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FACTORS INFLUENCING LIMB TEMPERATURE DURING EXPERIMENTS ON SKELETAL MUSCLE

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During a study of the influence of lowered body temperature on the action of neuromuscular blocking drugs, muscle temperature was recorded, as well as oral or rectal temperatures. It was observed that the temperature of the hind limbs was often lower than that of the rest of the body and also that the difference between limb and body temperature varied considerably from animal to animal. As changes in muscle temperature have a marked influence upon the action of neuromuscular blocking drugs it was decided to investigate factors contributing to the varying differences between limb and body temperature.

A preliminary account of this work has already appeared (Bigland & Zaimis, 1956).

METHODS

Cats, dogs and rabbits, the animals used in the present study, were anaesthetized with a mixture of chloralose (0·08 g/kg for cats, 0·11 g/kg for dogs and 0·1 g/kg for rabbits), and pentobarbitone sodium (3–6 mg/kg). The tibialis anterior muscle was prepared for recording, shielded silver electrodes were applied on the sciatic nerve and the nerve was ligated centrally to the electrodes. Twitches of the tibialis muscle were elicited by square-wave pulses of 0·2 msec duration and twice the strength required to evoke a maximal contraction. As little hair as possible was removed during dissection and all skin incisions were sewn up again to reduce heat loss. The hind limb was mounted on a Brown–Schuster myograph stand, and the tendon attached to a flat steel spring.

The apparatus for the recording of muscle temperature consists of a simple bridge circuit having a thermistor as one arm of the bridge. Any change in the thermistor resistance unbalances the bridge and the potential difference thus produced is fed into a four-stage d.c. amplifier. The amplified output is then fed into a driving unit consisting of a two-stage cathode follower amplifier and an electronic trigger circuit which operates a high-speed relay. This relay is connected to a unidirectional motor, mechanically coupled to a variable potentiometer, the latter forming another arm of the bridge circuit. The motor movements adjust the potentiometer to rebalance the bridge. A pointer, mechanically coupled to the unidirectional motor, records every change in the thermistor resistance on a smoked drum. The instrument is calibrated in degrees centigrade before use.

For the recording of muscle temperature the thermistor was inserted through a small incision

in the skin so that its tip lay between the gastrocnemius and digitorum extensor longus muscles at about the middle of the limb. Once the thermistor was in position the skin was drawn up around it with a thread. Oral or rectal temperatures were measured by means of mercury thermometers.

RESULTS

Generally when the contractions of the hind-limb muscles of different mammalian species are recorded the limbs are immobilized in a horizontal or preferably a vertical position. In a first series of experiments, therefore, the influence of the position of the limb on muscle temperature was examined.

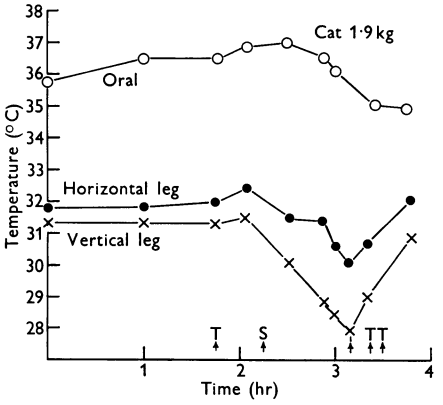

Fig. 1

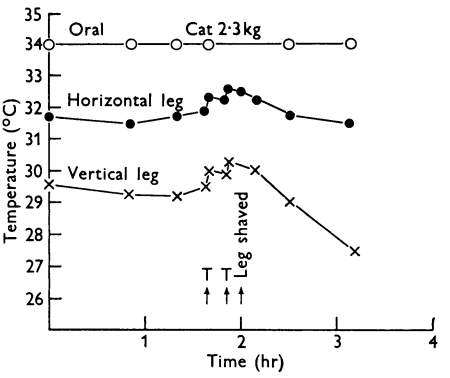

Fig. 2

Fig. 1. Cat, 1·9 kg. Changes in muscle and oral temperatures. In all experiments one limb was mounted horizontally and the other vertically; throughout each experiment both tibialis anterior muscles were stimulated indirectly with single shocks at 10 sec intervals, except where otherwise indicated. T, tetanus of 50 shocks/sec and 5 sec duration; S, stimulation stopped.

