URINARY DIVERSION

By JOHN HOPEWELL, F.R.C.S.
Surgeon, The Royal Free Hospital

The convenient storage and evacuation of the urine is essential to a tolerable existence. Surgical methods to restore these functions, when they have been lost as a result of congenital abnormality or acquired disease, have mostly been based on the principle of urinary diversion into some part of the intestinal tract, isolated or intact. The history of these attempts is an interesting one, and follows a pattern that has often recurred in the evolution of surgical procedures. Early surgeons planned operations which were logical but which had to be abandoned as impracticable in the surgical context of their day. For many years simpler expedients became accepted as standard practice, until impatience with their defects led to a renewed search for improvements. Schemes that had earlier been rejected were tried again, sometimes indeed claimed as innovations, and proved feasible.

Historical Survey

It was in 1851 that John Simon of London first successfully established a fistula between each ureter and the rectum in a young man with exstrophy of the bladder. His patient lived only a year, yet even so limited a survival could not be achieved by any of the ingenious methods devised at the end of the nineteenth century. These were completely reviewed by Hinman and Weyrauch (1936), but some are now particularly notable in the light of future developments. In 1888 Tizzoni and Foggi used an isolated ileal segment in an experimental animal, implanting the ureters into one end and joining the other to the prostatic urethra; however, they did not put this method into clinical practice. In 1895 Mauclair made a recto-sigmoid bladder by dividing the sigmoid colon and bringing out its proximal end as a terminal colostomy. The distal end was closed off and the ureters transplanted to drain into it. In 1899 Gersuny proposed a similar arrangement, but with the upper cut end of the colon brought out on to the perineum within the ring of the subcutaneous external sphincter of the anus, which might thereby control urine and faeces. This operation was tried in a few instances but was found unsuitable for adoption at that time.

In 1908 Verhoogen advocated the use of the isolated ileocaecal segment as an artificial bladder.

By that time a sound method of uretero-colic anastomosis had been devised, and proved safe enough to be adopted as the standard method of diversion for nearly half a century. There are, however, many problems which arise from its use, the most notable being that of maintaining efficient renal function, and it is for this reason that this account has been included in a symposium on disorders of the kidney. These complications are reduced by the use of a short isolated intestinal segment as a reservoir. Advances in surgical management have allowed these operations to be performed with greater confidence, and the place of those earlier operations based on this principle is again under review. Successful use of the ileocaecal segment has been described by Cortes (1946) and by Powell (1949). The ileal segment was reintroduced in the United States by Bricker (1950) and by Mersheimer (1950), and experience of its use has been recorded in this country by Wells (1956), Rickham (1956) and Nash (1956). The recto-sigmoid bladder of Mauclair was tried by Kinman (1953), and Pyrah (1957) has reported his experience of its use. Gersuny's operation was successfully performed by Lowsley and Johnson (1955) and the latter has published his further experience of it (Johnson, 1956).

The Complications of Uretero-colic Anastomosis

These may be divided into the complications attendant upon the surgical procedure of urinary diversion and those resulting from the physiological changes which it imposes.

Surgical Complications

Early: Leakage and peritonitis.

Late: Ureteric reflux.

Stenosis with obstruction of the upper renal tract.

Ascending infection (pyelitis).

Renal failure.

The first requirement is an operative technique that ensures sound anastomosis between ureter and bowel. This was first achieved by the 'mus-

cularizing' principle in which the terminal segment of the ureter and its point of entry into the colon are buried by Lembert sutures after the manner of Witzel's (1891) gastrostomy. Hinman and Weyrauch note that this method has become attributed to native invention in the United States (Martin, 1900), in France (Depage and Mayer, 1904), in Russia (Tichoff, 1908) and in England (Stiles, 1911). Its adoption allowed uretero-colic anastomosis to become an established procedure. Coffey (1911) sought to fashion a valve by burying the end of the ureter in a submucous tunnel. It is doubtful in fact how far a valvular action is achieved by this method, and Vermooten (1934) suggested that its success may have been due largely to the security of the anastomosis that it affords. From either of these 'indirect' methods there is a high incidence of late complications. Reflux due to the high pressures developed in the normal colon may commonly be observed, and intestinal gas is frequently seen to outline the upper renal tract in a straight X-ray of the abdomen taken after this operation.

