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New Evidence Favouring Long Loop Reflexes in Man*

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Summary. Further evidence for a spino-bulbo-spinal reflex in man has been obtained by electronic averaging of multiple EMG-responses after electrical stimuli to the sole of the foot and various other peripheral sites. Our findings show that the evoked reflex potential is conducted not only via spino-bulbo-cranial but also in spino-bulbo-spinal pathways and occurs in ipsi- and contralateral muscles of the head, the trunk and the extremities. Its efferent conduction velocity—computed from recordings of the interspinal muscles — is ca 20 M/sec which is about $^1/_4$ of the afferent one.

Key words: Spino-Bulbo-Spinal Reflex — Somatomotor Response.

Zusammenfassung. Mittels Summation von Muskelaktionspotentialen nach elektrischen Reizen der Fußsohle wird beim Menschen ein langschleifiger spinocerebraler Reflex nachgewiesen. Das evozierte Reflexpotential benutzt spino-bulbocraniale und spino-bulbo-spinale Bahnen und aktiviert nacheinander Kopf-, Rumpf- und Extremitätenmuskeln der ipsi- und kontralateralen Körperhälfte. Seine *efferente spinale Leitungsgeschwindigkeit* ließ sich durch Ableitung von der Interspinalmuskulatur berechnen. Sie ist mit ca. 20 m/sec wesentlich langsamer als die afferente.

Schlüsselwörter: Spino-bulbo-spinaler Reflex — Somatomotorische Reaktion.

Introduction

A spino-bulbo-spinal reflex in animals was described by Shimamura (1963). It was elicited by stimulation of dorsal roots and consisted of an ascending arc to the bulbar reticular formation and a decsending path producing serial an bilateral ventral root discharges. It was evoked most easily and regularly by cutaneous nerve stimulation (Shimamura and Akert, 1965).

Though it might be expected that any strong sensory input in animals or man would be conducted to higher centers and from there reflected again to the periphery, the existence of such a spino-bulbo-spinal reflex in man has not yet been conclusively proved.

Indirect evidence for such circuits has however been claimed by Shimamura *et al.* (1964) and by Taborikova *et al.* (1966) from clinical

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experiments. Gassel (1970) argued, that Shimamuras response might be a simple flexion reflex and that the explanation of Taborikova *et al.* would require long loop reflexes conducted to extensor motor neurones from flexor muscle afferents, a pathway for which no clear evidence has been obtained.

Gassel and Ott (1970), after cutaneous stimulation of the dorsal and plantar surfaces of the distal foot, found a late period of H-reflex facilitation which they considered could be a reflection of long loop spino-bulbo-spinal reflexes. Their evidence, however, was indirect, and we have approached this problem by a more direct method. By averaging of EMG responses from multiple partially activated muscles following electrical stimuli to the sole of the foot we obtained direct evidence for a spino-bulbo-spinal reflex in man. Our results show that, following stimulation of the plantar foot surface a delayed reflex response can be recorded in the cranial and neck muscles. The reflex can also be recorded in many other muscles with progressively increasing latency after the cephalic response. By serially sampling from the monosegmentally innervated interspinal muscles the cranio-caudal conduction velocity can be estimated, and unusual delay or focal absence of the reflex might be useful in localizing spinal and radicular lesions.

Methods

In 52 normal persons single rectangular pulses of 0.2 msec duration were applied with an intensity 3 or 4 times above sensory threshold and a frequency of 6/sec either to the sole of the foot, the skin of the finger tips, or the base of the second and third finger. Electromyographic records were obtained from the muscles of the head, arms and legs and from the monosegmentally innervated dorsal interspinal muscles (A. Struppler, 1969). For recording, either two monopolar steel needle-electrodes or two surface skin electrodes were used, both with an interelectrode distance of 2 cm. The evoked muscle activity was amplified by a Schwarzer or by a Siemens-Schönander-EEG-apparatus recorded on magnetic tape (Siemens), 100 to 800 samples of the recorded activity (post-stimulus epochs of 100—200 msec duration) were averaged by a computer (Intertechnique, DIDAC 800) and displayed on an X—Y recorder. Since the reflex transients of interest were only visible upon a background of partial motoneuron excitation (Bickford, Jacobson, Cody, 1964; Cracco and Bickford, 1968), the subjects were asked to tense the sampled muscles, so as to produce a submaximal interference pattern on the recording instruments. Direct writeout of the EMG activity permitted the establishment of a satisfactory and stable level of the interference pattern in each patient and each muscle prior to and during stimulation.

