Electromyographic Studies on Urinary Tract

IV. The Effects of Muscular Relaxants on the EMG of the Human and Canine Ureters

By

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(Received for publication, January 27, 1961)

INTRODUCTION

With 14 patients and 50 adult dogs, and using the recording method of the ureteral EMG referred in our 1st report¹⁾, the effects of the two muscular relaxants, succinylcholine chloride (SCC) and d-tubocurarine chloride (d-Tc), on the ureteral smooth muscle were observed. The ureteral EMG and the EMG of the respiratory muscles which belong to the striated muscles were recorded simultaneously. We obtained a few interesting findings.

EXPERIMENTAL METHODS

1) 14 patients with intestinal diseases and seemingly healthy in their urinary organs were laparotomized under endotracheal anesthesia, and the ureters were exposed. Then bipolar (electrode distance: 1-3 cm) or unipolar leading was made before the scheduled operation.

2) The experimental dogs (6-20 kg) were fixed in dorsal position in a laboratory 15-25°C in temperature, then laparotomized under i.v. anesthesia with thiopental sodium. The ureteral EMG was recorded by bipolar leading (electrode distance: 3 cm).

For recording of the EMG of smooth muscle, a four stages amplifier (one CR-coupled and three direct, time constant: 2.5 sec.), Sanei & Co. or a Poly-Viso, Sanborn & Co. were used. Silver needle electrodes were used. For bipolar leading, one electrode was located at the proximal part and the other at the distal part of the ureter. For unipolar leading, the different electrode was located on the ureter and the indifferent one in the fatty tissue around the ureter.

For recording of the EMG of striated muscles, a CR four stages amplifier (time constant: 0.05 sec.), Tokyo Denki Seiki & Co. and as electrode a coaxial needle electrode were used. The EMG was led from the external intercostal muscle.

For recording of the EMG, the heat writing recorder attached to the Poly-Viso or an H-type vibrator of Yokokawa's electromagnetic oscillograph was used.

As the experimental drugs, the two muscular relaxants SCC and d-Tc were used.

These drugs were administered intravenously to the patients under assisted respiration or controlled respiration and in the cases of dogs, under artificial respiration with automatic negative-positive respiration. As the usual dose, SCC 1 mg/kg, d-Tc 0.1 mg/kg, and in the cases of dogs, SCC 10 mg/kg., and d-Tc 1 mg/kg. were used as the larger doses.

Reading of the ureteral EMG: The classification of wave patterns and measuring of frequency, amplitude, duration and propagation velocity were the same as described in the 1st report¹⁾.

The frequency of the waves shows variation according to the lapse of the time as we have already pointed out; therefore, the author decided that it showed an increase or a decrease in frequency when it varied over or below 3 w/min. after the administration of the drugs.

EXPERIMENTAL RESULTS

I. EMG of the human ureter

1) Findings after i.v. administration of SCC (8 cases)

In all the cases after i.v. administration of SCC in the usual dose of 1 mg/kg., the respiratory movement stopped about 1 min. after the injection and recovered about 3 min. thereafter. The EMG before and after the injection showed nearly the same figures in all the 8 cases.

The frequency of the waves was 1-5 w/min. before and 1-4 w/min. after the injection, thus no marked difference in frequency was found before and after the administration of SCC in the usual dose, as shown in Fig. 1.

The wave pattern showed no change by the injection (Fig. 2), and the amplitude was 0.8-1.4 mV before and 0.8-1.5 mV after the injection and the duration of the waves stood at the same value of 0.23-0.59 sec. before and after the injection. The propagation velocity of the waves was 18.0-27.7 mm/sec. before and 19.0-27.7 mm/sec. after the injection, showing no marked change.

In a case in which the usual dose of SCC was administered three times at the interval of 10 min., no marked change on the EMG was observed.

2) Findings after i.v. administration of d-Tc (6 cases)

In all the cases injected with the usual dose of d-Tc 0.1 mg/kg., the respiratory movement diminished or disappeared about 1 min. and 30 sec. after the injection and recovered about 15 min. thereafter. Electromyographically, the wave frequency (1-6 w/min. before and after the injection) and the wave pattern showed

Fig. 1. Frequency in EMG of the human ureter by i.v. injection with 1 mg/kg. of SCC.

Fig. 2. Wave pattern in EMG of human ureter in the above case.

no marked change as shown in Fig. 3. The amplitude, the duration and the propagation velocity showed the same values of 0.8–1.3 mV., 0.2–0.4 sec. and 15–26 mm/sec. before and after the injection, respectively.

