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Original Research Article

ANATOMICAL LOCALIZATION OF MOTOR ENTRY POINTS OF HAMSTRING MUSCLES - FOR NEUROLYSIS IN HAMSTRING SPASTICITY

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ABSTRACT

Objectives: To study the motor entry points of hamstring muscles of lower limb and to suggest ideal sites for motor point procedures for treatment of spasticity in the above muscles.

Materials and Methods: The study was done after approval from Institutional Review Board. Sample size was estimated using Population mean-Absolute precision method. A total of 10 adult lower limbs were chosen. The nerve branches to hamstring muscles were dissected up to its motor entry point. Position of proximal and distal motor entry points were marked and following variables measured: a) The length of muscle; b)Number of motor entry points; c)The distance of proximal entry point (PEP) and distal entry point (DEP) from the origin of muscle; e)The position of PEP and DEP as a fraction of length of muscle; f) Ideal site of motor entry point injection; g) Ideal site of motor point injection expressed as a percentage of muscle length.

Results: The proximal and distal motor entry points of long head of Biceps Femoris were located at 35% and 51% of the total length of muscle. Most of the motor entry points of Semitendinosus were located between 43% and 48% of muscle length ie, in the third-fifth of total muscle length. Semimembranosus had its motor entry points located between 52% and 70% of the total muscle length ie, in the third-fifth and fourth-fifth of muscle length.

Conclusion: The interventions done for relief of spasticity will have the best outcomes if planned at the above mentioned areas of the respective muscles.

KEY WORDS: Motor entry point, Hamstring, Chemical neurolysis, Selective motor fasciculotomy, Spasticity

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INTRODUCTION

Spasticity is defined as a motor disorder characterized by an increase in muscle tone. It is associated with exaggerated deep tendon reflexes, resulting from hyper-excitability of the stretch reflex [1]. Spasticity may accompany cerebral or spinal pathology [1] and is seen commonly in conditions like stroke, traumatic brain injury, spinal cord injury, cerebral palsy, multiple sclerosis and other disorders of central nervous system [2]. Spasticity profound interferes with activities of daily living, nursing

care, personal hygiene and causes severe disfigurement, contractures, bone fractures and dislocations.

Treatment modalities for spasticity include: a) Supportive treatment such as splints, b) Physical modalities like application of cold or heat therapy, c) Pharmacological modalities such as chemical neurolysis and d) Surgical treatment such as neurotomy. The latter two are the more commonly used modalities of treatment with direct intramuscular injections being the best choice for treating focal spasticity with minimal systemic side-effects [3].

When spasticity is focal and segmental such as affecting a single muscle group or limb, it can be effectively treated by chemical neurolysis or denervation. Motor-point block is a type of chemical denervation aimed at blocking the motor branches of the nerve as it enters the neuro-vascular hilus of the muscle [3].

The agents commonly used in chemo-denervation are phenol, ethanol and botulinum toxin. Phenol and ethanol denature surface proteins and cause a conduction block. Complications of using phenol and alcohol include pain, dysesthesia and cardiac arrhythmias [1].

Neurotoxins like OnabotulinumtoxinA, RimabotulinumtoxinB, and AbobotulinumtoxinA inhibit the release of acetylcholine at the presynaptic level of the neuromuscular junction and serve as extremely potent neuromuscular blocking agents when injected at the motor entry point [3].

There is significant reduction in muscle tone, relief from spasticity and improved range of motion [1,3]. The advantage of botulinum toxin is that it acts selectively on motor nerves without affecting sensory nerves [4]. Maximum therapeutic dose of Botox in adults is 400 units [3].

The effect of Botox is dose- dependent, i.e. greater the dose higher the degree of relief from spasticity. When injected in high doses, botulinum toxin has more chance of diffusing to surrounding tissue causing weakness of adjacent muscles. Injection of low doses of Botox aimed precisely at or very close to the motor entry point, would be ideal for optimum effect in decreasing spasticity with minimal systemic side-effects [5].

