EX VIVO RENAL PERFUSION AND AUTOTRANSPLANTATION IN TREATMENT OF CALCULOUS DISEASE OR ABDOMINAL AORTIC ANEURYSM*

CHARLES W. PUTNAM, M.D.
CHARLES G. HALGRIMSON, M.D.
DEREK P. STABLES, M.D.
RONALD PFISTER, M.D.
ROBERT W. BEART, JR., M.D.
GAUKE KOOTSTRA, M.D.
MEHMET HABERAL, M.D.
DALE ATKINS, M.D.
THOMAS E. STARZL, M.D.

From the Departments of Surgery and Radiology, the Veterans Administration Hospital and the University of Colorado Medical Center, Denver, Colorado

ABSTRACT — Two more indications are described for temporary ex vivo perfusion of kidneys with revascularization of these organs as autografts to orthotopic or heterotopic locations. One of the patients had staghorn calculi which were removed from a solitary kidney. The other patient had both kidneys autografted in the course of a surgical procedure on an extensive abdominal aortic aneurysm.

The term "bench surgery" to describe reconstructive surgery on diseased kidneys receiving asanguineous perfusion outside the body was coined by Guerriero, Scott, and Joyce.[1] The objective of carrying out complex extracorporeal operative procedures in an asanguineous state was made possible by the instruments and techniques which were developed by Belzer, Ashby, and Dunphy[2] to preserve cadaveric kidneys for renal homotransplantation. The first uses of bench surgery were reported by Corman *et al.*[3] Their report and subsequent ones about bench surgery have shown how this sophisticated approach is a significant advance in urologic operative procedures. So far, kidney salvage has been achieved after traumatic injury,[3] with renal carcinoma in a single kidney,[4] with renal arterial atherosclerosis, fibrous dysplasia, or aneurysm,[3-6] and with deficiencies in ureteral length.[4]

In this report two more uses of bench surgery will be described. One patient had staghorn calculi in his remaining kidney and had been refused surgical intervention at at least two other major urology centers. The other patient had an abdominal aortic aneurysm with abnormalities of both renal arteries and early renal failure.

Case Reports

Case 1

The right kidney of a fifty-five-year-old man was removed in 1951 for cystic disease and chronic pyelonephritis. In 1968 regional enteritis developed, and in 1972 a large staghorn calculus of his remaining left kidney was diagnosed. The kidney also contained three cysts, the largest measuring 5 cm. in diameter. There was beginning hydronephrosis. Between 1972 and July,

*The work was supported by research grants from the Veterans Administration; by Grants AI-AM-08898 and AM-07772 from the National Institutes of Health; and by Grants RR-00051 and RR-00069 from the General Clinical Research Centers Program of the Division of Research Resources, National Institutes of Health.

