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Research paper

Anterior shin muscles CMAP measurements: Normal limits of symmetry and intra- and interobserver reliability

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ABSTRACT

Objective: The normal limits of symmetry for the compound muscle action potential of the shin muscles (CMAPshin) have not been determined yet. The goal of this study is to provide extensive data on the limits of symmetry and the reliability of CMAPshin.
Methods: The study was conducted in normal healthy males and females. All subjects underwent CMAPshin measurements bilaterally. The median percent differences of right/left amplitude/area, with range of these measurements, were calculated. In addition, the intra- and interobserver reliability was examined in a separate population.
Results: The study group consisted of 58 healthy individuals. The median percent right/left difference for amplitude and area were respectively 7.2% (range 0–23.6%) and 5.4% (range 0.7–25.6%). Right/left difference of the amplitude/area of the CMAPshin greater than 24%/26% respectively can be considered as pathological. The Pearson correlation coefficients (r) for the intra-observer reliability amplitude/area are 0.905/0.882 and for the inter-observer reliability are 0.968/0.981.
Conclusions: The results confirm symmetry and good intra- and interobserver reliability in CMAPshin measurements.
Significance: CMAPshin can be used in practice to estimate axonal loss in case of a foot drop. Data studies examining symmetry of CMAPshin can facilitate in the clinical interpretation of these nerve conduction studies.

1. Introduction

The study of nerve conduction has evolved into a major tool for diagnosis of neuropathies. Generally, when performing nerve conduction studies, the electromyographer studies the asymptomatic side for comparison with the clinically-affected limb. The symmetry of motor nerve conduction measures in the median nerve, ulnar nerve, tibial nerve, and fibular nerve have already been investigated. These studies concluded that side to side difference of <50%, in the amplitude of multiple nerves, can be considered as normal (Falck and Stålberg, 1995; Kothari et al., 2000). However, there is a paucity of data on symmetry in motor nerve conduction recording over the shin muscles (anterior tibial muscle (TA), extensor digitorum longus muscle (EDL), and extensor hallucis longus muscle (EHL)). The measurements of the motor nerve conduction of the shin muscles can play an important role in estimating the amount of axonal loss in lesions causing a footdrop (e.g. L4 or L5 radicular lesion and fibular entrapment lesions) (Katirji and Wilbourn, 1988). To better understand the analysis of asymmetric responses, we conducted a study in which we examined the symmetry in motor nerve conduction of the shin muscles in a large group of healthy individuals. The compound muscle action potential (CMAP) was measured bilaterally. In addition to this study, the authors determined the intra- and inter-observer reliability of the CMAP of the shin muscles (CMAPshin) by performing serial measurements on multiple normal and pathological subjects.

2. Methods

2.1. Subjects

All subjects were studied at the Middelheim Hospital of the Hospital Network of Antwerp (ZNA), Belgium. All studies were per-

Abbreviations: CMAP, Compound Muscle Action Potential; CMAPshin, Compound Muscle Action Potential of the Shin Muscles; EDL, Extensor Digitorum Longus Muscle; EHL, Extensor Hallucis Longus Muscle; EMG, Electromyography; SD, Standard Deviation; TA, Anterior Tibial Muscle.

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formed between November 2015 and June 2018. Subjects were selected from normal healthy males and females, volunteers from the hospital staff, with ages between 18 and 65 years.

To control for intra- and inter-observer reliability a mixed group of healthy individuals and patients with other peripheral nerve pathology (radicular lesions, polyneuropathy, entrapment of fibular nerve at the fibula head), males and females between 18 and 65 years old, were assessed.

2.2. Methods

All subjects underwent CMAP measurements of the shin muscles (TA, EDL, and EHL) bilaterally. The averages and standard deviations (SD) of the right/left amplitude/area and the differences were calculated. All the subjects of the mixed group of the reliability study were assessed several times by two different clinicians (JW and DG). The intra-observer reliability was evaluated by repeating the assessment at an interval of several weeks. The inter-observer reliability was evaluated with a 10-minute interval between assessments. The electrodes were removed after the first examination and the second examiner placed the electrodes again, blinded to the electrode location placed by the first examiner. The study was approved by the local Medical Ethics Committee and informed consent was given by all participants.

The EMG examination was performed using a Viking IV (Nicolet Biomedical Inc. Madison Wisconsin USA). The CMAPs of the shin muscles were measured bilaterally. The surface electrodes were placed as follows: the active or G1 electrode at the junction of the proximal 1/3 – distal 2/3 on the line that joins the tibial tuberosity and the lateral malleolus. The reference or G2 electrode was placed on the lateral malleolus. The ground electrode or G0 was attached between G1 and G2 (Fig. 1). The temperature of the leg was measured to be >32 °C at the muscle belly of the TA. The CMAP was recorded with this positioning, measuring the combined activity of the TA, EDL and EHL. The G1 and G2 electrodes were disposable surface electrodes with an area of 7.7 cm^2 (Kendall soft H 59P Tyco Healthcare Mansfield USA). To exclude an entrapment neuropathy at the fibular head, a short-segment incremental study (SSIS) was performed at the proximal and distal of the fibular head, at a fixed interval of 2 cm. By this method latency and amplitude/-configuration changes of the CMAP over 2 cm intervals were evaluated.

