Bench Surgery and Renal Autotransplantation in the Pediatric Patient

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SURGERY at the work bench has developed as a by-product of the extensive experience in renal homotransplantation. A basic tenet of the transplant operation is organ survival outside the human body for a finite period. Recent refinements in kidney preservation have extended the permissible ex vivo period to several days. Consequently, extracorporeal procedures have become highly feasible and a practical adjunct for operative renal surgery.

Bench surgery and autotransplantation thus far have been underexploited in pediatric surgery despite potential applicability in a significant number of childhood lesions. At the University of Colorado Medical Center, 14 patients have been treated by extracorporeal renal surgery and have been reported in part.[1-3] The purpose of this communication is to review the technical aspects of this new operative procedure, present two case reports, and discuss the potential role of extracorporeal surgery and renal autotransplantation as it pertains to the pediatric patient.

PATIENT MATERIAL

The clinical experience with extracorporeal renal surgery and autotransplantation is shown in Table 1. There has been no mortality. Autotransplantation failed in one patient (Patient 4).[4] Although partially described earlier,[1,2] Patients 7 and 1 are presented in detail to illustrate several specific indications and technical points in management.

CASE REPORTS

Patient 7

This was a 6-yr-old boy admitted for consideration for permanent urinary diversion. At 5 mo old he was found to have bilateral hydronephrosis secondary to posterior urethral valves. Multiple operative procedures performed over the ensuing 5 yr had resulted in a scarred, rigid, distal ureter, massive ureteral reflux, marked caliectasis of the left kidney and a functionless right kidney (Fig. 1). He continued to have recurrent urinary tract infections.

At surgical exploration, the distal one-half of the left ureter was discarded. The proximal ureter, although dilated, was supple and appeared salvageable. An attempt to obtain ureteral length by mobilizing the kidney was unsuccessful, and it was decided to carry out autotransplantation. Because of long-standing hydronephrosis, the kidney was too large to be confined

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Table 1. Renal Autotransplantation (University of Colorado Series)

Patient No.	Diagnosis	Age (Yr)	Sex	Autografted Kidney	Kidney Salvaged
1*	Renavascular hypertensian (medial fibroplasia)	23	F	R + L	Yes–Yes
2	Renavascular hypertension (stob wound)	20	M	R	Yes
3	Renavascular hypertension (medial fibraplasia)	42	F	R	Yes
4*	Bilateral renal cell carcinomas	45	M	R + L	No–No
5	Renavascular hypertension (atherosclerosis)	43	M	L	Yes
6	Renal cell carcinoma (solitary kidney)	52	F	R	Yes
7	Congenital obstructive uropathy	6	M	L	Yes
8	Thrombosis, homagraft renal artery	30	M		Yes
9	Renovascular hypertension (renal artery stenosis after bypass graft)	44	M	L	Yes
10	Calculi (solitary kidney)	55	M	L	Yes
11	Renovascular hypertension and aortic aneurysm	63	M	L	Yes
12†	Renavascular hypertension and aortic aneurysm	63	M	R + L	Yes–Yes
13†	Renovascular hypertension (medial fibroplasia)	44	F	R + L	Yes–Yes
14	Renovascular hypertension (medial fibroplasia)	39	F	R	Yes

* Bilateral autotransplantation (delayed).

† Bilateral autotransplantation (simultaneous).

Fig. 1. The preoperative excretory urogram of Patient 7. The right kidney does not function. The left kidney shows marked caliectasis; the proximal ureter is dilated; the distal ureter is poorly visualized and on other films is rigid and stenotic. Metallic clips are from prior attempts at ureteral reimplantation.

to the iliac fossa and be revascularized by iliac vessels. Therefore, the left aortic bifurcation and the left common iliac vein were prepared for subsequent renal anastomosis.

The left kidney and proximal ureter were removed and flushed for 10 min with chilled (5°C) Perfudex. Revascularization was by end-to-side anastomoses of the renal artery and vein to the aorta and left common iliac vein, respectively. Total ischemic time was 45 min. The proximal ureter reached the bladder easily and was reimplanted by the Leadbetter–Politano technique[5] after a "tailoring" procedure.[6] His postoperative course was unremarkable.

