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Does the Location of the Motor Point Identified with Electrical Stimulation Correspond to that Identified with the Gross Anatomical Method?

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Abstract. [Purpose] The purpose of this study was to determine whether the location of the motor point (MP) identified with the gross anatomical method corresponds with that identified with electrical stimulation in the tibialis anterior muscle (TA) in order to test the validity of adopting the nerve entry point as the target for electrical stimulation. [Subjects] We used 16 lower limbs from 12 cadavers and 26 lower limbs from 13 healthy adults. [Methods] We identified the location where the thickest motor nerve entered the muscle belly of TA in cadavers as the anatomical MP and where the surface electrical stimulation threshold of TA was lowest in healthy adults as the electrical MP. We defined the line connecting the fibular head and the lateral malleolus as the reference line and drew a line perpendicular to this that intersected the MP. We measured each MP as the length from the fibular head to the perpendicular line, and expressed this as a proportion of the reference line length. The distribution of each MP was compared. [Results] There was significant unequal variance between the two types of MP. The electrical MP was significantly more distal than the anatomical MP. [Conclusion] The anatomical MP does not appear to correspond to the electrical MP, hence adopting the nerve entry point as the target of electrical stimulation is inappropriate.
Key words: Motor point, Gross anatomy, Electrical stimulation

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INTRODUCTION

In neuromuscular electrical stimulation (NMES), which promotes muscle contraction with electrical stimulation, it is recommended that one electrode is placed over the muscle's motor point (MP), where the muscle contraction is most efficiently generated[1]. The MP is a target not only in NMES but also in diverse clinical settings such as nerve conduction velocity testing[2,3]. The MP has been defined as the location where the surface electrical stimulation threshold is lower than at other sites on the same muscle[4]. However, the MP has also been defined as the location where the motor branch of the innervating nerve enters the muscle belly[5-8]. Most previous studies of MPs have used the gross anatomical method: cadavers were examined and the location where the motor branch of the innervating nerve entered the muscle belly was explored and identified quantitatively relative to palpable anatomical landmarks[6–9]. These reports also mention that the surface location of the MP in the clinical setting should be identified more precisely using the gross anatomical location of the MP as a guide and using electrical stimulation to pinpoint the location within this area[6–8].

The tibialis anterior muscle (TA) is often chosen as the stimulation target for NMES of patients with hemiplegia[10] and it is also used in nerve conduction velocity testing[2,3]. Using the gross anatomical method, the location of the TA MP is identified quantitatively and reported as the recommended location for placement of one electrode[9]. However, we could not find any reports that had studied whether the location where the motor nerve entered the muscle belly (anatomical MP) corresponded to that where the surface electrical stimulation threshold was lowest on the same muscle (electrical MP). Hence, the validity of adopting the anatomical MP as an index of the surface MP and as a target for electrical stimulation is questionable, and the present study was conducted to determine whether the anatomical and electrical MPs correspond in the TA.

SUBJECTS AND METHODS

In order to locate the anatomical MP, we examined 16 lower limbs from 12 cadavers, which had been donated to our institution for use in anatomical studies. There were 7 male (6 right and 4 left limbs) and 5 female (2 right and 4 left limbs) cadavers. The mean age of death (± standard deviation) was 81.4 ± 11.8 years (range, 59 to 100). We excluded the legs of cadavers with known lower limb disorders. These cadavers were formalin-preserved as in previous studies[11–13].

Each cadaver was placed in the supine position. The skin and subcutaneous tissue were removed from the leg, exposing the TA, extensor digitorum longus, and fibularis longus muscles. The latter two muscles were horizontally cut slightly distal to the fibular head and posterolaterally reflected. The deep peroneal nerve was then found. Several branches diverge from the nerve. A previous study noted that it is most appropriate for one surface electrode to be placed over the MP of the thickest branch[9]. Therefore we identified the thickest branch of the deep peroneal nerve and traced it to its entry point into the muscle belly of TA (i.e., the anatomical MP of TA). To locate the surface position of the anatomical MP, a needle was inserted from the surface of TA toward the anatomical MP because the branch entered the muscle belly from the deep side.

We defined the line connecting the most prominent point of the fibular head and the lateral malleolus as the reference line. We also drew a line perpendicular to this that intersected the MP. Focusing on only the reference line direction, because TA is oriented in this direction, we measured the surface position of the anatomical MP as the length (l) from the fibular head to the perpendicular line intersecting the reference line. The length (l) was divided by the total length (L) of the reference line and expressed as a percentage (l/L × 100 %).

To locate the electrical MP, we recruited 13 healthy adult volunteers with no history of neurological or neuromuscular disorders, and investigated their 26 lower limbs. Subjects' mean age was 23.2 ± 4.0 years, their mean height was 168.0 ± 9.2 cm, and their mean weight was 57.8 ± 9.5 kg. All subjects read and signed an informed consent form explaining the details of this study, which was approved by the Ethics Committee of Hirosaki University Graduate School of Medicine.

Subjects rested on a bed in a relaxed supine position. The lateral edge of TA was identified by palpation and marked, and the skin of the lower leg was cleaned with a cotton alcohol wipe.

