Electromyographic Studies on Urinary Tract

III. Influence of Pinching and Cutting the Ureters of Dogs on Their EMGs

By

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INTRODUCTION

In sequence to the previous study, the ureters of dogs were pinched or cut under laparotomy, and their EMGs were recorded under such conditions. The results obtained are remarked in the present report.

EXPERIMENTAL METHODS

Thirty two adult dogs were subjected to the experiments described below under the same conditions as given in our second report¹⁾. Their ureters were pinched or cut at the pyeloureteral and ureterovesical junctions and at the middle part of the ureter.

EXPERIMENTAL RESULTS

I. EMG of pinched ureters

1) When the ureters were pinched at the pyeloureteral junction in the 5 cases, as shown in Fig. 1, left side and Fig. 2, one normoperistaltic discharge was set off at the pinching, then the peristaltic discharge was suspended for 1.0-2½ min. before the spontaneous normoperistaltic discharges were reinstated.

The pinching little affected the frequency, the amplitude, the duration or the wave pattern.

2) When the ureters were pinched at about the median point in 5 cases, as shown in Fig. 1, middle portion and Fig. 3, upward and downward propagating discharges occurred simultaneously at each pinched part. Thereafter, normoperistaltic discharges continued to occur in the part above the clamp, but in the part distal to it, peristaltic discharges were in abeyance for 1½-2½ min. before the normal discharges came through the pinched part. Here again, the properties about the discharges were not perceptibly affected by the pinching.

Fig. 1. The ureters were pinched at three points.

Fig. 2. EMG by pinch at the pyeloureteral junction.

Fig. 3. EMG by pinch at the middle part of the ureter.

Fig. 4. EMG by pinch at the ureterovesical junction.

Fig. 5. EMG led off with two pairs of bipolar leading by pinch at the ureterovesical junction when the spontaneous normoperistaltic discharges reappeared.

3) When the ureters were pinched at the ureterovesical junction in 7 cases, as shown on the right of Fig. 1 and Fig. 4, only a single antiperistaltic discharge arose at the pinched part, the normal normoperistaltic discharges from above being neither suspended nor perceptibly changed in their propagation velocity and such properties.

In the experiment with two pairs of bipolar leading, as shown in Fig. 5, when the ureter was pinched at the ureterovesical junction at the time of appearance of normoperistaltic discharges at the upper twin electrodes, the antiperistaltic discharges set off from the pinched part were detected only by the lower pair of electrodes without being transmitted to the upper pair, while the normoperistaltic discharge from above faded out before reaching the lower pair, so that it is clear that the two opposite discharges collided and cancelled out each other midway.

II. EMG of cut ureters

1) When the ureter was cut at the pyeloureteral junction in 6 cases, as shown in Figs. 6 and 7, the normoperistaltic discharges of 3–14 w/min. observed before the cut were stopped at once, and 16 sec.–4 min. 25 sec. thereafter, antiperistaltic discharges of 0–7 w/min. began to be set off from the ureterovesical junction and remained active throughout the period of observation for 17–50 min. In 2 of the 6 cases, these antiperistaltic discharges came forth as solitary discharges at irregular intervals ranging between 13 sec. and 187 sec. (Fig. 7), in one case, they appeared at the group-intervals of 32–111 sec. in groups of two or three discharges of 1.8–2.3 sec. intervals, and in the other three cases at the irregular intervals of 18–232 sec. as solitary discharges mingled with groups of 2–7 discharges (Fig. 8).

In these cases, the measured values of the propagation velocity, the amplitude, the duration and the wave pattern were 20–45 mm/sec., 0.3–3.4 mV., 0.2–0.9 sec. Type I or II of normoperistaltic discharges and 27.3–45 mm/sec. 0.3–

Fig. 6. The ureters were cut at parts indicated by broken line.

Fig. 7. EMG led off with 4 electrodes after cut at the pyeloureteral junction.