Three months later excretory urogram showed increasing obstruction of the ureteroneocystomy. At reoperation there was still sufficient ureter available to redo the ureterovesical anastomosis, which was done by a Paquin technique.[7] He has done well in the 14 mo since operation.

Patient 1

Hypertension developing in late adolescence was proved to be due to bilateral medial fibroplasia in this 23-yr-old girl. The right renal artery was most severely involved by excretory urography, arteriography, and the right-to-left ratio of plasma renin activity. Following bench surgery the right kidney was autotransplanted to the left iliac fossa by end-to-end anastomosis of the hypogastric arterial branches to three arterial branches from the main renal artery. Postoperatively, hypertension disappeared but during the ensuing months it gradually recurred. On repeat arteriography all branches to the transplanted kidney were patent, but the left renal arterial stenosis was seen to have progressed. Consequently, the left kidney was autotransplanted to the right iliac fossa, again using ex vivo renal arteriography, and all visualized lesions were resected at the bench. The three segmental renal arterial branches were individually anastomosed to the right hypogastric artery branches. The kidney was revascularized after 5 hr and 35 min. Postoperatively, the patient has been normotensive. An arteriogram 6 wk after the second autotransplantation showed that all six arterial anastomoses were patent (Fig. 2).

RATIONALE

The unusual tolerance of the kidney to an ex vivo state permits a variety of special operations that would be difficult or impossible in situ. Exposure of intrarenal lesions and dissection of secondary arterial branches, for example,

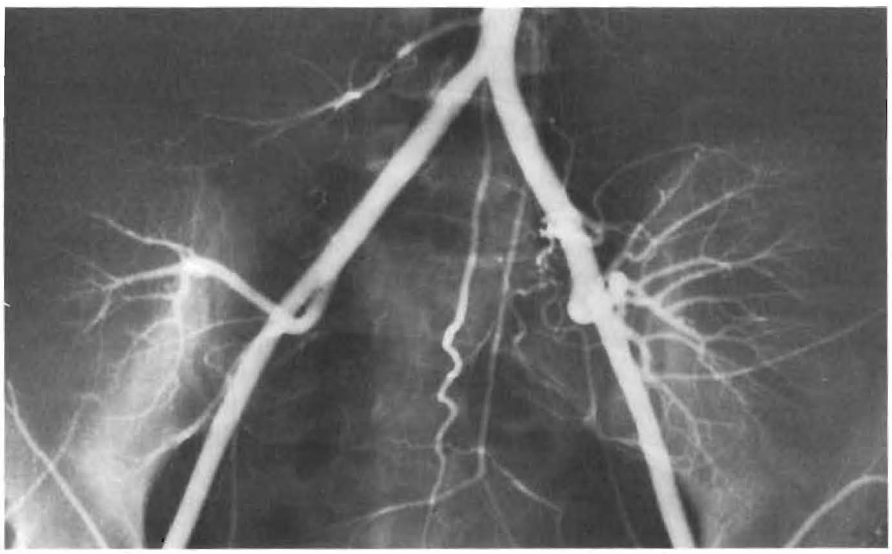

Fig. 2. Postoperative angiogram of Patient 1. Both kidneys have been autotransplanted into the contralateral iliac fossa. Revascularization in both instances required triple anastomoses between the branches of the hypogastric and renal segmental arteries.

are greatly facilitated by operating on the organ in a free state. Furthermore, a totally bloodless field allows a more deliberate and unhurried surgical approach that might be otherwise hazardous or unsuccessful. In addition, if constant perfusion is being used, the operative repair can be tested and revised before reimplantation.

It is unnecessary to point out that kidney transplantation is more expeditiously performed in the iliac rather than the renal fossa. The iliac vessels are relatively superficial, readily accessible and, by their proximity to the bladder, predispose to handy ureteral reimplantation. Moreover, the trifurcation of the hypogastric artery makes several large arterial branches available for anastomosis to segmental renal arteries that may be advantageous in certain cases of renovascular hypertension (Patient 1). The iliac fossa is still a preferable transplant location even if the organ is oversized, which may be the case in a solitary, hypertrophied kidney or in long-standing hydronephrosis. In this situation, the proximity of the nearby aorta and vena caval bifurcation make these vessels more suitable for renal revascularization (Patient 7).