Results

Spino-Bulbo-Cranial Reflex

When a suprathreshold stimulus was applied to the sole of the foot the earliest consistent transient after the stimulusartefact was recorded in muscles of the head. This small response was brought out only by

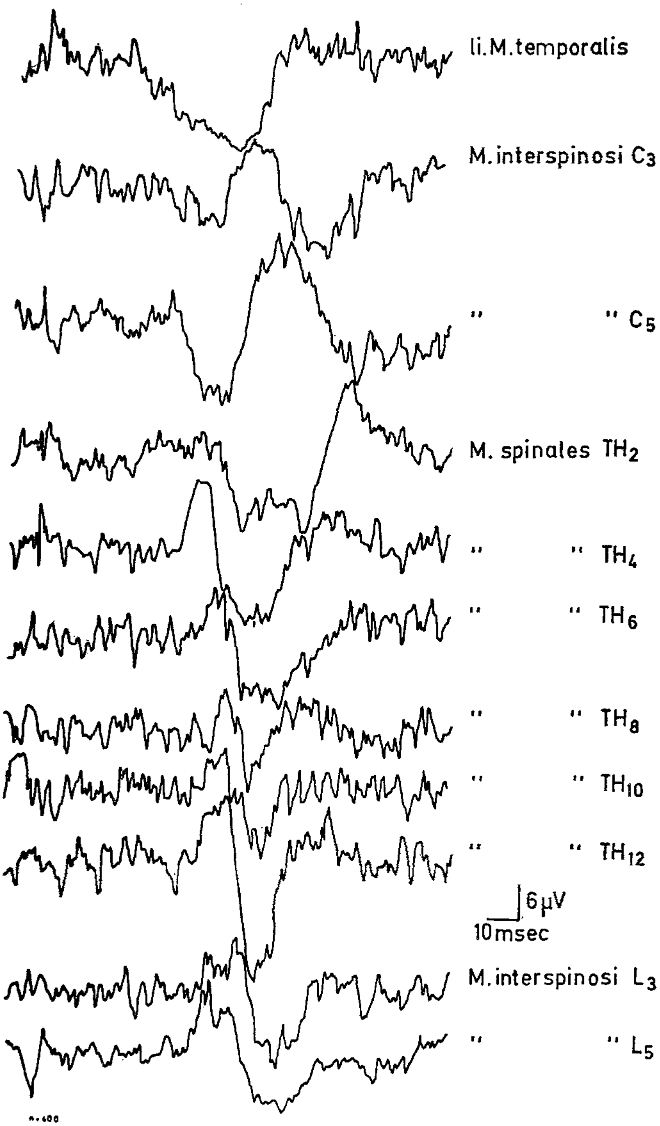

Fig. 1. *Averaged recordings from the M. temporalis and the interspinous muscles* following electrical stimuli to the base of the right second and third finger. From the latencies C_5—L_5 and the distance between the two recording sites an efferent spinal conduction speed of ca 20 M/sec can be computed. Such recordings might be used to localize spinal and radicular lesions. Summation of 400 recordings. Stimulus parameters: As in Fig. 2

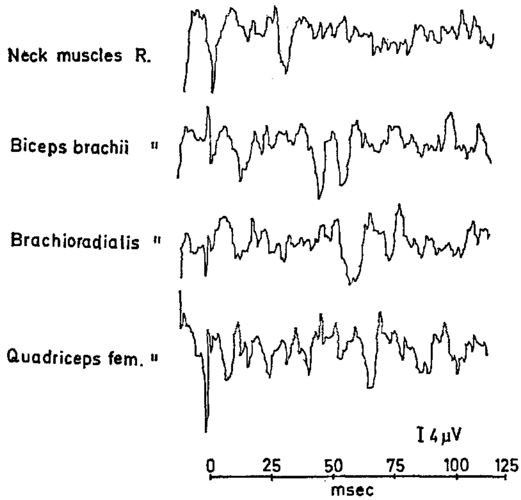

Fig. 2. *Averaged recordings from neck, arm, and leg muscles of the right side of the body* following electrical stimuli to the sole of the left foot. The records show a cranio-caudally spreading reflex potential first occurring in the neckmuscles. Stimulus parameters: Duration 0.2 msec, intensity four times sensory threshold, frequency 6/sec. Summation of 500 recordings

electronic averaging of 50—400 epochs (Fig. 1) and was of 5—40 μV in amplitude and 20—60 msec duration. The latency to head muscles was less than that for the other tested muscle groups and averaged 28 msec to temporalis (Figs. 1 and 2).