Fig. 3. Frequency and wave pattern in EMG of human ureter by the i.v. injection with 0.1 mg/kg of d-Tc.

Thus in the ureteral function no significant change was observed by the administration of the SCC or d-Tc in the usual dose, though they were effective in inhibiting or stopping the respiratory movement (Tables I and II).

TABLE. I. Measured Values of Wave Frequency, Pattern, Amplitude, Duration and Propagation Velocity before and after the Injection of S.C.C.

	Number of Case	Dose of SCC	Frequency in w/min	Wave Pattern	Amplitude (mV)	Duration (sec)	Velocity (mm/sec)
Human	8	1 mg/kg	Bef. 1-5	unchanged	0.8-1.4	0.23-0.59	18.0-27.7
			Aft. 1-4		0.8-1.5	0.23-0.59	19.0-27.7
Dogs	18	1 mg/kg	15 cases Bef. 2-8	unchanged	0.5-1.8	0.21-0.48	20.0-39.4
			3 cases Aft. 2-9		0.5-1.8	0.20-0.47	21.2-40.5
	10	10 mg/kg	9 cases Bef. 1-6	unchanged	0.3-4.0	0.26-0.51	21.7-39.4
			1 case Aft. 4-15		0.3-4.0	0.24-0.49	19.5-38.5

II. EMG of the dog's ureter

1) Findings after i.v. administration of SCC.

In all the 18 cases, macroscopically, the respiratory movement stopped about 30 sec. –1 min. after the injection of the normal dose of SCC 1 mg/kg. and did not recover within 20 min. after the injection.

TABLE II. Measured Values of Wave Frequency, Pattern, Amplitude, Duration and Propagation Velocity before and after the Injection of d-Tc.

	Numder of Case	Dose of d-Tc	Frequency in w/min	Wave Pattern	Amplitude (mV)	Duration (sec)	Velocity (mm/sec)
Human	6	0.1 mg/kg	Bef. 1-6 Aft. 1-6	unchanged	0.8-1.3	0.20-0.41	15.0-26.0
Dogs	12	0.1 mg/kg	10 cases Bef. 2-7	2 cases 2-9	0.7-1.7	0.19-0.35	22.8-34.1
			Aft. 1-6	0-5	0.6-1.8	0.18-0.36	22.5-34.5
	10	1 mg/kg	8 cases Bef. 2-9	2 cases 6-9	0.5-1.4	0.20-0.45	22.0-36.4
			Aft. 0.4	(9-13) 0-1	0.5-1.4	0.20-0.45	21.5-38.4

In 15 of the 18 cases, the frequency of the waves was 2-8 w/min. before and 2-9 w/min. after the injection, showing no significant change after the injection of SCC in a usual dose (Fig. 4). In the other 3 cases, it rose from 2-5 w/min. before to 5-8 w/min. after the injection, showing an increase in frequency, and then it recovered 3-5 min. after the injection. The wave pattern showed no change with the administration of this drug in all the cases (Fig. 5), and the

Fig. 4. Frequency in EMG of canine ureter by the i.v. injection with 1 mg/kg of S.C.C.

Fig. 5. Wave pattern in the above case.

amplitude, the duration and the propagation velocity were 0.5–1.8 mV., 0.21–0.48 sec., 20.0–39.4 mm/sec. before and 0.5–1.8 mV., 0.20–0.47 sec., 21.2–40.5 mm/sec. after the injection, respectively, showing no significant change by the injection.

In the 10 cases, when a larger doses of SCC 10 mg/kg. was injected intravenously, the respiratory movement stopped within 20–50 sec. after the injection and did not recover within 30 min.

In 9 of the 10 cases, the frequency of the waves was 1–6 w/min. before and 4–15 w/min. after the injection, showing a marked increase, however, normalized 2–6 min. after the injection (Fig. 6). In the other one case, it was 5 w/min. before and 6 w/min. after the injection.

Fig. 6. Frequency in EMG of the canine ureter by i.v. injection with 10 mg/kg. of SCC.

In these cases, the wave pattern showed no significant change after the injection. The amplitude, the duration and the propagation velocity of the discharge waves were 0.3–0.4 mV., 0.26–0.51 sec., 21.7–39.4 mm/sec. before and 0.3–0.4 mV., 0.24–0.49 sec., 19.5–38.5 mm/sec. after the injection, respectively, showing no marked change, either.

That 3 of the 18 cases injected with the usual dose of SCC, and 9 of the 10 cases injected with the larger dose of SCC showed an increase in number of the peristaltic discharges (Table I) seemed to indicate that SCC accelerates the peristaltic movement of the dog's ureter.