TECHNIQUE

The essential components of bench surgery are: (1) nephrectomy; (2) renal perfusion; (3) extracorporeal operation, and; (4) autotransplantation. The technical aspects of the procedure are straightforward and, to some extent, elementary. The operation may be varied according to the preference of the surgeon and the renal lesion to be corrected. The nephrectomy may be done through a flank incision and, after extracorporeal reconstruction, the kidney reimplanted via a standard transplant approach.[8] Alternatively, the entire operation may be carried out through a single transperitoneal incision. The ureter may be left attached to the bladder or it may be divided, taken with the kidney to the work bench, and then reunited to bladder, ureter, or renal pelvis. The kidney may be transplanted in its normal anatomic relationship or turned front to back or upside down using either the ipsilateral or contralateral iliac fossa as the transplant bed.

Flushing the kidney with chilled electrolyte solution to which procaine and/or heparin have been added is a simple, effective method of renal preservation for 1 or 2 hr. Employment of continuous pulsatile perfusion extends the "safe" ischemic period of the kidney to at least a half a day and perhaps as long as 3 days.[9] In addition, a continual assessment of the functional status of the organ is permitted and the opportunity afforded to alter pressure and flow rates. Its disadvantages are the expense and the need for a trained technician.

After removal, the kidney may be perfused and refrigerated while the operation continues or, taken to the work bench and operated on immediately. If the ureter is left in situ, special long tubing is required between the machine and the kidney. Under these circumstances, it is important to keep collateral ureteric blood out of the perfusate by obstructing the ureter during perfusion with an atraumatic clamp.

POTENTIAL ROLE IN THE PEDIATRIC PATIENT

Whatever the technical methodology, there are certain pediatric renal conditions in which the operation appears to have a very specific role. These are: (1)

selected cases of renovascular hypertension; (2) some cases of congenital obstructive uropathy; (3) patients with bilateral Wilms' tumor, and; (4) occasionally renal trauma.

Renovascular Hypertension

With a few notable exceptions [10,11] operative treatment of renovascular hypertension in children has been unsuccessful,[12-14] and nephrectomy has been required despite awareness of the significant incidence of either concomitant or subsequent disease in the other kidney.[14] The high technical failure rate of angioplastic operations is primarily due to the tiny caliber of the renal vessels. The difficulty is compounded by the obligatory inflow occlusion that predisposes to vascular thrombosis. Conversely, renal blood is washed out during the initial perfusion in ex vivo surgery. The resultant hypothermic state permits a meticulous and precise vascular repair. The use of an operating microscope during surgery and high-resolution arteriography after correction [1,4] are additional technical refinements available to the surgeon at the work bench.

Cure of renovascular hypertension by extracorporeal operation in children has been reported on several occasions.[11,15] In the future, vascular repair at the work bench should be attempted in most cases before resorting to nephrectomy.

Congenital Obstructive Uropathy

Urinary diversion by ileal conduit or other exteriorization operations has been widely employed for treatment of certain kinds of obstructive uropathy in infants and children. As long-term follow-up data have accumulated, it has become apparent that these procedures have a significant incidence of delayed complications and, more importantly, have not protected from gradual deteriorization of renal function.[16,17] Hendren [18] has been the principle advocate for preservation of natural urologic anatomy and, in fact, has carried out reconstruction in 32 children who had previously undergone urinary diversion. The technical ingenuity in reclaiming previously diverted urinary tracts using intestinal bridges is remarkable. However, in a number of patients with short proximal ureters, renal autotransplantation to the iliac fossa eliminates the problem of the ureteric-bladder gap (Patient 7). Furthermore, autotransplantation may avoid urinary diversion in the first place in patients whose principal lesion is ureteric.

Bilateral Wilms' Tumor

In spite of major advances in adjunctive cancer chemotherapy and radiotherapy, the long-term outlook for bilateral Wilm's tumor is poor. Fay et al.[19] have reported only 13.8% 5-yr survival in 58 patients. Since the overall incidence of tumor bilaterally is nearly 10%, the problem is not an inconsequential one, and current recommendations for "individualization" [20] of cases seem to avoid the issue of providing definitive surgical guidelines. Of the different operative approaches presently used in this condition, one of the most popular is total excision of the more involved kidney and partial nephrectomy of the contralateral organ. Along with other adjunctive therapy, limited radiation is given postoperatively to the renal remnant.