Spino-Bulbo-Spinal Reflex

In the cervical interspinal muscles, following electrical stimuli to the plantar foot, a response occurred shortly later or at about the same time as in temporalis, but the latencies of the evoked muscular responses increased thereafter as samples were obtained from trunk, arm and leg muscles (Fig. 2).

Input-Output Relationships

The *afferent conduction* velocity of these reflexes is higher than 70 m/sec, as can be roughly estimated from the earliest cephalic and cervical responses (C_7 latencies approx. 30 msec, temporalis latencies approx. 28 msec in normal persons with a body heigh of 1.70 m). If 18 msec are required for the impulses to travel up the n. ischiadicus of 1 m length (55 m/sec), 10 msec are left for the final 70 cm to the trigeminal motoneurones and then out to the muscle temporalis. The spinal afferent conduction speed must then be near 70 m/sec. If synaptic delay and

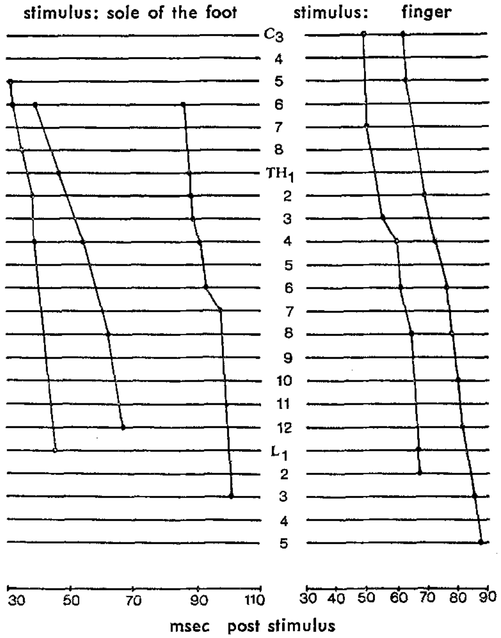

Fig. 3. *Scheme giving the latencies of interspinous muscle responses* following electrical stimuli to the base of the second and third finger (see right side of the figure) or to the sole of the foot (see left side of the figure) in four different persons (one person was stimulated at fingers and foot). From the slope of the curves given the efferent conduction velocity of the reflex can be estimated (see text)

outflowtime are taken into consideration, the velocity upwards of the response we are recording may approach 80 m/sec.

The efferent spinal conduction speed of the spino-bulbo-spinal reflex may be estimated from recordings of the monosegmentally innervated interspinal muscles (Fig. 1) and averages around 20 m/sec. The latency of the early (cervical) reflexes varied considerably from person to person, but serial plots of response latencies in more caudal segments gave curves of similar slope (Fig. 3).

Asymmetry of the Reflex Response

It was reported previously (Cracco and Bickford, 1968; Meier-Ewert *et al.*, 1971) that demonstration of this reflex requires a background of some voluntary innervation and that its amplitudes vary considerably from person to person. However the latencies are remarkably stable in the same subject (Fig. 4). In these experiments we found the reflex potential most often having higher amplitude on the side ipsilateral to

