J. Physiol. (1966), **185**, *pp.* 185–196
With 10 *text-figures*
Printed in Great Britain

THE EFFECTS OF SOMATIC STIMULI ON THE BLADDER IN THE CAT

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(*Received* 15 *December* 1965)

SUMMARY

1. Measurement of the intra-vesical pressure in cats during contractions of the bladder was found to be a more reliable method of studying bladder function than the cystometrogram. Under suitable conditions the pressure curves of these bladder contractions were constant and could be examined statistically.

2. In the anaesthetized cat cold decreased the pressure developed by bladder contractions and shortened the interval between them. There was no evidence that this effect was reflex in nature.

3. In the anaesthetized cat stimulation of the sural nerve sometimes produced contraction of the bladder or increased the pressure developed by spontaneous contractions.

4. In the anaesthetized cat stimulation of any hind-limb nerve from muscles with conduction velocities of approximately 50 m/sec inhibited bladder contractions.

5. In the acute spinal cat somatic stimuli had no effect on bladder activity.

6. In the chronic spinal cat cutaneous stimuli produced reflex contraction of the bladder or the augmentation of a spontaneous contraction. Stimulation of nerves from hind-limb muscles, however, had no effect on bladder activity.

7. In the decerebrate cat cutaneous stimuli increased bladder activity, and this was probably 'reflex' in nature. Stimulation of nerve fibres from hind-limb muscles either produced bladder contractions or augmented spontaneous contractions.

INTRODUCTION

Previous experiments described the effects of distension of the bladder on mono- and polysynaptic reflexes elicited from the lumbar segments of the spinal cord of cats and also the effects of bladder distension on hind-limb reflexes recorded myographically. Bladder distension was found either

to inhibit or facilitate hind-limb reflexes depending on the preparation and on the intra-vesical pressure. It was suggested that these effects may be mediated by bladder tension receptors acting upon the gamma-efferent system, and that some of the effects may be supraspinal in origin (Evans & McPherson, 1959).

The present experiments were designed to study the effects of stimulation of somatic nerve fibres of the hind limb on the activity of the urinary bladder.

METHODS

The experiments were performed on adult cats (2–4 kg) (*a*) under anaesthesia; (*b*) after decerebration; (*c*) several hours after total transection of the spinal cord; (*d*) 6–7 weeks after the latter.

Anaesthesia was induced with fluothane or ethyl chloride and ether and maintained with chloralose (70 mg/kg I.V.).

Cats were decerebrated stereotaxically at the intercollicular level while under ether anaesthesia.

Some of the acute spinal cats had their transection (either at the level of T 2 or 3 or at T 11 or 12) while anaesthetized with chloralose, others while anaesthetized with pentobarbitone (25 mg/kg) and others following decerebration. Neither the level of transection nor the type of anaesthesia made any difference to the results.

For the recovery experiments cats in good condition and weighing at least 3 kg received bilateral laminectomy and total transverse spinal cord section (T 11 or 12) under strict aseptic conditions using pentobarbitone (25 mg/kg).

They were nursed with care on polythene foam mattresses to avoid the development of abrasions. Their bladders were expressed twice a day by gentle manual pressure on the abdomen. Specimens of urine were examined bacteriologically at 5-day intervals or more frequently if infection was suspected.

With this regimen all the cats remained healthy and more than regained their pre-operative weight.

Six to seven weeks after the spinal cord section the hind-limb and bladder reflexes were investigated under chloralose (70–80 mg/kg) using the methods described in previous papers (Evans & McPherson, 1958).

Unlike the majority of previous experiments (Evans & McPherson, 1958, 1959 and 1960) only the spontaneous contractions of the bladder were recorded, measuring the intra-vesical pressure through a double-bore, perurethral, intra-vesical cannula, one arm of which was connected to a pressure transducer and then through a carrier amplifier to a potentiometric recorder. After careful closure of the abdomen it was bound with a many-tailed bandage as this facilitates the occurrence of spontaneous bladder contractions. Locke solution at 37° C was injected into the bladder through the other arm of the cannula in 1 ml. steps until the first small bladder contraction was seen. This usually developed about 5 cm H_2O pressure, and Locke solution was then injected in 0·1 or 0·2 ml. steps until large contractions occurred.

