are exposed above and behind the pancreas, which requires careful and complete dissection from the celiac ganglion tissue and the median arcuate ligament. The distal anastomoses are constructed in an end-to-end manner to the individual visceral arteries, beyond the point of atherosclerotic involvement. The conduit is almost always prosthetic (n = 24, 92.3%).

Intraoperative Monitoring

Monitoring of cardiac function and assessment of the technical adequacy of the visceral repair have advanced

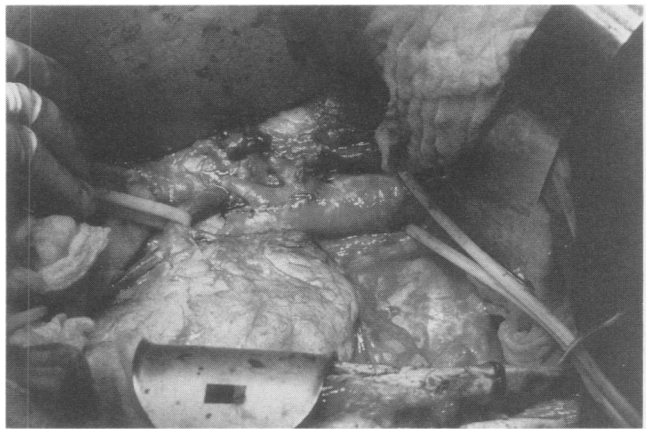


FIG. 5. Operative photograph showing the aorta and visceral vessels after completion of the endarterectomy and closure of the aortotomy.

with application of ultrasonographic imaging techniques. Two-dimensional transesophageal echocardiography allows real-time determination of cardiac filling status as well as detection of wall motion abnormalities[15] (Fig. 7). Duplex scanning of the vascular reconstruction provides immediate assessment of the appearance and flow characteristics in the bypassed or endarterectomized arteries.[16] These techniques have been used in 16 patients (21.6%) in this study group. In two cases (15.4%) significant technical defects were identified by Duplex scan that warranted reopening of the artery and allowed correction of the problem (Figs. 8 and 9).

Results

There was no difference between the antegrade bypass group and the transaortic TEA group in gender distribution, age at operation, presenting symptoms, or physical findings (Table 1). The majority of patients were women (61 of 74, or 82.4%) with classic postprandial pain (62 of 74, or 83.8%). Physical findings were generally nonspecific and most notable for significant weight loss, which averaged 25.7 ± 16.5 lbs for both groups, but was significantly greater in the antegrade bypass group (Table 1). The pattern of visceral vessel involvement did not differ between the two groups, with all but one patient having multivessel occlusive disease (Table 1). However the frequency of renal artery involvement by atherosclerosis was somewhat greater in the transaortic TEA group in comparison to the bypass group ($p = 0.07$, Fisher's exact test, one tailed).

The two treatment groups were also identical in the prevalence of risk factors for atherosclerosis, the prevalence of associated illnesses, and the frequency of previous abdominal and peripheral vascular surgery (Table 2). Although most patients smoked tobacco (55 of 74, or 74.3%), very few had diagnosed pulmonary disease (6 of 74, or 8.1%). Diabetes was equally uncommon. Symptomatic vascular disease affecting other vascular beds was common (44 of 74, or 59.5%), as was previous vascular surgery (29 of 74, or 39.2%). Notably four patients had already required segmental intestinal resection for ischemia or infarction some time before visceral reconstruction.

The transabdominal approach was used significantly more often for antegrade bypass, while the thoracoretroperitoneal approach predominated in the transaortic TEA group ($p = 0.0001$, chi square test) (Table 3). Recently both antegrade bypass and transaortic TEA have been performed using the transabdominal approach with medial rotation of the viscera from the left. To date MVR has been used equally often in both groups, although the numbers are still small. In both operative groups, celiac revascularization was almost universal, while the SMA was revascularized significantly less often among patients undergoing antegrade bypass than among those treated by transaortic TEA ($p = 0.0001$, chi square test) (Table 3). Inferior mesenteric artery reconstruction was also more frequent among transaortic TEA patients, but this did not quite achieve statistical significance ($p = 0.07$, Fisher's

