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Neurophysiological mechanism of the unloading reflex as a prognostic factor in the early stages of idiopathic adolescent scoliosis

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Abstract This paper presents a new neurophysiological method of evaluating the risk of progression in idiopathic scoliosis in the early stages of the disease, by investigating the unloading reflex in paraspinal muscles. The study included 394 patients with scoliosis and 70 healthy children. Latency of the unloading reflex and repeatability of the rebound and silent period were analysed for each reflex evoked. Prolonged latency and minimal number of cycles are the

most important factors in the evaluation of progressive idiopathic scoliosis. The method can be used to detect progressive idiopathic scoliosis in the early stages of the disease. The high sensitivity of the method means it can be used as a basis on which to take an early decision to perform surgery.

Key words Idiopathic scoliosis · Unloading reflex · Rebound · Latency · Silent period

Introduction

Progression of idiopathic scoliosis has been the subject of many clinical, radiological and electromyographic investigations. There is, however, no simple quantitative or qualitative prognostic method that can be employed in the early stages of the disease. Monitoring of the unloading reflex in paraspinal muscle appears to be a reliable method of discriminating between different forms of scoliosis. The unloading reflex can be evoked in all the skeletal muscles through a sudden shortening of voluntary innervated muscle [2–6]. When a muscle is unloaded rapidly during an isometric contraction, the normal reaction is an electrically silent period followed by a burst of action potentials called “rebound”. The pause in discharge can be observed only when a certain threshold value of acceleration and shortening of the muscle is exceeded, and it occurs with constant latency corresponding to that of the proprioceptive reflex [9, 18, 20]. The rebound after the silent period in the unloading reflex results from activation of a pool of motoneurons, all of which reach the firing threshold simultaneously after previous silence [1, 3, 4, 20].

The aim of this study was to evaluate the use of the unloading reflex for detection of progressive idiopathic adolescent scoliosis in its early stages in order to take a decision to perform surgery as soon as possible.

Materials and methods

Investigations were carried out on 394 patients with adolescent scoliosis and 70 healthy children. The scoliosis group consisted of 311 girls and 83 boys aged 9–18 years (mean age 12.5 years). The controls were 60 girls and 10 boys aged 10–17 years (mean age 12.8 years). Among the subjects studied were 9 patients with cervico-thoracic scoliosis, mean Cobb angle 22.7°; 121 with thoracic scoliosis, mean Cobb angle 30.9°; 111 with thoraco-lumbar scoliosis, mean Cobb angle 26.8°; 63 with lumbar scoliosis, mean Cobb angle 27.9°, and 90 with double major curve scoliosis, mean Cobb angle 29.2° and 28.5°. The study group included 231 right-sided and 163 left-sided scoliotic patients. There were 112 patients with progressive idiopathic scoliosis (76 right-sided and 36 left-sided); 182 with non-progressive idiopathic scoliosis (113 right-sided and 69 left-sided); and 100 with pelvic tilt (static) scoliosis (42 right-sided and 58 left-sided).

Scoliosis is considered “progressive” if the Cobb angle increases by more than 6° in 1 year, and “non-progressive” if the annual increase is less than 6°. The Cobb angle ranged from 8° to 77° in the patients with progressive scoliosis (mean 36.1°), from 3° to

Fig. 1 Electromyographic response of paraspinal muscles to the unloading reflex in a healthy child. Short latency as well as repeatability of rebound and silent period are shown

48° in those with non-progressive scoliosis (mean 20.3°), and from 2° to 25° in those with pelvic tilt scoliosis (mean 8.2°).

The unloading reflex in paraspinal muscles was evoked mechanically with the use of a specially constructed "trap-door" (own design, Polish patent no. 165233) connected to an electromyograph (Medelec Sapphire 4 ME). The device consists of a frame, a plate, a releasing gear, a lifting gear, a retaining block and a buffer pad. The reflex is evoked with the subjects standing on the plate, which can tilt suddenly (to an angle of 8°), causing a right- or left-sided body tilting. The test was repeated four times for each side, with 30-s intervals between the recordings. During the test the vestibular and visual reflexes were eliminated through fixation of the subject's head in a cervical stabilizer and the use of protective dark glasses. In order to maintain the proper position of the pelvis, the subject's knees were immobilized in plastic splints.

With the use of bipolar surface electrodes the electromyographic recordings of the reflex were obtained at the T8, L1 and L3 levels and at the apex of the curve. The electrodes were placed

Fig. 2 Electromyographic response of paraspinal muscles to the unloading reflex in a patient with non-progressive right thoracic scoliosis, Cobb angle 25°. The latency is slightly prolonged and the repeatability of rebound and silent period slightly diminished

15–20 mm away from the processus spinosus symmetrically on either side of the paraspinal muscles. The ground electrode was placed on the palm side of the right wrist. Inter-electrode resistance was below 3 k Ω . It was found that, at lower levels of the spine (L2, L3), the reflex response was prolonged in both the patients and controls. To obtain reproducible and reliable results, the unloading reflex must be elicited under the same conditions.