RESULTS

Much of the work on the activity of the bladder has been done by means of cystometrograms but this method proved unreliable in this series of experiments. The cystometrogram not only varies considerably and inconsistently during the course of a prolonged experiment but it also varies from minute to minute. Figures 1 and 2 show cystometrograms. The

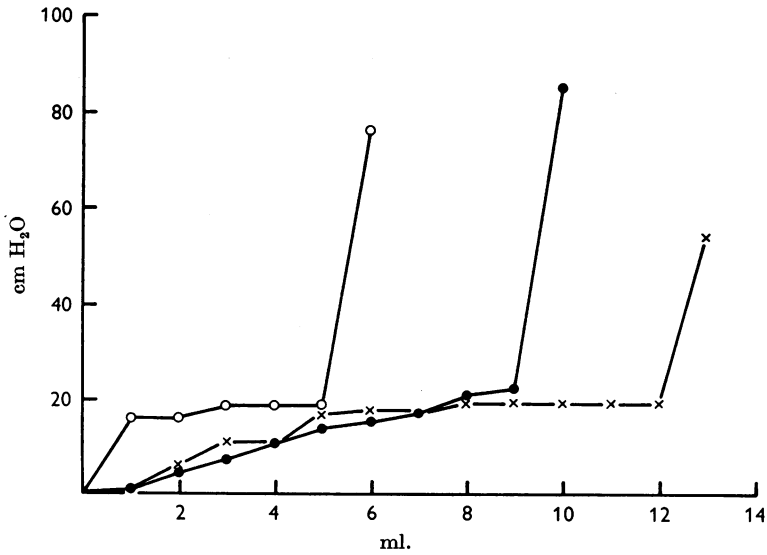

Fig. 1. Cystometrograms recorded at different intervals during the same experiment. Abscissa: successive injections of 1 ml. of Locke solution. Ordinate: intravesical pressure. ● = first cystometrogram; ○ = cystometrogram 100 min after first; × = cystometrogram 125 min after first.

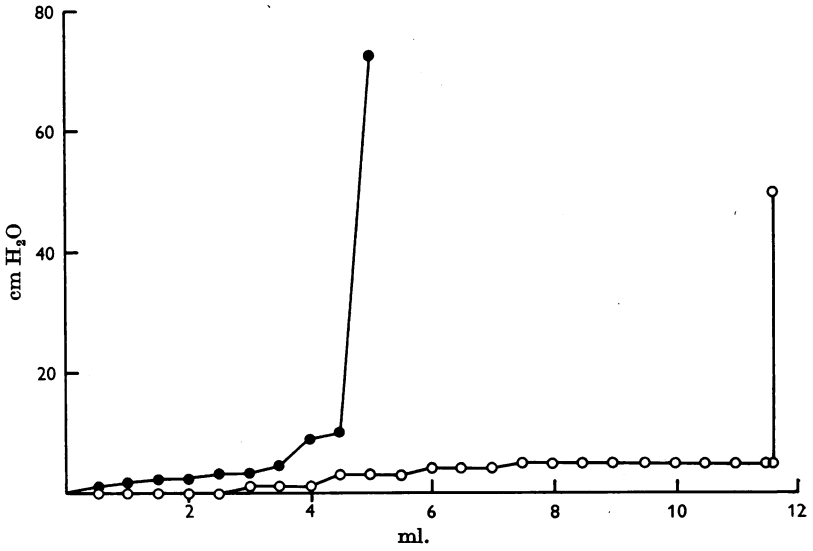

Fig. 2. Cystometrograms recorded within 2 min of each other. Ordinates as in Fig. 1. ● = first cystometrogram; ○ = cystometrogram 2 min after first.

