The Effect of Transureteroureterostomy upon Conduction of Peristaltic Waves

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HARADA, T. The Effect of Transureteroureterostomy upon Conduction of Peristaltic Waves. Tohoku J. exp. Med., 1979, 128 (1), 51–61 —— Transureteroureterostomy was performed in 32 adult dogs, and the results were evaluated by electroureterographic, roentgenographic and histological investigations. The results revealed no significant ill effect on ureteral and renal functions, indicating the procedure to be quite reasonable and clinically acceptable.

The first clinical cases treated by transureteroureterostomy were reported byiggins (1935). In 1960, Anderson and his associates reported 7 cases using this procedure and subsequently many cases have been reported. Although their results were considered satisfactory, the procedure is still not generally accepted, important questions concerning ureteral function subsequent to ureteroureteral anastomoses remain unanswered.

Using transureteroureterostomy, Boyarsky and associates (1968) operated on dogs, and examined the ureteral function by intravenous urographic cinefluorography and peristaltic pressure studies. Their experimental work showed abnormal peristalsis, failure of conduction of urine through the anastomosed site, and the frequent occurrence of retrograde transport of urine to upper ureters. They pointed out also the predisposition to infection caused by ureteral dyskinesia.

The shortcoming of the study lies in their use of indwelling catheter and cinefluorography to study the ureteral functions, since it is impossible in their experimental design to distinguish between normal peristalsis and retrograde peristalsis, and between retrograde transport of urine and retrograde peristalsis. Furthermore, introduction of a catheter into the ureter may modify the ureteral function.

From these considerations, we examined the effect of transureteroureterostomy upon ureteral function by electroureterograms and ureteral pressure studies.

MATERIALS AND METHODS

The experimental animals were adult mongrel dogs weighing 12 to 16 kg. Different dogs were observed at 2 postoperative intervals: 10 dogs over a short period of time (up
to 6 hr after the operation) and 21 dogs over a long period (between 1 and 6 months postoperatively). In both groups, electroureterograms and pressure changes at the sites of anastomosis and the renal pelvis were taken (Fig. 1). Intravenous and retrograde pyelography and histological analyses were added to the long-term study.

The dogs were anesthetized with sodium pentobarbital, and the operations were performed by transureteroureterostomy using retroperitoneal end-to-side anastomosis. The electroureterographic recordings were made at 3 sites on the anastomosed ureter (left upper, right upper and left lower) to examine the peristaltic frequency, conduction velocity and direction of peristalsis. The electrodes were the extraluminal bipolar type similar to those described by Fredericks and his associates (1968), and the ureteral action potentials were recorded together with other measurements on a Nihon Kohden RM–85 polygraph. To record the pressure changes at the anastomosed site, a 22G hypodermic needle bent into an “L” shape was inserted into the lumen and directly connected to the Statham P 37 transducer. Renal pelvic pressures were recorded with a Nihon Kohden strain guage manometer through a No. 3 Fr. polyethylene tube inserted into the renal pelvis through the nephrostomy.

RESULTS

Short-term study

Electroureterograms. Electroureterographic recordings were examined preoperatively (Fig. 2). Peristaltic action potentials recorded at the 3 sites of the ureters always showed normalperistalsis. The average peristaltic frequency was 9.1 waves/min (range; from 5 to 17 w/min), and conduction velocity was 30.2 mm/sec (range; from 15 to 39 mm/sec).

Postoperative electroureterograms were also taken with the following results: The right upper ureter; although the discharge intervals of action potentials showed some irregularity 1 to 3 hr after the operation, they returned to preoperative levels within 6 hr, except 2 cases in which discharge intervals were increased. Conduction velocity was decreased in 2 cases. Retrograde peristalses, observed in 2 cases 2 hr
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after the operation, completely disappeared 3 hr later. The left upper ureter; the
lischarge intervals in 7 cases were the same as preoperative levels, while those in 3
ases remained longer than preoperative levels up to 6 hr after the operation. The
 conduct velocity was almost constant in 7 cases, but showed a 20 to 30 percent
crease in 3 cases. The retrograde peristalsis which was observed between the
irst and second hr returned to normal 3 to 4 hr after the operation. The left lower
ere; the action potential discharge of the left lower ureter either synchronized or
esychronized with that of the ureters above the anastomosed site (Fig. 3). The
lischarge intervals showed marked variation: a 20 percent decrease in 1 case
nd a 30 to 70 percent increase in 3 cases. The conduction velocity was the same
s preoperative levels in 9 cases, and decreased in 1 case. Antiperistalsis was
erved in 1 case after 1 hr, although it returned to normoperistalsis within 6 hr.