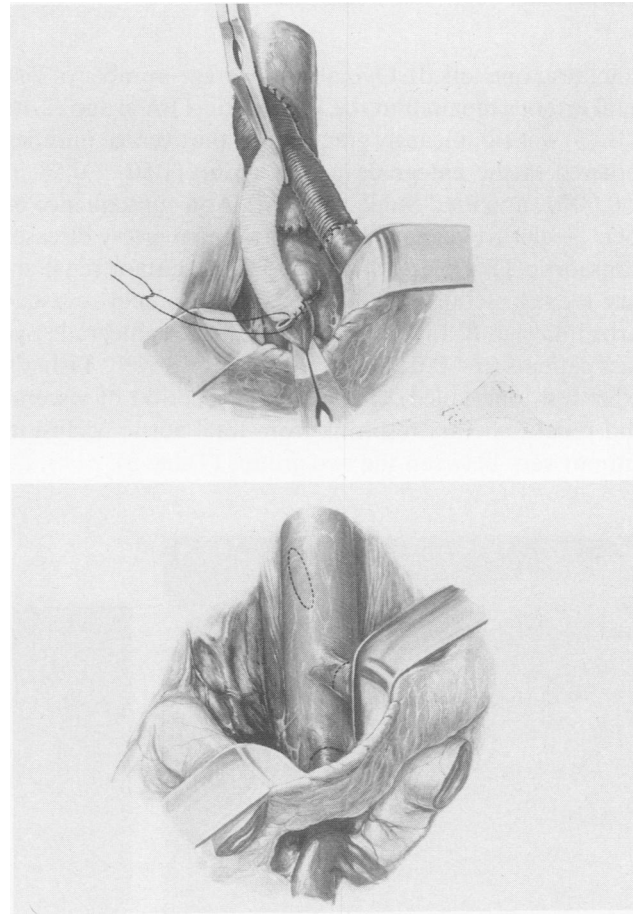
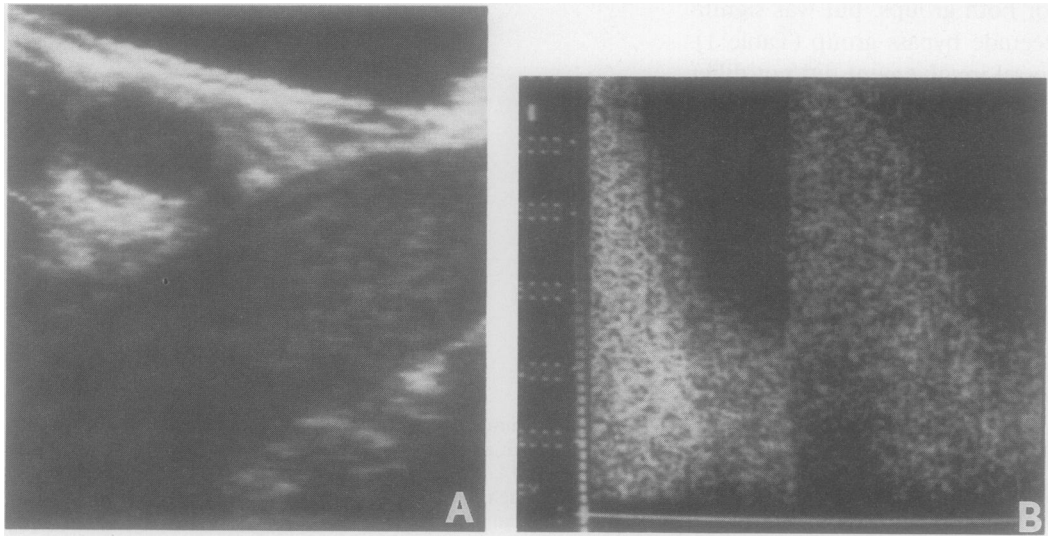


FIG. 6. Diagrammatic demonstration of the location and orientation of the proximal anastomosis for a bifurcated antegrade bypass to both the celiac and SMA. After completion of the proximal anastomosis, flow is restored through the aorta and the individual graft limbs are clamped for each visceral anastomosis.

FIG. 7. Transesophageal echocardiographic views of the left ventricle, during systole (right frames) and diastole (left frames). Bottom frames show hypovolemia with empty left ventricle at end-systole.

exact test, one tailed). Overall the average number of visceral arteries repaired in the transaortic TEA group (2.10 ± 0.43) was significantly greater than the average number repaired in the antegrade bypass group (1.50 ± 0.58, $p < 0.0001$, unpaired Student's t test). As a consequence of their greater frequency of associated renal artery disease, transaortic TEA patients required concomitant renal artery reconstruction or concomitant aortorenal revascularization significantly more often than did antegrade bypass patients ($p = 0.01$ and $p = 0.03$, respectively, Fisher's exact test, one tailed). The obligatory period of visceral and renal ischemia resulting from total aortic occlusion did not vary between the two groups (Table 3).

Nine patients died in the perioperative period (12.2%), five from complications of bleeding, two of whom were re-explored for this bleeding. One patient developed pneumonia following a stroke and ultimately died of respiratory failure. One patient developed myocardial failure and died in multiple-system failure. One patient died of recurrent sepsis and enterocutaneous fistula formation following colonic perforation of uncertain etiology. The resected colon showed extensive mucosal ulceration but no transmural infarction and at autopsy, the visceral reconstruction (transaortic TEA) was patent without technical defect. One patient developed irreversible visceral ischemia intraoperatively in spite of a patent, functioning



FIGS. 8A and 8B. Intraoperative duplex scan of a celiac artery showing tight bandlike proximal stenosis (A) with elevated peak systolic frequencies (B).

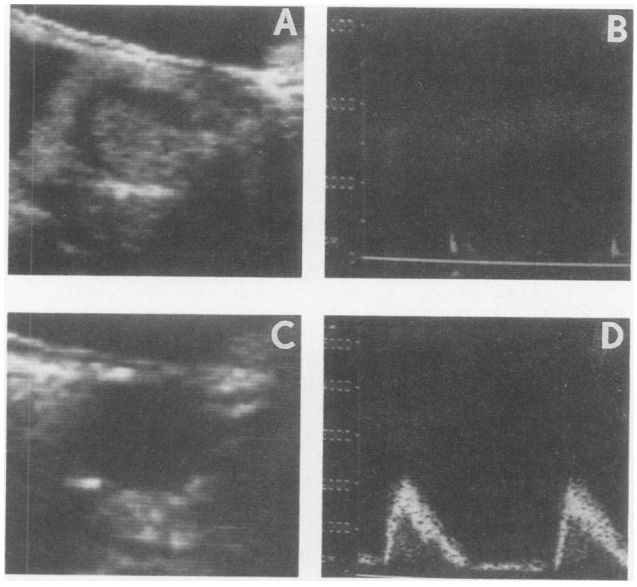


FIG. 9. Intraoperative duplex scan of superior mesenteric artery (SMA) after transaortic endarterectomy. (A) A large filling defect, with the appearance of thrombus, occupies most of the lumen and the associated flow signal (B) is almost nonexistent. (C) Appearance of the SMA following reopening to remove the thrombus and the associated intimal flap. (D) Note the normal flow signal in the artery after reopening.

