

EXPERIMENTAL RECONSTRUCTION OF URETERS BY SUBSTITUTION OF SMALL BOWEL SEGMENTS*

ARTHUR M. DAVIDS, M.D. AND GERSON J. LESNICK, M.D.

NEW YORK, N. Y.

FROM THE DEPARTMENTS OF GYNECOLOGY AND SURGERY
MOUNT SINAI HOSPITAL, NEW YORK, N. Y.

THE INCREASING FREQUENCY of the operation of pelvic evisceration for advanced pelvic carcinoma has restimulated interest in the development of functioning substitutes for the lower urinary tract. The problem of developing a substitute for the urinary bladder is not a new one and a voluminous literature has accumulated. In 1908, Verhoogen¹¹ attempted to divert the urinary stream into an isolated segment of ileum and ascending colon. Because of the high mortality at this time, the procedure was discarded only to be revived again in recent years with excellent results. Bricker and Eiseman¹ reported in 1950, the successful use of this procedure in two cases of pelvic carcinoma. Later in the same year Bricker and Eiseman² reported the use of an isolated segment of terminal ileum as a substitute for the bladder. Isolated segments of the sigmoid and descending colon have been used as substitutes for the bladder in benign conditions as well as in extensive pelvic carcinoma. Swann and Swenson¹⁰ treated children with urinary incontinence due to myelomeningocele by construction of bladder from an isolated loop of the sigmoid.

In 1948, we began a series of animal experiments to establish the feasibility of using segments of the ileum as substitutes for various portions of the urinary tract. It was our aim at that time to determine the possibilities of (1) the formation of a new

ureter and (2) the construction of a new bladder. While the work was in progress, the report of Bricker and Eiseman appeared, utilizing the terminal ileum as a bladder in cases of pelvic carcinoma. Since this procedure has become an established fact, we shall limit this report to the construction of a substitute ureter. There have been clinically successful attempts to substitute for portions of lower third of the ureter by utilizing a tube of bladder wall in the fashion of the Ockerblad⁷ operation or to save a kidney by means of a uretero-ureteral anastomosis as devised experimentally by Sharpe,⁹ and first performed clinically by Charles C. Higgins.⁴

In an attempt to substitute small bowel for ureter, the problem of reabsorption of urinary nitrogenous substances is of prime importance. In 1922, Hinman and Belt⁵ experimentally transplanted the ureters into the duodenum of animals and they died within 12 days, with retention of nitrogenous substances in the blood. In these experiments, the urinary output bathed the mucosa of the entire small and large bowel. The absorptive surface was great and proved fatal.

In the studies to be presented in this report, segments of terminal ileum were utilized as substitutes for the terminal portions of a single ureter, practically the entire length of a single ureter and for two thirds or more of the length of both ureters. There was a restoration of essen-

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tially normal urinary function in all instances.

METHOD

Adult male dogs were used in this study. In our first experiments, only a portion of the distal end of one ureter was resected and later almost the entire ureter on one side was removed and a segment of terminal ileum substituted for it. The animal survived in both instances and samples of blood revealed normal chemical findings. The presence of a normal ureter and kidney on the opposite side made us uncertain

The continuity of the bowel was restored by an end to end, or a side to side anastomosis. The proximal end of the isolated segment of bowel was closed. An opening of approximately three quarters of an inch was then made in the dome of the bladder and an anastomosis of the distal end of the intestinal loop and bladder was performed. The intestinal loop was then placed along the course of the right ureter. The lower two thirds or more of the right ureter was excised and the proximal stump of the ureter was implanted into the side of the intestinal loop.

TABLE I.

Date:

3/ 3/50—Operation performed.	Blood urea	Uric acid	Chlorides	Phos	CO ₂	Creatinines	Ca	Alb	Glob
3/17/50	25								
8/ 1/50	11								
9/27/50	30								
11/25/50	29								
5/19/51	32	1.3	106	3.8	50	1.05	11	3.2	4.1
11/ 5/51	23	0.9	108	3.6	48	1.3	10	3.1	4.3

of the completely normal function of the kidney on the side of the ureteral substitution despite an excellent anatomic result. With this in mind, we decided to resect both ureters, removing at least the distal two thirds on both sides.

The operation in this experiment will now be described in detail. The preoperative preparation consisted of a 24-hour period of starvation. The dogs were anesthetized with intravenous sodium pentothal and the abdominal wall shaved and prepared for laparotomy. A mid-line incision was made extending from the symphysis pubis to the mid-point of the abdominal wall. Both ureters were isolated and ligated about one quarter of an inch from their entrance into the base of the bladder. The ureters were then cut across above the level of the ligatures and freed from their retroperitoneal bed to the level of the kidney pelvis. A six to 18 inch segment of the terminal ileum was then isolated, preserving its mesentery.