In both short-term and long-term studies, the conduction of peristaltic waves
nder the condition of transureteroureterostomy showed different patterns. In
ome cases, peristaltic waves coming from the upper ureter (right or left) were
duced through the anastomosed site, while in other cases they were blocked
ere and never reached the lower ureter. These peristaltic waves moving through
 anastomosed site were classified into 5 types (Fig. 4). Type I; peristaltic
aves coming from the upper ureter are conducted through the anastomosed site
nd reach the lower ureter. Type II; peristaltic waves coming from the upper
ere are conducted through the anastomosed site to the lower, while anti-
eristaltic waves occur simultaneously at the anastomosed site and move towards
 renal pelvis. Type III; peristaltic waves coming from the upper ureter are
ompletely blocked at the anastomosed site and never reach the lower ureter.
Fig. 4. The manner of conduction of peristaltic wave through the anastomosed site. In each diagram, the top curve was obtained from the left upper ureter, the middle curve from the left ureter lower than the anastomosis, and the bottom curve from the right upper ureter.

Type IV; antiperistaltic waves coming from the urinary bladder are conducted through the anastomosed site and reach the renal pelvis via either the left upper ureter or the right upper ureter. Type V; antiperistaltic waves, independent of electrical activity of the lower ureter, originate at the anastomosed site and move towards the renal pelvis.

Thirty waves of peristalsis in the upper ureter above the anastomosis were counted in each dog. Taking the 10 dogs in the short-term study, the total number of discharges was 300. This total number was then classified according to the criteria of the conduction pattern mentioned previously. The results of this classification for the short-term study were as follows: For peristaltic waves
oming from the right upper ureter, the percentage of Type III was 100; and for eristalses coming from the left upper ureter, the percentage of Type I was 62.8, nd type III, 36.2.

**Pressure changes at the anastomosed site.** Pressures at the site of anastomosis were recorded together with electrouretrographic recordings in 4 cases. During the lasting time of electrical activity in the upper ureters above the anastomosis, the average anastomotic pressure was 4.8 cmH\(_2\)O (range; from 3 to 6 cmH\(_2\)O). When eristalsis came from the upper ureters, the average was 20.8 cmH\(_2\)O (range; from 0 to 30 cmH\(_2\)O). As indicated in Fig. 5, when peristaltic waves coming from ether left or right upper ureter arrived at the anastomosed site, the pressures were increased markedly. However, when action potential discharges occurred at the right lower ureter, the pressure increased to 35.1 cmH\(_2\)O on the average (range; from 8 to 42 cmH\(_2\)O).

![Graph](image)

**Fig. 5.** Case 2. Pressure at the anastomosed site.

**Long-term study**

**Electroureterograms.** 16 cases were examined in an oliguric state where the urine flow rate was under 0.5 ml/min, and 21 cases in a diuretic state where the urine flow rate was 2 ml/min. The right upper ureter: the average frequency of action potential discharges was 3.9 waves/min (range; from 2 to 5 w/min) in an oliguric state and 7.0 w/min (range; from 4 to 13 w/min) in a diuretic state. Conduction velocity of peristalsis in the right upper ureter was 16 to 35 mm/sec (average, 28.8 mm/sec) in an oliguric state and 17 to 35 mm/sec (average, 28.3 mm/sec) in a diuretic state. In 5 cases, antiperistalses were observed in an oliguric state at the frequency of 1 to 4 w/min (average, 1.6 w/min), and 8 cases in a diuretic state, averaging 0.5 w/min and ranging from 1 to 3 w/min. The left upper ureter: the average frequency of peristalses was 3.1 w/min (range; from 1 to 6 w/min) in an oliguric state and 6.5 w/min (range; from 4 to 10 w/min) in a diuretic state. The velocity of peristalsis was 19.4 to 36.4 mm/sec (average, 27.3 mm/sec) in an oliguric state and 22.1 to 33.3 mm/sec (average, 26.4 mm/sec) in a diuretic state. There
were 12 cases in which antiperistaltic waves were observed in an oliguric state, 8 cases in a diuretic state. The average frequency of antiperistalsis was 2.1 w/min (range; from 1 to 4 w/min) in an oliguric state and 1.5 w/min (range; from 1 to 2 w/min) in a diuretic state. The left lower ureter: the average frequency of peristalsis was 3.8 w/min (range; from 4 to 10 w/min) in a diuretic state. The velocity of peristalsis was 22.0 to 34.7 mm/sec, (average, 28.8 mm/sec) in an oliguric state and 22.0 to 35.1 mm/sec (average, 29.0 mm/sec) in a diuretic state. Antiperistaltic waves were observed in neither oliguric nor diuretic states.