It is more often a matter for remark that this invasion is so well tolerated rather than that some develop pyelitis from ascending infection. However, it is infection superimposed upon obstruction that is most damaging and this results either from a terminal granulomatous stenosis of the ureter or from a stricture in a submucous tunnel. To avoid this worst of complications, wide 'direct' anastomosis of ureter and bowel has been advocated (Nesbit, 1949; Cordonnier, 1949). Leadbetter (1951) believes the best compromise to be a direct anastomosis in this manner, making an ample ureteric stoma, combined with a submucous tunnel. All these methods implant the ureter into the bowel from outside. Willard Goodwin (1953) devised the intraluminal method, whereby the colon is opened by an incision along its anterior border, relying upon antibiotic preparation to prevent contamination of the peritoneal cavity. The ureters are then drawn into the bowel through small stab incisions in its posterior wall. By this means the ureters have a straight run from the posterior abdominal wall into the bowel, they may be given a long intramural course if this is desired, and the anastomosis may be completed under full vision with every opportunity to adjust the lie and tension of the ureter. The method has not yet gained acceptance in this country, but its theoretical advantages seem from a limited experience to be well borne out in practice.

In the last ten years it has been realized that no method of anastomosis may be able to allow satisfactory function in every case with the ureter implanted into the intact colon with its high working pressures (Smith and Hinman, 1955) and

contaminated contents. These factors are avoided by drainage of urine into an isolated intestinal segment such as an ileal loop or the recto-sigmoid. Such an arrangement also offers advantages in minimizing physiological disturbances, and these will therefore be considered next.

Physiological Complications of Uretero-sigmoidostomy

- (1) Clinical features.
- (2) Experimental studies.
- (3) Interpretation—mechanism and adaptive responses.

(1) Clinical Features

Dehydration.
Acidosis with hyperchloraemia.
Hypocalcaemia.
Hypokalaemia.

Whilst some patients enjoy a fully normal life after this operation, many suffer ill-effects. These may vary from a mild deterioration in well-being, often with some thirst and loss of weight, to nausea, vomiting, prostration and coma.

These symptoms have been found to be associated with a well-defined pattern of biochemical disturbance. Boyd in 1931 first noted an acidosis in children undergoing operation for exstrophy of the bladder, but it was not realized how commonly this occurred until 1950 when Ferris and Odel reported its presence in 80 per cent. of their patients. They further drew attention to the accompanying hyperchloraemia, and observed that the biochemical disturbance could be corrected by colonic lavage. The ability of the colonic mucosa to absorb chloride selectively was elegantly demonstrated by Pyrah and his colleagues in 1952 by observations upon a patient undergoing a two-stage transplantation of the ureters into the colon. The importance of hyperchloraemia as a causative factor was fully established, and indeed the disturbance became generally referred to as 'hyperchloraemic acidosis.' Nevertheless, it was observed that hyperchloraemia might occur without acidosis. Lapidès (1951) concluded that its incidence depended upon a renal tubular defect, but Stamey (1956) demonstrated that hyperchloraemic acidosis can be induced in the normal subject with healthy kidneys by instillation of urine into the colon. Experience of patients suffering acidosis has also shown that some may suffer marked calcium depletion, presenting the clinical picture of osteomalacia, with bone pain, stiffness of the joints and osteoporosis. Others may give evidence of potassium deficiency with asthenia, hypotension and finally coma, accompanied by electrocardiographic changes. These two syn-

dromes of depletion do not as a rule occur together, though they can do so.

