Postoperative Evaluation of 1st Dorsal Interosseus Muscle Using ^{31}P -MRS in Cubital Tunnel Syndrome

by

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Abstract

Metabolic changes in human 1st dorsal interosseus muscle before, during and after the voluntary static abduction of the index finger in cubital tunnel syndrome were studied using ^{31}P nuclear magnetic resonance spectroscopy. Cross section of 1st dorsal interosseus muscle was calculated by ultrasonogram. Endurance tasks were performed at assigned contraction level of 20% of maximal voluntary contraction (MVC). Muscle pH was calculated using chemical shift between inorganic phosphate (Pi) and phosphocreatine (PCr) on the ^{31}P -MRS spectra. The value of affected side was smaller than that of control side in cross section of 1st dorsal interosseus muscle and MVC, but there was no significant difference in MVC per unit area between affected side and control side. High Pi/PCr showed after the exercise. Qualitative progression was recognized followed by quantitative progression in denervated 1st dorsal interosseus muscle in cubital tunnel syndrome.

Key words : ^{31}P -MRS, energy metabolism (エネルギー代謝), 1st dorsal interosseus muscle (第一背側骨間筋), cubital tunnel syndrome (肘部管症候群)

Introduction

Musculoskeletal imaging has been profoundly affected by the development of cross-axial computer-based imaging techniques of magnetic resonance imaging (MRI). Phosphorus-31 nuclear magnetic resonance spectroscopy (^{31}P -MRS) is a safe and noninvasive technique useful in the study of energy metabolism in human muscle. With high-field-strength superconducting magnets, investigators have measured relative tissue concentrations of phosphocreatine (PCr), inorganic phosphate (Pi), ATP, phosphomono- and diesters, pH and changes in these values in response to manipulations such as exercise⁵⁾. Previous studies of normal muscles and muscle cell mitochondria by MRS have shown the importance of the ratio of PCr to Pi as an expression of the tissue's ability to perform work⁶⁾. In this study, postoperative evaluation of 1st dorsal

interosseus muscle using ^{31}P -MRS method in cubital tunnel syndrome was performed.

Materials and methods

Seven cases (5 males and 2 females) with postoperative unilateral cubital tunnel syndrome were investigated. They were treated by vascularized anterior transposition surgery of ulnar nerve. Contralateral side was also evaluated as control. The age range at the time of surgery was from 50 to 71 years (mean 62.1 years). Postoperative follow-up time was from 4.5 to 7.9 years (mean 5.8 years).

1) Nerve conduction study

Nerve conduction studies were performed using standard electrodiagnostic equipment (Nihon Kohden Neuropack 4). All tests were carried out in a warm room (around 20°C). The terminal latency and motor nerve conduction velocity (MCV) were measured in each patient. The criteria for the diagnosis of cubital tunnel syndrome was that normal terminal latency and the MCV from above elbow to below elbow was less than 45m/sec.

2) Cross section area of 1st dorsal interosseus muscle using ultrasonogram

A cross section area was calculated using ultrasonogram at the point of intermediate between metacarpal bone of thumb and index finger.

3) Maximum voluntary contraction force (MVC) of 1st dorsal interosseus muscle

MVC was measured by Nihon Kohden TB-611T five times in abduction of the index finger isometrically by a strainage connected to proximal interphalanx joint of the index finger. Mean MVC was calculated except maximum and minimum values.

4) Analysis of muscle energy metabolism

Spectroscopic examinations at before, during and after exercise (20% load of MVC) were conducted with 1.9 Tesla, 28cm bore superconducting magnet (Otsuka Electronics, USA Inc. BEM 250/80). The subject inserted a hand into the magnet bore while sitting beside the magnet or lying on a nonmetallic stretcher. The hand was placed over a surface coil embedded in a plexiglass armrest. Radiofrequency pulses were applied at 2 seconds intervals. Muscle pH was calculated from the chemical shift between PCr and Pi according to Taylor et al⁵⁾. Pi to PCr ratio (Pi/PCr) was calculated from the peak area measured by a planimeter.

Results

Pre- and postoperative terminal latency and MCV across the elbow were summarized in Table 1. MCV of control side showed normal range (over 45m/sec) at forearm and elbow. In affected side, mean MVC between above elbow and below elbow was $37.3 \pm 5.6\text{m/sec}$. There was no significant difference in terminal latency. Values of affected side was smaller than those of control side in cross section area and MVC of 1st dorsal interosseus muscle ($p < 0.05$). But there was no

Table 1 Pre and postoperative nerve conduction study

MCV (m/sec)	affected side	control side	significance
Elbow	37.3 ± 5.6	53.5 ± 7.5	$p < 0.05$
Forearm	54.6 ± 10.6	55.0 ± 4.0	n.s.
terminal latency (m/sec)	3.46 ± 0.35	3.17 ± 0.35	n.s.