Fig. 8. EMG led off with 4 electrodes after cut at the pyeloureteral junction.

Fig. 9. EMG after cutting the middle part of ureter.

3.4 mV., 0.2–0.8 sec. I or II of antiperistaltic discharges, respectively.

2) When the ureter was cut off midway in 8 cases, the normoperistaltic discharges of 4–13 w/min. in frequency coming from above to the cut point were nearly the same frequency as those before the cutting (2–17 w/min.) as shown in Fig. 9.

In the ureter below the cut, the normoperistaltic discharge was suspended after the cutting, transiently in 4 cases, in which antiperistaltic discharges of 0–10 w/min. in frequency began to be set off in 50 sec.–3 min. from the ureterovesical junction and remained in force during the period of observation for 10–28 min., but in the remaining 4 cases, we could not observe such upward discharges.

In 2 of the 4 cases with the antiperistaltic discharges, they were grouped in 2–10 discharges at 1.8–3.2 sec. in intervals, the groups occurring at the intervals of 84–176 sec., in other cases, they occurred in solitary discharges at the irregular intervals fluctuating between 10 sec. and 79 sec. and in another case, solitary and grouped discharges appeared in mixture at the intervals of 44–152 sec.

The propagation velocity, the amplitude, the duration and the wave pattern of these normoperistaltic and antiperistaltic discharges above and below the cut were summarized in the following Table. I.

In the cases in which no discharge was found to occur in the ureter below the cut, i.v. administration of 10 mg/kg. of 2% xylocaine caused occurrence of antiperistaltic discharges of 0–8 w/min., as shown in Fig. 10, and the frequency of the normoperistaltic discharges in the part above the cut was raised thereby from 5–8 w/min. to 20–30 w/min. A similar injection in the case with antiperistaltic discharges of 1–3 w/min. caused an increase of the frequency of both the normoperistaltic discharges above the cut and the antiperistaltic discharges below it, as shown in Fig. 11.

TABLE I. The Measured Values of Discharges before and after the Cutting

	Direction	Propagation velocity mm/sec.	Amplitude mV.	Duration sec.	Wave pattern
Upper ureter	Before cut. Normo.	22.7-46.9	0.3-1.45	0.25-0.6	I-II
	After cut. Normo.	22.7-44.1	0.3-1.5	0.3 -0.55	I-II
Lower ureter	Before cut. Normo.	16.6-46.2	0.3-2.5	0.25-0.65	I-II
	After cut. Anti.	23.2-46.2	0.4-2.6	0.3 -0.55	I-II

Fig. 10. EMG by i.v. injection of 2% xylocaine 10 mg/kg. in a case in which discharge disappeared following cutting at the middle.

Fig. 11. EMG by i.v. injection of 2% xylocaine 10 mg/kg following cutting at the middle part of the ureter.

3) When the ureter was cut at the ureterovesical junction in 5 cases, two pairs of bipolar leading placed in the upper part of the ureter continued to record the discharges (2-8 w/min.) of the same frequency as before the cutting (2-9 w/min.) throughout the period of observation for 26-52 min. (Figs. 6 and 12). Their propagation velocity, amplitude, duration and wave pattern were not

Fig. 12. EMG by cut at the ureterovesical junction.

Fig. 13. EMG by trisection of ureter.

Fig. 14. EMG of trisected ureter. The direction of the discharge found at the middle part was unknown.

perceptibly affected by the cutting either.

4) When the ureter was trisected lengthwise in 5 cases, the normal normo-peristaltic discharges persisted at unvarying frequency (3–9 w/min. before and 4–9 w/min. after the trisection) in the upper 1/3, as shown in Fig. 13. In the median 1/3, we found no discharge occurring at all in 3 cases throughout the period of observation for 20–45 min., while in the other 2 cases, as shown in Fig.

Fig. 15. EMG of trisected ureter. In the lower part antiperistaltic discharges were found.