(2) *Experimental Studies*

Understanding of the mechanism of these disturbances has been assisted by studies in the experimental animal of the effects of reabsorption of urinary constituents from the bowel. The methods used have been those of transplanting the ureters into different levels of the intestinal tract (Baird, Scott and Spencer, 1917; Bollman and Mann, 1927; Geer and Dragstedt, 1938; Boyce, 1951), by instillation of urine or its constituents into the intestine (Hartman, 1933) and into ileal segments of different lengths (Hopewell, 1959). The changes have been found to be:

(a) *General*. Dehydration, with loss of weight, increased fluid intake and output.

(b) *Biochemical*. Uraemia and acidosis. Hyperchloraemia if absorption is by colonic mucosa.

(c) *Hypertrophic changes in the kidney*.

The degree of these changes is dependent upon the area of mucosa involved so long as the urine flows freely over it (Hopewell, 1959), but may be increased when this flow is disturbed, as by retrograde peristalsis in the colon, or stenosis at the stoma of an isolated segment. With a high degree of reabsorption, the changes will be progressive and result in death within one to two weeks, with severe uraemia and acidosis, but without hyperchloraemia unless the mucosa involved is that of the colon. When the degree of reabsorption is not great enough to be fatal, the uraemia and acidosis progress for one to three weeks, and there is then a gradual return towards normal levels.

The renal changes are also proportional to the degree of reabsorption. They consist of increase in total renal mass, with increased vascularity and mitotic change in the tubules, similar to the change in the remaining kidney after nephrectomy. At the same time some deleterious effect with localized destruction of tubular cells is seen when reabsorption is marked. The renal hypertrophy has been shown to reflect an increase in the kidneys' capacity for clearance of plasma constituents (Hopewell, 1959).

(3) *Interpretation—Mechanism and Adaptive Responses*

(a) Renal.

(b) Colonic.

(a) *Renal*. The experimental changes noted seem to result chiefly from the reabsorption of urea, which imposes an obligatory diuresis upon the kidneys. Loss of weight and dehydration ensue despite the increased fluid input and output. The renal tubule is so overwhelmed by these con-

ditions as to be unable to exercise its control over acid-base balance, and acidosis occurs. When the absorbing mucosa is that of the colon, which selectively takes up chloride, hyperchloraemia will increase the tendency to acidosis. Perhaps more striking than these changes is the ability of the experimental animal to acquire a tolerance to them. This implies a notable adaptive response. The changes of structure and function noted in the kidney suggest that the adaptation is largely a renal responsibility, and this is consistent with the known potentiality for compensatory changes of the kidney in disease.

It is possible that adaptation is also effected by a reduced rate of absorption from the intestinal mucosa. There had been no real evidence that this occurred until 1958, when Pyrah recorded a diminution in the rate of chloride absorption from the colon of a patient who had undergone uretero-sigmoidostomy previously.

In clinical practice the evidence of adaptive change is by no means obvious, and indeed experience anticipates rather renal deterioration from reflux, stenosis or ascending infection, which cannot be excluded as they are in an experimental preparation. Nevertheless, it has been noted that episodes of biochemical imbalance might occur shortly after a colonic transplant, later to undergo permanent remission. More striking still, uretero-sigmoidostomy in the young subject has always been observed to hold out a better prospect of trouble-free survival than in the older patient, and it is certainly reasonable to suppose that the young kidney is better able to undergo an adaptive change.

Experimental findings have thrown little light on calcium and potassium depletion. The former seems a likely result of a long-standing acidosis. Hypokalaemia possibly results chiefly from loss of potassium into the bowel from the colonic mucosa.

It will be clear that these biochemical disturbances, arising mainly as they do from the reabsorption of urinary constituents from the intestine, are commonly seen in clinical practice after uretero-sigmoidostomy, since absorption is a normal function of the colon. The retrograde peristaltic waves which occur in the large bowel will further assist absorption. For this reason the use of an isolated intestinal segment, of no more than eight to ten inches total length, whether ileum or recto-sigmoid, will minimize the incidence of biochemical disturbance.