Neurotomy includes division of both motor and sensory fibres (sensory afferent Ia and Ib) at the neurovascular hilus leading to relief from spasticity. It is performed in cases of localized spasticity without musculotendinous shortening that is resistant to chemical denervation. In adults, neurotomy provides functional improvement in 81% to 97% of cases [6].

Selective motor fasciculotomy (SMF), is a novel procedure in which the nerve supplying the spastic muscles is exposed close to the motor point and the component fascicles stimulated. The fascicles found carrying excessive motor impulses, are ablated, (but not more than three-fourth) thereby obtaining permanent relief in harmful spasticity without losing sensory feedback, control and balance [7].

Most common muscle groups involved in spasticity following cerebrovascular accidents, cerebral palsy and spinal injuries are the adductor and hamstring groups of lower limb. The aim of this study was to determine the motor entry points of hamstring muscles of thigh and to suggest ideal sites for interventional procedures such as motor point injection of chemical neurolytic agents, and selective motor fasciculotomy for relief of muscle spasticity.

MATERIALS AND METHODS

The study was done after approval from the Institutional Review Board of our institution. The ideal sample size was calculated based on data reported by Woodley and Mercer (2005) and was estimated to be 10 lower limbs (Population mean-Absolute precision method). A total of 10 lower limbs from 5 formalin embalmed adult cadavers (4 male and 1 female) aged between 33 to 92 years of age available in the Department of Anatomy were chosen for the study. Lower limbs having gross malformation or flexion deformities were excluded from the study. All measurements were carefully standardised by co-investigators which included a Physiatrist. Motor entry points of long head of Biceps femoris, Semitendinosus and Semimembranosus muscles were studied. A pilot study was done to assess feasibility. Variables were measured using a Sliding Digital Vernier Calliper (ROBUST, Germany) with a resolution of 0.01mm, a measuring tape and a metre scale.

Dissection: With the cadaver in prone position, and the hip, knee and ankle joint in normal anatomical position, a midline longitudinal incision- A was made extending from the ischial tuberosity to the middle of calf along the long axis of lower limb. A horizontal incision was made at the proximal and distal end of incision-A. After reflecting the skin, subcutaneous tissue and deep fascia, the hamstring muscles (long head of Biceps femoris, Semitendinosus and Semimembranosus) were carefully exposed. Soft tissue over ischial tuberosity, medial aspect of proximal tibia and head of fibula were removed to expose clearly the origins and insertions of the above muscles.

Motor entry point: All muscles were supplied by nerves from its deeper aspect. Under suitable lighting, the nerve branches to each muscle were carefully identified and dissected up to the motor entry point (Figure 2). Intramuscular course of nerve branches were not studied. The point/points of entry of each nerve branch/branches to the muscle i.e. the motor entry point (MEP) were identified (Figure 1). The point where the first branch of the nerve pierced the muscle was described as proximal entry point (PEP) (Figure 1). The point where the last branch of the nerve pierced the muscle is called distal entry point (DEP) (Figure 1). The position of proximal and distal entry points were marked using colored pins to make accurate measurements (Figure 3). The distance of both the PEP and DEP from the origin of the muscle was measured using a measuring tape.

Measurement of variables

The variables measured (Figure 2) were:

a) The length of the muscle (L) - The length of each muscle from its origin to insertion along its long axis was measured using a measuring tape (figure 2).

b) Number of motor entry points (MEP) for each muscle

c)The distance of the proximal entry point (PEP) from the origin of the muscle – $D_{(o\text{-}pep)}$(Figure 2)
d)The distance of the distal entry point (DEP) from the origin of the muscle – $D_{(o\text{-}dep)}$(Figure 2)
e) The position of PEP and DEP as a fraction of the length of muscle along its long axis was calculated and expressed as a percentage. It was calculated using the following formula:

$PEP_{\%}$ = (PEP/L) x 100

$DEP_{\%}$ = (DEP/L) x 100

f) The ideal site of motor entry point injection ($D_{PEP\text{-}DEP}$)–was defined as the region between PEP and DEP having the maximum concentration of motor entry points. Hence, a nerve block attempted in this region would cause maximum relief from spasticity.

g) As described in (f), the ideal site of motor point injection was also expressed as a percentage of the muscle length ($D\%_{PEP\text{-}DEP}$).