Table 2 Cross section area and MVC of 1st dorsal interosseus muscle

cross section area (cm ²) and MVC (N)	affected side	control side	significance
cross section area (cm ²)	1.02±0.23	1.47±0.21	p<0.05
MVC (N)	8.27±3.20	10.68±3.42	p<0.05
MVC/area (N/cm ²)	7.22±1.79	6.71±1.47	n.s.
exercise time (min)	7.06±4.04	9.60±4.17	n.s.

Table 3 ³¹P-MRS in 1st dorsal interosseus muscle

³¹ P-MRS	affected side	control side	significance
before the exercise pH	7.00±0.02	7.04±0.02	n.s.
Pi/PCr	0.31±0.22	0.26±0.02	n.s.
after the exercise pH	6.74±0.16	6.85±0.11	n.s.
Pi/PCr	0.66±0.06	0.42±0.04	p<0.05
ΔpH	0.04±0.01	0.02±0.01	n.s.
ΔPi/PCr	0.08±0.03	0.02±0.01	n.s.

Table 4 ΔpH and ΔPi/PCr

$\Delta\text{pH} = \frac{\text{pH (after the exercise)} - \text{pH (before the exercise)}}{\text{Exercise time}}$
$\Delta\text{Pi/PCr} = \frac{\text{Pi/PCr (after the exercise)} - \text{Pi/PCr (before the exercise)}}{\text{Exercise time}}$

significant difference in MVC per unit area between affected and control side (Table 2).

Intracellular pH at before and after the exercise by ³¹P-MRS method showed no significant difference between affected and control side. Although Pi/PCr at before the exercise showed no significant difference between them, Pi/PCr after the exercise showed high value in affected side (p<0.05) (Table 3).

ΔpH and ΔPi/PCr were calculated as Table 4. There were no significant differences in ΔpH and ΔPi/PCr between affected and control side (Table 3).

Discussion

Abnormal structures with reduced mitochondrial enzyme activities may be seen in various neuromuscular diseases with no primary mitochondrial involvement. Biochemical studies revealed decreased cytochrome c oxidase activities in the biopsies after denervation, that was thought to result from a secondarily induced mitochondrial defect³⁽⁴⁾.

Experimental studies by ³¹P-MRS demonstrated that high Pi and low PCr before the exercise in the denervated muscle compared with the intact muscle¹⁽⁷⁾. High Pi and low PCr was getting obvious in severe cases, and these changes improved as the improvement of symptoms. Moreover, Frostik et al.²⁾ demonstrated that Pi/PCr before the exercise was progressive with time after

denervation, and there appeared to be a plateau occurring at about sixth weeks, and it tended to return to normal in some periods in the rabbit data. In our study, postoperative follow-up time was mean 5.8 years, so the experiment was thought to be done after the plateau occurring of 1st dorsal interosseus muscle restoration.

No statistical difference in pH was found between before and during the exercise per time. Experimental studies using ^{31}P -MRS in the denervated human muscle by Frostik et al.¹⁾ and Zochodne et al.⁷⁾ demonstrated that pH before the exercise showed high value and the alteration tended to be obvious as the symptoms was severe. It showed that pH returned to normal as reinnervation same as Pi/PCr.

It is suggested that the changes of energy metabolism after denervation occurred in intra cellular buffer system, that is to say, protein, bicarbonic acid, PCr, Pi and ATP. But there is no obvious explanation for these mechanism.

We concluded that the denervated muscle in cubital tunnel syndrome, 1st dorsal interosseus muscle, restored not quantitatively but qualitatively, although our data was different from previous data.

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〈和文抄録〉

肘部管症候群術後における第一背側骨間筋の ^{31}P -MRS による検討

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肘部管症候群術後の第一背側骨間筋のエネルギー代謝を ^{31}P -MRS 法にて測定し、筋肉機能の評価を行った。

片側罹患の肘部管症候群術後 7 症例（男性 5 例，女性 2 例，平均年齢 62.1 歳，平均術後観察期間 5.8 年）において，①尺骨神経の伝導速度（MCV）および終末潜時の測定 ②超音波断層による第一背側骨間筋の筋断面積の測定 ③第一背側骨間筋の最大随意収縮力（MVC）の測定 ④ ^{31}P -MRS 法による安静時および運動中，運動終了時の第一背側骨間筋のエネルギー代

謝の測定等を行なった。

《結果・考察》患側での肘部 MCV の低下や，第一背側骨間筋 MVC の低下が認められたが，単位面積当たりの静的収縮力，筋細胞内 pH，安静時の Pi/PCr には有意差はなかった。

肘部管症候群においては，筋の量的回復より質的回復が先行すると考えられる。患側の運動終了時の Pi/PCr の高値は，筋疲労を起こしやすい状態の残存と考えられる。