Conditioning of H reflex by a preceding subthreshold tendon reflex stimulus

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SUMMARY The soleus H reflex excitability cycle has been studied using, as conditioning stimulus, a mechanical tap, subthreshold for the tendon reflex, which was applied either on the Achilles tendon, the short biceps tendon, or the quadriceps tendon. In all cases there was an early facilitation followed by a longlasting inhibition of the test H reflex. The same results were obtained in patients with a complete spinal cord section. Wherever the site of the conditioning stimulation, these modifications disappeared after ischaemia of the leg. It is concluded that the effects observed are due to the activation by the tendon tap of the Ia nerve fibres from the soleus muscle, and that the longlasting inhibition is probably due to a transmitter depletion.

Since its first description in man by Schenck (1951), Magladery *et al.* (1952), and Paillard (1955), the H reflex excitability cycle has been studied extensively. However, the interpretation of the late facilitation and inhibition remains controversial. These modifications are observed even when the conditioning stimulus is subthreshold for the H reflex (Taborikova and Sax, 1969). These authors conclude that the late facilitation is due to a long loop reflex activated by Ia afferent nerve fibres; Gassel (1970), however, interprets the facilitation as resulting from an activation of cutaneous nerve fibres by the conditioning stimulus. Late inhibition is supposed to be due to a transmitter depletion at the junction of Ia fibres with motoneurons. The results recently obtained by Delwaide *et al.* (1976) seem not to support such an interpretation since a similar longlasting inhibition is observed after conditioning taps supraliminal for various tendon reflexes of the explored leg.

In the present investigation, the test reflex was a soleus H reflex. To activate only the primary spindle endings, a conditioning tap subthreshold for the tendon reflex was applied on the soleus tendon and to other tendons of the explored leg. In the latter case the effects of the spread of the conditioning stimulus to the soleus spindles were

eliminated by an ischaemic block of the Ia nerve fibres from the soleus muscle.

Methods

The investigation was performed on 11 healthy adult volunteers aged between 28 and 41 years: the experiments were repeated several times on each subject with similar results. Two patients with a complete spinal cord section at the T6 segmental level were also examined.

The subjects were seated comfortably in an arm-chair with hip and knee flexed at 120°. The variations of the soleus H reflex after a conditioning mechanical stimulation applied to the tendons of the soleus, the quadriceps, or the short biceps femoris were studied.

Surface electrodes were used for both stimulation and recording. The soleus H reflex was obtained by stimulating the posterior tibial nerve at the popliteal fossa with single rectangular electrical pulses of 1 ms duration delivered through a monopolar electrode. The intensity of the stimulation was adjusted so that the amplitude of the reference H reflex was half maximum. The reflex responses obtained were measured in terms of the electromyogram (EMG) and recorded by two surface electrodes placed 10 mm apart over the soleus muscle below the gastrocnemius. The EMG responses were recorded on magnetic tape and analysed by a NOVA 1200 computer. Recording electrodes were also placed on the ipsilateral

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quadriceps and short biceps femoris, and on the contralateral quadriceps, short biceps, and soleus.

The conditioning mechanical stimulus was a blow from an electromagnetic hammer (Bruel and Kjaer model 4809) which produces a very quick stretch (8 mm during 5 ms). The mechanical stimulus intensity was subthreshold for the tendon reflex and this was verified by EMG recordings throughout the experiments. The conditioning stimulus was applied to the homolateral tendon of the soleus, the quadriceps, or the short biceps. In addition, in some experiments, we delivered taps to the tendons of contralateral muscles. We also studied the effects of mechanical stimuli of the same intensity applied to the tibia or the tarsus. Usually the conditioning stimulus was a single mechanical tap, but in some experiments we have used a repetitive volley of mechanical taps (a volley of six stimuli at 150/s or 16 at 200/s). In this case it was verified that the stimulation remained subthreshold for the tendon reflex.

The effect of the conditioning tap was tested by a soleus H reflex. The interval between the conditioning tap and the H reflex stimulation varied from 0 to 3000 ms. The H reflex was evoked every five seconds. We alternatively triggered off one isolated unconditioned H reflex and one conditioned H reflex. For each given interval between the conditioning tap and the test H reflex, 10 H reflexes were evoked. Each conditioned response was expressed as a percentage of the preceding unconditioned H reflex. The mean of the five measurements was calculated for each interval.

In order to determine the role of Group I afferent nerve fibres from the soleus, we made the

leg ischaemic with a sphygmomanometer cuff placed at the high part of the leg, and below the site of the H reflex stimulation. In order to know the role of cutaneous afferent fibres, we repeated the same experiments after anaesthetising the skin at the site of the mechanical stimulation by 1% xylocaine.