repair (transaortic TEA). In spite of resection of the involved bowel (mainly colon), profound metabolic abnormalities led to her death intraoperatively. The exact mechanism of the development of the visceral ischemia was not established by examination of the resected bowel or at autopsy. Neither the mortality rate nor the overall complication rate was significantly different between the two operative groups ($p = 0.32$ and $p = 0.37$ respectively, Fisher's exact test, one-tailed), although both types of events occurred more frequently in the transaortic TEA group (Table 4). However the incidence of multiple complications was significantly greater in the transaortic TEA group ($p = 0.03$, Fisher's exact test, one-tailed), whether all complications or only those occurring in surviving patients were considered (Table 4). In addition, the type of complication varied significantly with the operative technique, with all of the pulmonary complications ($N = 11$) developing in the transaortic TEA group ($p = 0.04$, Fisher's exact test, one-tailed). Although all of the renal complications ($N = 3$) occurred in the transaortic TEA group, and all of the visceral complications ($N = 2$)—one graft thrombosis and one intestinal resection for infarction—occurred in the antegrade bypass group, the numbers were too small to detect any significance.

Two patients (2.7%) were lost to follow-up, both from the transaortic TEA group. The remaining 63 patients (85.1%) were followed for a mean interval of 71.1 months (range, 4.2–263.9). Nine patients (12.2%) developed recurrent symptoms of visceral ischemia. One patient (mentioned above) was known to have an occluded antegrade bypass (celiac and SMA) at the time of discharge. No further reconstruction was technically feasible. When his symptoms recurred as expected, resection of all ischemic and infarcted bowel was performed, but persistent inanition ultimately led to his death 14.1 months later. One other patient had persistence of all of her symptoms after transaortic TEA and arteriography showed occlusion of the SMA and stenosis of the celiac. About 5 months postoperatively, further visceral revascularization was attempted but could not be performed, and she died of extensive visceral infarction. The seven other patients experienced reappearance of their symptoms at 4.6, 14.6, 27.0, 28.9, 38.9, 66.3, and 98.1 months postoperatively, three following antegrade bypass and four after transaortic TEA. Three patients underwent a single repeat visceral revascularization. All again became asymptomatic and remain so 18.7, 108.6, and 179.4 months later. One patient was reoperated twice and then remained asymptomatic until the time of her death from a thoracic aortic dissection 55.8 months later. One patient was reoperated three times for recurrent visceral ischemia symptoms. After the final reconstruction, she had intermittent nausea and diarrhea, but gained weight and had no further deterioration of her status until her death 53.7 months later from complications after aortofemoral bypass grafting. The sixth patient had been troubled by repeated episodes of partial small bowel obstruction, which ultimately led to a perforation, complicated by recurrent enterocutaneous fistula formation. Three weeks after her fourth, and apparently successful, fistula resection, the patient returned to the hospital with acute mental status changes. She underwent exploratory laparotomy for a presumptive diagnosis of recurrent fistula formation with sepsis, but was found to have extensive bowel infarction and she subsequently died. The final patient who developed recurrent symptoms had a normal visceral angiogram. She subsequently underwent an exploratory laparotomy and resection of a short segment of ischemic bowel. She, too, remained asymptomatic for 59.4 months, when she died of a stroke.

The cumulative percentage of patients who remained asymptomatic following antegrade bypass and transaortic TEA was (respectively) 95.8% and 97.3% at 1 year, 87.8% and 86.1% at 5 years (Fig. 10). There was no difference in the long-term relief of visceral ischemia symptoms obtained with either of these two revascularization techniques. Similarly the long-term patient survival following either operation was equivalent: 92.3% and 80.6% at 1 year, 68.1% and 66.3% at 5 years, and 62.1% and 55.1% at 7 years for patients undergoing antegrade bypass and transaortic TEA, respectively (Fig. 11).

Only 27 patients (42.9%) underwent visceral angiography following reconstruction, one half before discharge (perioperative interval) and one half during later follow-up. The lack of follow-up arteriograms in a significant proportion of the study group prevents us from docu-

