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Original article

Selective neurotomy of the sciatic nerve branches to the hamstring muscles: An anatomical study

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ABSTRACT

Background: Hamstring spasticity can bring about a flexion deformity of the knee, liable to cause disability. Surgical treatment by selective neurotomies of the sciatic nerve branches leading to the hamstring muscles may then be indicated. Few studies have investigated the precise origin of these branches on the sciatic nerve, describing the innervation pattern of the hamstring muscles. Further anatomical data are needed to enhance surgical techniques in neurotomies of the sciatic nerve branches, to define the best incision and surgical approach and what section and length of the SN need to be exposed. Therefore, we performed an anatomical study to: (1) define a surgical approach to perform selective neurotomies of the sciatic nerve branches for hamstring spasticity?(2) whether the anatomical variants of the hamstring innervation have been identified?

Hypothesis: Our anatomical data could lead to the definition of an approach to the sciatic nerve for the purpose of selective neurotomy.

Material and methods: Twenty posterior compartments of the thigh were dissected. We counted each branch of the sciatic nerve leading to the hamstring and described their arising point using the centre of the lateral surface of the great trochanter and the lower edge of the gluteus maximus muscle as main anatomical landmarks. We also described the presence of branch divisions and their muscular penetrating points.

Results: The mean distances between the center of the lateral surface of the great trochanter and the emergence of branches from the SN were: 2.2 ± 3.6 cm (−5 to 9 cm) for the long head of the biceps femoris muscle, 2.3 ± 3 cm (−4 to 10 cm) for the semitendinosus muscle, and 2.2 ± 3 cm (−5 to 8 cm) for the semimembranosus muscle. No branches originated from the sciatic nerve below the lower edge of the gluteus maximus muscle. In summary the branches innervating the hamstrings originated from the SN within an interval of 15 cm (5 cm above and 10 cm below the centre of the lateral surface of great trochanter). The average number of sciatic nerve branches for the hamstring muscles was 4.7 (minimum: 3; maximum: 6) with 1.8 branches for the long head of the biceps [1 in 7/20 (35%), 2 in 10/20 (50%), and 3 in 3/20 (15%)], 1.5 branches for the semitendinosus [1 in 11/20 (55%) and 2 in 9/20 (45%)], 1.4 branches for the semimembranosus [1 in 12/20 (60%) and 2 in 8/20 (40%)]. No branches had a common origin with cutaneous nerves.

Discussion: This anatomical study enabled us to propose an approach to exposing the sciatic nerve in order to perform a selective neurotomy: horizontal cutaneous incision on the gluteal fold, incision of the lower edge of the gluteus maximus, exposure of the sciatic nerve to a distance of 10 cm below the great trochanter, and visualization of the nerve branches to the hamstring muscles. Exposure of the nerve above the great trochanter is not necessary because the branches which emerge from the SN above the great trochanter are still contiguous with the SN.

Level of evidence: IV: prospective study without control.

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1. Introduction

A lesion of the central nervous system with impairment of the corticospinal tract may induce varying motor deficits such as spastic hypertonia of the hamstring muscles [1,2]. There are three hamstring muscles: the biceps femoris (long and short head), semitendinosus and semimembranosus. They are muscles of the posterior compartment of the thigh, crossing the hip and knee. Their functions are extension of the hip and flexion of the knee when the foot is not in contact with the ground. The sciatic nerve (SN) enters the thigh through the infrapiriformis canal, descends in the posterior compartment of the thigh and innervates the hamstring muscles before its division into tibial and common fibular nerves. Increased muscular tone of the hamstring muscles in patients can affect passive movement of the knee with problems of popliteal crease hygiene, painful phenomena and deformities of joints [3–6]. The assessment of spasticity is of prime importance in order to identify, locate, quantify and judge its functionally harmful character. In the case of diffuse spasticity, systemic treatments (oral medications, intrathecal baclofen) are indicated. In the case of focal spasticity, focal treatments are indicated (injection of botulinum toxin, alcohol neurolysis) [7–14]. Selective neurotomy is a treatment indicated in the case of focal spasticity in cases of failure of less invasive local treatments. Preoperative evaluation is essential: a preoperative motor block makes it possible to predict the effectiveness of the neurotomy and to allow the patient to evaluate the functional gain that the neurotomy could bring, its effects being definitive [13,14]. In this context, focal surgical treatment for relief of harmful spasticity focusing on hamstrings may be proposed for selected patients no longer relieved by rehabilitation and medical treatment [7,8].

