Alternative Methods of Renal Revascularization

JOSEPH L. MULHERIN, JR., M.D., F.A.C.S. and WILLIAM H. EDWARDS, M.D., F.A.C.S.

Saphenous vein aortorenal bypass is the most commonly used surgical procedure for relief of renovascular hypertension. Years of experience have shown the procedure to be effective with satisfactory long-term results. Coexisting disease conditions of the aorta sometimes make alternative methods of renal revascularization preferable, especially when more than one renal artery is involved. Such alternative procedures include transaortic endarterectomy, bilateral renal endarterectomy *via* a transverse incision across both renal arteries, or extra-anatomic bypass from the splenic, hepatic, or iliac arteries. Two hundred twenty-five renal revascularization procedures performed either alone or in combination with other abdominal vascular procedures during the last 5 years is reported. In 18 patients, one of the above procedures was performed. This experience with these various types of renal revascularization will be discussed with particular reference to indications, technique, and potential pitfalls of each procedure.

From the Department of Surgery, Section of Surgical Sciences, Vanderbilt University Medical Center, and the Surgical Service of St. Thomas Hospital, Nashville, Tennessee

SAPHENOUS VEIN RENAL artery bypass has been and remains the mainstay in the surgical management of renovascular hypertension. Long-term studies have indicated satisfactory patency rates and good functional results in properly selected patients.[1] In our practice, saphenous vein bypass to the renal artery has been the most frequently performed renal revascularization procedure either alone or in conjunction with other aortic procedures. Over the past 5 years, we have performed 207 aortorenal bypasses using saphenous vein. One hundred twenty-five of these procedures were performed in conjuction with other abdominal vascular reconstructions.

In certain patients, however, the standard aortorenal bypass may present technical problems, usually related to severe calcific or soft atheromatous disease involving the aorta. In patients with stenotic lesions in multiple renal arteries, individual bypass grafts to each vessel become tedious and time consuming, and an alternative method of revascularization becomes preferable. Occasionally, the cardiac status of a patient requiring renal revascularization may be such that cross-clamping of the aorta should be avoided.

When faced with the above and similar situations, the vascular surgeon must be prepared to consider alternative methods of renal revascularization. These may include unilateral or bilateral renal endarterectomy, transaortic endarterectomy, or extra-anatomic bypass from either the splanchnic or iliac arteries. Over the past 5 years, we have performed one of the above procedures on 18 patients. This report reviews the results of these operations as well as the indications, advantages, and potential hazards of each procedure.

Methods and Materials

From January 1981–1986, we performed 225 renal revascularization procedures. Slightly more than half of these procedures were performed in conjuction with other major abdominal vascular procedures, usually aneurysm resection or aortofemoral bypass.

Table 1 shows a breakdown of the various procedures performed with mortality rates in each group. It should be noted that in 20 patients it was necessary to resect the abdominal aorta and replace it with a graft to have an adequate site for origination of an aortorenal bypass. The mortality rate in these 20 patients was 5%.

In 18 patients, an alternative to aortorenal bypass was selected. Alternative procedures included transaortic endarterectomy in eight patients, transrenal endarterectomy in eight patients, and extra-anatomic bypass in

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Reprint requests and correspondence: Joseph L. Mulherin, Jr., M.D., Suite 205, 4230 Harding Road, Nashville, TN 37205.

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two patients. There were nine men and nine women in this group. Age range was 51–80 years.

In seven of the eight patients who had transaortic endarterectomy, multiple renal artery stenoses were present. Four of these patients had simultaneous aneurysm resection or aortofemoral bypass. Significant complications developed in three patients. One patient had a severe ileus requiring prolonged nasogastric decompression and parenteral alimentation. Another patient thrombosed one of three renal arteries on which endarterectomy had been performed. In the third patient, technical problems in a severely diseased proximal aorta led to a bleeding diathesis and mesenteric emboli that ultimately were fatal.

Of the surviving seven patients, hypertension was cured in two patients. In four patients, control of hypertension was possible with reduced doses of antihypertensive medications. In the patient who thrombosed one of the endarterectomized renal arteries, there was no improvement.