cystometrogram in Fig. 1 illustrates graphically the intra-vesical pressure developed by successive injections of 1 ml. of Locke solution. In the first cystometrogram (●) the first micturition contraction occurred after 9 ml. of Locke solution had been injected. The second cystometrogram (○) was carried out 100 min later and the first micturition contraction occurred after the injection of 5 ml. of Locke solution. The third cystometrogram (×) was carried out 125 min after the first and the first micturition contraction then only occurred after the injection of 13 ml. Figure 2 illustrates that even within minutes the micturition threshold may change by more than 100%. It was concluded that the measurement of cystometrograms is an unreliable means of estimating bladder activity and it was therefore decided to use the spontaneous contractions of the partly filled bladder to study vesical function.

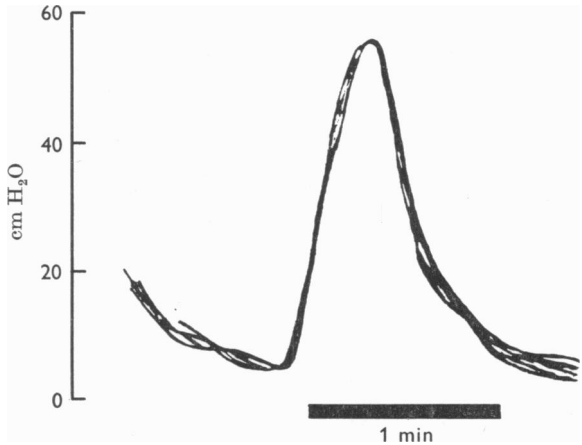

Fig. 3. Six superimposed recordings of intra-vesical pressure during bladder contractions developing the same peak pressure.

When the cat is allowed from 3 to 4 hr to recover from the induction of anaesthesia with ether or fluothane it is possible to record bladder contractions which occur at regular intervals and which are remarkably consistent in form. This is illustrated in Fig. 3 in which six bladder pressure curves, which developed the same peak pressure, are superimposed on each other. This consistency makes it possible to analyse bladder activity quantitatively under different conditions. As the resting bladder pressure rises with the accumulation of excreted urine the regular and simple contractions may become both irregular and compound. By withdrawing fluid from the bladder they may be restored to their previous form.

There is a statistically significant correlation between the peak bladder pressures developed (or the areas of the pressure curves) and the intervals

between the bladder contractions. The greater the pressure developed the longer is the delay before the next contraction. Calculating the regression line on the assumption that the peak pressure (y) is known and the interval from the commencement of one bladder contraction to the next is to be predicted, the regression coefficient $b = 0{\cdot}795$ and $a = 1{\cdot}245$ (Fig. 4). The sample correlation coefficient $r = 0{\cdot}743$. This figure is significantly different from zero at the 0·001 level (50° of freedom).

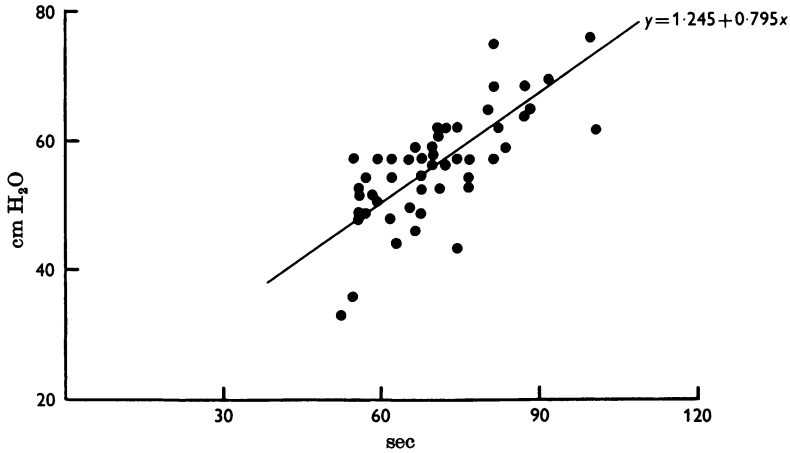

Fig. 4. Regression line of peak bladder pressures on the intervals between the commencement of one bladder contraction and another. $y = 1{\cdot}245 + 0{\cdot}795x$.