Few anatomical studies have described hamstring innervation. In 1946, Sunderland and Hughes measured the shortest and longest distances of origin of motor branches leading to the hamstring according to the ischial tuberosity in 10 cadavers [9]. In 1996, Seidel et al. [15] published the results of an anatomical study of the origin of the motor branches to the hamstring muscles, with the objective of guiding percutaneous neurolytic procedures. They defined two zones located along a line from the ischial tuberosity to the lateral femoral condyle. Zone 1 containing the first motor branches to the long head of the biceps femoris and semitendinosus muscles at 20% of the length of the line. Zone 2 at 33% of the length of the line, containing the motor branches of semimembranosus and secondary branches for the other two muscles. More recently, Woodley and Mercer, described the innervation pattern of the hamstring in six cadavers, but no precise data about the origin of motor branches on the SN was reported [10]. Further anatomical data are needed to enhance SN neurotomy surgical technique, especially to define the best incision and surgical approach and what part and length of the SN need to be exposed.

Therefore, we performed an anatomical study to describe: (1) the SN branches leading to the hamstring muscles using anatomical observations; (2) for each branch the key points of the morphological data of the nerve and anatomical variants. Our working hypothesis was that our anatomical data could lead to the definition of an approach to the sciatic nerve for the purpose of selective neurotomy. The questions that we aimed to answer were: (1) define a surgical approach to perform selective neurotomies of the sciatic nerve branches for hamstring spasticity? (2) whether the anatomical variants of the hamstring innervation have been identified?

2. Material and methods

2.1. Specimens

Twenty posterior compartments of the thigh and buttock, 7 formalin-preserved and 13 fresh adult specimens were dissected, 10 left sides and 10 right sides (7 women, 4 men). Dissections were carried out by three authors (MB, JML, EB). Specimens were positioned in prone position. Exclusion criteria of cadavers were: previous surgery of the lower limb, poor preservation of the anatomical structures. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

3. Methods

A median incision from the top of the buttock to the top of the popliteal fossa was made, enlarged by two perpendicular incisions at each extremity. The gluteus maximus muscle was then sectioned on its medial and superior insertions and retracted laterally. The SN was identified at its proximal emergence from the infrapiriformis canal and dissected thoroughly with its branches as far as its division into tibial and common fibular nerves, then the tibial and common fibular nerves were dissected as far as the femorotibial joint line (Fig. 1). The region of interest was divided into 3 parts of equal length in the craniocaudal direction: the superior, middle and inferior parts. The superior limit was the centre of the lateral surface of the great trochanter and the inferior limit was the femorotibial joint line. The location of the branches' penetrating points was determined according to this division (Fig. 1).

3.1. Methods of assessment

We measured the following parameters using a flexible ruler, as represented in Fig. 2:

- the distance from the great trochanter to the origin of each branch on the SN;
- the distance from the great trochanter to the lower edge of the gluteus maximus;
- the number of branches of the SN innervating the long head of the biceps femoris (lhBF), semitendinosus and semimembranosus muscles;
- the location of their penetrating point in each hamstring muscle;
- the distance between the centre of the lateral surface of the great trochanter and the sciatic division into tibial and common fibular nerves.

3.2. Statistical analysis

Descriptive statistics (median, mean, standard deviation, minimum, first quartile, third quartile, maximum) were calculated using Excel 2016 (Microsoft Corporation, Redmond, WA, USA).