Of the eight patients who had transrenal endarterectomy, five patients had bilateral procedures, extending the arteriotomy across the anterior wall of the aorta from one renal artery to the other. In most of these patients, endarterectomy was chosen because of calcific disease in the infrarenal aorta. Anatomic proximity of the origins of the left and right renal ostia was also a consideration when bilateral endarterectomies were required. An associated vascular procedure was performed in only one patient who had simultaneous left renal endarterectomy and saphenous vein bypass to the superior mesenteric artery. Significant complications developed in two patients. In one patient, respiratory insufficiency and a seizure disorder required prolonged ventilatory support. In the other patient, bilateral renal artery thrombosis occurred in the early postoperative period. In spite of thrombectomy, renal failure developed, and the patient died 3 months after operation while undergoing chronic dialysis.

Of the seven surviving patients, one had no improvement in her hypertension, five patients were controlled on reduced dosages, and one patient discontinued medications altogether.

In two patients, extra-anatomic bypass of bilateral renal artery lesions was performed because of extensive calcific disease involving the entire abdominal aorta. One patient, an 80-year-old man with severe hypertension and renal insufficiency, had a saphenous vein bypass from the common hepatic to the right renal artery and a direct anastomosis of the divided splenic artery to the left renal artery with improvement in his renal function and control of his hypertension. In the other patient, embolic occlusion of both femoral arteries occurred after bilateral iliac-to-renal saphenous vein grafts.

TABLE 1. *Renal Revascularizations 1981–1986*

	Number	Deaths	Per cent
Single renal artery bypass	46	1	2.2
Bilateral renal artery bypass	16	1	6.2
Single combined*	81	2	2.5
Bilateral combined*	44	6	13.6
Single with aortic resection	11	0	0
Bilateral with aortic resection	9	1	11.1
Endarterectomy or extra-anatomic	18	3	16.6
Total	225	14	6.2

* In conjunction with AAA resection or A-F bypass.

On the second postoperative day, the patient had a myocardial infarction from which she subsequently died.

Transaortic Endarterectomy

Case Report

A 65-year-old retired salesman was admitted to St. Thomas Hospital after experiencing episodic weakness and light headedness for 6 weeks. His blood pressure at the local health clinic was 220/120 mmHg.

His previous health had been excellent except for obesity and a 10-year history of mild hypertension, controlled with hydrochlorothiazide and propranolol.

Weight on admission was 242 pounds. Blood pressure was 160/100 mmHg in both arms. Grade I retinal arteriosclerotic changes were present. Results of cardiac and abdominal examination were normal. Pulses in the lower extremities were normal.

Chest x-ray revealed borderline cardiomegaly. An electrocardiogram showed left ventricular hypertrophy. An intravenous pyelogram (IVP) was normal. Renal arteriograms revealed two renal arteries to each kidney with severe proximal stenoses of three of the four arteries (Fig. 1). Renal vein renins did not lateralize. Preoperative BUN/creatinine levels were 41/2.5 mg/dL.

At operation, the aorta was exposed from the superior mesenteric artery to the inferior mesenteric artery and all four renal arteries dissected free. The left renal vein was mobilized after dividing the adrenal and gonadal veins. After cross-clamping the aorta just below the superior mesenteric artery, a longitudinal aortotomy was made and endarterectomy of the origins of all four renal arteries was performed. In all four renal arteries, the plaque was extracted cleanly with no fragmentation of the distal intima. The aortotomy was closed primarily. Total time of renal ischemia was 40 minutes.

The patient's postoperative course was uneventful. Before discharge, a repeat aortogram was performed and revealed complete resolution of all the stenoses in all renal arteries (Fig. 2). BUN/creatinine levels at discharge were 31/1.6 mg/dL.

Transaortic endarterectomy through a longitudinal aortotomy offers a good alternative to renal artery bypass when multiple renal arteries are present and require surgical relief of proximal stenoses. Aortic exposure must be considerably more extensive than for renal artery bypass since the aortotomy must be extended well above the origins of the renal arteries to afford visualization of the origins during the course of the endarterectomy. In most patients, this proximal aortic exposure