Results

NORMAL SUBJECTS

Conditioning stimulus applied to the soleus tendon
Single shock conditioning stimulus In Fig. 1A the effects of the conditioning tap on the H reflex are plotted against the time interval between the conditioning stimulus and the test H reflex stimulation. From 0 to 20 ms, a slight facilitation of the H reflex was seen. From 20 to 80 ms, the test H reflex amplitude decreased progressively and reached its minimum value (27% of its reference value) at 80 ms. From 70 to 2500 ms this inhibition progressively disappeared. The general aspect of the curve was identical in all the 11 normal subjects; quantitative differences were observed in the importance of the inhibition, the time of its maximum and its duration. The extreme values of the inhibited test H reflex were 6 and 51%; the extreme values of time of the maximum inhibition were 40 and 80 ms; the extreme values of the inhibition duration were 750 and 2500 ms.

Repetitive volley conditioning stimulus The results are illustrated in Fig 2. The results obtained with a single conditioning stimulus (Fig. 2A) were compared with those obtained during the same

Fig. 1 Conditioning of H reflex by soleus tendon tap, subthreshold for Achilles tendon; in control situation (A) and during ischaemia of the leg (B). Abscissa: time interval between conditioning tap and H reflex stimulation (Note the scale modification after 100 ms). Ordinate: amplitude of the test H reflex expressed as a percentage of the amplitude of the preceding reference reflex. Each point represents the mean amplitude of five conditioned H reflexes, each of them expressed as a % of the amplitude of an unconditioned H reflex. ●—●=before ischaemia of leg ▲—▲=after ischaemia of leg.

Fig. 2 Conditioning of H reflex by mechanical stimulation subthreshold for Achilles tendon. Mechanical stimulation is single tap ●—● (A) or repetitive volley of six taps ○---○ (B). Axes are the same as in Fig. 1. Each point represents the mean amplitude of five conditioned H reflexes, each of them expressed as a % of the amplitude of an unconditioned H reflex.

session from the same subject with a repetitive volley of either six (Fig. 2B), or 16 (not illustrated) stimuli. The duration of the conditioning volley was the same in all cases. It can be seen that by increasing the number of conditioning shocks, the inhibition is stronger, earlier and longer.

Essentially the same results were obtained after anaesthetising the skin at the site of the conditioning stimulus.

Results obtained when varying the site of stimulation

Tendon of the homolateral short biceps Figure 3

(filled triangles) shows that the results were roughly similar to those obtained when stimulating the Achilles tendon. However there were several differences: (1) the initial facilitation was more important and its duration was longer; (2) the consecutive inhibition was less important, and did not last so long. Similar results were obtained in all the subjects examined.

Tendon of the homolateral quadriceps The results, illustrated in Fig. 3 (crosses), were comparable with those obtained after stimulation of the short biceps tendon. Essentially the same re-

Fig. 3 Conditioning of H reflex of soleus by tap delivered to short biceps tendon, (▲), or to quadriceps tendon (×). Open symbols represent data obtained under ischaemia of leg when conditioning the H reflex by a tap delivered to the short biceps tendon (△), or to the quadriceps tendon (◇). Axes are the same as in Fig. 1. Each point represents the mean amplitude of five conditioned H reflexes, each of them expressed as a % of the amplitude of an unconditioned H reflex.

sults as those illustrated in Fig. 3 were obtained when the stimulus was applied to the tibia or to the tarsus.

Tendons of contralateral muscles No changes in the test H reflex were observed when the stimulus was applied to the tendons of the contralateral muscles.

Effects of ischaemia of the leg

Ischaemia was produced by a sphygmomanometer cuff positioned around the upper part of the leg just below the site for stimulating the H reflex and inflated to 300 mm Hg. Under these conditions, 20–25 mm after inflation of the sphygmomanometer cuff the Achilles tendon jerk was abolished. For a period of 10–15 min after the abolition of the Achilles tendon jerk, the reference H reflex and the maximum M response were not modified. It was during this period that the H reflex excitability cycle was studied. Under these conditions, striking the Achilles tendon did not modify the H reflex (Fig. 1B). In the same manner the modifications of the H reflex produced by a tap on the quadriceps or on the short biceps tendons completely disappeared after ischaemia of the leg (Fig. 3 open diamonds and triangles) although the tendon tap was applied above the ischaemic block.

PATIENTS

Changes in H reflex after a mechanical conditioning stimulation of the soleus and the short biceps were studied in two patients with a complete spinal cord section. Essentially the same results were obtained as in normal subjects (Fig. 4).

Discussion

We have studied the modifications of an H reflex of the soleus at various times after subthreshold mechanical stimulations of several tendons of the inferior limbs. Regardless of the tendon stimulated the excitability cycle of the H reflex was identical—an initial facilitation followed by a longlasting inhibition. Identical results have been obtained by Delwaide *et al.* (1976) using a supraliminal mechanical stimulation.