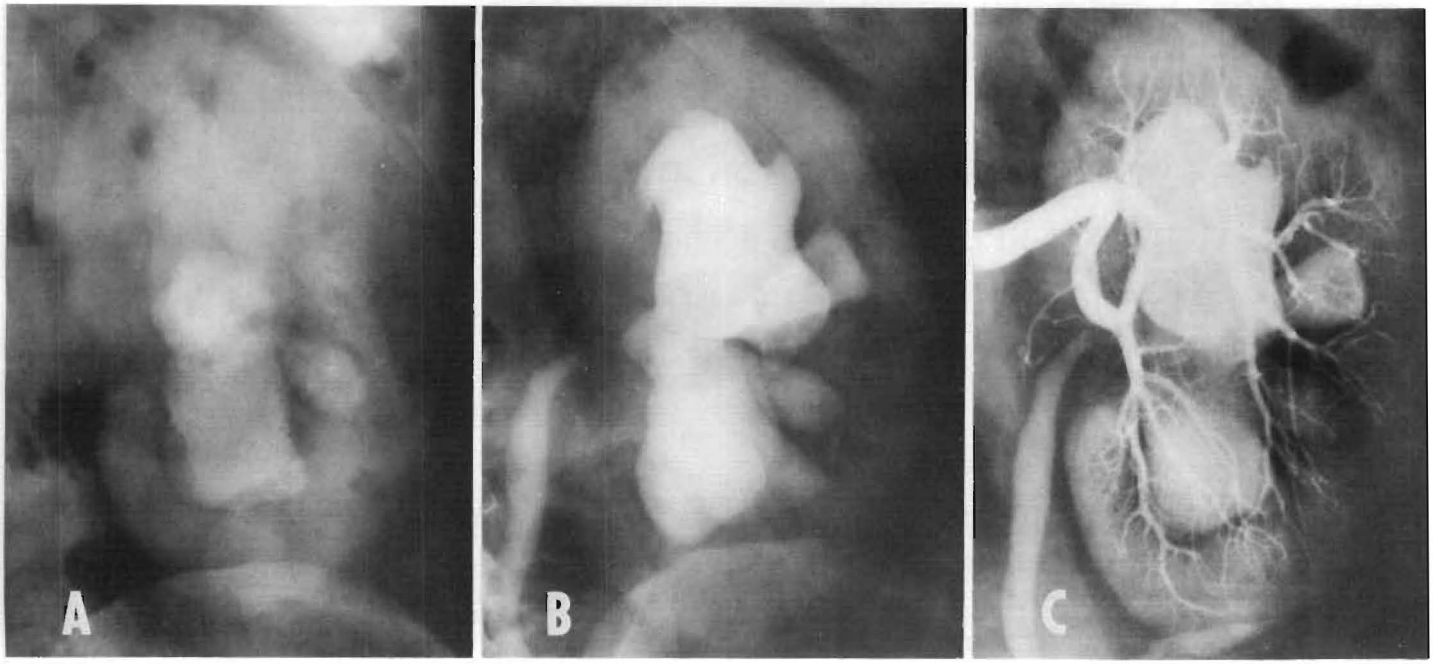

FIGURE 1. *Case 1. Preoperative x-ray films. (A) Plain film of abdomen demonstrating radiopaque calculi filling pelvis and calyces of single kidney. (B) Excretory urogram; cause of hydronephrosis was not apparent. (C) Selective renal arteriogram; single artery supplied left kidney.*

1974, the renal calculi enlarged, and the hydronephrosis increased. At admission to the Colorado General Hospital on July 15, 1974, the blood urea nitrogen was 20 mg. and the plasma creatinine 1.9 mg. per 100 ml., and the creatinine clearance 73 ml. per minute. Radiographic studies showed the enlarged kidney to be full of stones which were packed in the pelvis and calyces (Fig. 1A). The cause for the hydronephrosis could not be accurately determined (Fig. 1B). The kidney was supplied by a single artery (Fig. 1C).

The surgical procedure was carried out through a midline incision. The left kidney was mobilized, and the artery and vein were skeletonized. After transecting the vessels, blood was flushed from the organ using a balanced electrolyte solution containing low molecular weight dextran (Perfudex).* Initially, the perfusion was directed into one of the two main branches of the renal artery so that Brödel's line could be located and marked at the site of the color change.[7] This line was posterior to the mid-coronal plane. The flushing was then completed, and continuous hypothermic pulsatile† perfusion was begun with deflocculated plasma.[2]

Initially, the ureter was left intact but occluded with a noncrushing clamp to prevent blood from the ureteric vessels from backing up into the extracorporeal circuit. After taking a plain x-ray film (Fig. 2A), the kidney was opened by a total coronal incision along Brödel's line (Fig. 3A). The large stones of the staghorn calculus were removed as well as several thousand smaller stones (Fig. 3B). These were picked out, scooped out, or flushed out with a sterile dental spray (Water-Pik).‡ A second roentgenogram showed that all of the stones except two had been removed (Fig. 2B). The larger one was found within the kidney substance and extracted. The other could not be located and was assumed to be similarly buried.

The total extracorporeal time of the kidney was about three and one-quarter hours. After bivalving the kidney (Fig. 3A), the perfusion was made intermittent to minimize loss of the perfusate from transected vessels. When the perfusion was in effect, the spurting of fluid from these vessels permitted their identification and ligation or suture. A total of 2,800 ml. perfusate was used. After the stone removal was completed and after good hemostasis was achieved, an internal nephrostomy tube was inserted from within the kidney through the renal pelvis and ureter toward the bladder. It met with an obstruction several inches from the ureterovesical junction. This was shown to be caused by hundreds of small stones impacted in the distal ureter. Eventually, it was necessary to transect the ureter an inch or two from the bladder to milk and wash out all the stones in the ureter.

The bivalved kidney was then sewn back together. The calyces were accurately approximated using continuous 4-0 plain catgut. The

*Pharmacia Laboratories, Piscataway, New Jersey.
†Waters Instruments Inc., Rochester, Minnesota.
‡Teledyne Corporation, Fort Collins, Colorado.