4. Results

4.1. Definition of a surgical approach

Measured distances of the twenty specimens are displayed in Table 1 and in the box plot representing these measures in Fig. 3. Fig. 3 represents, for each hamstring muscle, the distance between

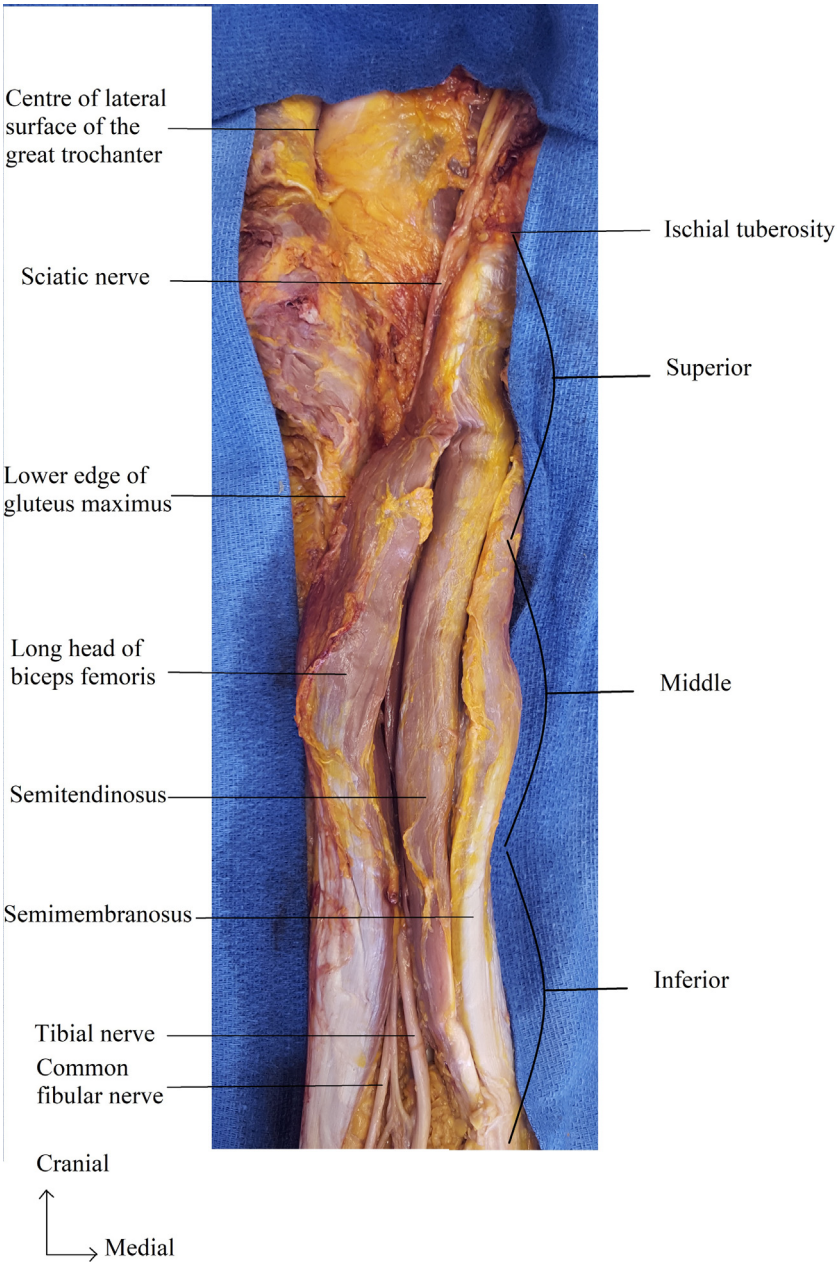

Fig. 1. Left posterior view of a dissected thigh and buttock. The gluteus maximus is sectioned on its medial and superior insertions and retracted laterally. The dissection is divided into three regions, superior, middle and inferior.

the center of the lateral surface of the great trochanter and the emergence of branches from the SN. The mean distance was 2.2 cm for the lhBF [standard deviation (SD): ± 3.6; minimum (min): −5; maximum (max): 9], 2.3 cm (SD: ± 3.0; min: −4; max: 10) for the semitendinosus and 2.2 cm (SD: ± 3.0; min: −5; max: 8) for the semimembranosus muscles. The branches innervating the hamstrings originated from the SN within an interval of 15 cm (5 cm above and 10 cm below the centre of the lateral surface of great trochanter) and above the projection of the lower edge of the gluteus maximus muscle.

According to our findings, we propose the following approach for a selective neurotomy of the SN for hamstring spasticity (Fig. 4):

- horizontal cutaneous incision on the gluteal fold, centered on the skin projection of the SN (between the ischial tuberosity and the great trochanter);
- incision of the lower edge of the gluteus maximus to a distance of about 10 cm in the middle of the buttock, the muscle could be split parallel to muscle fibers following the SN trajectory;
- exposure of the SN and its branches to a distance of 10 cm below the great trochanter (assessed by palpation).