RESULTS

The results of the variables measured are shown in Table 1.

Number of MEPs: In the overall hamstring group, the mean number of MEP's was 2.9 (median number of MEP's was 2-3). Biceps femoris and semimembranosus had a median number of three motor entry points, whereas Semitendinosus had two.

Proximal and distal motor entry points: In biceps femoris, the proximal motor entry point was located at a mean distance of 15.69 cms from the origin of muscle (or at 35% of the muscle length from its origin). Semitendinosus had its proximal motor entry point at 17.10 cm or at 43.6% of its muscle length from its origin. In Semimembranosus, the proximal motor entry point was at 20.2 cm or at 52.5% of its muscle length from its origin.

The distal motor entry points of Biceps femoris, Semitendinosus and Semimembranosus was at a mean distance of 21.25 cm (51.3%), 16.4 cm (48.1%) and 25.7 cm (70.1%) respectively from the origin of the muscle.

The hamstring group of muscles showed maximum number of motor entry points in the third-fifth of the muscle length from its origin. The long head of Biceps femoris had motor entry points in the second-fifth and third-fifth of the muscle length. Semimembranosus showed additional motor entry points in the fourth-fifth of the muscle length.

Comparison of ideal localizing points for motor point procedures: We studied the motor entry points of each muscle, the position

of PEP and DEP, and recommended ideal sites for pharmacological and surgical motor point procedures. The results are tabulated in Table 2.

Ideal site for motor point procedures: All the motor entry points of the hamstring group of muscles where present in the middle-third of the muscle. Maximum number of motor entry points were situated in the third-fifth of all muscles in hamstring group; long head of Biceps femoris had additional motor entry points in the second-fifth also; semimembranosus showed additional motor entry points in the fourth-fifth of the muscle. In view of these observations we propose that all the interventional procedures for the treatment of spasticity like motor point injections and selective motor fasciculotomy should be performed at the above mentioned zones for maximum efficacy.

Fig. 1: Schematic diagram showing the motor entry points to a muscle. Proximal motor entry point (A) is the entry point of the most proximal branch of the motor nerve into the muscle. Distal motor entry point (C) is the entry point of the most distal branch to the muscle

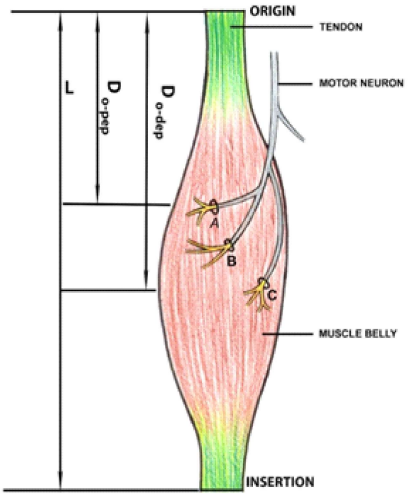

Fig. 2: Showing two motor entry points (indicated by black arrows) to Semitendinosus. (ST=semitendinosus, SM=semimembranosus, BF=Biceps femoris)