Expectation of Survival after Urinary Diversion into the Bowel

There are not good records of the results of these operations. Harvard and Thompson (1951) gave an excellent review of the experience at the

Mayo Clinic of the results of uretero-sigmoidostomy in exstrophy of the bladder, for which it remains the standard accepted treatment. They quote Dr. C. H. Mayo's opinion that of children born with this condition, only half will survive their twentieth year without treatment. Of those patients undergoing uretero-sigmoidostomy at the Mayo Clinic since 1912, 75 per cent. survived their twentieth year. The longest recorded survivals are of 43 years (Stevens, 1941) and 38 years (Cordonnier and Spjut, 1957). Some estimate of the much poorer expectation following operation in later years may be gained from the collected figures of the British Association of Urological Surgeons (Jacobs and Stirling, 1952), in which an operative mortality of 39.7 per cent. was found for urinary diversion as a first stage in the treatment of carcinoma of the bladder.

Indications and Choice of Method

Exstrophy of the Bladder

Attempts at plastic repair of the bladder must still be regarded as experimental, and the accepted treatment is by uretero-sigmoidostomy.

Spina Bifida

It is not generally accepted that surgical interference offers any advantages in the treatment of incontinence from this condition. Where the anal sphincter is incompetent, the only practicable form of diversion is into an isolated ileal segment, and advocates for this method believe that the risks involved are worth while for the convenience of collecting urine into a bag worn over the ileostomy stoma, rather than into a perineal apparatus.

Total Cystectomy

Primary and secondary bladder growth.

Tuberculous cystitis not amenable to ileo-cystoplasty.

Severe interstitial cystitis.

When renal function is good and the anal sphincter competent, uretero-sigmoidostomy is generally accepted as the method of choice, since it confers continence with the least operative procedure. It still remains the first choice with many surgeons even if there is dilatation of the upper urinary tract, for normal renal anatomy and function will often return following the diversion. If diversion is demanded in the presence of evidently poor excretory function, it would appear wise to drain at once into an isolated segment. Use of the recto-sigmoid imposes a colostomy, but is a shorter operation and one apparently less liable to post-operative complications than the ileal segment. It offers the blessing of urinary continence, and seems well suited to the older patient so long as the anal sphincter is sound, or

to one of any age who can accept a permanent colostomy.

When a patient after uretero-sigmoidostomy suffers severe biochemical disturbance or repeated attacks of pyelitis, it is wise to convert their drainage to an isolated segment, and this is most simply done by bringing out the proximal colon to the skin and closing the distal end above the ureteric anastomoses.

Management

Pre-operative. Bowel preparation must be carried out for operations upon the colon. Neomycin by mouth for two days will virtually sterilize its contents. If renal function has been impaired, testosterone propionate 30 mg. per day by intramuscular injection may be given, although its value is not established. The bladder should be catheterized and a rectal tube inserted as high as it can be passed.

Operation. One-stage transperitoneal operation is generally preferred. The two-stage extraperitoneal procedure was of value in patients with renal damage, but in such cases diversion into an isolated segment is to be preferred. If severe back pressure has led to gross dilatation of the upper renal tract, preliminary nephrostomy may be used.

The chief aim of the operation is to secure sound anastomosis between bowel and ureter; leakage remains a serious early complication. The author favours Goodwin's method for the security it offers in this respect. However, if an extraluminal method is used, it is important to carry the colon over to each ureter and to secure it in such a way that the ureter has a short direct route from the point at which it comes forwards off the posterior abdominal wall. It is important to preserve the blood supply of the ureter, whatever the method used. It must be handled carefully, and mobilized as little as possible, with as much surrounding areolar tissue as can be retained. Daniel and Shackman (1952) stressed that its blood supply comes from numerous vessels, contributing to a variable 'marginal' artery, but if this cannot be clearly seen and preserved, the safest point of division was 1.5 cm. below the bifurcation of the common iliac vessels.

Anastomosis should be carried out with many accurately placed interrupted stitches of 2/0 atraumatic chromic catgut.

