EFFECT OF INTRAVESICAL AND INTRAURETERIC PRESSURE ON THE RATE OF URINARY FLOW

By

S. KUMAR AND N. SHUKLA

Department of Physiology, K. G. Medical College, Lucknow

(Received October 10, 1963)

The effect of increasing the intravesical and intraureteric pressure was studied in separate dogs both in intact and in denervated organs. Increase in the intraluminal pressure in the intact urinary bladder or ureters resulted in a decrease in the rate of urinary flow, whereas after denervation of these organs the rate of flow increased. It has been suggested that the mechanism of urine suppression on raising the intraluminal pressure of the bladder or ureter is a vesico–uretero renal reflex. Evidence has been presented to show that whereas the vesico–renal reflex is more effective in suppressing the urine formation, the uretero-renal reflex has a more long lasting effect. Further, the increase in urine formation on raising the intravesical or intraureteric pressure in denervated organ has been suggested to be due to a hormonal mechanism.

In cases of acute urinary retention decreased production of urine formation was observed as early as in 1861 by Carl Ludwig. Winton (1931) attributed it to back pressure. He suggested that an increase in the ureteral pressure is reflected to the kidney where it raises the intrarenal pressure and thus reduces the rate of glomerular filtration. Lawson and Tomlinson (1951) while working on dogs observed oliguria secondary to urinary bladder distension. They attributed it to a vesico-renal reflex mechanism. Their observations were subsequently confirmed by Tolls and Dille (1955). May and Barelare (1958) also confirmed their work, but in addition observed that in 23% of their experiments there occurred an increase in the urine formation on raising the vesical pressure. Because of the diverse observations it was planned to investigate the nature of suppression of urine on increasing the intravesical and intraureteric pressures without altering the intrarenal pressure.

METHODS

Experiments were performed on 36 healthy dogs of both sexes weighing from 6.75 to 15 kg. They were anaesthetised with chloralose (80 mg/kg.) given intravenously. The ureters were exposed by a midline abdominal incision. A polythene tube of 1.5 mm external diameter was passed upwards in the ureters through a nick near its vesical end. The output from the right kidney alone was recorded by a drop recorder, whereas from the left kidney was discarded.

The experiments were divided into two groups. In one, the effect of increasing the intravesical pressure in both intact and denervated urinary bladder was studied in separate dogs. The intravesical pressure was raised by injecting normal saline through a catheter passed per urethra. The pressure was recorded by a mercury manometer. Bladder denervation was done by cutting the pelvic and the hypogastric nerves. In the other set of experiments the effect of increasing the pressure in the ureter was studied both before and after its denervation in separate dogs. The back pressure was avoided from acting by ligaturing the left ureter near the pelvis of the kidney and letting the urine flow from the pelvis through an indwelling catheter. The ureter was denervated by stripping away the adventitia around it. In all the experiments the intraluminal pressure was raised in steps of 20 mm up to 100 mm Hg and then lowered in similar steps. At each step the pressure was maintained for 10 minutes before taking the readings. Normal saline was continuously infused intravenously at a rate of 30 to 40 drops per minute.

RESULTS

The results are reproduced below in Tables I to IV.

DISCUSSION

It is logical to believe that in a case of retention of urine there should operate a physiological protective mechanism resulting at least in a reduction in urine formation. Winton (1931) explained it as due to back pressure reducing the rate of urine formation by raising the intrarenal pressure. In the present study the factor of back pressure was completely ruled out as urine was allowed to flow freely from the kidney.

On raising the intravesical pressure the urine output gradually decreased from an initial mean of 4.8 drops per min to 2.1 drops per min at 100 mm Hg pressure - reduction of 56.3%. When the pressure was reduced the output first continued to decrease and then started to increase till at 0 mm intravesical pressure it exceeded the resting value by 16.6% (Table I).

When the intraureteric pressure alone was raised the urine output once again gradually decreased and was reduced to 4.6 drops per min at 100 mm Hg pressure from an initial mean of 9.4 drops per min at zero intraureteric pressure—a reduction of 50.0%. On lowering the pressure, the rate of urine output very gradually increased but did not reach the resting value (Table II). The reason for such a marked variation in the initial rate of urinary outflow in the above two series is not clear. It could be due to a difference in their state of hydration produced by continuous saline transfusion given to these animals. Irrespective of their initial rate of urine formation, the fact that the rate decreased on raising the intravesical or the intraureteric pressure goes to show that there does operate a mechanism which results in suppression in urine output on raising their intraluminal pressures. Further, complete suppression was observed in 25% of dogs when intravesical pressure was raised above 80 mm Hg (Table I), but in none of the dogs on raising the intraureteric pressure. It appears, therefore, that the vesical mechanism of urine suppression is