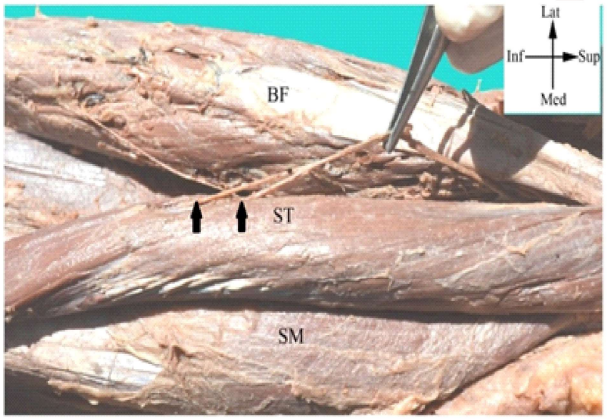

Fig. 3: Showing the dorsal aspect of thigh. Colored pins are inserted to mark the proximal and distal motor entry points of Semitendinosus. Red pin marks the proximal motor entry point. Green pin marks the distal motor entry point.

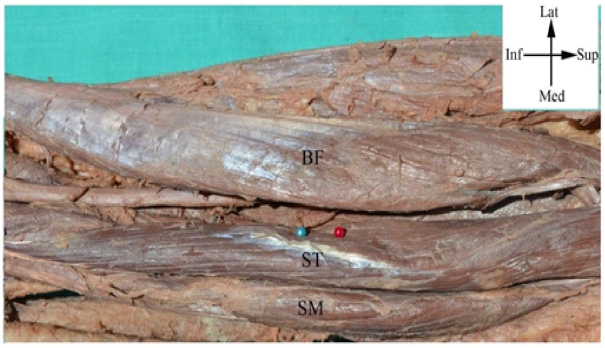

Fig. 4: Showing the ideal site for motor point procedures in the hamstring muscles. a – Biceps femoris. b – Semitendinosus. c – Semimembranosus.

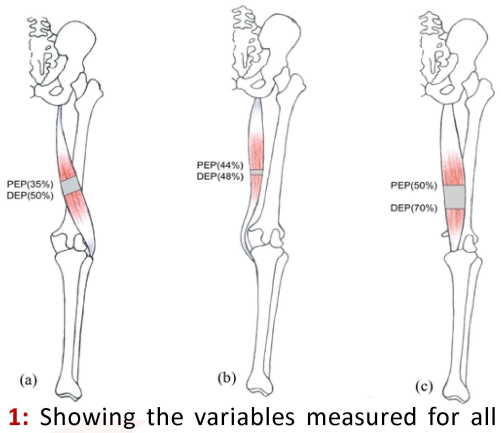

Table 1: Showing the variables measured for all the muscles. IQR – interquartile range. MEP – motor entry point. PEP – proximal entry point. DEP – distal entry point. L – length of the muscle

	Biceps femoris	Semi-tendinosus	Semi-membranosus
Length(cm)			
Median	40.00	41.25	36.00
IQR	38.5-42.2	39-42.6	34.9-39.5
Mean	40.36	41.15	36.82
SD	1.73	2.29	2.56
No: of MEP			
Median	3.00	2.00	3.00
IQR	2-4	1.8-2.3	2-4.3
Mean	3.00	2.50	3.3
SD	0.82	2.01	1.64
PEP from origin(cm)			
Median	15.00	17.55	19.85
IQR	10.8-19.4	16.8-19.3	17.4-23.9
Mean	15.69	17.09	20.19
SD	5.25	4.40	3.69
DEP from origin(cm)			
Median	20.65	19.25	25.25
IQR	19.2-24.2	18.6-22.6	23.5-27.5
Mean	21.25	16.39	25.65
SD	3.15	8.86	2.19
PEP/Lx100(%)			
Median	35.08	43.63	52.49
IQR	27.9-48.3	38.7-48.2	45.2-65.8
Mean	38.94	41.54	54.83
SD	13.31	10.97	9.35
DEP/Lx100(%)			
Median	51.34	44.73	70.12
IQR	47.6-58.2	44.5-58.3	65.9-74.4
Mean	52.78	40.15	69.83
SD	8.34	22.14	6.03
DEP-PEP(cm)			
Median	6.45	1.65	3.85
IQR	1.9-8.8	1.3-4.8	2.6-9.5
Mean	5.56	0.07	5.46
SD	3.61	9.46	3.51
(DEP-PEP)/Lx100(%)			
Median	15.25	4.06	10.38
IQR	4.7-21	3.2-12.5	7.2-25.9
Mean	13.83	1.39	15.00
SD	9.19	23.22	9.95

Table 2: Showing the PEP%, DEP% and ideal site for motor point procedures.