At this point one of the two following procedures was used, depending on the length of the left ureter to be retained. A small hole was made in an avascular area of the mesentery of the bowel at the level of the kidney. If the segment of the left ureter was about half its length, it was passed from left to right through the hole in the mesentery and implanted into the isolated loop of the bowel as it lay on the right side of the abdomen. If the left ureter was to be cut in its upper third, a longer loop of bowel was isolated and it was passed through the opening in the mesentery so that the left ureter could be implanted into it without tension at the point of anastomosis. The ureter of the dog is of very small caliber and the implantation into the bowel was of two types. The Coffey (3) and Jordan (6) technics were both used with satisfactory results. The abdominal wall was then closed and the dogs returned to their cages. They were

given injections of 300,000 units of procaine penicillin daily without any other supportive therapy. Fluids were given *ad lib*, and soft diet started on the second post-operative day. No attempt was made to drain the newly established urinary tract

ities were due to leaks of the uretero-intestinal implantation. These may be attributed to technical failures due to the small size of the dogs' ureters and the very thick muscle of the intestinal wall. The mucosa to mucosa suture technic applied in humans should avoid these difficulties. The remaining dogs resumed their natural existence in the general dog kennels and held their own in competition with the unoperated animals.

Four dogs were sacrificed from four to six weeks after operation to determine the immediate results of the operation. Two



FIG. 1.—Dog No. 7. Intravenous pyelogram in which the lower half of both ureters were resected. The bladder and the intestinal portion of the reconstructed ureters are well outlined. The implanted portions of the upper half of the ureters show no dilatation.

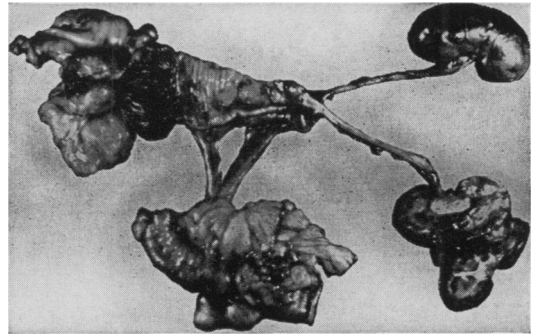


FIG. 2.—Dog No. 7. The extirpated specimen is shown opened demonstrating the points of anastomosis of the ureters into the intestinal segment and the anastomosis of the bowel and bladder. The ureters are normal and undilated.

with indwelling catheters. Convalescence was uneventful in the absence of any mechanical defects of the anastomosis. The dogs rapidly returned to good health and displayed no abnormal behavior.

RESULTS

Nine dogs were operated upon; three of which died within two weeks of the time of operation. One death was due to leakage of the enteroenterostomy. The other fatal-

dogs were kept for long term observation. One of these was sacrificed at the end of two years, and one dog remains alive and normal at the present time, 30 months after operation. The general health of both dogs was excellent and both animals had gained weight since the time of operation. Blood chemical studies were performed at intervals on the dogs. In both the acute experiments of one to two months duration, and those of dogs living two years, blood chemical studies showed no abnormalities except for slight elevation of blood urea concentration. The blood chemical studies were performed frequently, and in one of the long term dogs on whom a bilateral resection of two thirds of both ureters was performed, the results are shown in Table I.

Intravenous pyelograms revealed no hydronephrosis in either of the dogs surviving two years (Fig. 1).

When sacrificed, the postmortem specimens showed no gross or microscopic abnormality of the kidney or ureters. The isolated segment of small bowel was not

The presence of some urethritis and cystitis in the adult male dog is an almost constant postmortem finding. A photograph of the extirpated specimens of kidneys, ureters, ileal substitution and bladder is shown opened in Figure 2.

DISCUSSION

The foregoing experiments clearly demonstrate that a segment of terminal ileum can be utilized to bridge a gap in a ureter, or be substituted for almost the entire length of one or both ureters and permit restoration of an essentially normally functioning urinary tract. The surgical technic is not difficult; in fact it should be simpler in the human than in dogs. The ureter of the human is of much larger caliber than that of the dog, and the anastomosis of ureter and bowel segment should be done with comparative ease. The preoperative preparation and postoperative care can be better controlled in the human than in the animal, where supportive therapy was minimal.

There are a number of conditions in which substitution of the ileum for the ureter in humans might be attempted:

(a) In extreme cases of megaloureter, many plastic operations have been used but where the wall of the ureter is thin and fibrotic and lacking in peristalsis, the operation of choice at the present time is nephro-ureterectomy.

(b) In penetrating injuries of the ureter due to shrapnel, gun shot or stab wounds, the diagnosis may be difficult and a fistula may form later. The treatment of choice, if possible, is anastomosis, depending on the location of the lesion. When recognized late and anastomosis or plastic procedure is not possible, nephrectomy may be necessary. Prather and Robinson⁸ obtained data on 45 cases of penetrating ureteral injuries occurring during World War II. Five per cent of the cases had a nephrectomy overseas, and of the remainder, 38 per cent, required nephrectomy on return to the United States.