2.3. Data analysis

Data analysis was performed using the statistical package: IBM SPSS Statistics. Results per side were presented in terms of mean +/− SD. Differences between means within the same patient were investigated with paired *t*-test and a 95% confidence interval (95% CI) of the difference. Percent difference (% Difference) was defined as the absolute value of the difference in left and right side divided by the maximum of the left and right side. Median and range for the % Difference Amplitude and Area were reported. Relationship between parameters was investigated with regression analysis and Pearson correlation coefficients (r). A significance level of $p < 0.05$ was used.

3. Results

For the study group 58 volunteers were recruited. The study group consists of 22 males and 36 females, with group average age of 41.7 (19.8–64.7) years.

The average right/left amplitude/area of the CMAPshin in the study group was calculated (Table 1). The mean amplitude was 8.18 mV at the right side and 8.25 mV at the left side. The mean

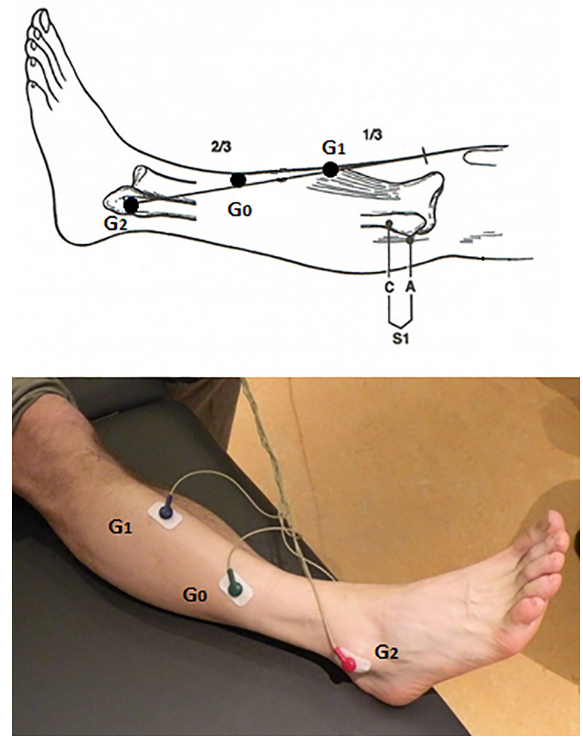

Fig. 1. Location of the 3 surface electrodes. (G0) Ground electrode. (G1) Active electrode. (G2) Reference electrode.

area was 55.48 mVms at the right side and 54.59 mVms at the left side. There was no significant difference between left and right side for either the amplitude or the area measurements.

The median percent right/left difference for amplitude was 7.20% with range 0–23.63%. The median percent right/left difference for the area was 5.44% with range 0.71–25.62%. Using this range, the limit of symmetry for right/left difference of the amplitude and area of the CMAPshin was ±24%/26%.

For determining the intra-observer reliability 25 patients (i.e. 50 legs) were assessed and for the inter-observer reliability 38 patients (i.e. 76 legs). Both showed good reliability. Figs. 2 and 3 show the regression analysis and Pearson correlation coefficients (r) of the intra-observer and inter-observer reliability, respectively.

4. Discussion

Extensive data studies examining symmetry between commonly studied nerves are essential in the clinical interpretation of nerve conduction studies. Still, the limits of symmetry for the CMAPs of the shin muscles (TA, EDL and EHL) have not been determined yet. However, these measurements can provide very useful information about the number of working axons, at least in the acute phase, in all major muscles causing a foot drop. Adopting the limits of symmetry established on other muscles (e.g. extensor brevis muscle) has limited value. Because there is a very wide interval, with side to side difference of 50% (Falck and Stålberg, 1995; Kothari et al., 2000).

The study results showed that there was no statistical difference between the average left and average right measurements of the CMAPshin. It is important to be able to set a limit from our results when a side-to-side difference may be considered pathological. As the percent difference of the right/left amplitude and area of CMAPshin is skewed, we used the maximum range to calculate the limits of symmetry. The limit of symmetry for side-to-side difference for CMAPshin is 23.6% for the amplitude and

Table 1
Description of the control population and normal values.

n = 58					
Age: mean(range)					41.7(19.8–64.7)
Male/Female%					38%/62%
Normal values	**Left mean (SD)**	**Right mean (SD)**	**Difference (95% CI)**	**p-value**	**% Difference median (range)**
Amplitude (mV)	8.25 (1.77)	8.18 (1.66)	0.06 (−0.18, 0.31)	0.604	7.20 (0–23.63)
Area (mVms)	54.59 (10.15)	55.48 (11.69)	−0.89 (−2.42, 0.64)	0.250	5.44 (0.71–25.62)