NERVE FIBRES RESPONSIBLE FOR THE MODIFICATIONS OF THE H REFLEX

Cutaneous nerve fibres are not involved in the early facilitation nor in the following inhibition of the H reflex since the same results were observed whether the skin was anaesthetised or not.

Fig. 4 Paraplegic patients with complete spinal cord section. Conditioning of H reflex by mechanical stimulation subthreshold to Achilles tendon (A) or the short biceps tendon (B). Axes are the same as in Fig. 1. Each point represents the mean amplitude of five conditioned H reflexes, each of them expressed as a % of the amplitude of an unconditioned H reflex. ●—● = tap subthreshold for soleus tendon reflex ○—○ = tap subthreshold for biceps tendon reflex.

As shown in Fig. 1B the effects of the conditioning stimulus applied to the Achilles tendon completely disappear under ischaemia. Ischaemia blocks Group I nerve fibres before blocking alpha fibres (Magladeri *et al.*, 1950). The selectivity of our blockade is proved in these experimental conditions because the M response remained unchanged whereas the tendon jerk was abolished. It may be assumed that group II nerve fibres, which are smaller than alpha fibres, were not blocked by ischaemia so the observed early facilitation and longlasting inhibition, which disappear under ischaemia, must be due to group I fibres. According to animal data, it is probable that group Ib fibres are not recruited by a slight conditioning stimulus applied to a non-contracting muscle (Lundberg and Winsbury, 1960). Under these conditions, the activation of Ia afferent fibres by the tendon tap is likely to be responsible for the observed modifications of the soleus H reflex. If these fibres are accepted as arising in the stimulated muscles, our results, and those obtained by Delwaide *et al.* (1976) with supraliminal tendon taps, would seem rather puzzling. They would mean that activating the Ia afferent nerve fibres from the quadriceps (synergist to the soleus) or the short biceps (antagonist to this muscle) could result in the same modifications of the soleus motoneurone's excitability. In fact, the Ia fibres involved do not come from the spindles of the quadriceps or short biceps muscles since ischaemia of the leg, which only blocks Group I nerve fibres coming from the soleus, suppresses the observed

modifications of the H reflex. It can, therefore, be assumed that test H reflex modifications after a tap applied to the short biceps or quadriceps tendon are due to activation of primary nerve endings of the soleus by the remote percussion. Such an interpretation fits with clinical data obtained in spastic patients in whom a tendon tap can excite distant muscles receptors. Moreover this has been verified recently by electrophysiological methods (Lance, 1965).

SPINAL MECHANISMS

The observed early facilitation and the subsequent longlasting inhibition must be explained by exclusively spinal mechanisms since essentially the same results were found in patients with complete spinal cord section.

Activation of the soleus Ia afferent nerve fibres by the conditioning stimulus can easily explain the early facilitation of the H reflex. However, it would seem surprising to find a more important facilitation after percussion of the short biceps or quadriceps tendons than after a tap applied on the Achilles tendon. This could be explained by a presynaptic inhibition exerted by soleus Ia fibres upon each other. Such a phenomenon has been demonstrated in animals (Barnes and Pompeiano, 1970), and its existence in human subjects is likely (Delwaide, 1971). As shown by Eccles (1964), the more the fibres recruited by the stimulus the more important the presynaptic inhibition; this presynaptic inhibition reaches its maximum 20 ms after the stimulus. Under these conditions it can be assumed that this presynaptic inhibition of the soleus Ia nerve fibres is more important after percussion of the Achilles tendon than after percussion of the short biceps or quadriceps tendons. This presynaptic inhibition could partially mask the excitatory effects due to the activation of the Ia fibres.

According to animal data (Eccles, 1964), it seems very unlikely that such a presynaptic inhibition would last more than 200 ms. The longlasting inhibition could be due to depletion of transmitter at the junction between Ia fibres and motoneurons (Curtis and Eccles, 1960; Taborikova and Sax, 1969). The fact that this inhibition increases with the number of mechanical stimuli favours this hypothesis (Curtis and Eccles, 1960).

In addition, unlike Taborikova and Sax (1969) and Paillard (1955), we have not observed any secondary relative facilitation of the test reflex. This discrepancy can be easily explained since they used an electrical subthreshold stimulus. However, since both techniques involve Ia nerve fibres it

seems unlikely that the secondary facilitation, observed with an electrical subthreshold stimulus, can be due to a long loop reflex involving Ia fibres. This facilitation, which is not seen after a mechanical conditioning stimulus, is probably due to stimulation by the conditioning electrical shock of cutaneous fibres, as postulated by Gassel (1970).

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