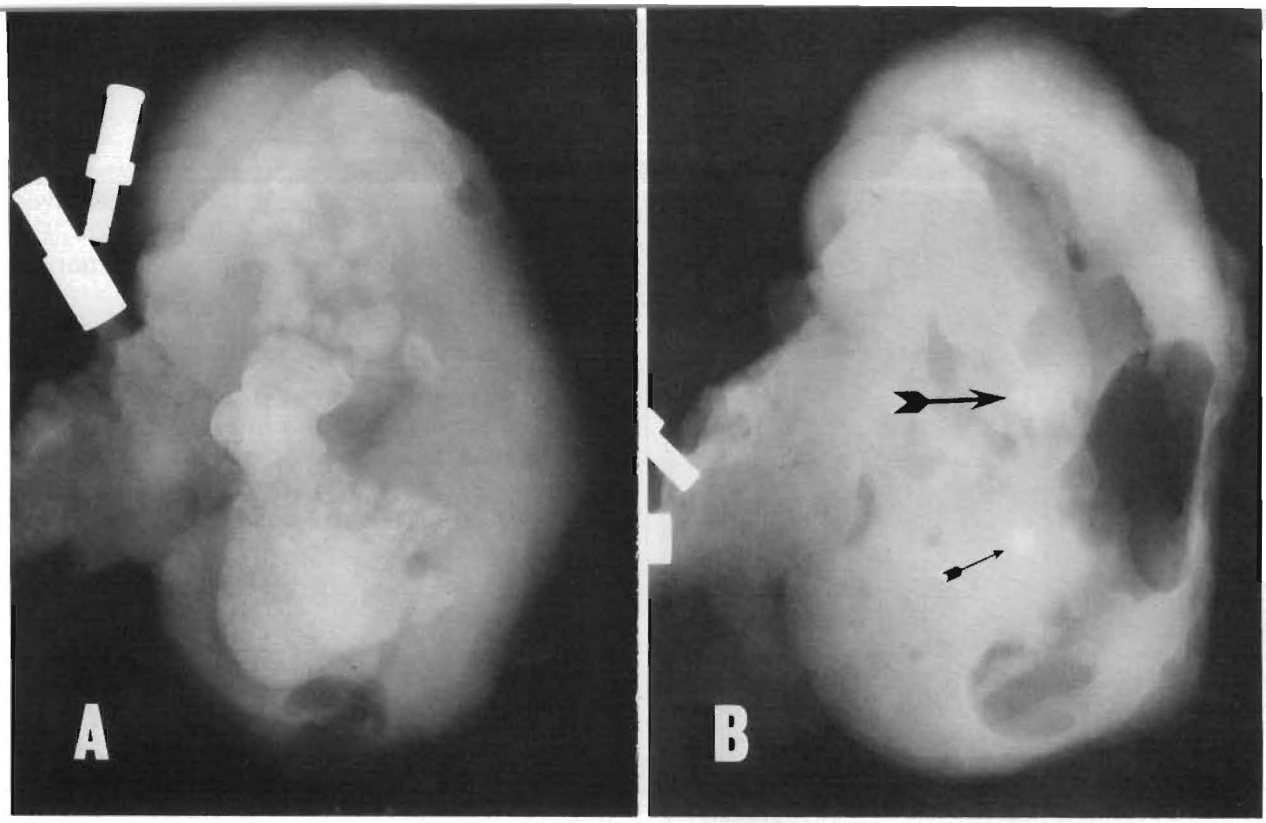

FIGURE 2. *Case 1. Operative roentgenograms taken during ex vivo perfusion. (A) Plain film before splitting kidney demonstrating many stones. (B) After bivalving kidney and removing as many stones as possible, second film demonstrated two residual calculi (arrows), larger one of which (large arrow) was located and extracted. Second smaller stone could not be found and was assumed to be lodged in renal parenchyma.*