Effects of somatic nerve stimulation on the bladder contractions of anaesthetized cats

Cutaneous stimuli (heat, cold, pain and sural nerve). The fore and hind paws of cats were placed in water at 45° C for 15 min or the skin of the hind limbs was pinched vigorously for 3 min. Neither stimulus had any effect on the peak intravesical pressures or on the intervals between contractions. Ice applied to the hind paws decreased the peak pressures ($t = 2{\cdot}475; P < 0{\cdot}02$) and also the intervals between the contractions ($t = 2{\cdot}454; P < 0{\cdot}025$). These effects did not occur until ice had been applied for 2–5 min.

In over half of the experiments, stimulation of the sural nerve had no effect on bladder contractions. In the other experiments stimulation either interpolated a contraction or increased the peak pressure and duration of the contraction. This is illustrated in Fig. 5.

Stimulation of hind-limb nerves. Stimulation of the cut central ends of the L6 and 7 and S1 dorsal spinal roots and of the cut central ends of the posterior tibial, lateral and medial popliteal nerves and the nerves to m. semitendinosus, m. semimembranosus and the medial and lateral heads

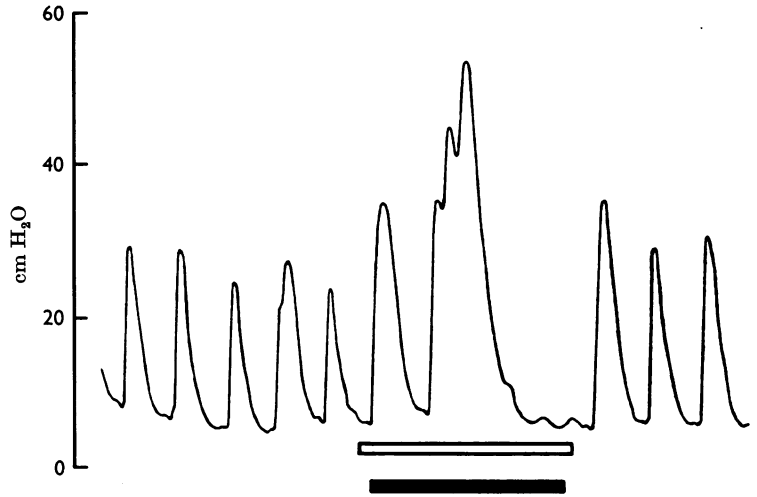

Fig. 5. The facilitatory effects of stimulation of the sural nerve on bladder contractions. □ = duration of stimulation. ■ = 1 min.

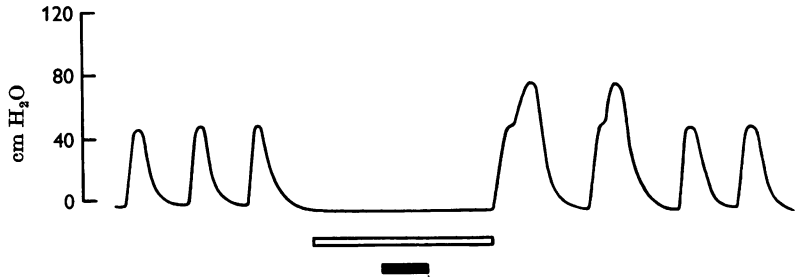

Fig. 6. The inhibitory effects of stimulation of the medial popliteal nerve at 1·8 V, 100 μsec duration and frequency of 12/min on bladder contractions. Symbols as in Fig. 5.

