stimulation of Deiters' nucleus, which increased the decerebrate rigidity of the fore-limbs, was completely ineffective on the electrically induced hind-limb reflexes.

The present experiments show that the striking abolition of the proprioceptive reflexes occurring during desynchronized sleep cannot be explained simply with a withdrawal of a facilitatory influence descending from the the brain stem since (i) this effect could still be observed when the spinal section affected the dorsolateral and the ventral funiculi of both sides, as soon as the effects of the spinal shock had disappeared, and (ii) no appreciable manifestation of spinal shock occurred when a complete section of the spinal cord was later carried out. The experimental evidence suggests, therefore, that the abolition of the spinal reflexes during the episodes of deep sleep is due to descending inhibitory volleys impingeing upon the proprioceptive reflex arcs. These suppressive influences originate from supraspinal structures, localized probably within the inhibitory regions of the brain stem reticular formation; they descend mainly, although probably not exclusively, along the ventral half of the lateral funiculi.

Riassunto. La scomparsa di riflesi spinali mono- e polisinaptici nel corso del sonno desincronizzato è legata a meccanismi inibitori esercitantesi sugli archi riflessi spinali. Questa azione di controllo viene trasmessa da centri sopraspinali al midollo spinale attraverso vie che decorrono principalmente, per quanto non esclusivamente, nei funicoli ventro-laterali.

S. GIAQUINTO, O. POMPEIANO, and I. SOMOGYI

Istituto di Fisiologia della Università di Pisa (Italy), July 8, 1963.

Generalized Inhibition of Spinal Reflexes Induced by Cutaneous Nerve Stimulation in Unrestrained Cats[1]

It was previously reported that low rate stimulation of group II cutaneous afferents, performed in unrestrained unanaesthetized cats, produces EEG synchronization and behavioural sleep[2]. On the other hand, high rate stimulation of group II and low or high rate stimulation of group III cutaneous afferents produces EEG desynchronization and behavioural arousal[2]. A study of the spinal reflexes during sleep and wakefulness has shown, moreover, that in normal, unanaesthetized animal monosynaptic (MR) and polysynaptic (PR) spinal reflexes are completely abolished during deep, desynchronized sleep[3], an effect due to tonic inhibition from supraspinal structures[4].

The present experiments show that the generalized inhibition of spinal reflexes which characterizes episodes of deep sleep may be reproduced by low rate stimulation of the lower threshold cutaneous afferents.

The experiments have been performed on unrestrained, unanaesthetized cats with chronically implanted electrodes (see [2]). EEG cortical electrodes, EMG electrodes recording from the extensor neck muscles, and stimulating electrodes applied on the superficial radial nerve of one or both the sides were implanted under barbiturate anaesthesia. EMG electrodes were also applied to the lateral gastrocnemius and tibialis anterior muscles of one side, in order to record respectively the monosynaptic and polysynaptic reflex responses to graduated stimulation of the central stump of the ipsilateral medial gastrocnemius nerve, following a technique which has been previously described[3]. In order to avoid irritation, the recording sessions never started before the third or fourth day following the chronic implantation of the electrodes. The following results have been obtained.

(1) Low rate stimulation (from 1 to 10/sec, 0.05 msec pulse duration) of the superficial radial nerve, for stimulus intensities capable of activating only the group II cutaneous afferents, does not produce any change in postural tonus when performed on a background of strong arousal. However, when performed on a background of relaxed wakefulnes or of light synchronized sleep, the same stimulation is followed (i) by a decrease of the tonus of the neck musculature and of the lateral gastrocnemius (antigravity muscles), and (ii) by a reduction or abolition of the after-discharge of the tibialis anterior (flexor muscle) following stimulation of the flexion reflex afferents (FRAs) of the medial gastrocnemius nerve. Within the range of 1 to 10/sec, the effects reported above increase in intensity and occur earlier when the rate of stimulation is increased. However, when the rate is raised to 20/sec, the initial decrease in the tonus of the neck muscles is followed by marked enhancement, while at 100/sec only an increase of the electromyographic activity of neck muscles is observed.

(2) The effects on postural tonus may be accompanied by EEG synchronization, but they can be observed independently from it. The synchronized response actually occurs only when the stimulation of the superficial radial nerve is performed on a proper background of EEG activity[2].

(3) Low rate stimulation of group II cutaneous afferents reduces (Figure, A), or abolishes (Figure, B) the MR produced by stimulating the medial gastrocnemius nerve at 100/sec with stimulus intensities ranging from 1.0 to 1.2 times the threshold for the MR. This effect may also outlast the stimulus (Figure, C, D). It is particularly striking when the stimulus applied to the muscular nerve is just supraliminal for the MR, is increased by raising from 1 to 10/sec the rate of stimulation of the superficial radial nerve as well as its intensity, provided the stimulus remains subliminal for group III cutaneous afferents. The reduction or the abolition of the MR are scarcely evident in the aroused animal. They may be accompanied by induced EEG synchronization, but the relationship between EEG and spinal effects is not constant.

(4) The abolition of the MR produced by low rate stimulation of group II cutaneous afferents is the consequence of an inhibitory process which does not depend upon mechanisms of reciprocal innervation, since (i) it is observed by stimulating both the ipsilateral and the contralateral superficial radial nerve, while (ii) the reduction of

[1] This investigation was supported by PHS research grant B-2990 from the National Institute of Neurological Diseases and Blindness, N.I.H., Public Health Service (U.S.A.).