Most surgeons do not place a tube up the ureter. However, it may be used without hesitation when there is any doubt of the security of the transplant, and it is convenient always to have a rectal tube in place to assist delivery through the anus.

Post-operative. After uretero-sigmoidostomy a

rectal tube should be left for a few days for continuous drainage of urine, and after this time frequent evacuation should be encouraged. The fluid intake must be high, and 4 g. of sodium bicarbonate taken daily. If thirst or lethargy are experienced, a salt-free diet is prescribed and 8 g. of bicarbonate given. If dehydration is progressive and nausea and vomiting occur, the patient must be admitted to hospital for full biochemical investigation. Marked acidosis or hypokalaemia will require careful intravenous replacement therapy. In hypocalcaemia, in addition to correction of acidosis, vitamin D₂ should be given by mouth in adequate dosage to restore a positive calcium balance, that is, 10,000 to 100,000 units a day (Harrison, 1958).

Cutaneous Ureterostomy

Bilateral cutaneous ureterostomy has had few advocates because storage of the urine depends upon an external appliance worn over each stoma. It has not proved easy to carry out the operation without sloughing of the ureter or stricture formation. Those most adept in its performance have advised against any indwelling drain, and some advocate a spout fashioned as a skin pedicle for neat collection of the ureteric efflux. The expectation that the method might avoid deleterious effects upon the kidney does not seem to be realized, and its advantage in cases of renal deterioration from ureteric obstruction is equally offered by an isolated intestinal segment.

BIBLIOGRAPHY

- BAIRD, J. S., SCOTT, R. L., and SPENCER, R. D. (1917), *Surg. Gynec. Obstet.*, **24**, 482.
 BOLLMAN, J. L., and MANN, F. C. (1927), *Proc. Soc. exp. Biol. Med.*, **24**, 923.
 BOYCE, W. H. (1951), *J. Urol.*, **65**, 241.
 BOYD, J. D. (1931), *Amer. J. Dis. Child.*, **42**, 366.