TABLE 1. *Clinical Presentation*

	Antegrade Bypass (n = 26)		Transaortic Endarterectomy (n = 48)	
	n	%	n	%
Age*	61.8 ± 12.8		59.8 ± 9.2	
Gender				
Women	20	76.9	41	85.4
Men	6	23.1	7	14.6
Symptoms				
Abdominal pain				
Postprandial	24	92.3	38	79.2
Atypical	2	7.7	10	20.8
None	0	0.0	0	0.0
Other gastrointestinal symptoms	14	53.8	33	68.8
Physical Findings				
Abdominal bruit	16	61.5	35	72.9
Positive stool guaiac	3	11.5	3	6.3
Abdominal peripheral pulses	16	61.5	24	50.0
Weight loss	23	88.5	36	75.0
Average (lbs)*†	35.9 ± 19.5		22.4 ± 12.0	
None	2	7.7	7	14.6
Preoperative weight (lbs)*	119.0 ± 20.6		116.3 ± 24.7	
Preoperative Aortography				
Visceral arteries involved				
Celiac	0	0.0	0	0.0
SMA	0	0.0	1	2.1
Celiac/SMA	10	38.5	16	33.3
Celiac/SMA/IMA	16	61.5	31	64.6
Renal arteries involved‡	6	23.1	28	58.3

* mean ± SD.
† p = 0.003 (unpaired Student's *t* test).
‡ p = 0.07 (Fisher's exact test, one-tailed).
SMA, superior mesenteric artery; IMA, inferior mesenteric artery.

menting the long-term patency of these visceral repairs. However, of 18 angiograms obtained in asymptomatic patients, 14 (77.7%) showed that all operated visceral vessels were widely patent (Fig. 12), 2 (11.1%) showed occlusion of a single visceral artery (celiac), and the results of two studies were not available.

Discussion

The surgical treatment of chronic visceral ischemia caused by atherosclerosis was initiated by the reports of Shaw and Maynard in 1958[9] and Mikkelsen and Zaro in 1959.[10] Both surgeons used transarterial TEA to reconstruct the SMA, which Mikkelsen believed was technically easier and more reliable than reimplantation or short bypass grafts. Despite this early experience, retrograde bypass grafting rapidly became the most frequently used technique for visceral revascularization.[3,7,8–11,14,17–24] This approach was preferred because exposure of the distal SMA and celiac branches for the distal anastomosis is easy,[3,14,22] infrarenal aortic exposure and control—the site of origin of these grafts—is easier than paravisceral aortic exposure and control,[3,11,14] there is no danger of dissection from the anastomosis,[8,11,14] and antegrade bypass can be performed from the transabdominal approach.[23] In addition some surgeons felt that visceral endarterectomy increased the difficulty of simultaneous aortic repair.[23] The consensus was that direct repair of occlusive celiac and SMA lesions was dangerous, unnecessary, and technically ambitious.[3,8,11] Williams[7] correctly noted that this early experience was almost uniformly lacking in any significant follow-up data and concluded that it had not actually been

TABLE 2. *Patient Profile*

	Antegrade Bypass (n = 26)		Transaortic Endarterectomy (n = 48)	
	n	%	n	%
Risk Factors				
Diabetes	1	3.8	1	2.1
Smoking	16	61.5	39	81.3
Hypertension	15	57.7	28	58.3
Hypercholesterolemia	3	11.5	10	20.8
Associated Illnesses				
Peripheral vascular	15	57.7	29	60.4
Cardiac	11	42.3	15	31.3
Renal	4	15.4	14	29.2
Pulmonary	3	11.5	3	6.3
Prior Surgery				
Peripheral vascular	12	46.2	17	35.4
Gastrointestinal tract	9	34.6	23	47.9
Gastrointestinal tract for ischemia/ infarction	1	3.8	3	6.3
Other	10	38.5	17	35.4

TABLE 3. *Operative Details*

	Antegrade Bypass (n = 26)		Transaortic Endarterectomy (n = 48)	
	n	%	n	%
Approach				
Transabdominal†	23	88.5	5	10.4
Thoracoretroperitoneal†	1	3.8	36	75.0
Medial visceral rotation	2	7.7	7	14.6
Arteries repaired				
Celiac	26	100.0	47	97.9
SMA†	12	46.2	45	93.8
IMA‡	1	3.8	9	18.8
Mean repaired arteries§	1.50 ± 0.58		2.10 ± 0.43	
Associated vascular repairs				
Visceral + aorta	2	7.7	2	4.2
Visceral + renal‖	0	0.0	12	25.0
Visceral + renal + aorta¶	1	3.8	11	22.9
Ischemia times				
Visceral*	26.0 ± 15.8		30.5 ± 15.5	
Renal*	25.2 ± 16.8		30.4 ± 16.0	

* mean ± SD.
† p = 0.0001 (chi square); ‡ p = 0.07; § p < 0.0001 (unpaired Student's *t* test); ‖ p = 0.01; ¶ p = 0.03 (Fisher's exact test (one-tailed).
SMA, superior mesenteric artery; IMA, inferior mesenteric artery.

established whether these visceral revascularization techniques would protect against fatal acute mesenteric infarction in the long term.

At about this time we became concerned that the limited exposure of transarterial TEA did not allow complete removal of the aortic portion of the atheromatous lesion and that reimplantation or retrograde bypass was threatened by the inevitable progression of atherosclerosis in the infrarenal aorta. Furthermore proper graft alignment was difficult with the retrograde grafts[25] and this prompted many surgeons to favor prosthetic conduits because they resisted kinking better[21–23] and some surgeons to modify the technique.[25,26] These concerns led us to adopt the almost exclusive use of transaortic endarterectomy or antegrade bypass from the supraceliac aorta as our two preferred methods of visceral revascularization. We have previously reported the initial and intermediate follow-up results obtained with these two techniques.[27,28] Accumulating experience and continuing observation of the patients now allows us to present long-term follow-up data in life table format and to compare the results obtained in the two operative treatment groups.