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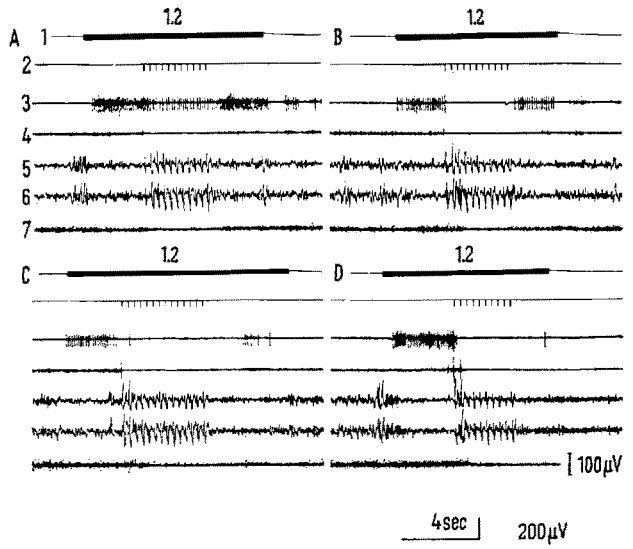
the tonus and the decrease of the monosynaptic response of the antigravity muscles are not accompanied by reciprocal effects on the antagonistic flexor muscles. The usual patterns of reciprocal innervation appear only when group III cutaneous afferents are co-stimulated



Aboliton of the monosynaptic reflex by low frequency stimulation of group II cutaneous afferents. Unrestrained, unanaesthetized cat. Experiment made 3 days after the implantation of the electrodes. (1) Stimulation of the left medial gastrocnemius nerve at 100/sec, 0.05 msec pulse duration, 1.2 times the threshold for the monosynaptic reflex. The nerve was crushed and ligated distally to the stimulating electrode. (2) Stimulation of the left superficial radial nerve at 3/sec, 0.05 msec pulse duration, 0.4 V. (3) Left lateral gastrocnemius muscle. (4) Left tibialis anterior muscle. (5) Left fronto-temporal; (6) Right fronto-temporal. (7) Posterior cervical muscles. – Reduction (A) and abolition (B, C, D) of the monosynaptic reflex by low frequency stimulation of the lower threshold cutaneous afferents. This effect may outlast the stimulus (C, D). – Note also the decrease of the tonus of the posterior cervical muscles and of the tibialis anterior (flexor muscle). These effects are accompanied by induced EEG synchronization. Calibration of 100 μV is referred to channels 3, 4 and 7.

(5) When not only the MR but also the PR is elicited by stimulating the medial gastrocnemius nerve with intensities supra-threshold for the FRAs, low rate stimulation of cutaneous group II fibres inhibits both reflexes. Only when cutaneous group III fibres are co-stimulated is the flexor response elicited by exciting the high threshold muscular afferents enhanced, while the MR is still decreased. This flexor response is accompanied by an increased activity in the cervical EMG (orienting reaction) and by EEG desynchronization.

(6) When low rate stimulation of group II cutaneous afferents is applied during the stage which precedes the appearance of an episode of deep sleep (as shown by the spontaneously occurring gradual reduction of the cervical EMG), the EMG and behavioural patterns of deep sleep are precipitated. In these instances, low rate stimulation of group II cutaneous fibres does not produce EEG synchronization, but only flattening of the EEG and EMG silence.

It is concluded that low rate stimulation of group II cutaneous afferents performed in unrestrained, unanaesthetized cats produces a partial inhibition of both spontaneous and reflex muscular activities. This phenomenon is a generalized one and affects both flexor and extensor muscles, as well as monosynaptic and polysynaptic spinal reflexes. The induced pattern of generalized inhibition of the spinal reflex activity is sometimes accompanied by an electrocortical synchronization as previously described[2]; however, it does not necessarily depend upon it. Under certain circumstances, low rate stimulation of group II cutaneous afferents may also precipitate the pattern of deep sleep.

Riassunto. Nell'animale integro non anestetizzato la stimolazione a bassa frequenza delle fibre cutanee del gruppo II produce una riduzione generalizzata del tono posturale e dei riflessi spinali mono- e polisinaptici, che si accompagna di solito, ma non necessariamente, ad un quadro di sincronizzazione elettroencefalografica[2]. In particolari condizioni sperimentali la stimolazione cutanea suddetta può anche precipitare il quadro di sonno desincronizzato.

S. GIAQUINTO and O. POMPEIANO

Istituto di Fisiologia della Università di Pisa (Italy), July 8, 1963.

The Effect of DOPA on Spinal Reflexes from the FRA (Flexor Reflex Afferents)

Recent biochemical and histochemical investigations make it likely that there are descending pathways with noradrenergic synaptic terminals in the spinal cord[1]. In acute spinal cats L-DOPA (L-3, 4-dihydroxyphenylalanine, precursor of the catecholamines dopamine, noradrenaline and adrenaline) gives a pronounced increase of the flexor reflex evoked by pinching the skin. An electrophysiological analysis has now been made of the effect of L-DOPA on transmission from the FRA (flexor reflex afferents) to α-motoneurones, ascending pathways and primary afferents. It has been a constant finding that the DRP (dorsal root potentials), which are caused by primary depolarization in the FRA[2], are markedly reduced after intravenous administration of L-DOPA (67 mg/kg). The Figure shows this for the effects from high threshold muscle afferents (B, D, H, J). There is no effect on the DRP evoked from group 1 muscle afferents (E and K). The effect is completely reversible within 1–2 h and effectively antagonized by the adrenergic blocker Phenoxybenzamine. In addition DOPA reduces excitatory and inhibitory actions from the FRA to motoneurones and to ascending pathways, but in the Figure the reduction in the ventral root discharge caused by high threshold muscle afferents is small (F and L).

The finding that DOPA increases the flexor reflex in the acute spinal cat is possibly accounted for by the more

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