Anatomical Consideration of the Motor Point Location of the Tibialis Anterior Muscle for effective Neuromuscular Electrical Stimulation

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Abstract. [Purpose] We attempted to locate the motor points (MPs) of the tibialis anterior muscle (TA) for more effective neuromuscular electrical stimulation (NMES). [Subjects] We dissected 16 legs from 12 cadavers. [Methods] Branches of the deep peroneal nerve were traced to their entry into TA (MPs). We defined the FH-LM line connecting the fibular head to the lateral malleolus and the pFH-LM perpendicular to the FH-LM lines that ran through each MP. The distance from the fibular head to MPs projected on the FH-LM line was measured. On the pFH-LM line, the width of TA and the distance from the lateral edge of TA to each MP were measured. The location of each MP was expressed as a percentage of total length of the FH-LM line and of TA width, respectively. [Results] The median number of MPs was 8 per cadaver. About 68% of all MPs were located within the proximal one-third of the FH-LM line. The average location of the thickest motor branch MP was 4.2 cm (13.9 %) on the FH-LM line and 0.9 cm (33.5 %) medial from the lateral edge of TA. [Conclusion] This data should enable more effective NMES.

Key words: Muscle spasticity, Electric stimulation, Rehabilitation

INTRODUCTION

Spasticity in patients with hemiplegia induces a typical upper and lower limb posture, and may lead to permanent contractures and disability if it is not treated adequately1,2). Furthermore, these impairments and disabilities can restrict patient autonomy resulting in low quality of life. Therefore, it is important to treat spasticity appropriately to prevent these impairments and disabilities.

Various medical treatments exist for spasticity. Neuromuscular electrical stimulation (NMES) is one that is considered as an effective means of rehabilitation3–5). NMES decreases spasticity of the muscles by reciprocal inhibition through electrical stimulation of antagonistic muscles3). In NMES, 2 surface electrodes are usually used for electric stimulation, and it is recommended that for efficient stimulation 1 electrode is placed over the motor point (MP) of the muscle and the other is placed in an arbitrary position on the same muscle6). The MP has been defined as the location where the motor branch enters the muscle belly1,2,7–12), and motor endplates have been shown to cluster around this point10–13). It is believed that the MP has a lower surface electrical stimulation threshold than other sites on the same muscle14,15).

Ankle plantar flexor spasticity in patients with hemiplegia often causes difficulty in standing and walking. In NMES, the tibialis anterior muscle (TA), which is one of the antagonists of the ankle plantar flexors16), is often chosen as the stimulation target in a clinical setting. However, because few studies have investigated the precise
location of the MP of TA, it is not exactly clear where a surface electrode should be placed to ensure that it is over the MP site where muscle contraction is generated most efficiently. So, in clinical settings, we often see a surface electrode that has been arbitrarily placed on TA or the placement changes with each treatment. In such instances, even when the stimulation intensity is increased, TA may contract slightly resulting in poor efficacy of the treatment. Therefore, in order to increase the efficacy of NMES, the present study was conducted to better identify the location of the MP of TA relative to palpable anatomical landmarks.

SUBJECTS AND METHODS

The present study examined 16 formalin-preserved lower limbs from 12 cadavers, which had been donated for use in anatomical studies at our institution. 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 was 81.4 ± 11.8 years old (average ± standard deviation: range, 59 to 100). We excluded the legs of cadavers with apparent lower limb disorders.

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 extensor digitorum longus and fibularis longus muscles were cut horizontally slightly distal to the fibular head and were reflected posterolaterally. The deep peroneal nerve was identified, and all branches diverging from it were traced to each entry point into the muscle belly of TA (i.e., MPs of TA). To locate the surface position of each MP, a needle was inserted from the surface of TA toward each MP because the branches entered the muscle belly from the deep or posterolateral side.

In this study, as a reference line, we defined the line connecting the fibular head to the lateral malleolus (FH-LM line). We also defined lines perpendicular to this that pass through each MP (pFH-LM lines) (Fig. 1). The surface position of each MP was measured as the distance from the fibular head on the FH-LM line and as the distance from the FH-LM line on the pFH-LM line (Fig. 1). In addition, on the pFH-LM line, we measured the width of TA and the distance from the lateral edge of TA to the MP. To make these absolute values more generalizable, the distance on the FH-LM line from the fibular head to each MP, and the distance from the lateral edge of TA to each MP were expressed as a percentage of total length of the FH-LM line and of the width of TA, respectively.