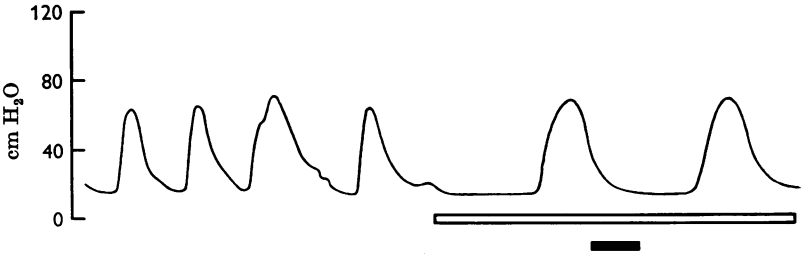

Fig. 7. The 'escape' of bladder contractions when, in the same experiment as that illustrated in Fig. 5, the stimulus voltage is reduced to 1·4 V, the other stimulus parameters remaining the same. Symbols as in Fig. 5.

of m. gastrocnemius all produced inhibition of bladder contractions. The strength of the stimuli necessary to produce this inhibition varied in different experiments, but definite inhibition was produced with R.F. output voltages of 1·6 V, of 100 μsec duration. The minimum frequency of stimuli producing inhibition was 10/min and increasing the frequency beyond 45/min did not appreciably change the inhibition. The stimuli producing inhibition of bladder contractions had no effect on arterial B.P., heart rate or respiration.

Figure 6 shows the inhibition of bladder contractions produced by stimulating the medial popliteal nerve. In this, as in every experiment producing inhibition of bladder contractions, when the nerve stimulation was stopped there was a 'rebound' of the bladder contractions which developed higher peak pressures and were of longer duration.

Threshold stimulation of hind-limb nerves may allow the bladder contraction to 'escape'. Figure 7 shows the effect of reducing the stimulus voltage to 1·4 V in the same experiment which is illustrated in Fig. 5. The other stimulus parameters were the same. The bladder contractions during stimulation were not arrested but were of longer duration and separated by longer intervals.

In a number of experiments the conduction velocity of the nerve fibres producing inhibition of bladder contractions was measured.

The potentials at the dorsal root which were associated with inhibition of the bladder contractions were sometimes complex in form and their conduction velocities ranged from 33 to 110 m/sec. In more simple wave forms it could be seen that complete inhibition of bladder contractions was produced by stimulation of nerve fibres conducting at rates above 50 m/sec.

Effects of somatic nerve stimulation on the bladder contractions of acute spinal cats

According to Ruch (1960), after the cat's spinal cord is divided no bladder contractions can be seen, i.e. there is a state of 'complete vesical areflexia'. In the present experiments small bladder contractions were always seen after thoracic spinal transection, although the pressure they developed was rarely more than 10 cm H_2O. Figure 8 illustrates small spontaneous bladder contractions occurring approximately 2 hr after a total transverse spinal section at the level of T 3. The completeness of the section was confirmed post mortem. The amplitude of these contractions usually decreased gradually 3–5 hr after the spinal section. It is not known whether this decrease was due to vesical areflexia as it may also have been secondary to a deterioration of the cat's general condition towards the end of these lengthy experiments (16–18 hr).

Electrical stimulation of the cut central ends of cutaneous or muscle nerves of the dorsal lumbar spinal roots had no effect on the resting bladder pressure nor did it affect the spontaneous contractions in the acute spinal animal, no matter what parameters of stimulation were used.

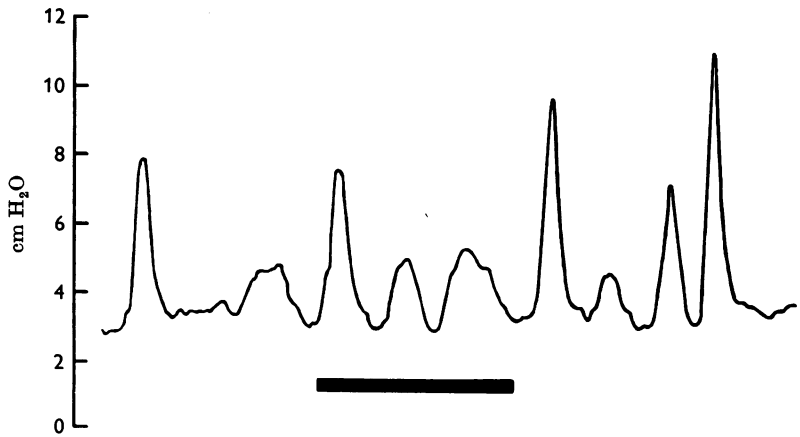

Fig. 8. Contractions of the bladder in the cat 2 hr after total transection of the spinal cord at the level of T 3. Symbols as in Fig. 5.