2) Findings after i.v. administration of d-Tc

When the usual dose of d-Tc 0.1 mg/kg. was administered intravenously in 9 of the 12 cases, the respiratory movement was inhibited and in the other 3 cases, it was stopped 42 sec.-1 min., 30 sec. after the injection but recovered 3-12 min. after the injection, macroscopically.

Electromyographically it was observed that in 10 of the 12 cases, the frequency was 2-7 w/min. before and 1-6 w/min. after the injection, showing no marked change (Fig. 7).

Fig. 7. Frequency in EMG of canine ureter after i.v. injection with 0.1 mg/kg. of d-Tc.

In the other 2 cases, it was 2-9 w/min. before and 0-5 w/min. after the injection, showing a decrease in frequency, then it recovered 7-10 min. after the injection. In these 12 cases, the wave pattern showed no significant change by

Fig. 8. Wave pattern in the above case.

the injection (Fig. 8). Besides, the amplitude, the duration and the propagation velocity of the waves were 0.7–1.7 mV., 0.19–0.35 sec. and 22.8–34.1 mm/sec. before and 0.6–1.8 mV., 0.18–0.36 sec. and 22.5–34.5 mm/sec. after the injection, respectively, showing no marked change by the injection of the larger doses of d-Tc 1 mg/kg.

In the 10 cases, macroscopically, the respiratory movement was found stopping 30 sec. – 1 min. after the intravenous administration of d-Tc in a dose of 1 mg/kg., and not recovering within 30 min. after the injection.

On the electromyographical examination, in 8 of the 10 cases the frequency registered 2–9 w/min. before and 0–4 w/min. 3–6 min. after the injection, showing a decrease in frequency, then it did not recover within 30 min. in many of the cases (Fig. 9). In the other 2 cases, it increases from 6–9 w/min. before to 9–13 w/min. after the injection, then it diminished to 0–1 w/min. and it did not recover within 30 min. after the injection.

Fig. 9. Frequency in EMG of canine ureter by i.v. injection with 1 mg/kg. of d-Tc.

In all the 10 cases, the wave pattern showed unchanged forms, and the amplitude, the duration and the propagation velocity were 0.5–1.4 mV., 0.20–0.45 sec., 22.0–36.4 mm/sec. before and 0.5–1.4 mV., 0.20–0.45 sec., 21.5–38.4 mm/sec. after the injection, respectively, showing no marked change by the injection.

In short, that 2 of the 12 cases injected with the usual dose of d-Tc and 8 of the 10 cases injected with the larger doses of d-Tc showed a decrease in

frequency seemed to indicate that d-Tc acts inhibitory on the peristaltic movement of the ureter (Table II).

III. EMGs of the external intercostal and the ureteral muscles in dogs (10 dogs)

The EMGs of the external intercostal muscle and of the ureter were recorded simultaneously.

1) Findings after the i.v. administration of SCC

In the 2 cases, before the injection of SCC, dense respiratory discharges with the amplitude of 100–150 μ V. were observed. They decreased or disappeared 30–60 min. after the injection. Before the disappearance, denser discharges with the amplitude of 100–250 μ V. were observed simultaneously with marked dyspnea.

Electromyographically speaking, the frequency, the wave pattern, the duration and the propagation velocity in the ureter showed no marked change after the injection with SCC 1 mg/kg.

In the other 3 cases, dense respiratory discharges with the amplitude of 100–150 μ V disappeared 20–40 sec. after the injection of SCC 10 mg/kg. of larger doses. Before the disappearance denser discharges with the amplitude of 100–250 μ V were observed coinciding with marked dyspnea, as shown in Fig. 10.

Fig. 10. In the above case, the administered drugs were increased to 10 mg/kg.

In the ureteral EMG, the peristaltic discharges showed an increase in frequency 25 sec. –1 min. after the injection, but the wave pattern, the duration and the propagation velocity of the discharges showed no marked change by the injection.

2) Findings after i.v. administration of d-Tc

In the 2 cases, as shown in Fig. 11, before the injection, dense respiratory discharges with the amplitude of 150–200 μ V. were found. They showed a slight decrease in frequency, when the amplitude was 100–200 μ V, 40 sec. –1 min. after the injection of d-Tc 0.1 mg/kg., but in the ureteral EMG, the frequency, the duration and the propagation velocity of the discharges showed no significant change as referred to above.

Fig. 11. Synchronous recording of EMG of external intercostal muscle and ureter by i.v. injection with 0.1 mg/kg of d-Tc.