Fig. 2. Cat, 2·3 kg. Effect of shaving the limb on muscle temperature.

Both tibialis anterior muscles were prepared for recording and the limbs mounted, one vertically and the other horizontally. Blood pressure, muscle temperature and the contractions of both muscles, elicited indirectly at 10 sec intervals, were recorded simultaneously on a smoked drum. Oral or rectal temperatures were read at regular intervals.

In cats the temperature of both limbs was almost always lower than the oral or rectal temperature. The usual difference between the horizontal limb and body temperature was of $1\frac{1}{2}$–2° C, but a difference of as much as 4° C was occasionally recorded. The vertical position, however, always increased the difference, in some experiments to as much as 5° C (Figs. 1–3). When stimulation of the muscles was discontinued the difference between body and limb temperature usually increased, but again the fall was more pronounced in the vertical limb (Fig. 1).

A reduction of muscle temperature could also be produced by shaving the limb. 'Shaving' here involved cutting off as much hair as could be conveniently removed with a pair of scissors, a procedure which is often used when preparing a limb for experiments on skeletal muscles. In the experiment illustrated in Fig. 2 the temperature of the vertical limb was 2° C lower than that of the horizontal one. This difference remained unaltered for 2 hr while the muscles were stimulated with single shocks at 10 sec intervals, or with tetani of 5 sec duration and 50/sec frequency. After both limbs had been shaved, however, the temperature of the vertical limb fell considerably more than that of the horizontal limb, thus increasing the difference in temperature between the two limbs.

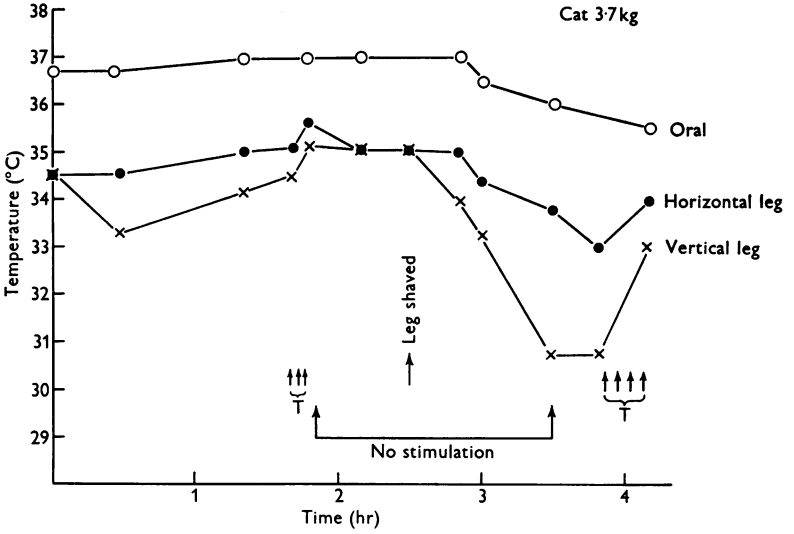

Fig. 3. Cat, 3·7 kg. Effect of shaving the limb and cessation of stimulation on muscle temperature.

In some animals the temperature of the limb was very little affected either by cessation of stimulation or by the 'shaving' process. A combination of the two, however, was always effective, particularly in the vertical leg. Fig. 3 shows the results of such an experiment. Cessation of stimulation had little effect but when this was followed by 'shaving' the temperature fell by 2° C in the horizontal limb and by 4° C in the vertical one. This figure also shows that after a short series of tetani the temperature of the limb was increased.