14, discharges suggestive of antiperistaltic direction were caught by the lower electrode in 28 and 107 sec.; in one of them only two groups of three discharges each at 3–3.5 sec. of intervals appeared at the group-interval of 13 min. apart (0–3 w/min.), and in the other 14 solitary discharges came forth at the irregular intervals of 28–145 sec. (0–2 w/min.).

In the lowest 1/3 of the cut ureter, 6–17 antiperistaltic discharges appeared in 4 cases 128–272 sec. after the trisection, at the irregular intervals of 6–252 sec. and the frequency of 0–4 w/min. continuing throughout the period of observation of 20–45 min. as shown in Fig. 15. In the other case we observed no occurrence of such discharges.

The particulars of the discharges before and after the trisection were as follows (Table II).

In the cases where discharges failed to occur in the middle or the lowest part, i.v. injection of 10 mg/kg. of 2 % xylocaine caused antiperistaltic discharges of 1–4 w/min. in all the cases except in one middle portion, as shown in Fig. 16. In the upper 1/3, where the normoperistaltic discharges always persisted after the trisection, the frequency of the discharges was more than

TABLE II. The Measured Values of the Discharges by Trisection

	Propagation velocity mm/sec.	Amplitude mV.	Duration sec.	Wave pattern
In the upper 1/3				
Before cut	13.3–26.8	0.4–3.0	0.3–1.1	I–II
After cut	13.3–27.6	0.4–2.6	0.35–1.1	Ditto
In the middle 1/3				
Before cut	27.0–34.1	0.2–1.5	0.5–0.62	Ditto
After cut	Ditto	0.35–1.1	0.15–0.2	Ditto
In the lower 1/3				
Before cut	21.4–29.7	0.4–3.3	0.4–0.9	Ditto
After cut	29.7–40.6	0.4–2.9	0.6–0.9	Ditto

Fig. 16. EMG by i.v. injection of 2% xylocaine 10 mg/kg. in those cases in which the discharge at middle and lower parts faded out following the trisection.

Fig. 17. EMG by i.v. injection of 2% xylocaine 10 mg/kg. in those cases in which the discharge appeared at any parts following the trisection.

quadrupled by similar injection. A marked increase in frequency was observed also after similar injection in the case with discharges appearing in the middle and the lower part after trisection, enduring for a few min., as shown in Fig. 17. The increase in frequency and continuing time of the discharges was the largest in the upper 1/3, next in the lower and the smallest in the middle portion.

DISCUSSION

Alksne²⁾, Gruber³⁾, Wu⁴⁾, Nobuta⁵⁾, Takagi⁶⁾ and Satani⁷⁾ have reported on experiments with cut ureters, but these studies were conducted with excised ureters. We have made systemic experimental studies following pinching and cutting of vital ureters of dogs at different points and described the EMG records of the upper, the middle and the lower parts of the ureters in the above.

We found that a single normoperistaltic discharge occurred upon pinching the pyeloureteral junction, a pair of normo- and anti-peristaltic discharges upon pinching the middle part and a single antiperistaltic discharge upon pinching the ureterovesical junction, always at the pinching point. These findings are in complete concurrence with those by Engelmann⁸⁾ and Alksne²⁾. After pinching of

the pyeloureteral junction and the middle part of the ureter, the transmission of discharges was suspended for a few minutes.

In the experiments with cut ureters, we found that the ureter, even if bisected or trisected, has a capacity for contraction in any of the cut portions, and the pyeloureteral junction and the ureterovesical junction have each a direction-determining factor, the normoperistaltic wise and the antiperistaltic wise respectively, but the middle portion failed to show any definite direction determination.