TABLE 4. *Perioperative Results*

	Antegrade Bypass (n = 26)		Transaortic Endarterectomy (n = 48)	
	n	%	n	%
Outcome				
Alive	24	92.3	41	85.4
Dead	2	7.7	7	14.6
Complications (all patients)				
None	16	61.5	23	47.9
One	8	30.8	12	25.0
Two or more*	1	3.8	11	22.9
Complications (surviving patients)				
None	16	61.5	23	47.9
One	8	30.8	11	22.9
Two or more*	0	0.0	7	14.6

* p = 0.03 (Fisher's exact test, one-tailed).

Transaortic Endarterectomy

It has long been recognized that obstructing visceral atherosclerotic lesions are usually confined to the first 2 cm of the vessel origins. Initially it was not appreciated that these lesions really represent an overflow of aortic atherosclerosis into the visceral vessel orifices. Thus, although the limited extent of the lesion in the visceral artery makes transarterial endarterectomy attractive, complete removal of the aortic component of the atheroma requires a transaortic approach. We had found this to be a successful technique for renal artery occlusive disease and felt it was applicable to the visceral vessels as well. However safe performance demands unrestricted access to the upper abdominal aorta. The early transaortic visceral TEA procedures in this series were performed transabdominally, from the front of the aorta (n = 6). This resulted in very limited exposure, and complete removal of the visceral portion of the lesion was difficult, and often associated with tearing of the aorta or visceral vessel. Subsequently we began to use a left thoracoretroperitoneal approach,[29] which was a modification of previously reported retroperitoneal and thoracoabdominal exposures of the aorta.[30,31] The realization that medial rotation of the viscera from the left provided the same extensive aortic exposure[32] through the transabdominal approach now allows us to avoid entirely the use of two body cavity pro-

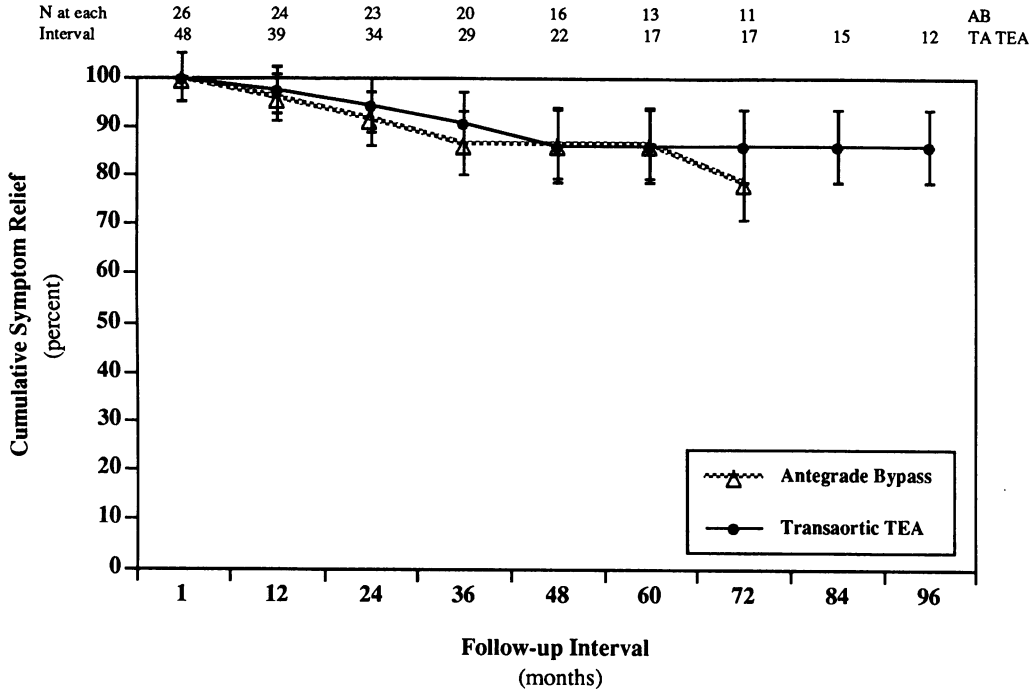


FIG. 10. Life table representation of the cumulative symptom relief provided by antegrade bypass (AB) and transaortic endarterectomy (TA TEA). All SE less than 10%.

cedures. Because all of the substantial pulmonary morbidity in this series occurred following transaortic TEA, we think that this modification in approach represents a significant improvement that will increase the applicability and safety of the transaortic TEA technique. Inevitably there will be some arteries that will not be amenable to endarterectomy, as indicated by the seven times we had to modify this technique in our patient group. The most common reasons for this are transmural calcification and very distal involvement of the visceral vessels by the occlusive process. It is imperative that the surgeon recognize this early and switch to an alternative approach before prolonged visceral ischemia has occurred. Visceral ischemia invervals exceeding 1 hour are almost always fatal. We did not find that transaortic TEA made concomitant aortic repair difficult,[23,33] as evidenced by the fact that 27.1% of the patients in the operative group (n = 13) underwent simultaneous aortic reconstruction. Tran-