The difference between limb and body temperature in dogs was small in comparison with that in cats, and in some instances non-existent. When present this difference was seldom affected by shaving or cessation of stimulation (Fig. 4).

Rabbits occupied an intermediate position between cats and dogs. There was usually less difference between limb and oral temperatures than in cats, but muscle temperature fell sharply after fur had been removed, especially in the vertical leg.

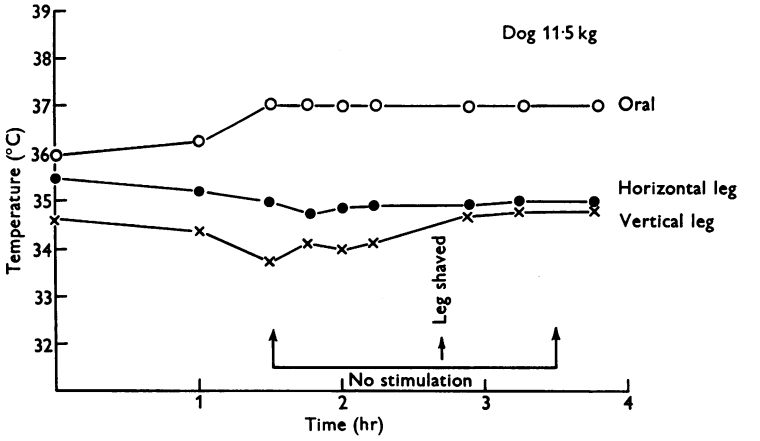

Fig. 4. Dog, 11·5 kg. Changes in muscle and oral temperatures.

DISCUSSION

It appears from the experimental results here demonstrated that in spite of every precaution taken during preparation of the animal, limb temperature, especially in cats, is lower than that of the body. Moreover, muscle temperature is considerably affected by the position in which the limb is mounted. The temperature of a limb in the vertical position tends to fall lower than that of a limb mounted horizontally. Cats, again, proved to be the most sensitive of the three species under consideration, dogs the least and rabbits somewhere between the two. Furthermore, any procedures such as cessation of stimulation or shaving the limb, which tend to lower muscle temperature, have a more pronounced effect in the vertically mounted limb. Dogs have proved to be less sensitive to these procedures than cats and rabbits. This lesser sensitivity of dogs is probably due to a more efficient blood flow through their limbs and a small dependence on hair for insulation, at least in the types of short-haired dogs used in the experiments.

It was not possible to correlate the size of the animal or its initial blood pressure with the degree of difference between limb and body temperatures. Rabbits are generally smaller animals than cats but their limb temperature proved less easily affected. Furthermore, great differences between body and muscle temperatures were found in large as well as small cats. Moreover, a much lower limb than body temperature was sometimes found in animals with high initial blood pressures.

The fact that experimental conditions can affect limb temperature is important, for temperature changes have a marked influence on drugs active at the neuromuscular junction (Bigland, Goetzee, Maclagan & Zaimis, 1958). On this account and because of the results obtained in the present study, it would appear that in experiments in which muscle temperature is important, the recording of oral or rectal temperature alone is not sufficient, and that the temperature of the limb itself must be taken. Furthermore, vertical mounting should be avoided as this position renders the limb more sensitive to any procedures which might tend to lower its temperature.

SUMMARY

1. During experiments on skeletal muscles limb temperature is often found to be lower than that of the rest of the body.

2. The temperature of a vertically mounted limb tends to fall lower than that of a limb mounted horizontally.

3. Procedures such as cessation of stimulation or shaving the limbs tend to lower their temperature but the effect on the vertically mounted limb is more pronounced.

4. Of the three mammalian species studied, the limb temperature of the cat proved to be the most easily affected, that of the dog the least and that of the rabbit somewhere between the two.

5. It is suggested that in experiments on skeletal muscles, in which temperature is important, vertical mounting should be avoided and the temperature of the limb itself should be recorded.

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