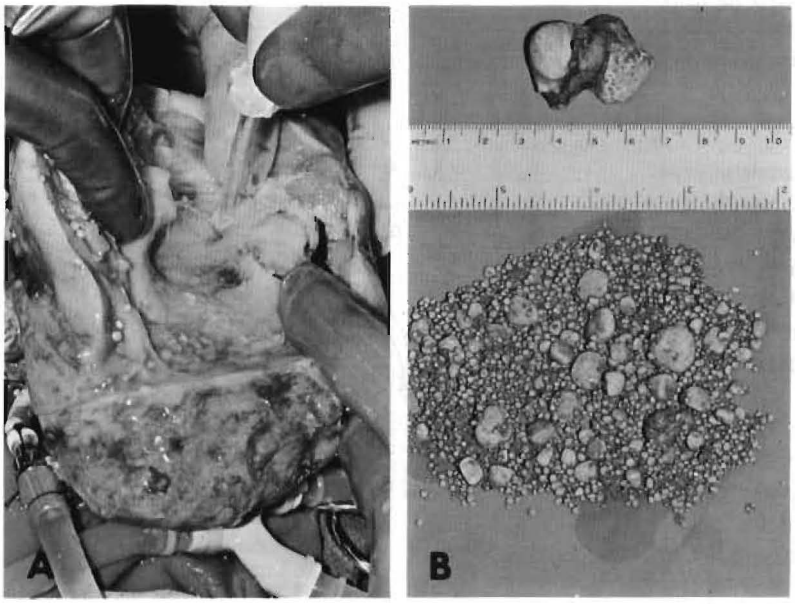

FIGURE 3. *Case 1. (A) Extraction of stones from bivalved kidney. Sterile dental spray being used to wash stones from recesses of renal pelvis and calyces. Note perfusion lines attached to renal vessels. (B) Some of stones removed from single kidney and its ureter. These were small fraction of total number removed.*

renal cortex was approximated with a few buried interrupted catgut sutures, and the surface, including the capsule, was closed with continuous 2-0 chromic catgut. Nephrostomy tubes were inserted through the superior and inferior extremities of the kidney for later exteriorization out the lower flank. The kidney was revascularized in the pelvis. The location was made extraperitoneal by dissecting the peritoneum off the left lateral wall of the abdomen, starting at the midline incision and carrying the peritoneal mobilization all the way around to the iliac vessels. The renal vein was anastomosed end to side to the external iliac vein, and the renal artery was anastomosed end to end to the hypogastric artery. After revascularization there was oozing from the kidney but no serious hemorrhage. Ureteroneocystostomy was performed as we have described

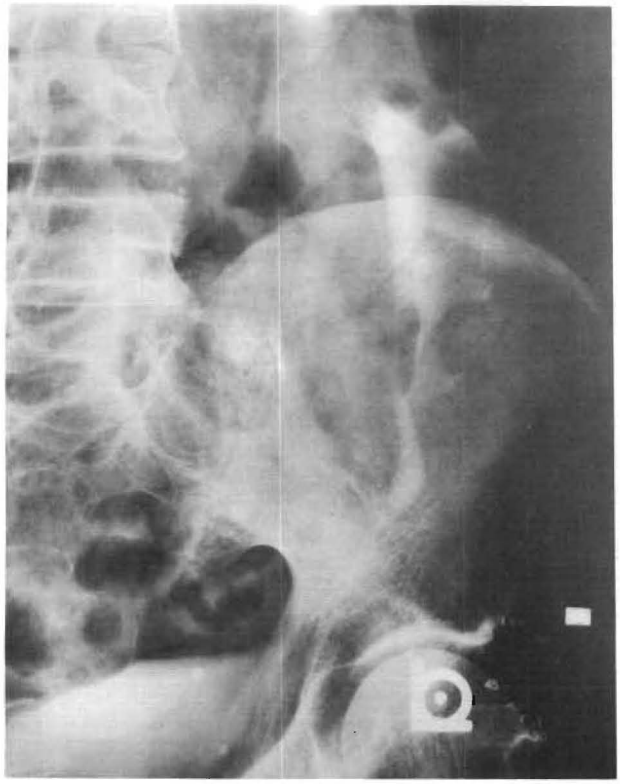

FIGURE 4. *Case 1. Excretory urogram two months after autotransplantation and one month after reoperation. Hydronephrosis present preoperatively has resolved.*

before.[8] The previously placed transureteral nephrostomy tube was brought out through the bladder incision and abdominal wall. Before closing the abdomen the regional enteritis was treated by resecting approximately 18 inches of the diseased terminal ileum and adjacent ascending colon. An end to end ileocolostomy was performed.