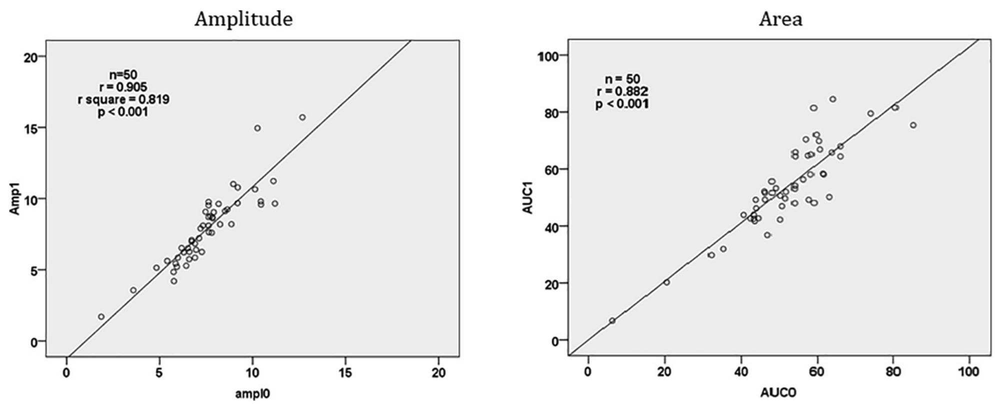

Fig. 2. Regression analysis and Pearson correlation coefficient (r) of the amplitude and area of the intra-observer reliability.

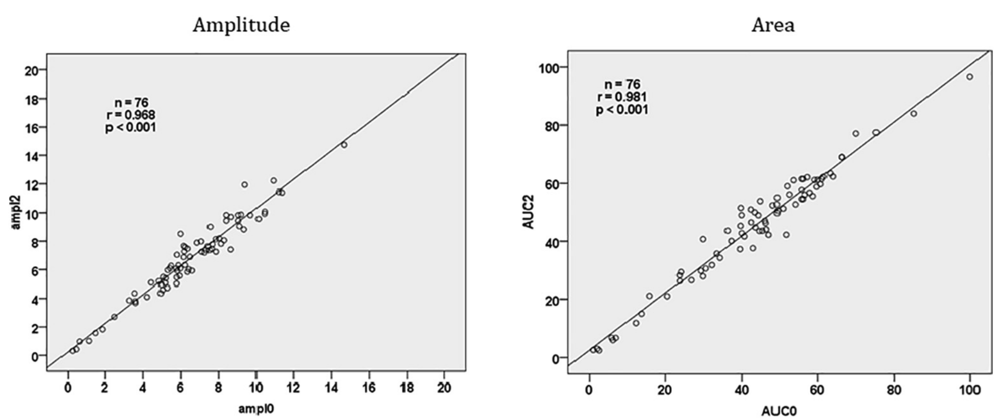

Fig. 3. Regression analysis and Pearson correlation coefficient (r) of the amplitude and area of the inter-observer reliability.

25.6% for the area. In conclusion, it can be assumed that a side-to-side difference greater than 24–26% can be considered pathological, indicating the affected muscles show significant axonal loss.

The study group used the CMAP measurements. The CMAP is the recording of the composite discharges of evoked muscle fiber membrane action potentials of a muscle. Its amplitude and area provide information on the number of axons in the motor nerve (Brown, 1984). We chose the motor end plate zone as described by Devi et al. (1977), but for the G2 placement we preferred the lateral malleolus, as this is an easily recognisable anatomical landmark. At the thenar eminence and the extensor digitorum brevis muscle a variation of 5 to 10 mm of the G1 electrode can give rise to a significant amplitude variation in the CMAP (Van Dijk et al., 1999). To avoid this, surface electrodes with an area between 4 and 10 cm^2 are necessary. We used electrodes of a large size to minimize this site-induced variability (Tjon-A-Tsien et al., 1996).

Our standardised laboratory's measurement protocol had good reproducibility with serial measurements in our study. Our measurement protocol was examined for test–retest reliability. It measures test consistency, i.e. the reliability of a test measured over time. Intra-observer (or within observer) reliability: i.e. the degree to which measurements taken by the same observer showed good reliability; and inter-observer (or between observers) reliability: i.e. the degree to which measurements taken by different observers were excellent.

The inter-observer reliability was likely to be better than the intra-observer reliability due to the measurements being performed just 10 min apart by the two different observers, as opposed to several weeks apart by the same observer. Therefore, inter-observer measurements were less susceptible to variation in factors such as temperature and fluid collection in the leg which affect skin thickness. Both are known to influence the CMAP amplitude (Barkhaus and Nandedkar, 1994).

5. Conclusion

This is the first study to provide complete data on the limits of symmetry in the shin muscles (TA, EDM, and EHL). The results confirm symmetry in CMAP in the shin muscles. The authors conclude that when comparing amplitudes and areas of CMAPshin on the affected side to the asymptomatic side, a response where the amplitude/area is greater than 24%/26% of the asymptomatic side is likely pathological. In addition, due to an optimized measurement protocol, the authors demonstrated an excellent inter- and intra-examiner reliability of the CMAPshin measurements. It can be inferred from these results that a comparison between left and right CMAP amplitude and area of the shin muscles may be used in clinical practice to demonstrate the degree of axonal damage in investigating a foot drop.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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To the best of our knowledge, the authors have no conflict of interest, financial or otherwise.

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