Conduction velocity at the anastomosed site. The velocity of normoperistaltic waves conducted through the anastomosis was measured in a diuretic state. When peristaltic waves came from the right upper ureter via anastomosis to the left lower ureter, the velocity at the anastomosis was 13.6 to 16.5 mm/sec (average, 18.6 mm/sec) and showed a greater rate of decrease than any other site on the ureters. When the peristaltic waves were moving from the left upper ureter via the anastomosis to the left lower ureter, the velocity was 15.5 to 35.3 mm/sec (average, 2.7 mm/sec), lower than normal, yet higher than those of waves coming from the right upper ureter.

The manner in which a peristaltic wave is conducted through the anastomosed site. As described in the short-term study, peristaltic waves moving through the anastomosis were classified into 5 types and ratios of these types were also calculated. In 16 dogs in an oliguric state, the total number of action potential discharges was 480. As for peristaltic waves coming from the right upper ureter, Type I appeared at a percentage of 9.1, Type II at 51.7 and Type III at 39.3. For those coming from the left upper ureter, the percentage of Type I was 85.5, Type II 13.9 and Type III 0.6. Fig. 6 indicates the conduction patterns as differentiated by electroureterograms 2 months after the operation. On the other hand, in 21 dogs in a diuretic state, the total number of action potential discharges was 630. For the peristalses coming from the right upper ureter, the percentage of Type I was 4.5, Type II 11.0 and Type III 85.3. For those coming from the left upper ureter, the percentage of Type I was 90.2, Type II 6.6 and Type III 2.2. Fig. 7 indicates the conduction patterns as differentiated by electroureterograms 4 months after the operation.

![Fig. 6. Case 11. Ureteromyograms in an oliguric state 2 months after the operation. The peristaltic wave was blocked at the anastomosed site (×) and never reached the lower ureter.](image-url)
Therefore, the characteristic type of peristaltic conduction found in the long-term study was Types I and II, which appeared in the peristalses coming from the right upper ureter. This phenomenon never occurred in the short-term study.

**Pressure changes at the anastomosed site.** These measurements were taken on 8 dogs in a diuretic state. Resting pressure at the anastomosed site was 0 to 8 cmH$_2$O (average; 1.9 cmH$_2$O). When peristalses coming from the right upper ureter were obstructed at the anastomosis (Type III), pressures were increased from 16 to 48 cmH$_2$O (average; 29 cmH$_2$O). Pressures were further increased when peristalses coming either from the left upper ureter (range, from 18 to 64 cmH$_2$O; average, 36 cmH$_2$O) or the right upper ureter (range, from 20 to 56 cmH$_2$O; average, 34 cmH$_2$O) were conducted through the anastomosis.

**Renal pelvic pressures.** Pressure changes in both renal pelves were measured in 4 cases and renal pelvic wave forms having constant frequencies were observed. The resting pressure was 0 to 5 cmH$_2$O (average, 2.2 cmH$_2$O) and the contracting pressure was 7 to 15 cmH$_2$O (average, 10.6 cmH$_2$O). Usually, each peristaltic wave was preceded by a renal pelvic contraction. However, the effect of antiperistalsis on renal pelvic pressures was so minimal that upon arrival of antiperistalsis, pressure changes in the renal pelvis were only 2 to 3 cmH$_2$O.

**Radiologic and histological studies.** Seven cases were examined by intravenous pyelography and retrograde pyelography 1 to 6 months after the operation (Fig. 3). Intravenous pyelograms in 6 cases showed good bilateral kidney function without enlargement of the renal pelvis and calyx. In these cases, stricture at the site of anastomosis was never observed by retrograde pyelography. Although the function of the right kidney deteriorated in 1 case, enlargement of the renal pelvis and ureters never occurred. Finally, autopsies performed on the 21 dogs showed the kidney to be almost normal, without hydronephrosis or stricture at the site of the anastomosis (Figs. 9 and 10A, B).

**DISCUSSION**

In the short-term observation, peristaltic frequency in the ureters above the anastomosis increased postoperatively, returning to preoperative levels in about 1 hr. Conduction of peristalsis was slower in the ureters above the anastomosis
than during the preoperative level, reaching a normal level usually between the 5th and 6th hr following the operation. These tendencies have also been noted by Butcher and Sleator (1956), and Weinberg and Siebens (1958). Butcher and Sleator (1956), using an intraluminal electrode, observed that conduction velocity was slower in the ureters above the anastomosis than below it when a significant hydroureter was present. We agree to their observation that both the frequency and velocity in the ureters above the anastomosis are increased, and that these tendencies appear to be induced by urine retention above the anastomosed site, the cause of which is a functional defect in the peristaltic conduction through the anastomosis.