TABLE I

Serial No.	Dog No.	Intravesical pressure in mm Hg										
		0	20	40	60	80	100	80	60	40	20	0
		Urine drops per minute										
1	1	1.5	2.0	4.0	9.0	6.0	3.0	—	—	—	—	—
2	2	2.0	2.0	2.0	0.5	1.5	—	—	—	—	—	—
3	3	2.0	4.0	7.0	7.0	5.0	5.0	—	—	—	—	—
4	4	3.0	2.5	0.8	0.1	0.0	—	—	—	—	—	—
5	5	2.5	1.5	2.0	1.5	1.5	—	—	—	—	—	—
6	6	1.0	0.5	0.5	0.3	0.0	0.0	0.0	0.0	0.8	1.3	1.0
7	7	6.0	9.0	2.0	2.0	2.0	1.5	1.5	1.5	3.0	4.0	—
8	8	7.0	8.0	4.0	4.0	5.0	20.0	17.0	5.0	3.0	2.0	2.0
9	9	10.0	7.0	4.0	3.5	3.0	1.5	0.8	0.8	0.5	1.0	3.0
10	10	3.0	3.0	4.0	4.0	4.0	3.0	3.5	4.0	5.0	6.0	5.0
11	11	5.5	6.0	3.5	3.3	0.0	0.0	0.0	0.5	0.5	3.0	14.0
12	12	16.5	14.0	8.0	4.5	4.5	3.0	2.5	3.0	4.0	5.0	5.0
Mean		4.8	4.7	3.4	3.2	2.5	2.1	1.4	1.6	2.3	3.4	5.6
S. E.		1.4	1.2	0.6	0.8	0.6	0.6	0.5	0.6	0.8	0.8	2.2
Percentage difference from the initial		0	2.1	−29.1	−33.3	−47.9	−56.3	−70.7	−66.6	−52.0	−29.1	+16.6

REMARKS Dog No. 8 was not included to calculate the mean.

TABLE II

Serial No.	Dog No.	Intraureteric pressure in mm Hg										
		0	20	40	60	80	100	80	60	40	20	0
		Urine drops per minute										
1	13	24.0	22.0	18.0	16.0	13.0	10.5	11.0	12.0	12.0	12.0	12.0
2	14	6.5	7.4	5.5	4.5	5.0	2.4	4.6	4.8	5.5	5.0	5.6
3	15	1.8	2.0	1.7	2.2	2.2	2.0	2.0	3.0	2.4	2.5	2.5
4	16	3.0	3.6	3.0	3.0	4.0	4.0	4.3	4.0	4.5	4.8	5.0
5	17	20.0	19.0	14.6	12.8	10.0	8.7	7.7	8.7	8.5	7.0	9.8
6	18	20.0	20.0	6.5	3.7	3.6	2.8	3.3	2.8	3.3	2.5	3.3
7	19	2.3	2.5	2.3	2.4	2.6	2.6	2.8	3.2	3.6	3.0	2.8
8	20	4.0	4.5	4.0	4.0	6.0	8.5	10.3	11.0	14.0	16.5	17.3
9	21	3.0	6.3	9.3	8.5	8.6	6.8	6.0	4.0	4.3	5.3	4.2
10	22	3.7	3.3	2.8	2.3	2.0	1.8	2.0	2.0	2.3	2.3	2.5
Mean		9.4	9.5	7.0	6.2	5.4	4.6	4.8	4.9	5.1	4.9	5.3
S. E.		3.0	2.7	2.3	1.6	1.2	1.0	0.9	1.1	1.0	1.0	1.0
Percentage difference from the initial		0	+1.0	−25.5	−34.0	−42.5	−50.0	−49.0	−47.9	−45.7	−47.9	−43.6

REMARKS Dog No. 20 was not included to calculate the mean.