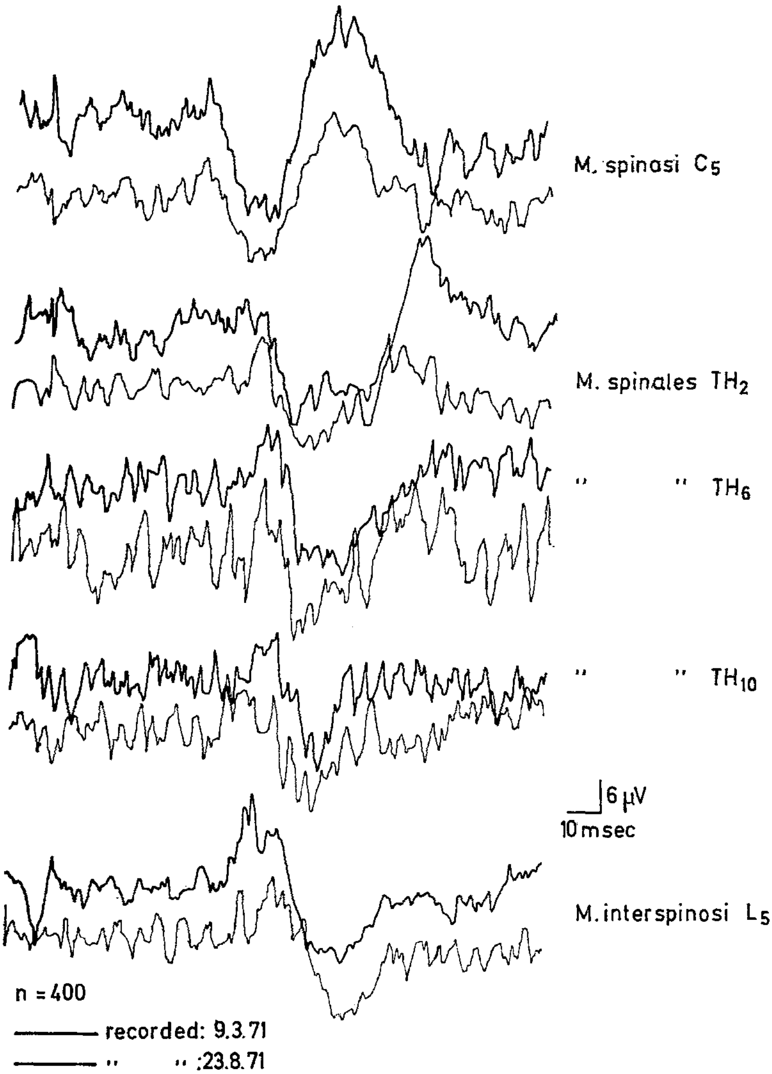

Fig. 4. Averaged recordings from the partially contracted m. interspinosi and m. spinales following electrical stimuli to the base of the second and third finger obtained on two different days in the same normal person. The latencies remain constant in the same person. Stimulus parameters: As in Fig. 2

the stimulus, but we also found it very distinctly on the contralateral side (Fig. 2). It was always obtained most easily within the first 50 to 100 EMG-samples and thus seems to fatigue rather early.

Discussion

The spino-bulbo-spinal reflex in animals was shown by recording from ventral roots in curarized and decerebrated cats or monkeys (Gernandt and Shimamura, 1961; Shimamura *et al.*, 1964). Our demonstration of this phenomenon in man was dependent on two conditions: 1. facilitation of the reflex potential by voluntary innervation. 2. electronic averaging of the EMG activity. Both are necessary to show the muscular responses in man to mixed nerve stimulation peripherally, as first demonstrated Bickford *et al.* (1964). These authors and Cracco and Bickford (1968) showed responses to median nerve stimulation in cranial muscles which were examples of a spino-bulbo-cranial reflex in man. They also mentioned responses from neck muscles and from midthoracic muscles, but their investigations did not deal with the question of pathways.

Bickfords reflex', which he called somatomotor response, was elicited by median or ulnar nerve stimulation and thus involved antidromic as well as group Ia and II afferent inputs to the cord. In order to excite cutaneous receptors only we stimulated the skin of the finger tips or the sole of the foot, and with this selective stimulus mode we found that essentially the same reflex may be provoked from a number of stimulation sites. It should be noted that our stimuli to the plantar foot, being rather strong, usually produced a slight contraction of small flexors of the toes and therefore obviously excited a number of different fibres. However, the same reflex response was always obtained with pure cutaneous stimulation of the finger tips.

The temporalis response to plantar foot stimulation must be evoked by impulses mediated to the medulla oblongata and connected there to the motor part of the V nucleus. It therefore represents a spino-bulbo-cranial reflex.

Evidence for the suprasegmental reflex nature of the EMG-responses in the trunk, arm, and leg muscles is derived from two considerations: 1. The responses evoked by plantar foot stimulation in thoracic and lumbar muscles cannot be mediated directly to the motor neurons of these segments, since muscles located closer to the brain stem and farther from the stimulus nevertheless have the shortest latencies. 2. The main variable in the EMG response to plantar stimulation was its progressively greater delay as the distance of the sampled muscles from the brain stem increased. Even a polysynaptic spinal reflex should not require twice the time to appear in quadriceps as in temporalis. The approximately equal latencies of temporal and cervical muscles are simply explained by their anatomical location at equal distance from the bulbar reflex center. Downward conduction from the brain stem, can be assumed to be mediated via a pathway having about 1/4 the axonal conduction velocity of the afferent arc. Such differences in input and output parameters for suprasegmental long loop have been documented in experimental animals by Shimamura (1963).

We feel that our stimulation technique of the finger tips has avoided major involvement of flexor muscle afferents and therefore the response more resembles a nociceptive than a flexor reflex.

Focal absence of the reflexpotential was found in patients with spinal tumours.

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