Effects of somatic nerve stimulation on the bladder contractions of chronic spinal cats

Cutaneous stimuli. The mechanism of the so-called 'mass reflex', in which stimulation of the inside of the thigh or sole of the foot causes flexion of the legs, sweating and evacuation of the bowels and bladder, is still in doubt, therefore this reflex was studied in the chronic spinal cats. In the conscious chronic spinal cat stimulation of the skin of the hind-limbs or perineum by scratching or tickling produced flexor spasms and dribbling of urine. The dribbling of urine was not merely due to increased intra-abdominal pressure produced by abdominal muscle contraction as Holmes (1933) has suggested. This was shown when the abdomen was opened under anaesthesia by a wide extraperitoneal incision, the abdominal contents being suitably protected with gauze soaked in Locke solution. The skin of the abdomen, perineum, back and hind limbs was stimulated by scratching, tickling and pinching. Stimulation of the perineum produced bladder contractions.

Figure 9 illustrates an experiment such as that described above in which the bladder was contracting at regular intervals. Gentle scratching of the peri-anal skin at the signal mark produced a large, interpolated contraction of the bladder.

Stimulation of the cut central end of the sural nerve had no effect on

extensor reflexes of the hind limb and only a slight effect on flexor reflexes, which were increased by 10–15%. This increase was significant ($P = < 0{\cdot}001$).

Stimulation of hind-limb nerves from muscles. In contrast to the results in anaesthetized cats, stimulation of the L 6 and 7 and S 1 dorsal spinal roots and of the cut central ends of the medial and lateral popliteal or posterior tibial nerves or the nerves to m. gastrocnemius had no effect on spontaneous bladder contractions.

Fig. 9. Upper trace. Interpolated bladder contraction produced by peri-anal scratching with the abdomen open. The contractions in this experiment were recorded with a curvilinear recorder. Symbols as in Fig. 5. Lower trace. Arterial B.P. recorded in carotid artery.

The effects of somatic stimuli in the decerebrated cat

Cutaneous stimuli. In the intercollicular decerebrate cat, cutaneous stimuli such as scratching or pinching of the abdomen, perineum and hind limbs produced contraction of the bladder or augmented an existing contraction. Whether this was due to the pronounced contraction of the abdominal muscles produced by such stimuli in the decerebrate cat, or whether the bladder contraction was a true skin-bladder reflex as in the anaesthetized cat, was not determined.

Stimulation of hind-limb nerves. Stimulation of the cut central ends of the medial and lateral popliteal or posterior tibial nerves produced contraction of the bladder or considerably augmented an existing contraction. Figure 10 illustrates an experiment in which the medial popliteal nerve was stimulated with pulses of 1·0 V, of duration 0·5 msec and frequency of 40/min. Stimulation was started towards the end of a small bladder contraction when the bladder pressure was decreasing and it produced a considerably larger contraction than the existing spontaneous ones.

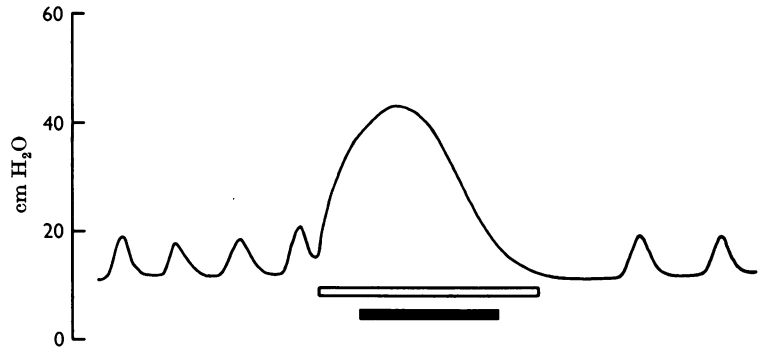

Fig. 10. The effects on bladder contractions produced by stimulation of the medial popliteal nerve with pulses of 1·0 V, 0·5 msec and frequency of 10/min in the intercollicular decerebrate cat. Symbols as in Fig. 5.