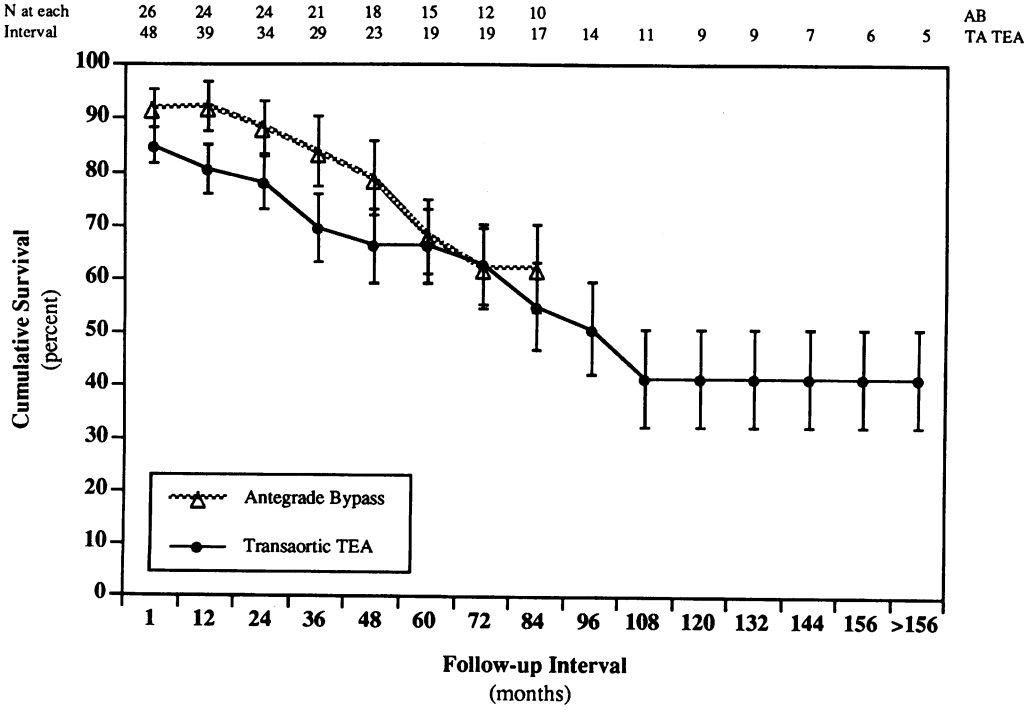
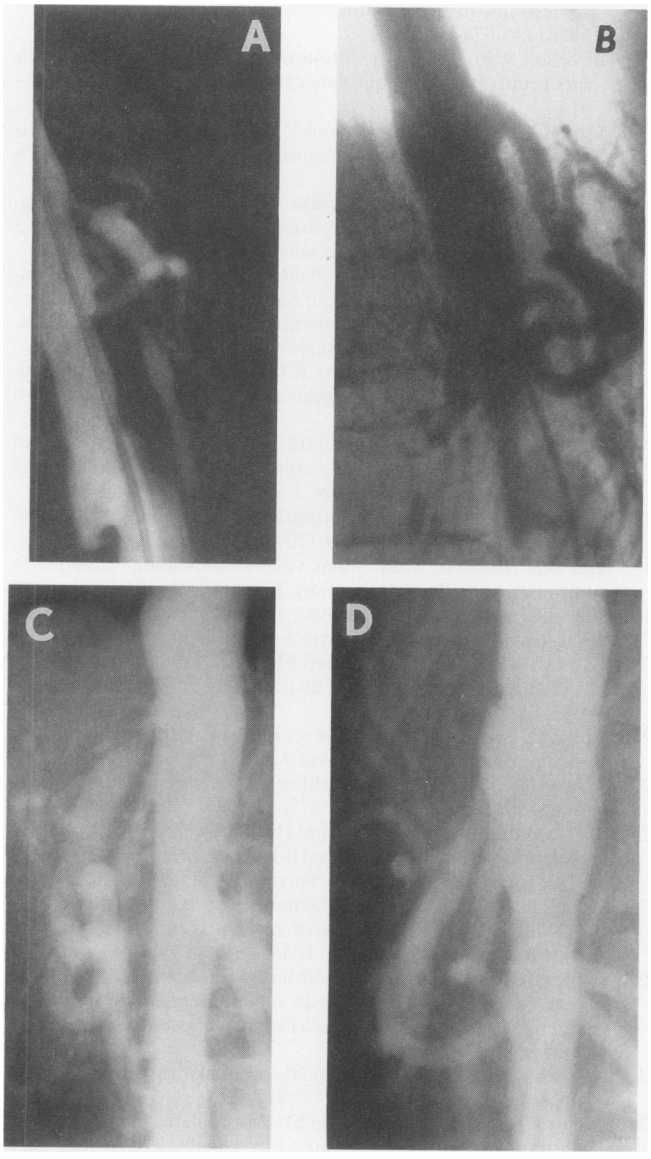


FIG. 11. Life table representation of the cumulative patient survival after antegrade bypass (AB) and transaortic endarterectomy (TA TEA). All SE less than 10%.