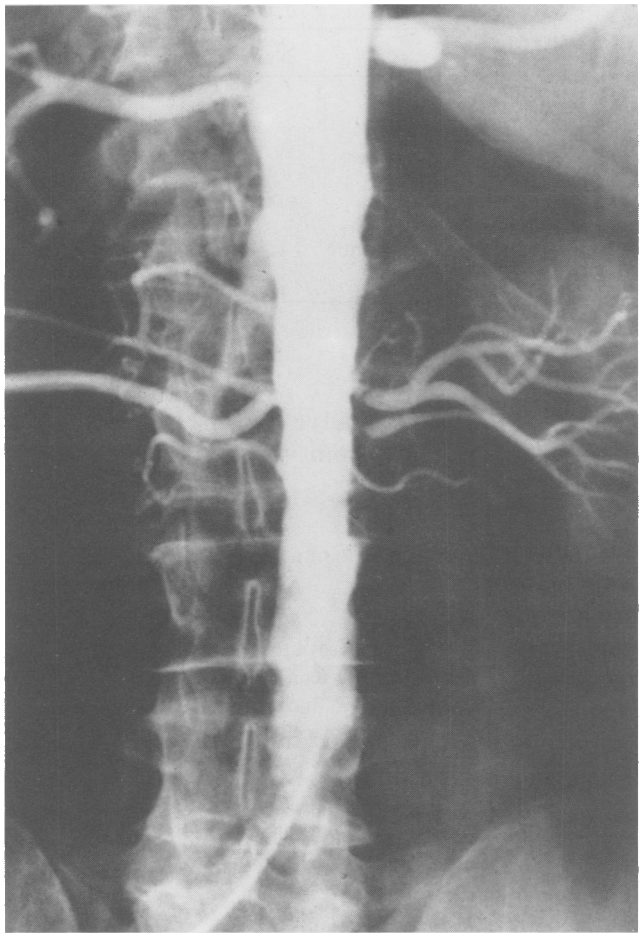

FIG. 1. Preoperative renal arteriograms demonstrating severe proximal stenoses in three of four renal arteries.

can be accomplished without significant difficulty by division of the inferior mesenteric vein near its junction with the splenic vein. The avascular plane beneath the pancreas is then developed, allowing the pancreas to be elevated off of the aorta (Fig. 3). After identification of the origins of the left renal and superior mesenteric arteries, the dissection proceeds up the left side of the aorta, dividing neural and lymphatic tissue along the way. The crus of the diaphragm is soon encountered and can be divided to allow even more proximal aortic exposure. Using this technique, it is usually possible to place a cross-clamp on the aorta above the level of the superior mesenteric or the celiac artery. We have on a few occasions used this extended anterior approach to the aorta for resection of abdominal aortic aneurysms extending above the renal arteries, with entirely satisfactory results.

After aortic exposure is obtained, each renal artery is exposed sufficiently to allow control. The aortotomy is begun anteriorly below the renal arteries and extended upward, coursing to the left between the origins of the left renal and superior mesenteric arteries and then up the left side of the aorta. Depending on the relationship of the superior mesenteric and renal arteries, it may be necessary to extend the incision above the level of the superior mesenteric artery. The left renal vein may be divided near its junction with the vena cava if necessary as long as the adrenal and gonadal branches are preserved, but it is usually possible to work above and below the vein and leave it intact.

The endarterectomy is then begun on the cut edge of the aorta and developed circumferentially around the aorta. The elevated plaque is then transected sharply proximally and distally, taking care to be sure that the endarterectomy does not extend to the superior mesenteric artery, since visualization of the origin of this vessel from the anterior approach is extremely difficult. As the origins of the renal arteries are approached during the course of the endarterectomy, the plaques in the origins of these vessels are removed by gentle steady traction on the aortic plaque. The orificial disease will usually come