We classified the manner of conduction through the anastomosis into 5 types in order to examine the various conduction patterns. In the short-term study, peristalsis of Type I coming from the left upper ureter showed a percentage of 60; that is, 60 percent of the peristaltic waves coming from the left upper ureter were effectively conducted through the anastomosis, whereas, for those of Type III coming from the right upper ureter, the percentage of Type II was 100, i.e., all the peristaltic waves coming from the right upper ureter were obstructed at the anastomosed site. The same result was reported concerning a transected and an anastomosed ureter by Butcher and Sleator (1956), Weinberg and Siebens (1958), and Caine and Hermann (1970).
If the failure of peristalsis causes significant stasis, pressures at the anastomosed site would be markedly increased and eventually elevate the pressure in the 'right' renal pelvis. However, pressure measurements showed that pressures at those sites were not markedly increased, although they were actually increased by about 20.8 cmH₂O when peristaltic waves arrived at the anastomosed site. In cases where peristaltic waves coming from the left upper ureter were conducted through the anastomosis, contracting pressures were increased to as high as 35.1 cmH₂O. Resting pressures were 3 to 6 cmH₂O (average, 4.8 cmH₂O), and did not exceed this pressure. These pressure changes were almost the same as those in normal ureters, as reported by Kiil (1957), and Tsuchida and associates (1969) using urometry, and our previous report (Tsuchida et al. 1973) using a hypodermic needle thrust into the lumen. Consequently, even if urine transported from the renal pelvis was retained at the site of anastomosis, it would be most likely transported to the urinary bladder by peristalsis of the lower ureter below the anastomosis. Therefore, urine stasis is a transient process.

In the long-term study, since the peristaltic frequency and velocity in the ureters above the anastomosis usually returned to levels close to those before the
Fig. 10. A: Case 16. Photomicrograph of the ureter transected longitudinally at the anastomosed site 3 months after the operation.
B: Case 17. Photomicrograph of the ureter transected transversely at the anastomosed site 5 months after the operation.

operation, the effect of the operation appeared to be minimal.

The conduction velocity at the anastomosis averaged 23.4 mm/sec when peristaltic waves came from the left upper ureter via the anastomosis to the left lower ureter, and 19 mm/sec when coming from the right upper ureter via the anastomosis to the left lower ureter. These velocities were less than those in the other portions of the ureter. Therefore, conduction delay at the site of the anastomosis was obvious, especially when the conduction pathway ran from the right upper ureter via the anastomosis to the left lower ureter. It seems that the delay of conduction at the anastomosis is related to the spatial irregularity of the ureteral smooth muscle layer caused by cicatricial tissue in the region of the anastomosis.

The next point examined is how peristaltic waves coming from the left or right upper ureter are conducted through the anastomosis. In the long-term study, we found that more than 60 per cent of the peristaltic waves in an oliguric state which traveled from both upper ureters were conducted through the anastomosis to the left lower ureter, whereas, in a diuretic state, peristalsis traveling from the right upper ureter were almost always obstructed at the anastomosed site (Type I, 4.5%; Type II, 11.0%; Type III, 85.3%), although a greater percentage of peristaltic waves in the left upper ureter were conducted through the anastomosis (Type I,
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0.2%; Type II, 6.6%; Type III, 2.0%). Through careful observation, obstruction of peristalses coming from the right upper ureter proved to occur immediately after peristalses in the left upper ureter arrived at the anastomosis. Therefore, the region of the anastomosis appeared to be still in a refractory period for action potentials coming from the right upper ureter. But, it is difficult to explain it in any detail with presently accepted theories of conduction.

Since pressures at the anastomosed site were in all cases similar to those in the normal ureters, it is certain that urine retention at the anastomosis never occurred. If transient stasis occurred, peristaltic motion in the left lower ureter probably transported urine to the bladder. One further point of emphasis is that the effect of antiperistalsis occurring at the anastomosis upon renal pelvic pressure is not significant. Although Boyarsky and his associates (1968) described the frequent occurrence of retrograde transport of urine between the upper ureters, our study showed that pressures in the renal pelvis were increased to as little as 3 cmH₂O when antiperistalsis reached the renal pelvis. This pressure change is within normal variation of intrapelvic pressure, and there seems to be little fear of deterioration of kidney function.

References