In the other 3 cases, as shown in Fig. 12, before the injection of d-Tc, dense respiratory discharges with the amplitude of 150–250 μ V were observed. They disappeared 30 sec. –1 min. after the injection of d-Tc 1 mg/kg.

In the ureteral EMG, the peristaltic discharges showed a decrease in frequency or disappearance 3–6 min. after the injection, but the wave pattern, the duration

Fig. 12. EMG of external intercostal muscle and ureter by i.v. injection with 1 mg/kg. of d-Tc.

Fig. 13. EMG of external intercostal muscle and bilateral ureters.

and the propagation velocity of the discharges showed no marked change by the injection.

In recording of the both respiratory and the ureteral EMG, when the paper moved slowly as shown in the above figures the detail of the wave pattern could not be observed clearly, but when it moved more rapidly the pattern became more clearly, as shown in Fig. 13.

DISCUSSION

It is an interesting problem how SCC and d-Tc, the useful muscular relaxants, affect the smooth muscles, but studies of the effects of the muscular relaxants on such muscles were quite fewer than those on the striated muscles.

Gross²⁾ has reported on the effect of curare on the intestines; he mentioned that after the i.v. administration of d-Tc in a dose of 1–1.5 mg/kg., the canine small intestine became atonic and the peristaltic movement in it disappeared. On the other hand, Swanson³⁾ reported that the i.v. administration of d-Tc in a dose of 10–15 mg/kg. caused no change in the peristaltic movement of the canine intestine. Thesleef⁴⁾ reported that a dose of 0.3–1.0 mg/kg. (1–3 times the d-Tc sufficient to paralyse the striated muscle) was required to block off the inferior mesenteric ganglion, but Everett⁵⁾ reported that the administration of d-Tc in a dose of 0.25–0.5 mg caused an acceleration of the peristaltic movement of the rabbit's excised intestines, and Ikeda⁶⁾ reported that the administration of curare in a dose of 10 mg. caused an increase in tonus in the excised rabbit's intestines.

On the effect of curare on the ureter, Lapides⁷⁾ reported that when unanesthetized patients who had probably intact urinary organs were injected with 120 units of intocostin, all striated muscles except in the diaphragm were paralyzed though the peristaltic movement of the ureter showed no change. Harris⁸⁾ reported a clinical case in which the peristaltic movement was observed even after the administration of d-Tc in a dose which did not cause anoxia, while Butcher⁹⁾ reported that when d-Tc 5 mg/kg. was injected i.v. and in the ureteral wall in a dose of 1 mg., the EMG of the dog's ureter showed no change.

From our experimental results, it was concluded that a usual dose of d-Tc causes no marked change in the peristaltic movements of human and canine ureters, but that a larger dose of d-Tc causes inhibition of the peristaltic movement of the dog's ureter, in accordance with the experimental results of the other authors.

On the effect of SCC on the ureteral function, no report has appeared.

CONCLUSION

1) Electromyographically, in human subjects, the i.v. administration of SCC in a dose of 1 mg/kg. and d-Tc in a dose of 0.1 mg/kg. caused no change in

the ureteral peristaltic movement.

2) The i.v. administration of SCC in the usual dose of 1 mg/kg. caused no marked change in the frequency in 15 of the 18 cases, but in the other 3 cases the frequency increased.

In all the 18 cases, the wave pattern, the duration, the amplitude and the propagation velocity showed no significant change after the injection.

The i.v. administration of SCC 10 mg/kg. caused an increase in frequency in 9 of the 10 cases, and no change in the other 1 case, but caused no significant change in the wave pattern, the duration, the amplitude and the propagation velocity of the discharges.

3) The i.v. administration of d-Tc 0.1 mg/kg. in 10 of the 12 cases, caused no marked change, and in the other 2 cases caused a decrease in frequency.

The i.v. administration 1.0 mg/kg. of a larger dose caused a decrease in frequency in 8 of the 10 cases, and a decrease after temporary increase in the other 2 cases while in the wave pattern, the amplitude, the duration and the propagation velocity no marked change was found in each of the cases.

4) The simultaneous recording of the EMG of the respiratory muscles and of the ureter showed that the i.v. administration of SCC 1 mg/kg. and d-Tc 0.1 mg/kg. caused the disappearance or the diminution of the respiratory discharges, but caused no marked change in the ureteral peristaltic discharges.

The i.v. administration of both SCC and d-Tc in larger doses, 10 mg/kg. and 1 mg/kg., respectively, caused the disappearance of the respiratory discharges, but on the ureteral EMG, the former caused an increase and the latter caused a decrease in wave frequency.

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