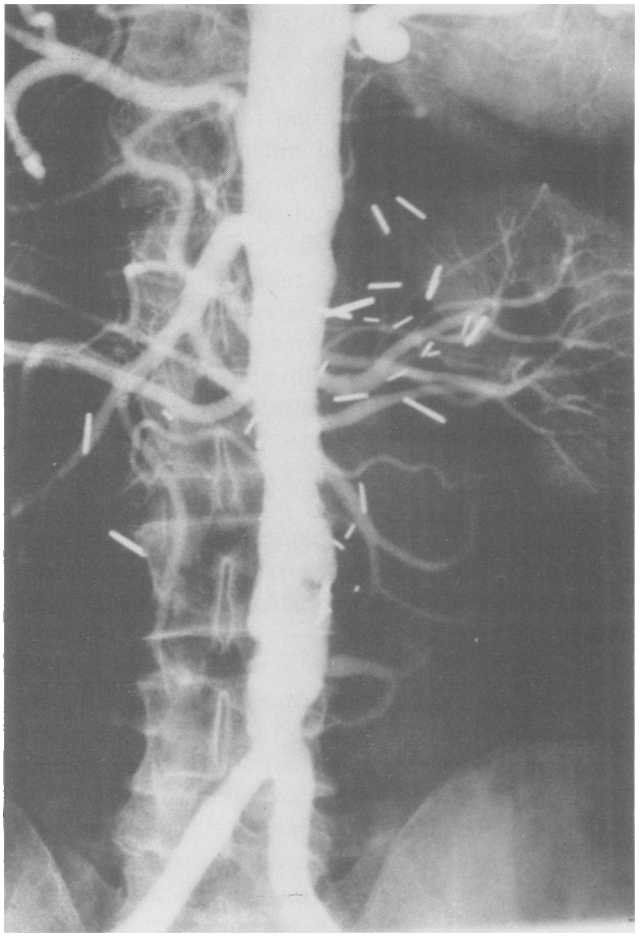

FIG. 2. Postoperative arteriogram showing complete resolution of all stenoses in all renal arteries.

out cleanly, leaving a smooth transition to the normal intima of the renal artery. It is sometimes possible to invaginate the renal artery into the aorta to directly inspect the transition point. Ater removal of the aortic plaque and removal of all debris, the distal intima in the aorta is secured, using tacking sutures if necessary, and the aortotomy closed. If any question exists concerning flow in any of the renal arteries, blood flow determination, doppler ultrasound examination, or operative arteriograms should be done.

Transrenal Endarterectomy

Case Report

A 72-year-old white female was admitted to St. Thomas Hospital for evaluation of poorly controlled hypertension of 3-years duration. She had a right hemispheric stroke 2 years previously and had subsequently had a right carotid endarterectomy with good recovery of function. Medications on admission included Inderal 20 mg t.i.d., Apresoline 50 mg t.i.d., Aldomet 500 mg t.i.d., and Lasix 40 mg q.d.

Blood pressure on admission was 200/100 mmHg in the right arm and 210/110 mmHg in the left arm. She had grade II fundoscopic changes. There were no abdominal masses and her lower extremities were well perfused with palpable pulses in both feet. Results of neurologic examination revealed minimal left-sided weakness.

On admission, her BUN/creatinine levels were 33/1.5 mg/dL, respectively. The remainder of her chemical profile was normal except for a mildy elevated fasting glucose.

Abdominal aortogram revealed atherosclerotic stenosis of both renal arteries proximally. Severe atherosclerotic disease was present throughout the infrarenal aorta extending into the iliac vessels.

At operation, the infrarenal aorta was densely calcified but the area between the renal arteries was relatively normal. A transverse incision was made extending from the anterior wall of one renal artery, across the aorta, and into the other renal artery. Endarterectomy of the renal arteries was then done followed by closure of the arteriotomy with a vein patch. Distal pulses and perfusion were unchanged after operation.

Her postoperative course was complicated by respiratory insufficiency requiring prolonged intubation and seizures believed to be related to her previous stroke. These were controlled with Dilantin. Serum creatinine level peaked at 1.8 mg/dL on the third postoperative day. The remainder of her hospitalization was uneventful and she was discharged 11 days after operation. BUN/creatinine levels at discharge were 10/1.3 mg/dL, respectively. Medications at discharge included Lopressor 100 mg t.i.d. and Dilantin 300 mg q.d.

Transrenal endarterectomy has the advantage of affording direct visualization when the plaque extends distally into the renal artery. We have found it most useful in patients with extensive calcification in the infrarenal aorta who need renal revascularization but have no indication for aortic resection.

The exposure necessary for an adequate endarterectomy is essentially the same as for transaortic endarterectomy since the arteriotomy will need to extend into the aorta to allow complete removal of the orificial plaque. To allow adequate intra-aortic visualization without distortion, it may be necessary to clamp the aorta above the level of the superior mesenteric artery.