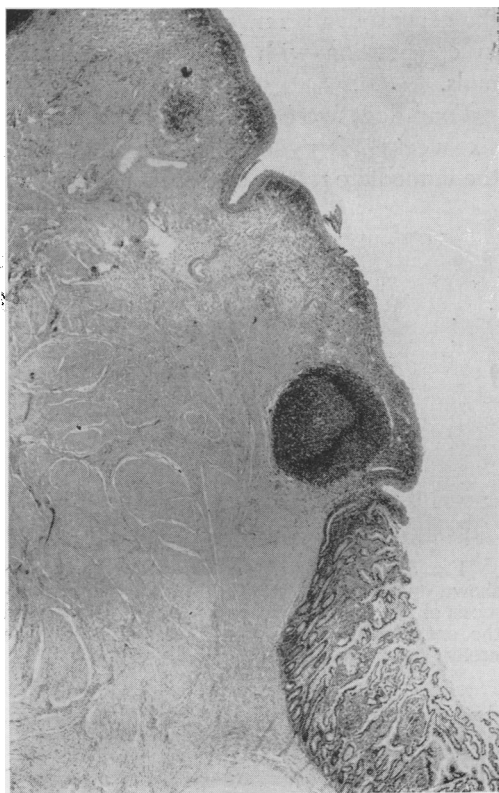


FIG. 3.—The junction of the anastomosis of the ileal portion of the reconstructed ureter and bladder are shown. The mucosa of the bowel merges into that of the bladder without the presence of any exposed submucosal tissue at the site of anastomosis.

dilated and the only change in its structure was slight hypoplasia of the mucosa. The ureteral implantations were intact and both ureteral orifices were patent and functioning. The anastomosis of bowel and bladder was firmly healed and there was continuity of the mucosa at the site of anastomosis (Fig. 3). The only significant pathologic change was a moderate degree of cystitis.

(c) Surgical injuries such as crushing, cutting or ligating the ureter may occur during gynecological procedures and result in a ureteral fistula. Ureteral fistulas may also occur following ureterolithotomy or intra-ureteral manipulation with stone extractors, loops and bougies. There may also be ureteral injury during urological investigations when inflammatory reactions occur around the uretero-pelvic junction. Changes in the ureteral wall may lead to accidental perforation or section of the ureter.

When the fistula occurs in an area where an anastomosis or reimplantation of the ureter into the renal pelvis or bladder is possible, these procedures are the ones of choice. In other cases when this has not been possible, a nephrostomy, with uretero-ureteral anastomosis at a later date, has been performed. Many urologists seriously question the advisability of jeopardizing a perfectly normal ureter and kidney when nephrectomy with a normal remaining kidney is attended with good results.

(d) Tumors of the ureter, either primary metastatic, or due to extension from adjacent organs, are most frequently treated by removal of the ureter, kidney and a small portion of the bladder. However, permanent ureterostomy or nephrostomy, with complete incision of the ureter, may be indicated when function of the opposite kidney is inadequate.

(e) Ureterectomy or nephrectomy and ureterectomy are also performed when pyogenic or tuberculous infections of the ureter are such that adequate drainage cannot be secured. Since the advent of streptomycin, many cases of tuberculous ureteritis have been treated with good results. The urines have remained sterile, but in the process of healing, a stenosis of the ureter may occur and produce a marked hydronephrosis.

In all the above cited situations where the final surgical procedure results in nephrectomy, permanent nephrostomy or ureterostomy, the question of the forma-

tion of a new ureter can be entertained. The attempt would be worth while when nephrectomy is contemplated, and the function of the remaining kidney is compromised. Permanent nephrostomy or ureterostomy is not desirable. Anything that would obviate such a procedure would be advantageous.

The results in our animal experimentation lead us to believe that reconstruction of a ureter from the terminal ileum may answer the need in such situations. The procedure can be performed either as a single or two stage operation, depending on the general condition of the patient and the pathologic condition present.

SUMMARY AND CONCLUSIONS

1. Nine dogs were used for the experimental reconstruction of segments of one or both ureters by substitution of a loop of the terminal ileum.

2. The substitution of a loop of ileum for one or both ureters proved to be a practical procedure and two dogs were kept alive for over a two-year period.

3. Kidney function was normal, except for a slight increase in blood urea, which had no effect on the health of the animals.

4. Intravenous pyelography demonstrated normal kidney function without dilatation of the remaining segments of ureter or kidney pelvices.

5. Postmortem examination of the kidneys, ureters, ileal segment and bladder revealed no changes which would contraindicate the use of the procedure of ileal substitution for the ureter.

6. A number of urological conditions have been listed that are now treated by ureterostomy, nephrostomy, ureterectomy or ureterectomy and nephrectomy. In many of these instances it might be practical to attempt reconstruction of the urinary tract by a substitution of a segment of terminal ileum.

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