

HYDRONEPHROSIS

AN EXPERIMENTAL STUDY*

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IN the course of a study of the causative factors of renal infection, the association of paralysis of the ureter and dilatation of the kidney pelvis and calyces was so frequent as to suggest experimental observations on hydronephrosis. The latter lesion may be defined as dilatation of the pelvis of the kidney by fluid attended by secondary dilatation and final obliteration of the calyces and by mechanical compression and atrophy of the parenchyma.

Clinicians⁷ explain the etiology of hydronephrosis in assuming mechanical obstruction to the outflow of urine by foreign bodies, neoplasms, inflammatory exudates, and the like.

Wagner,⁸ of Leipzig, describes the possible effects of traumatism to kidney and ureter. That traumatism gives rise to ureteral stricture or to peri-ureteral extravasation which may obstruct urine outflow and distend the kidney, he certainly affirms; that the intra-ureteral hemorrhage may coagulate and cause obstruction he faintly suggests. Ureters have been traumatized by ligation. They have been tied off experimentally as well as unwittingly. Experimentally "Guyon¹¹ and Albarran found congested kidney" after 57-70 hours of urethral ligation expressed by him in the following measurements:

Right kidney	P.M. cm.	A.M. cm.	Left kidney	P.M. cm.	A.M. cm.
Length.....	5.5	5.0	Length	5.8	5.5
Breadth.....	3.3	2.7	Breadth	4.0	2.8
Thickness	3.3	2.7	Thickness	4.0	2.9

Bradford⁶ ligated the ureter for 11-40 days. He found the ureter always completely obstructed and the kidney invariably distended so that on incision at second operation 50-70 c.c. of urine was liberated. Most frequently, hydronephrosis resulted; in three cases out of twelve, pyonephrosis followed. Both Guyon's "congested kidney" and Brad-

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ford's hydronephrosis were transitory conditions associated with marked atrophy. Rayner avoids the association of complete obstruction and hydroureter. Keen and Morris maintain that complete sudden obstruction brings about a rapid atrophy following a transitory distention. With this we agree. Experimentally both of a dog's ureters were stripped and one was ligated firmly at the ureterovesical junction. The animal lived for five days in a drowsy indolent state. At autopsy both kidneys were found hydronephrotic, the ligated ureter-kidney twice the size of the nonligated ureter-kidney. The measurements were as follows:

Right kidney	P.M. cm.	A.M.* cm.	Left kidney	P.M. cm.	A.M.* cm.
Length.....	9.0	6	Length.....	7.0	6
Breadth.....	6.0	4	Breadth.....	5.0	4
Thickness.....	4.0	2	Thickness.....	3.0	2

TABLE I

EFFECT OF STRIPPING URETER COMPARED WITH EFFECT OF STRIPPING AND LIGATING URETER

Experimental Surgical Laboratory, N. Y. U. 1913-14

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Dog No.	Gross Findings †	Microscopical Findings	Cause of Death	Days of Life
146	Left: Hydronephrosis, slight Right: Hydronephrosis, slight	Diffuse glomerular and intertubular congestion Local congestion; parenchyma degeneration	Hydronephrosis	5

Obstructive inflammation of the urinary tract may be acute or chronic. Delbet⁸ and others report ulcerative pyelitis or ureteritis following calculus irritation. Oertel¹⁰ reports a singular inflammatory change in the kidney pelvis analogous to the connective-tissue hyperplasia in productive senile arteritis which permits distention under normal conditions of intrapelvic pressure.

Morris⁸ reports many interesting anomalies of the ureter and the renal arteries obstructing urine delivery to the point of renal distention. Van der Bogert⁸ reports a congenital type of hydronephrosis following aplasia of the ureter.

* Estimate measurements.

† "Left" and "right" refer to animal and are reversely represented in table and in Fig. 8. Congestion is more marked in ligated ureter-kidney and degeneration has begun.



FIG. 1.—One of the steps in the technic of isolating and stripping of ureter, and irritating suppositional ureteral nerve plexus.



FIG. 2.—Pyonephrosis following stripping of the ureter. Other kidney and ureter normal.