FIGS. 12A–D. Preoperative (A) and postoperative (B) arteriograms from a patient who underwent antegrade bypass to the celiac artery showing a widely patent bypass graft in an asymptomatic patient. Preoperative (C) and postoperative (D) arteriograms from a patient who underwent transaortic endarterectomy of both the celiac and SMA showing widely patent native vessels, also in an asymptomatic patient.

saortic endarterectomy does require special expertise and consequently few surgeons have adopted this approach to the treatment of visceral atherosclerosis. Those few other groups who have used this technique report results similar to ours.[34]

Antegrade Prosthetic Bypass

It seems obvious that the durability of the bypass is favored when the site of origin (distal thoracic aorta) is disease free at the time of implantation and at little risk for disease progression during the life of the patient. The antegrade orientation of these grafts allows for very short segment conduits, which have no propensity to kink and which may actually endothelialize over much of their length. This orientation, combined with an end-to-end distal anastomosis, may minimize flow abnormalities reported to contribute to intimal hyperplasia. Although the concept of antegrade visceral grafts was introduced in 1977[27] and has recently been endorsed by others,[35,36] most recent series of visceral revascularization continue to show a marked predominance of retrograde visceral bypass grafts.[33,36–40] Crude outcome data are available from most of these series, but life-table presentation of the duration of symptom relief and survival are not. Furthermore most of the series do not analyze the outcome data according to the type of revascularization used and some series combine patients with acute symptoms, chronic symptoms, and no symptoms. Thus the durability of retrograde bypass grafts for chronic visceral ischemia remains somewhat undefined.

The perioperative mortality rate for this study group is comparable to that reported in the literature. It is somewhat surprising that there was no significant difference in the perioperative mortality rate between the two treatment techniques, despite the fact that transaortic TEA required more extensive exposure, involved multiple visceral artery repairs more often than did antegrade bypass and was more often combined with other vascular repairs (n = 25, 52.1%) than antegrade bypass (n = 3, 11.5%). Because our two operative groups were comparable in terms of the overall patient profile, risk factors and associated illnesses, these results cannot be attributed to selection of better-risk candidates for transaortic TEA. One factor that may have contributed to reducing the transaortic TEA mortality is the increased use of the transabdominal approach. This certainly reduces the length and magnitude of the operation and ultimately may improve the overall complication rate among transaortic TEA patients.

Because coexistent coronary artery disease largely determines the morbidity and mortality rates of patients undergoing vascular reconstruction, we attribute much of this improved perioperative survival to the use of intraoperative transesophageal echocardiography. This method of cardiac monitoring allows accurate, rapid real-time detection of volume changes as well as the identification of ischemia-induced cardiac wall motion abnormalities. Prompt correction of volume changes and relief of myocardial strain, which often accompanies supraceliac aortic clamping, can prevent the consequences of myocardial ischemia in the postoperative period. Despite 25- to 30-minute transient supraceliac aortic occlusion in both treatment groups, there were only five perioperative cardiac events (6.8%), only one of which was fatal.

We also found no difference in the long-term relief of symptoms achieved with these two operative approaches. After 5 years of follow-up, 86% of patients in each operative treatment group remained symptom free. Of equal interest was the fact that six of the nine patients with

recurrent symptoms were again rendered asymptomatic by repeat visceral revascularization (n = 5) or short-segment bowel resection (n = 1). Thus, during this extensive follow-up interval, only three patients (4.8%) experienced fatal recurrent visceral ischemia. We attribute these durable results to selection of the optimal revascularization technique and to intraoperative assessment of the reconstruction. The endarterectomy technique allows complete removal of all aortic and visceral atheroma, while the bypass technique provides antegrade flow from disease-free proximal aorta to disease-free distal visceral artery. The routine use of intraoperative duplex scanning to visualize the reconstructions and assess flow through the conduit or through the disobliterated native arteries ensures that the reconstruction will be technically perfect at the conclusion of the procedure. Undoubtedly this contributed significantly to the low incidence (n = 2) of early revascularization failures in our series because these are almost always due to a technical problem. Of interest many perioperative deaths reported by other groups resulted from early revascularization failure and intestinal infarction. We did not encounter that in this series. None of our perioperative deaths was due to failure of the visceral repair. Thus intraoperative Duplex scanning contributes importantly to perioperative survival and sets the stage for prolonged reconstruction patency.

The equivalent results seen in these two groups would suggest that durable relief of symptoms does not correlate with the number of visceral arteries repaired, in contrast to earlier published work.[41] Patients in the transaortic TEA group almost invariably had two or more visceral vessels endarterectomized, while nearly one half of the patients in the antegrade bypass group had only one diseased artery bypassed. Rather it would seem that the best way to insure long-term survival and durable relief of symptoms is to select the optimal operative technique, use aggressive intraoperative cardiac monitoring, and achieve technical perfection in the revascularization.

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Discussion

DR. JOHN E. CONNOLLY (Irvine, California): Dr. Stoney and I have shared a common interest in reconstructive procedures for chronic intestinal ischemia for a number of years.

I looked up the paper that he gave in 1977 before this organization, and I do not know whether any of you read over the discussions you have given years before, but it can be very interesting. I would like to quote what I said about the trapdoor procedure at that time.

> I would think that the trapdoor method suggested by the authors would be applicable in some patients but not in most patients, and I would think in the average surgeon's hands it would be preferable to use bypass grafts into the distal mesenteric vessels and stay away from such a major procedure on a dangerous portion of the proximal abdominal aorta.

In talking to colleagues over the years, I believe that what I said then continues to be the common opinion of most vascular surgeons regarding the trapdoor procedure. I have a confession to make, however. After the meeting in 1977, I went home and thought about the trapdoor approach and decided to try it. I used an oblique abdominal incision with a short extension into the eighth intercostal space, the same approach that we had been using for years previously to perform direct retroperitoneal operations on the renal artery.