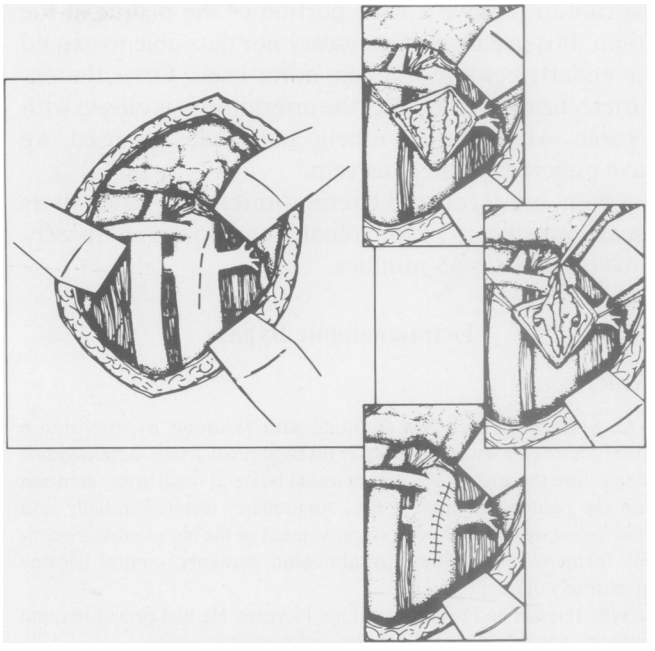

FIG. 3. Technique of transaortic endarterectomy.

After control is obtained, the arteriotomy is begun in the renal artery, beyond the distal extent of disease, and then extended back into the aorta (Fig. 4). When bilateral renal endarterectomies are planned, the arteriotomy is extended across the anterior aortic wall and out the opposite renal artery. Endarterectomy is then begun in the renal artery and proceeds back into the orifice, tak-

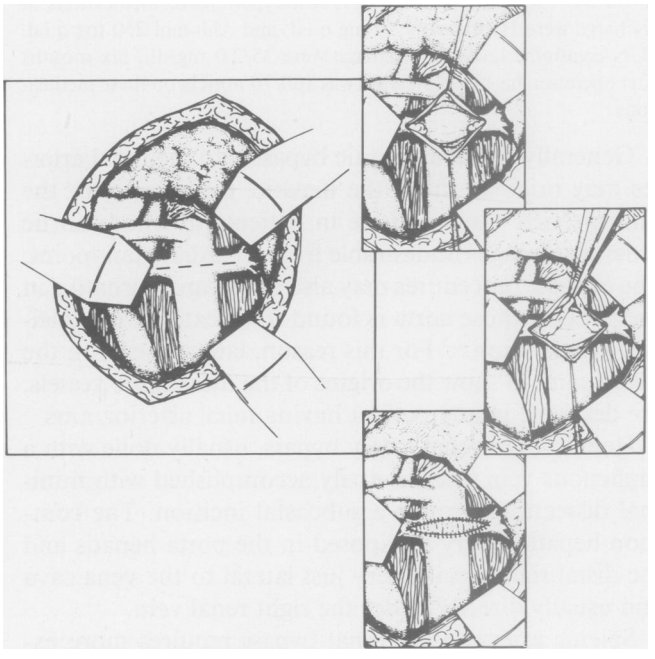

FIG. 4. Technique of bilateral renal endarterectomy.

ing care to remove a wide portion of the plaque at the origin. It is usually not necessary nor desirable to extend the endarterectomy into the aorta itself. Once the endarterectomy is complete, the arteriotomy is closed with a patch. Although a synthetic patch may be used, we have preferred saphenous vein.

When bilateral endarterectomies are done, it is usually possible to restore renal blood flow after an ischemic time of 30–45 minutes.

Extra-anatomic Bypass

Case Report

An 81-year-old man was admitted with recurrent hypertension 6 months after balloon angioplasty of his right renal artery. Arteriograms done before the angioplasty had revealed bilateral renal artery stenoses with the right being more severe. Angioplasty resulted initially in a good radiographic result with improvement in his blood pressure control. In the 6 weeks before his admission, however, control became increasingly difficult.

Hypertension had been present for 15 years. He had previously had coronary artery bypass and left femoral popliteal bypass.

Medications included Lopressor 100 mg q.i.d., Capoten 50 mg q.i.d., Quinidine 200 mg t.i.d., and Orinase 500 mg q.d.

Blood pressure on admission was 200/90 mmHg bilaterally. A-V nicking was present fundoscopically. Distal pulses were absent in the right leg, although femoral pulses were normal bilaterally.

BUN/creatinine levels on admission were 50/2.8 mg/dL, respectively. Renal arteriograms revealed bilateral renal artery stenoses, right being greater than left. Renal vein renins lateralized to the right.

At operation, his aorta was extensively calcified both above and below the renal arteries. Extra-anatomic bypass was performed to both renal arteries using a saphenous vein graft from the common hepatic to the right renal artery and by dividing and anastomosing, end-to-side, the splenic to the left renal artery.