As shown in classical anatomical literature, several motor branches arising from the trunk of the deep peroneal nerve diverge further and then enter TA. Because several branches exist, to show the features of the distribution pattern of the branches, we divided the FH-LM line into 3 equal segments (proximal, middle, and distal) (Fig. 1). The proximal segment is proximal to the fibular head. The number of motor branches within each segment immediately before entering the muscle (i.e., at the MPs) was counted. Additionally, we defined the entry point of the thickest branch into the muscle as the main MP because it is generally agreed that thicker nerve fascicles contain more nerve fibers, and the thickness of all the branches was also measured.

RESULTS

Table 1 shows the main distribution characteristics of all MPs, MPs at each segment and main MPs. The mean length of the FH-LM line was 30.0 ± 1.6 cm (average ± SD). The number of MPs varied between 6 and 11 per limb with a median value of 8, and the mean thickness of nerve branches at the MPs was 0.8 ± 0.3 mm.

Preferential distribution of MPs in the proximal segment was apparent (Table 1). The median number of MPs within the proximal segment was 5 (range, 4 to 8), and, in sum, about 68% of all MPs were distributed within the proximal segment. The median number of motor branches within the middle segment was 2.5 (range, 1 to 4). In most limbs, the distal segment contained the tendon of TA. In only 3 limbs, 1 branch was distributed within the distal segment.

The mean thickness of the thickest branch was 1.2 ± 0.2 mm. The location of the main MP, which was within the proximal segment in all limbs, was 4.2 ± 1.0 cm (range, 2.5 to 5.7 cm) along the FH-LM line from the fibular head, representing a proportion of 13.9 ± 3.6% of the FH-LM line. On the pFH-LM lines, main MPs were located at 3.5 ± 0.4 cm medial to the FH-LM line. The width of TA and the distance from the lateral edge of TA to the main MP on the...
The aim of our study was to improve the efficacy of NMES by identifying the MPs of TA and quantitatively relating these points to easily palpable anatomical surface landmarks.

In the clinical setting, TA is often chosen as a target for NMES which is performed to inhibit the spasticity of the triceps surae muscle and improve ankle extension because TA is the antagonist of the ankle plantar flexors. However, the literature contains few studies about the MPs of TA and their relationship with surrounding anatomical landmarks. Indeed, the qualitative drawing in Reid’s 1920 paper is still used. That study examined only half of a single cadaver; thus, variation among individuals was not considered. In this study, we quantitatively identified the MPs of TA based on the surface landmarks from a larger sample of cadavers.

In many previous studies, a single motor branch of the subject muscle was specified. However, in general, there are multiple MPs on each particular muscle, as we found for TA. This makes it difficult to determine the point at which to situate the electrode for NMES. Harrison et al. reported a median value of 5 motor branches in their research on 20 subscapularis muscles and reported site clustering of the MPs, which can be a good candidate for electrode placement. In this study, we also found that about 68% of all MPs were concentrated within the proximal segment of the FH-LM line. Further, the main MP always existed within this proximal segment. The MPs were most concentrated around the means of the main MP. This main MP was similar to that shown in Reid’s figure, and this is also consistent with the observation of Aquilonius et al. that the proximal area of TA was the richest in endplates.

Surface electrodes that are generally commercially available can cover a wide area, as they measure about 5 × 5 or 5 × 8.75 cm. A 5 × 5 cm surface electrode placed over the mean location of main MPs could therefore cover all main MPs and stimulate other surrounding MPs. For effective NMES, we therefore think it is most desirable for one surface electrode to be placed over the proximal segment of TA, aiming to cover the mean location of main MPs.

In previous studies of other muscles, the perpendicular distance from the reference line has been reported only in absolute values. In this study, the perpendicular distance is indicated not only as an absolute value from the reference line (the FH-LM line) but also as relative to the width of the muscle. The width of TA was measured after exposing the muscle. However, the medial and lateral edges of TA are found by palpation as the anterior border of the tibia and the boundary between TA and the extensor digitorum longus muscles, respectively. The relative value would appear to be useful because body size varies among individuals.

Clinically, electrophysiological testing such as with a surface stimulator is required to detect an effective point for muscle contraction. Quantitative measurement of anatomical location of motor points, as shown in previous studies, is useful for detecting such a point. However, for the TA muscle, the usefulness of our quantitative data for optimal NMES should be validated by electrophysiological and clinical studies.
REFERENCES