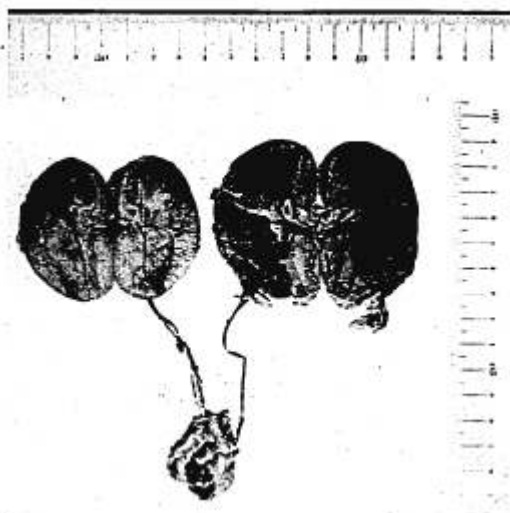


FIG. 3.—Dog No. 103. Hydronephrosis on right side following stripping of ureter; congested stage. Other kidney and ureter normal.



FIG. 4.—Dog No. 70. Hydronephrosis following stripping of ureter; dilated tubules stage. Other kidney and ureter normal.



FIG. 5.—Dog No. 17. Hydronephrosis following stripping of ureter shown on left side; dilated tubule stage. Other kidney and ureter normal.



FIG. 6.—Dog No. 54. Hydronephrosis and hydro-ureter following stripping of ureter; advanced stage. Other kidney and ureter normal.

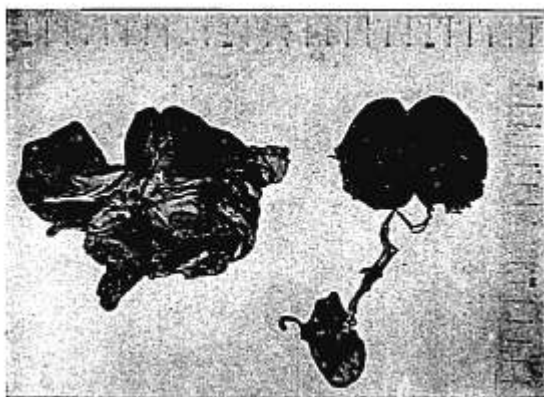


FIG. 7.—Dog No. 60. Pyonephrosis following secondarily infected hydronephrosis after stripping of ureter; terminal stage. Other kidney and ureter normal.



FIG. 8.—Dog No. 146. Hydronephrosis, both sides, produced on right by stripping of ureter and on left by ligation of ureter; congested stages. Notice perinephritic hemorrhage on left side.

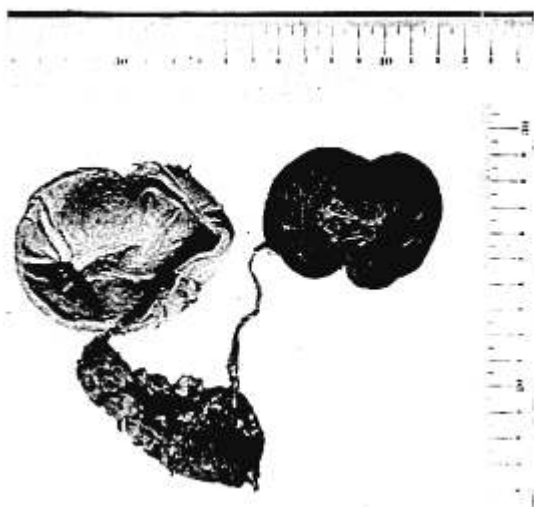


FIG. 9.—Dog No. 129. Pyonephrosis following stripping of ureter and circumcision of uretero-vesical valve; advanced stage. Other kidney and ureter normal.