TABLE III

Serial No.	Dog No.	Intravesical pressure in mm Hg in denervated bladder										
		0	20	40	60	80	100	80	60	40	20	0
		Urine drops per minute										
1	28	2.5	2.0	2.3	1.0	0.8	4.5	0.4	1.0	2.3	0.3	0.5
2	29	16.3	1.0	21.8	19.0	22.3	21.3	10.3	6.3	6.0	1.8	1·3
3	30	7.0	5.5	6.0	4.0	7.0	6.5	6.3	6.3	5.6	6.0	7.0
4	31	5.5	8.0	10.0	8.0	10.3	8.6	10.5	10.0	13.0	11.0	10.0
5	32	8.3	4.3	6.3	17.0	19.6	21.0	14.6	22.0	21.6	22.6	14.5
6	35	3.5	4.8	3.0	4.2	4.0	5.6	6.6	6.0	7.6	8.0	8.6
7	36	8.0	9.5	9.3	10.3	10.0	11.3	10.6	12.0	11.3	10.5	10.6
Mean		7.3	5.0	8.3	9.0	10.6	11.3	8.5	9.0	9.6	8.6	7.5
S. E.		1.7	1.1	2.4	2.5	2.9	2.5	0.7	2.5	2.4	1.0	1.9
Percentage difference from the initial		0	−31.5	+13.8	+23.2	+45.2	+54.8	+16.5	+32.2	+31.5	+17.8	+2.6

TABLE IV

Serial No.	Dog No.	Intraureteric pressure in mm Hg in denervated ureter										
		0	20	40	60	80	100	80	60	40	20	0
		Urine drops per minute										
1	23	1.4	1.3	1.5	1.8	1.3	2.0	1.5	1.5	1.8	1.5	1.8
2	24	1.3	2.3	2.8	2.2	2.4	2.5	4.0	3.7	1.8	2.6	3.5
3	25	1.3	0.8	0.3	1.7	1.0	0.6	0.8	0.3	1.0	1.3	2.0
4	26	1.8	2.0	1.7	3.0	2.3	2.3	3.2	2.0	2.0	1.8	2.3
5	27	1.6	1.2	1.6	2.0	1.7	2.6	2.0	3.6	0.7	1.3	1.5
6	33	5.3	5.0	6.7	5.0	5.3	5.5	5.0	4.7	6.8	4.7	4.5
7	34	1.3	1.3	1.7	1.0	1.0	1.3	1.3	1.3	1.3	1.3	1.0
Mean		2.0	2.0	2.3	2.4	2.1	2.4	2.5	2.5	2.2	2.1	2.4
S. E.		0.1	0.1	0.5	0.5	0.5	0.5	0.5	0.5	0.7	0.4	0.4
Percentage difference from the initial		0	0	+15.0	+20.0	+5.0	+20.0	+25.0	+25.0	+10.0	+5.0	+20.0

more effective than the ureteric. In spite of this, the effect from the ureters is more long lasting as when the intraluminal pressure was reduced back to 0 mm Hg, the vesical mechanism resulted in 16.6% increase over the resting value whereas with the ureters although the output increased but still it remained 43.6% below the resting value.

As the back pressure was prevented from acting, the mechanism of urine suppression could be reflex, hormonal or a combination of both. It was observed that when intravesical pressure was raised in denervated organ, the rate of formation of urine gradually increased and at 100 mm Hg pressure went up by 54.8% above the resting value. When the bladder pressure was reduced, the output also fell and at 0 mm pressure was a little more (2.6%) than the resting value (Table III). With denervated ureter, changing its intraluminal pressure showed increase in urine outflow in a heterogeneous manner (Table IV).

On comparing the results of intact and denervated urinary bladder and ureter it appeared that in intact series the rate of urine flow decreased and in denervated series it increased on increasing their intraluminal pressures. This, therefore, confirmed that the nature of suppression of urine outflow is reflex arising from these organs. But why should the rate increase after denervation ? It could not be the normal diuretic response of kidneys to saline infusion, because had it been so, the rate of urine formation should not have decreased on lowering the intraluminal pressure in a denervated organ. Since these organs were denervated, the response could not be reflex either. The only possibility that remained was that some chemical substance is released from the urinary bladder and the ureters on raising their intravesical pressure, which, acting on the kidney, increased the rate of urine outflow.

In an intact organ the reflex part of the mechanism takes an upper hand and decreases the urine output when the intraluminal pressure is raised. May and Barelare (1958) obeserved an increase in urine output in 23% of their dogs. In the present series also dog numbers 8 and 20 have shown increased rate of urine formation on raising the intraluminal pressure. This may be the result of the hormonal response gaining an upper hand over the reflex response. What physiological purpose should this hormonal response serve in intact animals is not clear, but whatever it may be it can be said that normally this response remains suppressed by the reflex response.

REFERENCES

Lawson, J. D. and Tomlinson. W. B. (1951) *J. Urol.*, **66**, 678.

May, R. D. and Barelare, B. (1958) *J. Urol.*, **88**, 337.

Tolls, R. E. and Dille, J. M. (1955) *J. Urol.*, **74**, 197.

Winton, F. R. (1931) *J. Physiol.*, **71**, 381.