Statistical analysis

Student's *t*-test was used to compare the means of analysed variables of the groups. The statistical analysis was carried out using the Statistica software package for IBM PC-AT.

Results

Quantitative and qualitative analyses of the unloading reflex were made. Silent-period latency and repeatability of the rebound and the silent period were evaluated, with one silent period and one rebound forming a cycle.

The reflex response was found to be symmetrical on both sides of the body when tilting to the right or left. However, in patients with progressive idiopathic scoliosis, the latency was prolonged on the side opposite the curve.

Fig. 3 Electromyographic response of paraspinal muscles to the unloading reflex in a patient with progressive right thoracic scoliosis, Cobb angle 30°. The latency is markedly prolonged and only one rebound and one silent period can be seen

Fig. 4 Changes in the mean duration of the unloading reflex latency at the T8 level in A children with fast progressive idiopathic scoliosis, B children with slow progressive idiopathic scoliosis, C children with pelvic tilt scoliosis and D healthy children

Long-term observations showed that changes in the recordings correlated with disease progression and not with age. The electromyographic responses to the unloading reflex are presented in Fig. 1–3.

Highly significant differences in silent-period latency were found between patients with fast progressive scoliosis and those with pelvic tilt scoliosis and controls at the T8 level.

Fig. 5 Changes in the mean number of cycles at the T8 level in A children with fast progressive idiopathic scoliosis, B those with slow progressive idiopathic scoliosis, C children with pelvic tilt scoliosis and D healthy children

sis and those with pelvic tilt scoliosis and controls at the T8 level. The mean latency of the unloading reflex in children with fast progressive scoliosis at the A8 level ranged from 73 to 94 ms, in those with slow progressive scoliosis from 51 to 60 ms, in children with pelvic tilt scoliosis from 41 to 50 ms and in healthy children from 47 to 49 ms (Fig. 4).

Pronounced differences in cycle structure were found between patients with fast progressive scoliosis, those with pelvic tilt scoliosis and the control group at the T8 level ($P < 0.001$). The number of cycles ranged from 1.5 to 2.1 in children with fast progressive scoliosis, from 3.0 to 3.8 in those with slow progressive scoliosis, from 4.1 to 4.3 in healthy children and from 4.2 to 4.7 in children with pelvic tilt scoliosis. In patients with pelvic tilt scoliosis the cycle repeatability was found to be the highest (Fig. 5).

Discussion

In clinical practice, electromyographic examination of the reflexes is carried out to evaluate the functioning of the sensorimotor system. The mechanically evoked unloading reflex causes muscle contraction by orthodromic afferent impulses to the alpha motoneurons. The unloading technique does not produce antidromic firing of motor axons, which stimulate the Renshaw cells, and there is no cause for discharge of Golgi tendon organs. The significant factor is shortening of muscle, which unloads the spindles and interrupts their firing, thus causing a silent period. The silent period can therefore be taken as a crude index of spindle sensitivity [5–7, 17–20]. A cyclic appearance of the silent period and the return of the motor activity of the muscle with sudden retention of movement in one evoked reflex is related to the mechanism of intramuscular rhythmic oscillation and the grouping of many active tonic motoneurons in the paraspinal muscles [1, 8, 14–16].

Reports from the literature show that studies of the unloading reflex concerning the silent period and the rebound have been carried out using electromyographic analysis in the upper and lower limbs, mostly in the biceps and triceps brachii, adductor pollicis tibialis anterior and soleus muscles.

The author of this paper was the first to conduct studies of the unloading reflex in paraspinal muscles, using a specially constructed device [11–13]. The study has shown that prolonged latency and a decreased number of cycles are significant factors in differentiating between progressive and non-progressive idiopathic scoliosis. The

most important finding was the simultaneous appearance of the electromyographic response on both sides of the paraspinal muscles while tilting to one side in all the subjects. Dimitrijevic et al., in a study of reflex responses of paraspinal muscles to unilateral, tapping, also observed a simultaneous bilateral response and cyclic patterns, which they called R_1 and R_2 [10].

In the present study the quantitative evaluation of the unloading reflex in paraspinal muscles showed a simultaneous latency of the silent period on both sides of the trunk. The silent-period latency was nearly twice as long in patients with progressive idiopathic scoliosis as it was in those with pelvic tilt scoliosis and the controls when recorded at the thoracic level. The qualitative evaluation of the unloading reflex demonstrated a marked decrease in the number of cycles in patients with progressive idiopathic scoliosis compared with those with non-progressive scoliosis, pelvic tilt scoliosis and healthy children.

Prolonged silent-period latency and the minimal number of cycles in progressive idiopathic scoliosis indicate defective functioning of the muscle spindles and disturbed oscillation in the paraspinal muscles.

Conclusion

Prolonged latency of the silent period and/or minimal number of cycles are the most important parameters in the evaluation of progressive idiopathic adolescent scoliosis in the early stages of the disease. Detection of progressive scoliosis using the method described enables an early decision to perform surgery.

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