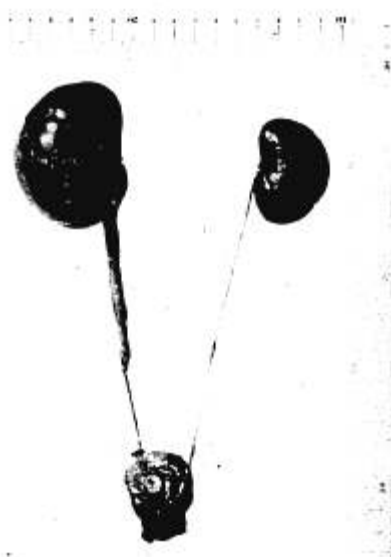


FIG. 10.—Dog No. 152. Hydronephrosis following ureteral calculus at junction of lower and middle thirds. Bladder shows vesical calculus.



FIG. 11.—Hydronephrosis following calculus at ureteropelvic junction of ureter. From clinical case.



FIG. 12.—Hydronephrosis following calculus at ureteropelvic junction of ureter. Showing cut section.



FIG. 13.—Dog No. 146. Showing intertubular and glomerular congestion occurring at the end of five days, following stripping of ureter.



FIG. 14.—Dog No. 70. Showing dilated peripheral tubules from dilated tubules stage of experimental hydronephrosis.

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Keen¹⁶ and others enumerate tumors of the ureter and bladder among the causes of nephrectasia.

We offer for consideration the following: Physiologic or adynamic ureteral obstruction may give rise to distended kidney. To determine this we used dogs, after properly narcotizing with morphia and anæsthetizing with ether. In nine cases¹⁸ the ureter was removed from its bed and stripped of every recognizable vessel nerve and fascial connection from kidney pelvis to bladder insertion, and in order to make sure it was absolutely freed from nervovascular connections through its course as well as to irritate the suppositional nerve plexus in the adventitia of the ureter, this organ was rubbed snugly with dry gauze throughout. It was then allowed to drop back into the abdominal cavity. In each case a cubical foreign body infected with autogenous colon bacilli and other organisms, and of such shape as not to cause valvular urethral obstruction as suggested by Draper and Braasch, was placed in the bladder through a mesoventrad incision, so that, as subsequent examinations of urine and bladder revealed, a permanent purulent cystitis was produced. The results were as follows:

TABLE II
SHOWING EFFECT OF STRIPPING URETER¹⁸

Case No.	Gross Findings	Microscopical Findings	Cause of Death	Condition of Ureter	Bacteriological Findings	Days of Life
103	Hydronephrosis	Congestion	Intussusception	Patent	Coccus colon-like organ	7
70	Hydronephrosis	Dilated tubules	Hydronephrosis	Stenosed	Coccus colon-like organ	21
17	Hydronephrosis	Dilated tubules	Hydronephrosis	Patent	Coccus colon-like organ. No change in fixation test for colon	31
54	Hydronephrosis; hydro-ureter	Nephritis	Hydronephrosis	Patent	Culture omitted	25
69	Pyonephrosis	Purulent nephritis	Pyonephrosis	Stenosed	Coccus colon-like organism	29
21	Normal	Glomerular congestion	Perforation of bladder	Patent	No change in fixation test for colon	24
22	Parenchymatous degeneration	Parenchymatous degeneration	Peritonitis (technical)	Patent	No change in fixation test for colon	8
24	Interstitial nephritis	Productive nephritis	Pneumonia	Patent	Culture omitted	121
100	Hydronephrosis	Nephritis	Hydronephrosis	Stenosed	Culture	69

In each of the three cases designated "stenosed" the obstruction appeared to be organized blood within the ureter. Wagner, referring to his clinical case, alluded to intra-ureteral hemorrhage following traumatism. Blood is allowed to remain, coagulate, and be organized because of ureteral paralysis and is, in our opinion, coincidental rather than causative in the development of hydronephrosis.

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To study the physiological effect of such traumatism upon the ureter a dog was etherized to analgesia and the following observations made upon ureteral movements:

Case 160.—(1) Waves of ureteral peristalsis were noted at 9-second intervals. (2) Waves of ureteral peristalsis were noted at 16-second intervals with middle ureter stripped. (3) Waves of ureteral peristalsis were noted at 25-second intervals with greater part of ureter stripped. (4) Waves not continuous. Fibrillary contractions noted at 69-second intervals with ureter completely stripped. While at the same time waves of peristalsis were observed at 7-second intervals in normal ureter.