I was amazed how easy the trapdoor procedure was once you got the exposure. It was very much like a carotid endarterectomy, except that you did not have to worry about whether to shunt. The 15 or 20 minutes required to do the endarterectomy is about one third of the time that the kidney flow can be safely occluded, especially if you place ice slush in the retroperitoneal area next to the kidneys.

I have now performed seven trapdoor operations without any complications or known late patency failures and think it is the procedure of choice for revascularization for chronic intestinal ischemia in most patients. I only wish that more patients in our area with chronic intestinal ischemia were diagnosed before gut gangrene developed, as this is one of the most completely corrective procedures without the need of bypassing graft that I have had the satisfaction of doing in vascular surgery.

The only modification is that I find it is usually easier to include the left renal artery in the trapdoor incision whether or not one needs an endarterectomy of that artery. I have not tried the trapdoor operation completely transabdominally, and maybe this approach described today will encourage trial of the trapdoor operations by vascular surgeons who do not feel comfortable with the standard thoracoabdominal retroperitoneal approach. I think that they would find that the method of direct endarterectomy is more totally corrective of the disease that we are dealing with and will provide higher long-term patency.

Finally I would like to congratulate Dr. Cunningham on his presentation and Dr. Stoney on his pioneering contributions to this field.

DR. MICHAEL E. DEBAKEY (Houston, Texas): I would like to make a few comments about this interesting pattern of arterial occlusive disease. In our experience we found some aspects of this form of atherosclerosis to be different from the regular patterns of atherosclerotic occlusive disease. As you know atherosclerotic occlusive disease that produces clinical manifestations of ischemia occurs in four major arterial beds of the body, and the interesting point is that, in any patient population, this form of the disease is the least frequent—in our own experience about 3% of the total patient population.

There are other interesting aspects of this disease. For example as Dr. Cunningham pointed out, in this group of patients—and this was true in our patients as well, and I think in most other studies—the predominant sex is the female, whereas in almost every other form of atherosclerotic occlusive disease, the male sex is predominant.

Another interesting aspect is related to the risk factors. If for example we compare this pattern of disease with coronary atherosclerotic occlusive disease, we find that the incidence of the primary risk factors, such as tobacco smoking, hypertension, and hyperglycemia, are different. In this pattern of the disease, only 17% had hypercholesterolemia, and this observation has been made by us as well—less than 20% in our experience—whereas in coronary atherosclerotic disease, the presence of hypercholesterolemia is at least twice or three times that. It is closer to 60% to 70%.

Hypertension also is more common in the other patterns of the disease than it is in this group.

It also should be pointed out that clinical manifestations develop most often and almost invariably when more than one of the vessels are involved. Usually both the celiac and superior mesenteric arteries are involved in production of clinical manifestations.

As far as the technique is concerned, our experience has led us more to use of the bypass procedure than to endarterectomy. I believe, however, that the transabdominal approach to endarterectomy is preferable to the thoracoabdominal approach that we originally described.

The results, nevertheless, are equally good, but I think the reason that they are is that in the hands of such experienced vascular surgeons as Dr. Stoney and his associates gratifying results can be expected in 95% of the patients.

With regard to duration of survival, the results presented here are excellent. A recent analysis of our own experience with these patients, most of whom had the bypass procedure, showed that the Kaplan-Meier survival curve for 10 years was about 70%, and for 20 years was a little more than 50%. So we can expect good results when the procedure is performed as excellently as has been presented by Dr. Stoney and his associates.

I also want to thank Dr. Stoney for letting me review his manuscript. It is an excellent study and most useful in presenting the kind of treatment that is indicated for this form of disease, despite the fact that is it relatively uncommon.

DR. VICTOR M. BERNHARD (Tucson, Arizona): This certainly is one of the largest, if not the largest, reported experiences relating to the surgical management of ischemia of the intestine, and the results presented strongly indicate that revascularization is a durable method of management.

My questions to the authors relate to the basis for their choice of operative technique. Most of us grew up with the concept of performing a bypass using the retrograde approach, especially when dealing with combined infrarenal aortic disease, either aneurysm or atheromatous obstruction. This is the most common setting in my practice and I have usually employed retrograde bypass with prosthetic conduits rather than veins under these circumstances. Conversely I like and have used the prograde approach either with bypass or with endarterectomy when the infrarenal aorta does not require repair and have found that both of these techniques are extremely satisfactory.

You suggest that the prograde approaches are better; nevertheless the data in the literature are anecdotal. Because you have experience with other techniques, what data do you have that support your preferences for the prograde rather than the retrograde approach? What do you do for those patients who require combined infrarenal aortic reconstruction and visceral revascularization? Do you avoid taking a bypass off the infrarenal aortic reconstruction and use a separate approach at the diaphragmatic crural area of the aorta?

With regard to bypass *versus* endarterectomy, do you have criteria that direct you to perform one rather than the other? Is this decision based on a preoperative assessment of collaterals and the ability to identify aortic wall disease by computed tomography (CT) or magnetic resonance imaging (MRI)? We have found that these studies may be helpful.

Finally I noticed that you obtained a more complete revascularization with endarterectomy, as both the celiac and the superior mesenteric vessels are repaired, whereas with the bypass technique, about half of your patients received only single-vessel repair. Was it merely the technical