We determined the location on TA, where the surface electrical stimulation threshold was lowest, stimulating the muscle electrically using a Recording Chronaxie Meter CX-31 (OG Giken, Okayama, Japan). For electrical stimulation, a pen-shaped stimulating electrode and a 5 cm × 8 cm rectangular indifferent electrode were used. The methods of stimulation and confirmation of TA contraction were based on those reported previously[2,3,14]. Briefly, we used a square wave of 0.25 msec pulse duration and 1 Hz frequency. We moved the stimulating electrode on the surface of TA while gradually increasing pulse amplitude from 0 mA until two examiners confirmed visible muscle contraction; at this point, we recorded the pulse amplitude and marked the location on TA (i.e., the electrical MP of TA). In addition, we ensured that the contact area of the stimulating electrode was uniform so that the current density did not change when we moved the electrode. The indifferent electrode was placed on the gastrocnemius muscle.

We defined the reference line and drew a perpendicular line intersecting the MP in the same way as for the anatomical MP. We measured the electrical MP as the length (l) from the fibular head to the perpendicular line on the reference line. The length (l) was divided by the total length (L) of the reference line and expressed as a percentage (l/L × 100 %).

For the statistical analyses, the Levene test and the two-sample test of mean difference were used to compare the percentage length of the anatomical MP to that of the electrical MP. The level statistical significance was chosen as 0.05 and statistical analyses were performed with the SPSS 16.0J for Windows software package.

RESULTS

The length (L) of the reference line was 30.0 ± 1.6 cm in cadavers and 34.6 ± 2.5 cm in healthy adults. The distance (l) from the fibular head was 4.2 ± 1.0 cm for the anatomical MP and 10.5 ± 3.7 cm for the electrical MP; in percentage terms (l/L × 100) these were 13.9 ± 3.9% and 30.5 ± 10.3%, respectively (Table 1). There was a significant unequal variance between the two types of MP ($F=13.0$, $p<0.01$); the electrical MP had a wider range than the anatomical MP. Because the null hypothesis of equal variance between the two types of MP was rejected by the Levene test, we used the Welch test to compare the percentage length of the anatomical MP with that of the electrical MP. The Welch test showed that the electrical MP was located significantly more distal than the anatomical MP ($p<0.01$).

DISCUSSION

The purpose of this study was to evaluate whether the location of the TA MP identified by the gross anatomical method corresponded with that determined by electrical stimulation, in order to investigate the validity of adopting the nerve entry point as an index of the surface MP and target for electrical stimulation.

Our results show that the electrical MP had a significantly wider range and more distal location than the anatomical MP. It therefore seems that the anatomical MP does not correspond to the electrical MP in TA.

Because the electrical stimulation threshold of the nerve is generally lower than that of the muscle, electrical stimulation does not excite the muscle directly. Rather, stimulation of the innervating nerve leads to muscle contraction. Thus, to generate muscle contraction by electrical stimulation, it is important to know the course of the innervating nerve. One study reported a certain pattern regarding the MP of TA, that is, the entry point of the

Table 1. Identification of the motor point with the anatomical method and with electrical stimulation

Measurement	Anatomical method (n=16)	Electrical stimulation (n=26)
Length of reference line	30.0 ± 1.6 cm	34.6 ± 2.5 cm
Distance from fibular head on reference line	4.2 ± 1.0 cm	10.5 ± 3.7 cm
Proportional distance from fibular head on reference line*	13.9 ± 3.9%	30.5 ± 10.3%

Data are expressed as the mean ± standard deviation (SD). *: $p<0.01$ by the Welch test.

thickest branch of the deep peroneal nerve always existed within the proximal part of TA and about 70% of all MPs were concentrated within this area[9]. However, after entering the muscle belly the nerve runs further within the muscle and diverges before reaching the motor end plates[15–17]. Wolf et al.[18] reported variation in the intramuscular branching pattern of TA among cadaveric legs. In addition, we found that the nerve innervating TA entered the muscle belly from the deep side. We therefore think it is easier to generate muscle contraction by stimulating the location where many nerves run close to the surface of the body rather than the nerve entry point. We speculate that the variety of intramuscular branching patterns of TA is a factor contributing to the wide range of locations of the electrical MP. In this study, because the intramuscular branching pattern of TA was not studied, we can only speculate about the intramuscular structure of the location where the surface electrical stimulation threshold was lowest. However, we can at least confirm that the anatomical MP does not correspond to the electrical MP, and that it is therefore inappropriate to adopt the nerve entry point as an index for the surface MP and as a target for electrical stimulation. In future studies, it will be necessary to investigate the intramuscular branching pattern and the location of the lowest threshold for surface electrical stimulation and to determine if there are any relationships between these two factors.

One limitation of this study was that we could not match the age of cadavers and healthy adults. Aging influences the morphological characteristics of the muscle such as cross-sectional area, fascicle length, and pennation angle[19]. However, because these age-related changes are not local and occur throughout TA, we feel that they are unlikely to exert much influence on variables such as the relative location of the nerve entry point to the muscle belly. Furthermore, a difference between anatomical MP and electrical MP was apparent in our results. For TA, the entry point of the motor branch of the innervating nerve to the muscle belly did not correspond to the location where the surface electrical stimulation threshold was lower than at other sites on the same muscle. Therefore we believe the present findings suggest that we should reconsider what is the best index of surface MPs as a target for electrical stimulation.

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