Case 161.—Case was similarly treated. Two ureters were exposed—one left intact, other stripped. On rolling normal ureter under finger contractions were elicited; on rolling stripped ureter under finger no contractions could be aroused.

From this observation it would appear that a cause of urinary stasis in the above experiments was ureteral paralysis. We, therefore, offer tentatively, and subject to further experimental proof as a cause of hydronephrosis, a ureteral condition analogous to adynamic ileus. It is true in several of the cases a mechanically obstructed ureter was found, but that such obstruction was irrelevant appears from a comparison of ten subsequent cases in which not one similarly obstructed ureter was found. These were cases in which the valve was cut and in addition, the ureter was stripped.

TABLE III
SHOWING EFFECT OF STRIPPING URETER AND CUTTING URETEROVESICAL VALVE¹⁸

Case No.	Gross Findings	Microscopical Findings	Cause of Death	Days of Life
74	Normal	Normal	Hamoperitoneum	0
80	Congested	Glomerular congestion	Hamoperitoneum	2
72	Pyelonephritis	Suppurative nephritis; abscesses; suppurative ureteritis	Pyelonephritis	7
77	Pyelitis	Congested parenchymatous swelling	Pyelonephritis	3
73	Pyelonephritis	Suppurative nephritis	Pyelonephritis(?)	23
89	Congested kidney	Parenchymatous degeneration; congestion	Pyelonephritis	20
88	Parenchymatous degeneration	11
83	Pyelonephritis	Suppurative nephritis; abscesses; tubules distended with pus cells. Glomeruli free	Pyelonephritis	13
81	Pyelitis; congested kidney	Glomerular congestion	18
84	Chronic nephritis	Ether	121

Histologically, the various changes in the kidney in experimental hydronephrosis have not yet been studied in sufficient detail to warrant more than passing mention at the present moment. The first step, however, appears to consist of widespread intertubular and glomerular congestion followed by granular degeneration and hydropic changes in

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the epithelium, particularly of the convoluted tubules. At a later stage, corresponding to moderately advanced dilatation of the pelvis, the cortical tubules become markedly distended, their lining epithelium undergoes atrophy and the interstitial tissues begin to show the effects of compression. Finally, with increasing dilatation of the pelvis and obliteration of the calyces, the kidney tissue becomes noticeably compressed and its individual elements—tubules and glomeruli—atrophy. In secondarily infected organs the mucosa of the pelvis is replaced by a thick membrane made up of degenerated polynuclear leucocytes.

Clinically, one of the recent cases occurring in the practice of one of the authors (Stewart) typifies the hydronephrosis complex and emphasizes the important relationship existing between experimental and applied surgery. In this case there were found at operation a large hydronephrotic kidney and a calculus snugly wedged into the ureteropelvic isthmus of the cephalad ureter. Through the courtesy of Professor Douglas Symmers, to whom we are indebted for the microscopical study of our specimens, it was determined beyond reasonable doubt that the specimen was an adult kidney which had undergone pressure atrophy from the extreme distention of the pelvis and calyces. Experimentally a similar case was produced in one of our dogs, dog No. 152, by a calculus accidentally slipped into the caudad ureter to the junction of the lower and middle thirds. But these cases, alike in their gross and microscopical pathology, corresponded with the specimens produced by paralyzing the ureters. There may be a relationship between the ureteral calculus and the prostatic wave that is in its effect the same as an atonic ureter. Especially does such a possibility seem likely when as in our human case the calculus intervened between the pelvic and straight portions of the ureter, the point where, as described by Lucas¹⁷ and observed by us, a change occurs in ureteral contractions and functions.

CONCLUSIONS

1. It is generally agreed that mechanical obstruction gives rise to urinary stasis and, when continued sufficiently long, to kidney distention.
2. This mechanical obstruction may be complete or incomplete, gradual or sudden. When the obstruction is sudden and complete transitory hydronephrosis with marked congestion follows. Atrophy intervenes and is proportionate to the duration of the obstruction.
3. Paralysis of the ureter is accompanied by urinary stasis and kidney distention in 66 per cent. of cases.

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4. The pathological changes in hydronephrosis of functional origin correspond to the age of the adynamic ureter.

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