- BRICKER, E. M. (1950), *Surg. Clin. N. Amer.*, **30**, 1511.
 COFFEY, R. C. (1911), *J. Amer. med. Ass.*, **56**, 397.
 CORDONNIER, J. J. (1949), *Surg. Gynec. Obstet.*, **88**, 441.
 CORDONNIER, J. J., and SPJUT, H. J. (1957), *J. Urol.*, **78**, 242.
 CORTES, S. T. (1946), *Bol. Trab. Acad. Argent. Cir.*, **30**, 558.
 DANIEL, O., and SHACKMAN, R. (1952), *Brit. J. Urol.*, **24**, 334.
 DEPAGE, A., and MAYER, L. (1904), *Arch. klin. Chir.*, **74**, 71.
 FERRIS, O. D., and ODEL, H. M. (1950), *J. Amer. med. Ass.*, **142**, 634.
 GEER, W. A., and DRAGSTEDT, L. R. (1938), *Ann. Surg.*, **108**, 263.
 GERSUNY, R. (1898), *Wien. klin. Wschr.*, **12**, 990, quoted by Foges.
 GOODWIN, W. E., HARRIS, A. P., KAUFMAN, J. J., and BEAL, J. M. (1953), *Surg. Gynec. Obstet.*, **97**, 295.
 HARRISON, A. R. (1958), *Brit. J. Urol.*, **30**, 455.
 HARTMAN, F. W. (1933), *J. exp. Med.*, **58**, 649.
 HARVARD, B. M., and THOMPSON, G. J. (1951), *J. Urol.*, **65**, 223.
 HINMAN, F. A., and WEYRAUCH, H. (1936), *Trans. Amer. Ass. gen.-urin. Surg.*, **29**, 15.
 HOPEWELL, J. P. (1959), *Ann. Roy. Coll. Surg. of Eng.*, **24**, 159.
 JACOBS, A., and STIRLING, W. B. (1952), *Brit. J. Urol.*, **24**, 259.
 JOHNSON, T. H. (1956), *J. Urol.*, **76**, 380.
 KINMAN, L. M., SAUER, D., HOUSTON, W. T., and MELICK, W. F. (1953), *A.M.A. Arch. Surg.*, **66**, 531.
 LAPIDES, J. (1951), *Surg. Gynec. Obstet.*, **93**, 691.
 LEADBETTER, W. F. (1951), *J. Urol.*, **65**, 818.
 LOWSLEY, O. S., and JOHNSON, T. H. (1955), *J. Urol.*, **73**, 83.
 MARTIN, F. H. (1909), *Amer. Gynec. Obstet. J.*, **16**, 395.
 MAUCLAIRE, P. (1895), *Ann. Mal. Org. gen.-urin.*, **13**, 1080.
 MERSHEIMER, W., KOLARSICK, A., and KAMMANDEL, H. (1950), *Bull. N.Y. med. Coll.*, **13**, 71.
 NASH, D. F. ELLISON (1956), *Brit. J. Urol.*, **28**, 387.
 NESBIT, R. M. (1949), *J. Urol.*, **61**, 728.
 PARSONS, F. M., PYRAH, L. N., POWELL, F. J. N., REED, G. W., and SPEIRS, F. W. (1952), *Brit. J. Urol.*, **24**, 317.
 POWELL, K. A. (1949), *Brit. J. Surg.*, **36**, 421.
 PYRAH, L. N. (1957), *J. Urol.*, **78**, 683.
 RICKHAM, P. P. (1956), *Brit. J. Urol.*, **28**, 394.
 SIMON, J. (1852), *Lancet*, **ii**, 568.
 SMITH, G. I., and HINMAN, F. Jnr. (1955), *J. Urol.*, **74**, 354.
 STAMEY, T. A. (1956), *Surg. Gynec. Obstet.*, **103**, 736.
 STEVENS, A. R. (1941), *J. Urol.*, **46**, 57.
 STILES, H. (1911), *Surg. Gynec. Obstet.*, **13**, 127.
 TICHOFF, P. I. (1908), *Zbl. Chir.*, **35**, 109.
 TIZZONI, G., and FOGGI, A. (1888), *Zbl. Chir.*, **15**, 921.
 VERHOOGEN, J. (1908), *Assoc. franc. Urol.*, **12**, 352.
 VERMOOTEN, V. (1934), *J. Urol.*, **32**, 273.
 WELLS, C. A. (1956), *Brit. J. Urol.*, **28**, 335.
 WITZEL, O. (1891), *Zbl. Chir.*, **18**, 601.

Bibliography continued from page 648—Kenneth Owen, M.S., F.R.C.S.

BIBLIOGRAPHY

- DE CAMP, P. T., and BIRCHALL, R. (1958), *Surgery*, **43**, 134.
 FREEMAN, N. E., LEEDS, F. H., ELLIOTT, W. G., and ROLAND, S. I. (1954), *J. Amer. med. Ass.*, **156**, 1077.
 GELLMAN, D. D. (1958), *Quart. J. Med.*, **27**, 105.
 GOLDBLATT, H., LYNCH, J., HANZEL, R. F., and SUMMERVILLE, W. W. (1934), *J. exp. Med.*, **59**, 347.
 HOWARD, J. E., CONNOR, T. B., and THOMAS, W. C. (1956), *Trans. Ass. Amer. Phys.*, **69**, 291.

- PEART, W. S. (1959), personal communication.
 POUTASSE, E. F. (1956), *Circulation (N.Y.)*, **13**, 37.
 POUTASSE, E. F., and DUSTAN, H. (1956), *Cleveland Clin. Quart.*, **23**, 3.
 POUTASSE, E. F., HUMPHRIES, A. W., McCORMACK, L. J., and CORCORAN, A. C. (1956), *J. Amer. med. Ass.*, **161**, 419.
 ROB, C. G., EASTCOTT, H. H. E., and OWEN, K. (1956), *Brit. J. Surg.*, **43**, 181.
 THOMPSON, J. E., and SMITHWICK, P. J. (1952), *Angiology*, **3**, 493.