行政院國家科學委員會補助專題研究計畫成果報告

引痛點自發性電位活動的功率頻譜分析以量化乙醯膽鹼接受器離子通道開啟時間

計畫類別： □ 個別型計畫  □ 整合型計畫
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計畫主持人： 陳若佟
共同主持人： 鍾高基
洪章仁

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□ 赴國外出差或研習心得報告一份
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□ 出席國際學術會議心得報告及發表之論文各一份
□ 國際合作研究計畫國外研究報告書一份

執行單位：國立成功大學醫學系復健學科

中華民國 91 年 10 月 28 日
中文摘要

由最近的電生理研究顯示，於人類及兔子骨骼肌引痛點(myofascial trigger point, MTrP)內的活化小點(operative locus)，均可紀錄到具有特徵化的自發性電位活動(spontaneous electrical activity, SEA)。活性愈高的引痛點，其 SEA 所紀錄到的高振幅尖波就愈多。很多的臨床觀察及實驗均支持 SEA 乃是一種不正常的終板電位(endplate noise)。本研究利用兔子實驗模式，經由自發性電位活動的功率頻譜分析來特徵量化乙醯膽鹼離子通道開啟時

間。自發性電位活動的功率頻譜係經由羅倫氏方程式(Lorentzian function)上的截頻(cut-off frequency)分析以推導求得乙醯膽鹼離子通道開啟時間及 SEA 平均積分面積這二個參數之間的關係。實驗結果顯示：兔子骨骼肌引痛點乙醯膽鹼離子通道開啟時間平均值為 0.414±0.010ms，且其值與 SEA 平均積分面積值呈負線性相關。人類骨骼肌引痛點乙醯膽鹼離子通道開啓時間平均值為 1.070±0.024ms。結論：引痛點自發性電位活動的平均積分面積及乙醯膽鹼離子通道開啟時間相當適

合做為量化引痛點敏感度的參數。

關鍵詞：引痛點、肌筋膜疼痛徵候群、微終板電位

Abstract

Myofascial pain syndrome (MPS) is suggested to represent a neuromuscular disorder and there are multiple active loci (dysfunctional motor end-plates) within an myofascial trigger point (MTrP) area, in which the spontaneous electrical activity (SEA) is shown by electromyography. SEA is considered as end-plate noise due to excessive acetylcholine (ACh) leakage. Characteristics of SEA were studied through power spectral analysis for channel open time of acetylcholine receptors (AChR) on end-plates. The channel open time of AChR was estimated from the corner frequency by fitting the power spectrum distribution of SEA through Lorentzian functions. The average integrated value (AIV) of rectified SEA signal was also calculated on each SEA for the sensitivity. The mean and standard deviation of the channel open times of AChR were 0.414 ± 0.010ms for all eight rabbits. The regression analysis results have revealed an inverse linear relationship between the AChR channel open time and the AIV of SEA. The mean and standard deviation of the channel open times of AChR were 1.070 ± 0.024ms for all eight human subjects. The power spectral analysis of electromyographic SEA may be helpful to characterize the sensitivity or intensity of MTrP, and more even to elucidate the pathophysiology of MPS.

关键词：Myofascial Pain Syndrome, Myofascial Trigger Point, End-plate potentials, Power Spectral Analysis

Myofascial trigger point (MTrP), a hyperirritable spot within a palpable taut band of skeletal muscle, is the most important characteristic of myofascial pain syndrome (MPS). Simons and others have proposed that MTrPs basically represent a neuromuscular disease associated with dysfunction of motor end-plates and there are multiple active loci (dysfunctional motor end-plates) within an MTrP area, in which the spontaneous electrical activity (SEA) is shown by electromyography. The SEA
consists of continuous, noise-like action potentials (5 to 50μV), accompanied by intermittent large-amplitude spikes (100 to 600μV). SEA is considered as end-plate noise due to excessive acetylcholine (ACh) leakage.

