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A strong linear relationship between Turns/Amplitude peak ratio and ratio at maximal effort

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ABSTRACT

In EMG interference pattern analysis, the peak value of turns to mean amplitude ratio [peak(T/A)] is an established clinically significant marker, but its calculation requires specific software available only in few EMG apparatuses. On the contrary, the turns to mean amplitude ratio obtained at maximal muscle contraction (T/Amax) is easily calculated but less well standardized. We aimed to quantitatively assess the association between T/Amax and peak(T/A). Data were derived from 642 muscle contractions (Nc) from 270 consecutive patients (Np) who underwent EMG at our laboratory (software Dantec Keypoint, QEMG) from May 2015 to September 2016 and had interference patterns obtained from at least one of the following muscles: triceps-lateral head, brachioradialis, extensor digitorum communis and biceps. Statistics were calculated separately for normal and neurogenic muscles. Peak(T/A) was calculated by the built-in "peak ratio" function. T/Amax was calculated by the built-in Interference Pattern analysis function. The ratio with the highest amplitude was selected as T/Amax. Linear regression models provided high Pearson correlation coeffficientscoefficients (R) between peak(T/A) and T/Amax for all 4 muscles, normal or neurogenic, except a subgroup of biceps in patients aged < 40y. Specifically, R were: (A) triceps normal 0.79 (Nc = 99), neurogenic 0.83 (Nc = 50) (B) brachioradialis normal 0.81 (Nc = 84), neurogenic 0.78 (Nc = 66) (C) extensor digitorum communis normal 0.72 (Nc = 92), neurogenic 0.73 (Nc = 61) (D) biceps (age > 40y) normal 0.77 (Nc = 77), neurogenic 0.67 (Nc = 62). We conclude that T/Amax has a strong linear association with peak(T/A) and, therefore, the former may be further investigated as a potentially useful quantitative diagnostic marker, especially in cases where the latter is not available.

1. Introduction

Quantification of interference pattern using the ratio of turns to mean amplitude (T/A) includes several different methods (Sanders et al., 1996). Among them, cloud analysis and peak-ratio are the most widely used. Peak-ratio [peak(T/A)] (Fuglsang-Frederiksen et al., 1985) (Liguori et al., 1992a) refers to the maximal ratio of turns to amplitude that is achieved during a ramp contraction of the muscle tested. Calculation is conducted with specialized software available in some, but far from all, commercially available EMG machines. To obtain an accurate assessment, the calculation is automatically performed at ten different sites of the muscle and the mean value is compared to reference values. Several studies have shown that peak(T/A) has a high sensitivity and specificity in discriminating neurogenic from myopathic diseases (Liguori et al., 1992b). It is assumed that peak(T/A) is highly sensitive and specific because it is achieved at moderate muscle contraction, where free space between motor unit potentials has been eliminated, yet not enough summation or cancellation has taken place to obscure possible pathologic changes (Fuglsang-Frederiksen, 2000).

In contrast to the quantitative use of peak(T/A), evaluation of interference pattern at maximal voluntary muscle contraction has been used mostly qualitatively and includes several grades of fullness of the pattern as well as the amplitude of the envelope (Buchthal and Kamieniecka, 1982). The main reason for this is that at higher levels of force, larger motor units are recruited (size principle) (Henneman et al., 1974), with these large motor units dominating the pattern and obscuring smaller ones. Furthermore, there is the possibility of motor unit potential interaction through summation and cancellation effects, leading to an artificial appearance of the pattern at maximal effort. There is also difficulty in achieving maximal contraction when the patient is stronger than the examiner or gives up due to pain or other reasons.

Despite these limitations, one study (Masanori et al., 1997) did conclude that T/A at maximal force can also have a high sensitivity in

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detecting neurogenic disease. This finding could be of great practical importance since T/A at maximal force can be easily calculated in every EMG apparatus.

In the present study we assessed the type and strength of the correlation between peak(T/A) and T/Amax in normal and neurogenic muscles.

2. Methods

This study was conducted on a total of Nc = 642 muscle contractions, each from a separate muscle, from all Np = 270 consecutive patients who were referred to our laboratory for EMG from May 2015 to September 2016 with any among a variety of clinical indications and had interference patterns obtained from at least one of the triceps-lateral head, brachioradialis, extensor digitorum communis or biceps muscles. In every patient, the EMG signal of one or two of the several muscle contractions performed during the routine EMG examination was randomly recorded for offline analysis. Usually, in each patient each muscle was examined bilaterally. Four muscles were sampled (triceps-lateral head, brachioradialis, extensor digitorum communis and biceps) according to standard recommendations (Preston and Shapiro, 2013). Each muscle contraction was slow, lasting 7-–10 s. Whenever the subject's maximal force was greater than the examiner's, the recording was discarded from further analysis. The position of the needle (concentric needle electrode, 26G) varied between several sites and depths of the muscle among subjects. Filter settings were 20 Hz–10 KHz.

Calculation of peak(T/A) and T/Amax for every contraction by the EMG acquisition software (Dantec Keypoint, QEMG) is demonstrated in Fig. 1.