After an uneventful recuperation, he was discharged from the hospital on the 13th postoperative day. Antihypertensive medications at discharge were Hydralazine 50 mg q.i.d. and Aldomet 250 mg q.i.d. BUN/creatinine levels at discharge were 35/2.0 mg/dL. Six months after operation his blood pressure was 160/70 mmHg on these medications.

Generally, extra-anatomic bypasses to the renal arteries may originate from the hepatic, the splenic, or the iliac arteries. Usually done in patients in whom aortic cross-clamping is undesirable from a cardiac standpoint, one of these procedures may also afford an alternative in the patient whose aorta is found to be extensively calcified at operation.[2,3] For this reason, lateral views on the aortogram, to show the origins of the mesenteric vessels, are desirable in any patient having renal arteriograms.

Hepato-right renal artery bypass, usually done with a saphenous vein graft, is easily accomplished with minimal dissection through a subcostal incision. The common hepatic artery is exposed in the porta hepatis and the distal right renal artery just lateral to the vena cava and usually directly under the right renal vein.

Splenic artery to left renal bypass requires more extensive dissection, exposing the splenic artery from beneath the pancreas. The splenic artery can then be directly anastomosed to the renal artery, either end-to-side or side-to-side or a vein graft can be constructed between the two.

Iliac-renal bypass may be useful in the occasional patient with extensive aortic disease that is nonocclusive and who has iliac vessels with soft anterior walls. When possible, we prefer to use either the hepatic or splenic arteries for extra-anatomic bypass because of the anatomic proximity and therefore shorter graft length.

Discussion

The decision to perform renal endarterectomy instead of a bypass procedure commonly is based on technical problems related to the status of the infrarenal abdominal aorta. In patients who have simultaneous renal reconstruction and aneurysm resection or aortofemoral bypass, the problem is solved by resection of the diseased aorta. Renal bypass grafts can then be safely brought off of the Dacron graft.

In the patient with a diseased aorta and no specific indication for its resection, the problem becomes more difficult. Attempts at aortorenal bypass from such a diseased aorta may result in a compromised anastomosis or, more frighteningly, aortic injury or embolization of debris into the distal circulation. The opening in the aorta in this situation is of insufficient size to allow adequate visualization of the interior of a diseased aorta to prevent these complications. In this situation, we have frequently replaced the infrarenal aorta with a Dacron graft to have a safe place from which to bring the renal bypass. The results of this technique have been quite satisfactory but the aortic resection does add to the magnitude of the procedure.

In those patients in whom the significant aortic disease is limited to the infrarenal aorta, leaving the aorta at the level of the renal arteries relatively free of calcific atheromatous disease, consideration for endarterectomy becomes appropriate. Careful analysis of the arteriograms as well as the operative findings and anatomic location of the various viscerial orifices should precede the decision to proceed with endarterectomy. Almost without exception, disease within the aorta is more extensive than is apparent from either angiographic or direct assessment. Clamping and opening a badly diseased aorta at this level carries significant risk, and in this situation resection of the infrarenal aorta may be safer. In two of our patients, severe disease in the juxtarenal aorta led to complications that were ultimately fatal.

In those patients in whom endarterectomy is believed to be preferable, wide exposure of the juxtarenal aorta is obtained so that cross-clamps can be placed proximally and distally. Partial occlusion aortic clamps that limit

visualization of the aortic lumen are never used. This wide exposure greatly facilitates the expeditious performance of the endarterectomy and allows thorough evaluation of the interior of the aorta, reducing the chance of embolic complications.

We have used transaortic renal endarterectomy through a longitudinal aortotomy primarily for dealing with patients who required relief of proximal stenosis in multiple renal arteries. Popularized by Wylie et al.,[4] the technique has also been used in conjunction with infrarenal aortic resection for aneurysmal or occlusive disease.[5] Extensive disease within the aorta makes the procedure somewhat more difficult, but the relatively larger size of the aortotomy allows adequate room for careful inspection and adequate securing of the distal end of the endarterectomy.

The procedure has the disadvantage of requiring a pull-out or blind endarterectomy of the renal origins. For this reason, it is appropriate only when the stenosis is limited to the proximal renal artery. Atheromatous disease extending out into the mid and distal portions of the renal arteries is a relative contraindication to this procedure. Although it is sometimes possible to remove these long plaques from within the aorta, treatment by transrenal endarterectomy is preferable and safer.