Postoperatively, the patient had moderate hematuria which cleared over the next several days. Renal function was always adequate. Eight days after surgery the internal nephrostomy tube which passed from the renal pelvis through the ureter, out the bladder, and through the abdominal wall was removed. Thereafter, urine flow to the bladder ceased because of an extrinsic obstruction near the ureteropelvic junction. At reoperation twenty-nine days after the primary procedure, it was found that this area was compressed by swollen and edematous fat and by scarring. This extraneous tissue was removed. A T-tube stent with one arm passing into the renal pelvis and the other directed toward the bladder was inserted in the midureter, and one nephrostomy tube was removed. The T tube and the second nephrostomy tube were finally removed after another three and one-half weeks. The patient has had a perfect result with a normal autograft excretory urogram (Fig. 4).

Chemical analysis showed that the stones were composed of uric acid. To prevent recurrent calculi, the patient is being treated with allopurinol and by alkalinization of the urine. His present renal function tests include a blood urea nitrogen of 23 mg. and a plasma creatinine of 1.9 mg. per 100 ml., and a creatinine clearance of 55 ml. per minute.

Case 2

A sixty-three-year-old man was referred because of severe hypertension, reduced renal function, and a large abdominal aortic aneurysm which involved the left renal artery (Fig. 5A). The right renal artery originated above the aneurysm but had a high grade stenosis at the origin (Fig. 5A). Selective left and right renal vein catheterizations showed serum renin concentrations of 12 and >35 ng. per milliliter per hour (normal 2.1 to

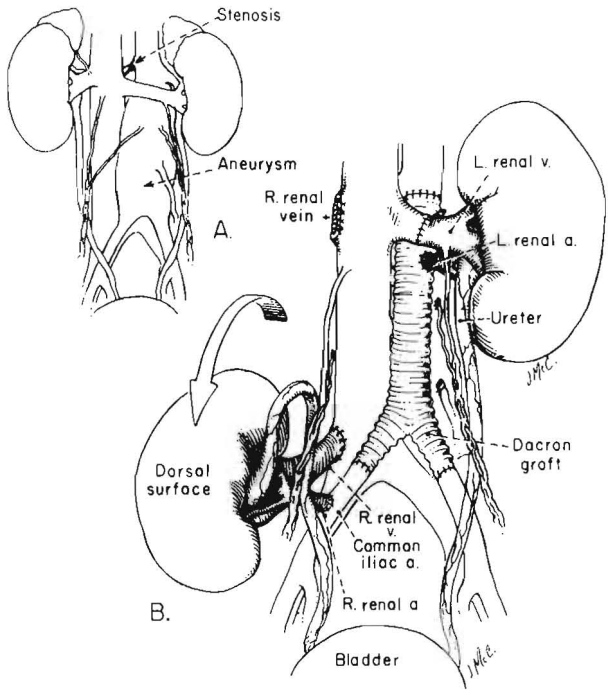

FIGURE 5. *Case 2. (A) Large abdominal aortic aneurysm involving left renal artery. Right renal artery had severe stenosis at its origin. (B) Bilateral renal autotransplantations after replacement of aneurysm with knitted Dacron graft. Left kidney revascularized orthotopically; right kidney rotated anteroposteriorly to facilitate vascular anastomoses and reimplanted heterotopically.*

FIGURE 6. *Case 2. Excretory urogram one month after bilateral renal autotransplantations; both kidneys visualized promptly.*

13.8), respectively. The blood urea nitrogen before operation was 50 mg. and the serum creatinine was 1.7 mg. per 100 ml., and the creatinine clearance was 43 ml. per minute.

On August 15, 1974, the abdomen was explored through a complete midline incision. Both kidneys were mobilized, removed from their fossae without interrupting the ureters, and placed on extracorporeal perfusion. The right kidney was about two-thirds normal size, measuring 8 cm. in length and of normal consistency. The left kidney was 13 cm. in length, but it was firmer than normal and had a pitted surface. Both ureters were occluded with noncrushing clamps to prevent backbleeding into the perfusion circuit through the ureteric vessels. The aneurysm was then opened and a preclotted, knitted Dacron bifurcation graft, developed by DeBakey *et al.*,[9] was inserted with the technique described by Creech.[10] The upper anastomosis was placed above the left renal artery and the lower anastomoses were to the common iliac arteries (Fig. 5B). Because of difficulties in achieving hemostasis, it was not possible to revascularize the left and right kidneys until four and five and three-quarter hours after they were placed on perfusion. The left kidney was revascularized in the orthotopic location, anastomosing the renal artery end to side to the Dacron graft and the renal vein end to end to the renal vein (Fig. 5B). The right kidney was turned anteroposteriorly and dropped into the extraperitoneal space of the right pelvis. The renal artery was anastomosed end to side to the distal common iliac artery and the renal vein to the side of the inferior vena cava (Fig. 5B).