Fig. 1a shows a plot of Amplitude vs Turns/Amplitude, generated by the "peak ratio" button, which calculates amplitudes and turns over a 100 msec period, 10 times per second, over a single contraction of gradually increasing force (triceps muscle in the example shown). The plot is generated by the EMG software, which performs averaging over the amplitude values and thus derives the peak(T/A) value (Fig. 1a line and arrow).

For calculation of the T/Amax value, a different function, namely "IP analysis", was used (Fig. 1b). When the IP analysis button is pressed, the software performs automatic calculation of turns and amplitude over a 400 msec period and plots Turns vs Amplitude. The T/A ratio calculated over the highest amplitude, obtained at maximal contraction, is the T/Amax (Fig. 1b arrow).

All contractions from the four tested muscles were classified into normal and neurogenic. To obtain this classification, we reviewed the reports of all patients and classified each contraction according to the final diagnosis of the muscle tested. Recordings were conducted in a Neurophysiology unit of a Primary Health center where patients with myopathic disease are rarely encountered. None was found among the 270 consecutive patients. Therefore, classification included normal and neurogenic, but not myopathic muscles.

Linear regression was performed using Origin Pro 8.5 software. Specifically, both peak(T/A) and T/Amax values of every contraction were copied as x and y values to an Origin software book and linear fit was performed using the fit linear dialog box that fits a straight line to the given dataset. The fitting model is written as $y = \beta_0 + \beta_1 x + \varepsilon$, where β_0 is the y intercept, β_1 is the slope and ε is the error term. The error term represents the unexplained variation in the dependent variable and is usually assumed to have a mean of zero. To estimate the parameters, the chi-square minimization or "weighted least-square" method was used. The goal is to minimize the sum of the squares of the deviations between the theoretical curve and the experimental points for a range of independent variables. After fitting, the model is evaluated using hypothesis tests and plotting of residuals. More specifically, standardized residuals were checked for normality, and the condition of homoscedasticity was tested with the plots of standardized residuals versus the predicted values.

An outlier was defined as any data point more than 1.5 interquartile ranges (IQRs) below the first quartile or above the third quartile.

3. Results

Combined results from normal and neuropathic muscles are given only in the text, whereas results separated into normal and neuropathic muscles are given in the text, shown in Figs. 2–9 and tabulated in Table 1.

3.1. Triceps

A total of 149 contractions from either normal or neurogenic muscles of 110 persons (age 51.2 ± 1.1 years, range 20–84 years) were analyzed. Peak(T/A) was 0.64 ± 0.017 and T/Amax was 0.50 ± 0.015. The ratio between the above values (peak/max) was 1.31 ± 0.02. Peak/max did not show significant correlation with age. Peak(T/A) and T/Amax values followed the normal distribution

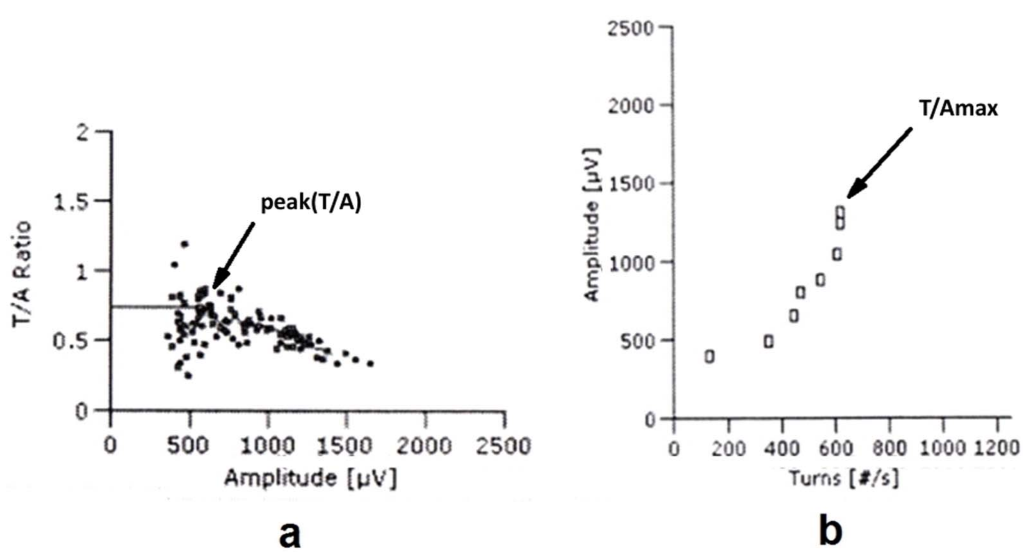

Fig. 1. Calculation of peak(T/A) and T/Amax by the EMG acquisition software (Dantec Keypoint, QEMG). (a) Plot of Amplitude vs Turns/Amplitude automatically generated by the "peak ratio" button, which calculates amplitudes and turns over a 100 msec period, 10 times per second, over a single contraction of gradually increasing force (triceps muscle in the example shown). The plot is generated by the EMG software, which performs averaging over the amplitude values and thus derives the peak(T/A) value (line and arrow). (b) For calculation of the T/Amax value, a different function, namely "IP analysis", was used. When the IP analysis button is pressed, the software performs automatic averaging of turns and amplitude over a 400 msec period and plots Turns vs Amplitude. The T/A ratio calculated over the highest amplitude, obtained at maximal contraction, is the T/Amax (arrow).