Extra-anatomic renal revascularization, like extra-anatomic procedures in other locations, is a compromise procedure. To hopefully lessen the morbidity of the procedure, inflow into the renal artery is obtained from a vessel in which flow may be compromised compared with the aorta. Our experience with extra-anatomic renal revascularization is limited, and in the past 5 years we have used it only twice. Transluminal renal angioplasty may be a potential alternative in patients whose general medical condition makes extra-anatomic bypass a consideration although balloon dilatation for ostial renal lesions has had disappointing long-term results.[6] Balloon dilatation had failed previously in the patient in whom we performed a hepatorenal bypass.

Even in patients with extensive calcific aortic disease, the anterior wall of the iliac arteries may be relatively disease free, and if no major proximal obstruction is present, may offer an easily accessible and safe site for the proximal anastomosis.

The mortaltiy rate of 16.6% in this group of patients was the highest of any group in our recent experience and deserves comment. A number of factors may have played a role. First, 14 of 18 patients had bilateral procedures. In our experience, bilateral procedures have carried a higher mortality rate than unilateral procedures whether simple renal artery bypass or combined procedures were performed. Renal revascularization in combination with other major abdominal vascular procedures was performed in five of 18 patients. Others have reported increased mortality with combined procedures.[7,8] Because of our preference for bypass grafts, our experience with renal and visceral endarterectomy is relatively limited. Stanley et al.[9] have pointed out that results of renal endarterectomy are better in the hands of surgeons who perform the operation on a frequent basis. Of paramount importance, however, is that, by the nature of the procedure, operations that require exposure, control, and intraluminal manipulation of the pararenal aorta carry potentially increased risk should problems develop. Two of the three deaths in this group occurred as a direct result of technical complications related to more extensive aortic and renal artery disease than was appreciated before the start of the procedure. In retrospect, renal artery bypass would have been safer, even though it would have necessitated infrarenal aortic resection in one patient.

Conclusions

Alternative methods of renal revascularization, including transaortic endarterectomy, direct renal endarterectomy, and extra-anatomic bypass, may be useful in certain patients, particularly those requiring revascularization of multiple renal arteries and those in whom the infrarenal aorta is severely diseased. Because of the potential for serious complications, however, patients should be carefully selected before a direct approach is taken to the pararenal aorta. In patients with extensive disease involving the aorta at this level and the renal arteries, bypass grafting is probably safer even if resection of the infrarenal aorta is necessary to have a point from which to originate the graft.

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Discussion

Dr. Charles H. Wray (Augusta, Georgia): It is always a distinct pleasure in watching the maturation of a surgeon. I remember with pleasure working with Dr. Mulherin when he was a medical student on Dr. Moretz' vena caval projects. Now he and Dr. Edwards are refining our knowledge about renal revascularization. They have, out of their experience, identified a subset of patients who, because of anatomic variation or severity of disease, present an unusual challenge to our technical ability. As usual, they have iterated in detail how to do this. The techniques are well described in the manuscript. They may also have identified a subset of patients who are challenging because the severity of the disease makes the risk–benefit ratio low. Certainly in this small subset the mortality was high, complications were severe, and few were cured of hypertension.

The illustrated cases did show improvement in renal function. Several times during this meeting questions have been raised about how to teach residents to operate. I believe Dr. Mulherin and Dr. Edwards have raised in my mind a more fundamental question, not about how to operate, but who should be operated on.

After this extensive experience, can they tell us, as a refinement of judgment, who with renal artery stenosis should not be operated on for renal hypertension or renal failure?

Dr. Joseph L. Mulherin, Jr. (Closing discussion): I am not sure there is an answer to your question to cover all the bases. Certainly I have found myself, as time has gone by and hopefully experience has been gained, becoming more conservative, especially in older patients in whom the indication for operation is an aneurysm or an aortofemoral bypass and have tended to let alone renal artery disease except in its most critical circumstances.

The majority of the patients in this group were operated on for renal artery stenoses, although certainly in the total series there are a number of patients in whom renal artery bypass was performed as a concomitant procedure.

The reason for looking back at this group of patients was our dissatisfaction or frustration in those patients who were operated on for renal artery stenosis in whom it was necessary to resect the aorta to be able to perform the bypass.

I have always believed that this was adding more to the operation than we wanted to do. In looking back at the results of aortic resection, the results seem to be certainly acceptable, and with morbidity and mortality rates that in our limited experience are preferable to those with endarterectomy.