Postoperatively, good urine excretion was initially obtained, but after twenty-four hours the patient became oliguric. Nine hemodialyses were required during the next twenty days following which adequate function returned. The patient was discharged from the hospital thirty-three days postoperatively. Renal function tests two months postoperatively, which were improved over the preoperative measurements, included a blood urea nitrogen of 25 mg. and a plasma creatinine of 1.3 mg. per 100 ml., and a creatinine clearance of 54 ml. per minute. His blood pressure is now 130/80 mm. Hg without antihypertensive therapy. His excretory urogram at one month postoperatively showed prompt visualization of both autotransplanted kidneys (Fig. 6).

Comment

The successful treatment of the patient with the staghorn calculus by conventional means would have involved a substantial risk. To remove the calculous material from the kidney required about three hours despite perfect exposure in a bloodless field. The stones were packed in every portion of the calyces to the extent that their discovery presented the main problem. Even after the kidney was free of stones, there were so many calculi in the ureter that ureteral transection was necessary to clean these out. Eventually urinary tract continuity was restored with ureteroneocystostomy.

In addition, the solitary kidney in this patient was larger than normal and badly distorted because of multiple cysts. These features would have made the large nephrotomy incision difficult to make and close under other than asanguineous conditions. Although the incision in the so-called avascular Brödel's line could be planned under ideal conditions, the incision plane actually crossed many vessels, some as large as a millimeter in diameter. These could be identified easily and controlled, especially during the perfusion which was intermittently provided during this phase of the procedure. Furthermore, hemostasis

was facilitated by the unparalleled exposure which permitted accurate approximation in layers of the bivalved kidney.

Although this patient had to undergo a reoperative procedure four weeks later to relieve an extrinsic compression of the ureteropelvic junction, his convalescence was surprisingly uncomplicated. From this experience, we have concluded that the approach of ex vivo perfusion and autotransplantation is the procedure of choice in selected cases of difficult staghorn calculi, which might otherwise be deemed inoperable.

In the second case, the reason for the acute renal failure postoperatively was not apparent. Initially the autotransplanted kidneys produced good volumes of urine, but this was followed by an apparent acute tubular necrosis with oliguria, severe enough to require hemodialysis for twenty days. Recovery was thereafter uncomplicated, and the eventual renal function was significantly better than that preoperatively. The kidneys may have been unusually susceptible to injury because of preexisting disease.

4200 East Ninth Avenue
Denver, Colorado 80220
(DR. PUTNAM)

References

1. GUERRIERO, W. G., SCOTT, R., JR., and JOYCE, L.: Development of extracorporeal renal perfusion as an adjunct to bench surgery, J. Urol. **107:** 4 (1972).
2. BELZER, F. O., ASHBY, B. S., and DUNPHY, J. E.: Twenty-four hour and 72 hour preservation of canine kidneys, Lancet **2:** 536 (1967).
3. CORMAN, J. L., *et al.*: Ex vivo perfusion, arteriography, and autotransplantation procedures for kidney salvage, Surg. Gynecol. Obstet. **137:** 659 (1973).
4. HUSBERG, B. S., *et al.*: Five cases and five unusual indications for autogenic renal transplantation, Acta Chir. Scand., in press.
5. ORCUTT, T. E.: Bilateral ex vivo renal artery reconstruction with autotransplantation, Rev. Surg. **30:** 374 (1973).
6. BELZER, F. O., SALVATIERRA, O., PERLOFF, D., and GRAUSZ, H.: Surgical correction of advanced fibromuscular disease of the renal arteries, Surgery **75:** 31 (1974).
7. HARRISON, L. H., and NORDAN, J. M.: Anatrophic nephrotomy for removal of renal calculi, Urol. Clin. North Am. **1:** 333 (1974).
8. STARZL, T. E., *et al.*: Urological complications in 216 human recipients of renal transplants, Ann. Surg. **172:** 1 (1970).
9. DEBAKEY, M. E., COOLEY, D. A., CRAWFORD, E. S., and MORRIS, G. C., JR.: Clinical application of a new flexible knitted Dacron arterial substitute, Am. Surg. **24:** 862 (1958).
10. CREECH, O., JR.: Endo-aneurysmorrhaphy and treatment of aortic aneurysm, Ann. Surg. **164:** 935 (1966).