Name of muscle	PEP% =(PEP/L)X100	DEP% =(PEP/L)X100	Ideal site for motor point procedures
Long head of Biceps femoris	35%	51%	In the second-fifth and third-fifth of the muscle length (or middle 1/3rd).
Semitendinosus	44%	45%	In the third-fifth of the muscle length (or middle 1/3rd).
Semimembranosus	53%	70%	In the third-fifth and fourth-fifth of the muscle length (or middle 1/3rd).

Table 3: Table comparing the optimum site for botulinum toxin injection.

Muscle	Present study, 2016	Berwick et al. (2003) [19]	Fheodoroff et al.(2005) [20]	Campenhout et al. 2011)[10]
Long head of Biceps femoris	35%-50% of muscle length	One point at 25% and another point at 50% of length of thigh.	Point distal to proximal third of line joining ischial tuberosity and medial end of popliteal fossa	-
Semitendinosus	44%-45% of muscle length	21-50% of femur length.	Middle or distal third of line joining ischial tuberosity to pes anserinus.	Half to two-third up the thigh.
Semimembranosus	53-70% of muscle length	64-77% of femur length.	Medial or lateral to semitendinosus at limit of middle and distal third of the thigh.	Half way or two-thirds up the thigh.

DISCUSSION

Precise localization of the motor entry points is essential for treatment of muscle spasticity especially during invasive or interventional procedures such as botulinum toxin injection and selective motor fasciculotomy [1,8]. Botulinum toxin acts pre-synaptically by blocking the release of acetylcholine [3]. This results in chemical denervation of the muscle and prevents muscle contraction [1]. Borodic et al., in their study on albino rabbits have observed that at lower doses (1 IU of Botulinum A), diffusion occurred over a small segment of muscle (15-30 mm). At higher doses (5-10 IU), diffusion of botulinum A toxin occurred throughout the entire muscle with no apparent end point [9]. In muscles of the human lower limb which have considerable length, a small dose given precisely at the motor entry point or regions of maximum concentration of motor entry points, would be highly beneficial. Injections of larger doses at multiple sites along the length of the muscle can lead to complications such as spread of the toxin to adjacent tissues and blood vessels [10,11].

Selective motor fasciculotomy is undertaken when the subject is resistant to chemical neurolysis [12]. It is mostly performed for the treatment of lower limb spasticity, with limited use for upper limb spasticity [13]. Previously, neuromuscular junctions were thought to be located in the middle third of the muscle, its position being inconsistent in most of the cases (14). The results of this study have elucidated the position of motor entry points of hamstring muscles of thigh in a very detailed manner.

Long head of Biceps Femoris

Number of motor entry points:

In our study, 40 % of long head of Biceps femoris muscles had three motor entry points (MEP's), 30% had two MEP's and another 30% had four motor entry points. In a study by Seidel et al.[15], in 30 cadaveric lower limbs in the Caucasian race80 % of long head of Biceps femoris had two MEP's and 20 % had three MEP's. A study done by Botter et al. [16],

by electric stimulation with a surface electrode, revealed the presence of only two motor entry points for long head of Biceps femoris.

Position of Proximal and Distal motor entry points: In our study, the distance of PEP from origin of the muscle was 15.6 cm (at 35 % of the muscle length), and DEP was at 21.25 cm (at 51 % of the muscle length). In the study done by Seidel et al.[15], PEP was at 9.2 cm from the origin and DEP was at 19.7 cm from its origin.