From the theory of channel kinetic of cell membrane, channel opening and closing is a random switch. Individual channel may have only two states, open and closed. If the probability of a channel being open is \( P (0 < P < 1) \), the probability of being closed is \( 1-P \). According to Binomial Theorem:

\[
NP = N_0
\]

where \( N \) is the number of total ion channels, \( P \) is the channel open probability, and \( N_0 \) is the number of channels open at any time \( t \). Channel conductance \( G = I/R \) is defined as:

\[
G = NP\gamma = N_0\gamma,
\]

where \( \gamma \) is the hole conductance and it follows that:

\[
\tau_C = RC = C/N_0\gamma.
\]

This means time constant in the many-channel cell is much smaller than that in the few-channel cell. Cell membrane with many channels that open randomly would be expected to produce noise with voltage profiles fluctuating at faster rates than for few-channels cell. The mean open and closed times of channels underlying the current influence the fluctuation rate. The distribution of frequencies within the channel noise therefore holds information on channel kinetics. Therefore, if there is excessive ACh release (\( N_0 \) increases) at the multiple active loci of MTrP, the time constant \( \tau_C \) of the SEA (end-plate noise) decreases.

Power spectral analysis of end-plate noise has never been used for the investigation of MTrP. In this animal study, electrophysiological characteristics of SEA recorded from multiple loci of MTrPs of skeletal muscle of rabbits were investigated by using digital signal processing and power spectral analysis for the channel open time of AChR on end-plates.

**Results and Discussion**

Figure 1 shows one example of the Lorentzian function fitting on noise-reduced spectrum distribution of spike-free SEA signal. The results of estimated channel open time of AChR recorded from 10 different loci within the MTrP region for each rabbit demonstrate a consistent trend of normal distribution (Fig.2). For all the 8 rabbits, the channel open time of AChR on end-plates also show a normal distribution with mean and standard deviation 0.414 ± 0.010ms (Table 1). The results of regression analysis has revealed an inverse linear relationship between the AChR channel open time and AIV of end-plate noise for the SEA characteristics, where correlation coefficient is \(-.64\) with a significance level at \( p < .05 \) (Fig. 3). The mean and standard deviation of the channel open times of AChR were 1.070 ± 0.024ms for all eight human subjects (Table 2).

![Fig 1: One example of the Lorentzian function fitting on noise-reduced spectrum distribution of spike-free SEA signal.](image1)

![Fig 2: (A) One example of the normal distribution of the AChR channel open time recorded from 10 different loci within the MTrP region of a rabbit. (B) For all the 8 rabbits, the AChR channel open time on end-plates also show a normal distribution.](image2)
Table 1: The Mean of Channel Open Time of AChR on End-plates Estimated from the Corner Frequency of Rabbits (msec)

<table>
<thead>
<tr>
<th>Rabbit</th>
<th>Mean ± SE</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>0.421 ± 0.022</td>
</tr>
<tr>
<td>2</td>
<td>0.431 ± 0.029</td>
</tr>
<tr>
<td>3</td>
<td>0.409 ± 0.021</td>
</tr>
<tr>
<td>4</td>
<td>0.398 ± 0.026</td>
</tr>
<tr>
<td>5</td>
<td>0.407 ± 0.019</td>
</tr>
<tr>
<td>6</td>
<td>0.410 ± 0.023</td>
</tr>
<tr>
<td>7</td>
<td>0.414 ± 0.026</td>
</tr>
<tr>
<td>8</td>
<td>0.423 ± 0.032</td>
</tr>
</tbody>
</table>

Mean 0.414 ± 0.010

Fig 3: A inverse linear relationship between the AChR channel open time and AIV of end-plate noise from SEA recording: Y = .4678 -.0056X, correlation coefficient (r) = -.64 (p< .05), and standard error (SE) = .05.

Table 2: The Mean of Channel Open Time of AChR on End-plates Estimated from the Corner Frequency of Human Subjects (msec)

<table>
<thead>
<tr>
<th>Subject</th>
<th>Mean ± SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.142 ± 0.027</td>
</tr>
<tr>
<td>2</td>
<td>1.029 ± 0.016</td>
</tr>
<tr>
<td>3</td>
<td>0.964 ± 0.031</td>
</tr>
<tr>
<td>4</td>
<td>0.998 ± 0.038</td>
</tr>
<tr>
<td>5</td>
<td>1.375 ± 0.029</td>
</tr>
<tr>
<td>6</td>
<td>1.020 ± 0.032</td>
</tr>
<tr>
<td>7</td>
<td>1.085 ± 0.028</td>
</tr>
<tr>
<td>8</td>
<td>0.945 ± 0.027</td>
</tr>
</tbody>
</table>

Mean 1.070 ± 0.024

The power spectral analysis of SEA may be helpful to characterize the sensitivity or intensity of MTrP, and more even to elucidate the pathophysiology of MPS.

References