DISCUSSION

It is well known that somatic stimuli such as pain or touch can produce visceral effects such as vasoconstriction or erection and these reflexes have been briefly reviewed by Colle (1952). According to Kuntz & Haselwood (1940), moderate cooling of the skin of the back or lateral surface of decerebrate cats elicits *reflex* vasoconstriction of those parts of the gastro-intestinal tract which have the same segmental nerve supply and moderate warming of the same areas of skin produces *reflex* vasodilatation. The vasoconstriction and dilatation were observed photographically, microscopically and plethysmographically, but the length of time of cutaneous stimulation necessary to produce the vascular effects was not stated.

Bisgard & Nye (1940), recording gastro-intestinal activity in patients, found that heat applied to the skin of the abdomen inhibits and cold stimulates gastro-intestinal movement, and they considered these effects to be reflex in nature. Other observers (Boas, 1926; Ludin, 1919) attributed these effects on gastro-intestinal activity resulting from cutaneous stimulation to be due to either direct warming or cooling of the gastro-intestinal tract or to generalized vasoconstriction or dilatation.

In the present experiments on anaesthetized cats, heat, pain or scratching had no effect on the bladder. On the other hand cold increased the frequency of contractions and decreased their amplitude. This would seem to accord with our everyday experience in cold weather. There was no evidence, however, that the changes in bladder activity were a reflex effect similar to vasoconstriction in response to cold. Vasoconstriction occurs almost immediately whereas the bladder activity is not affected until the cold stimulus has been applied for several minutes.

Cutaneous somatic nerves can have reflex effects on the bladder of the anaesthetized cat as shown by the augmentation or interpolation of bladder contractions on stimulation of the sural nerve. However, the most pronounced reflex effect of cutaneous stimuli on bladder contractions was seen in the spinal cat whose visceral reflexes had been allowed time to recover. In the cat the exact dermatomes seem to be unknown but, reasoning by analogy from human studies, the peri-anal skin should presumably have the same segmental nerve supply as the bladder.

Hitherto the only convincing experimental evidence of a reflex effect on viscera produced by stimulation of afferent nerves from muscles has been provided by Harrison, Calhoun & Harrison (1932). They completely separated the hind limb of dogs at the hip joint, preserving only the femoral vessels and the sciatic nerve and showed that passive exercise of the hind limb produced an increase in respiratory ventilation which was mediated by the sciatic nerve.

The present experiments demonstrate that stimulation of muscle nerves with pulses at a frequency of 10/min, of less than 2·0 V and of a duration of 100 μsec will abolish bladder contractions in the anaesthetized cat. The afferent nerve fibres from the muscles producing this inhibition conduct at rates of 50 m/sec.

Since, in both acute and chronic spinal cats, no effect on bladder contractions was seen on stimulation of muscle nerves, somatic-vesical interaction must occur at a supra-spinal level. The fact that stimulation of nerves from hind-limb muscles in the decerebrate cat produces the opposite effect on bladder contractions to that in the anaesthetized cat, suggests that the muscle afferents act both on supra-collicular areas which inhibit bladder activity and on infracollicular and probably supra-spinal areas which initiate or facilitate bladder activity. It is interesting to note that one of Langworthy's paraplegic patients was able to delay micturition by preventing the flexion movements of her feet which accompanied her bladder distension. In the anaesthetized cat inhibition predominates.

I would like to thank Professor Feldberg for his assistance with the manuscript and the Institute of Orthopaedics for their hospitality.

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