Semitendinosus

Number of motor entry points: In our study, 60% of Semitendinosus muscles had two MEP's, 20% had one and another 20% had three MEP's. In the study done by Seidel et al., (15) in 30 cadaveric lower limbs in the causcasian population similarly showed 93% of Semitendinosus had two motor entry points while 7% had one motor entry point. The study by Botter et al., [16] by electric stimulation with a surface electrode, revealed the presence of only one motor entry point.

Position of Proximal and distal entry points: In our study, the proximal entry point was at 17.6 cm from the origin of the muscle (at 44% of the muscle length); DEP was at 19.25 cm from the origin of the muscle (at 48% of the muscle length). The position of PEP & DEP as reported by other authors show much variability. None of them describe the position of the MEP as fraction of the muscle length. Seidel et al. says that, PEP was at 9.2 cm from the origin and DEP at 20.2 cm from the origin (15). Woodley et al., describes PEP of Semitendinosus to lie at a range of 4.2 - 12.2cm from the ischial tuberosity and DEP at a distance of 7.5 - 19cm from the origin [17].

Semimembranosus

Number of motor entry points: In our study, 40% of Semimembranosus muscle had two motor entry points, 30% had three motor points and rest had 4-5 motor entry points. Similar study done by An et al. in South Korea, showed an average of 3.4 motor entry points [18]. In sharp contrast Botter et al., reports only one motor entry point for Semimembranosus muscle [16]. Seidel et al. reports a maximum of five MEP'S in 47% of the cadavers, 20% having six motor entry points and only 33% with three motor entry points [15].

Position of Proximal and distal motor entry points: In our study, the PEP of Semimembranosus muscle was located at 19.9 cm from the origin of the muscle (52.5 % of muscle length); the DEP was located at 25.3 cm from the origin of Semimembranosus (70.1 % of muscle length).

Woodley and Mercer [10] report that, PEP is located 14.6 - 21.2 cm from the origin and DEP at 34.5cm from the origin; whereas Seidel el.al. report the location of PEP at 17.6 cm from the origin and DEP at 31.2 cm from origin [15].

Comparison of ideal injection sites suggested by different studies: Various studies have suggested different sites for botulinum toxin injection. This is largely due to the different reference lines and methods of measurement used. This is shown in Table 3.

CONCLUSION

All muscles of hamstring group are supplied by motor nerves from its deeper aspect. All muscles of the hamstring group had almost equal number of motor entry points (median = 2-3). The number of motor entry points has a weak positive correlation with the length of the muscle i.e. as the length of the muscle increases, the number of motor entry points increase. The position of PEP in every muscle of the hamstring group was consistently at the second-fifth of the length of muscle from origin. The position of DEP in most muscles of the hamstring group was at the third-fifth of the length of muscle from origin. As per the results of our study, the optimum site for motor point injection of chemical neurolytic agents and selective motor fasciculotomy in the hamstring group should be in the second and third-fifth of the muscle length from its origin (or its middle 1/3rd as a general rule). All the motor entry points to the long head of Biceps femoris are located between 35% and 50% of the muscle length from its origin; hence, ideal site for motor point procedures would be at the second-fifth and third-fifth of the muscle. Since all MEP's of Semitendinosus are located between 44% and 48% of the muscle length, ideal site for motor point procedures would be at the third-fifth of the muscle. As all the motor entry points of the Semimembranosus are located between 53% and 70% of the muscle length, the ideal site for motor point procedures would be at the third-fifth and fourth-fifth of the muscle. The description of motor points in this

study is the first study in the Indian population. This could be beneficial for planning motor point injection of chemical neurolytic agents and selective motor fasciculotomy for relief of muscle spasticity in neuromuscular disorders in this population.

ABBREVIATIONS

MEP – Motor Entry Point
PEP – Proximal Entry Point
DEP – Distal Entry Point
BF – Biceps femoris
ST – Semitendinosus
SM – Semimembranosus
IQR – Inter-quartile range
L – Length of the muscle

Conflicts of Interests: None

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