Gruber³⁾ experimented with excised ureters and found the mean frequency of contractions to be the highest in the upper portion (4.1 w/min.), next in the lowest portion (3.4 w/min.) and the smallest in the middle portion (2.0 w/min.), Alksne²⁾ made similar experiments with excised ureters of guinea pigs and reported the frequency of contractions per 5 min. of 4–6 in the upper portion, of 3–6 in the lowest portion and 1–4 in the middle portion. Our findings with trisected ureters seem to accord with these authors'. But Wu⁴⁾, Nobuta⁵⁾, Takagi⁶⁾ and Satani⁷⁾ who experimented with excised animal ureters arrived at results at variance with ours, claiming that the frequency of peristaltic movements was the highest in the upper, next in the middle and the lowest in the lowest portions.

Hryntschak⁸⁾ found upon resecting at the pyeloureteral junction of pig's ureter excised with a part of the urinary bladder attached to it, the original normoperistaltic movement was reversed into the antiperistaltic direction. Alksne²⁾ cut vital canine ureters and found antiperistaltic movement always arising at the vesical end in the lower portion of the ureter. Takagi⁶⁾ reports that in the ureters cut out from dogs, guinea pigs and rabbits without detaching the pyeloureteral junction, the peristalsis always runs downwards, and only very rarely upwards from the vesical end, but in the samples of ureter excised from the pyeloureteral junction, the antiperistaltic movement was usual. These findings are apparently in general concurrence with what we found in our cut ureters.

Gruber³⁾ investigated the spontaneous movement of bisected ureters sampled from pigs and said that the relative frequencies of observed normo- and antiperistaltic movements were 73.7% : 26.3% in the renal half and 28.1% : 71.9% in the vesical half, but these figures are apparently irreconcilable with our results, for we saw only normoperistaltic movements in the renal half and only antiperistaltic movements in the vesical half of cut ureters.

The results of the experiments with cut ureters above and our previous paper showing that the frequency and the increment of frequency of the discharges following xylocaine injection in the periureteral tissues are both the highest in the renal part of the ureter indicate that the pyeloureteral junction is the most sensitive to stimulation of all the ureter and it is probable that this part plays a leading part in the maintenance of physiological normoperistalsis.

CONCLUSION

The ureters of 32 adult dogs were exposed by laparotomy, pinched or cut at pyeloureteral junction or ureterovesical junction or some intermediate points and their EMG was studied. The results obtained were in summary as follows:

1) When the ureter was pinched at the pyeloureteral junction or the ureterovesical junction, one single normo- or anti-peristaltic discharge each was set off from the respective pinched part, while the clamp was applied to the middle part of the ureter, one upward antiperistaltic and one downward normoperistaltic discharges were simultaneously released from the pinched part. When the pyeloureteral junction or a mid-ureteral point was pinched, a suspension for $1\frac{1}{2}$ – $2\frac{1}{2}$ min. of discharge transmission occurred in the parts below the clamp.

2) Even after the ureter was bisected or trisected, the individual portions all showed spontaneous contraction and emitted peristaltic discharges, in the normoperistaltic direction in the upper portion, the antiperistaltic direction in the lower and in the antiperistaltic or suspiciously antiperistaltic direction in the middle portions. The frequency of these partial spontaneous discharges was the largest in the upper portion (2–13 w/min.), next in the lower portion (0–10 w/min.) and the smallest in the middle portion (0–3 w/min.).

3) Following i.v. administration of 10 mg./kg. of 2% xylocaine in the cases showing occurrence of discharges in all the portions of bisected or trisected ureters, the frequency of discharges was always raised in any portion, and in the case where no discharge came forth in the middle and the lower portions, such an injection caused the appearance of antiperistaltic discharges in the lower portion and suspiciously or clearly antiperistaltic discharges in the middle portion. The frequency and the continuing time of discharges after the injection were the largest in the upper, next in the lower and the smallest in the middle portions.

4) It was concluded that the pyeloureteral junction plays a leading part in the maintenance of physiological peristaltic function of the ureter and that the lower portion of the ureter severed from this junction shows a strong tendency of releasing antiperistaltic movements.

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