Admitting the greater malignant potential of bilateral Wilms' tumor, there

are several technical factors contributing to the high failure rate with this latter approach. Partial nephrectomy is an inexact, imperfect, and occasionally bloody undertaking having a good chance for leaving tumor behind either at the surgical margin or in separate, deep intrarenal locations. The unavoidable renal transection and tumor handling, unthinkable in unilateral disease, must result in tumor spillage. Additionally, the presence of the kidney remnant precludes proper lymph node dissection of the renal fossa. Nor can suitable radiation doses be delivered to the kidney bed because of the very real fear of radiation nephritis to the remaining renal tissue.[21]

The advantages of extracorporeal surgery are especially appealing in patients with bilateral Wilms' tumor. Careful definitive tumor excision in controlled situations is possible at the work bench not only for the less involved kidney but even for the more involved one, if necessary (Fig. 3). Semb[22] has shown that extensive partial nephrectomy, leaving as little as 15% of renal tissue, is compatible with good health. Calne[23] has carried out ex vivo bilateral excision of renal cancer in an adult, leaving an estimated one-third of renal substance for simultaneous autotransplantation with a good result.

Besides a more definitive tumor dissection, ex vivo excision of the nephroblastoma avoids tumor spill into the wound; removal of the organ from the renal fossa facilitates regional lymph node dissection, and transplantation of the organ to the iliac fossa permits full dose radiation to the empty renal bed.

Renal Trauma

The most common indication for nephrectomy following blunt abdominal trauma in children is the finding of renal hemorrhage in the presence of an associated injury, usually the spleen or liver. The patient is often hemodynami-

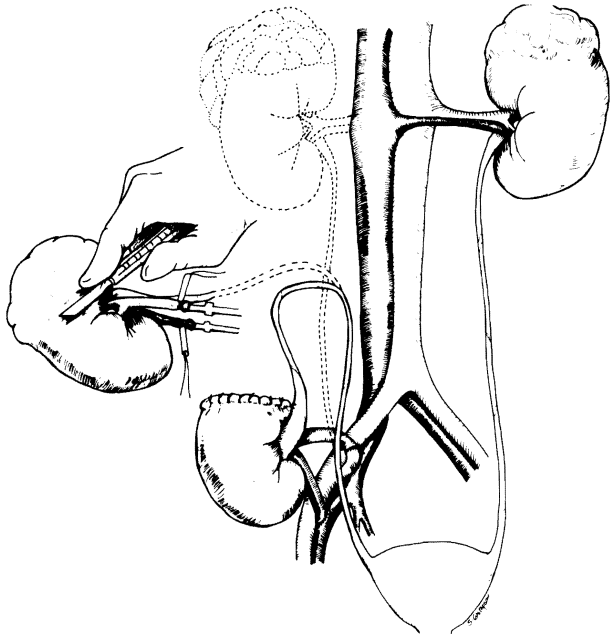

Fig. 3. Schematic illustration of bench surgery for bilateral Wilms' tumor. The four components of this procedure are depicted: nephrectomy, renal perfusion, ex vivo operation, and autotransplantation.

cally unstable, and the surgeon is faced with the alternative of nephrectomy or attempted renal repair. Nephrectomy is the usual choice despite the fact that many traumatic renal lesions are potentially correctable. A third alternative in this situation would be nephrectomy and extracorporeal surgery. With the kidney refrigerated or perfused, the associated injuries are tackled and the operation completed. The renal injury may then be repaired at the bench and autotransplantation carried out either at the same time or 12–24 hr later depending on the patient's condition.

In 1963, Hardy[24] reported the first successful case of renal autotransplantation using this general approach. In this instance, the injury was iatrogenic. Lim and colleagues[25] and we[1] reported treatment of renal gunshot and stab wounds, respectively, by autotransplantation techniques.

SUMMARY AND CONCLUSIONS

A new operative procedure in renal surgery has evolved from the extensive recent experience in kidney transplantation. Bench surgery and autotransplantation have not been, as yet, fully exploited by surgeons caring for children. This approach to reconstruction of renal substance and renal vessels has as its greatest dividend conservation of kidney tissue. The operation has specific applicability for selected cases of: (1) renovascular hypertension; (2) congenital obstructive uropathy; (3) bilateral Wilms' tumor, and; (4) renal trauma in children.

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Discussion follows next article.