Exposure of the nerve above the great trochanter is not necessary because the branches which emerge from the SN above the great trochanter are still contiguous with the SN: they branch off from it below the great trochanter.

4.2. Anatomical variants

Table 2 displays the number of branches for each hamstring muscle and the location of their penetrating point into the muscle. The branches of the SN for the hamstring muscles averaged 4.7 per SN (1.8 for the lhBF, 1.5 for the semitendinosus, 1.4 for the

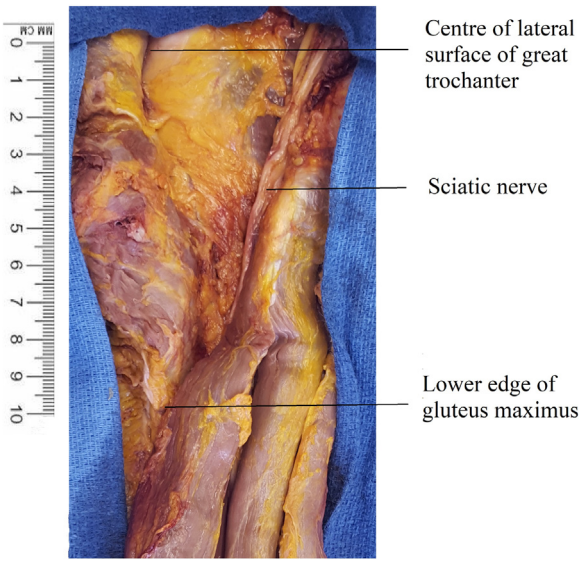

Fig. 2. Left posterior view of a dissected thigh and buttock. The main anatomical landmarks are highlighted. A 10 cm diagrammatic ruler is displayed.

semimembranosus). No branches had a common origin with cutaneous nerves. The lhBF was innervated by 1, 2 or 3 branches in 35% (7/20), 50% (10/20) and 15% (3/20) of cases, respectively. The semitendinosus was innervated by 1 or 2 branches in 55% (11/20) and 45% (9/20) of cases, respectively. The semimembranosus was innervated by 1 or 2 branches in 60% (12/20) and 40% (8/20), respectively. The majority of branches for the hamstring muscles penetrated the muscles in the superior and middle regions of the dorsal thigh and buttock. An example is shown in Fig. 5, which represents the most frequent pattern of innervation with 2 branches for the lhBF, 1 for the semitendinosus and 1 for the semimembranosus.

5. Discussion

The results of this study confirmed the working hypothesis allowing description of a surgical approach to perform a selective neurotomy of the sciatic nerve for hamstring spasticity. We described the location of the nerve branches leading to the hamstring muscles in twenty dissections. Our descriptive data focused on the location of the emergence of the branches from the SN considering the center of the lateral surface of the great trochanter as an anatomical landmark. As we have shown, the nerve roots leading to the hamstrings originated from the SN within an interval of 15 cm (5 cm above and 10 cm below the center of the lateral surface of great trochanter) and above the projection of the lower edge of the gluteus maximus muscle. However, locating the lower edge of the gluteus maximus can be difficult on a patient or necessitate ultrasound (obesity, atrophy). Therefore, we propose using the great trochanter as the main landmark to predict the emergence of hamstring nerves, as this bony landmark can be assessed by palpation. Knowledge of these anatomical data is essential for

Table 1
Statistical parameters of the measured distances for 20 dorsal buttocks and thighs.

Distance	Mean (cm) [± Standard deviation (cm)]	Range	
		Minimum	Maximum
Great trochanter to sciatic division	18.4 (± 4)	12	26
Great trochanter to the inferior edge of the gluteus maximus	9.8 (± 1.8)	7	13
Great trochanter to the emergence of the long head of Biceps femoris nerves	2.2 (± 3.6)	−5	9
Great trochanter to the emergence of semitendinosus nerves	2.3 (± 3.0)	−4	10
Great trochanter to the emergence of semimembranosus nerves	2.2 (± 3.0)	−5	8

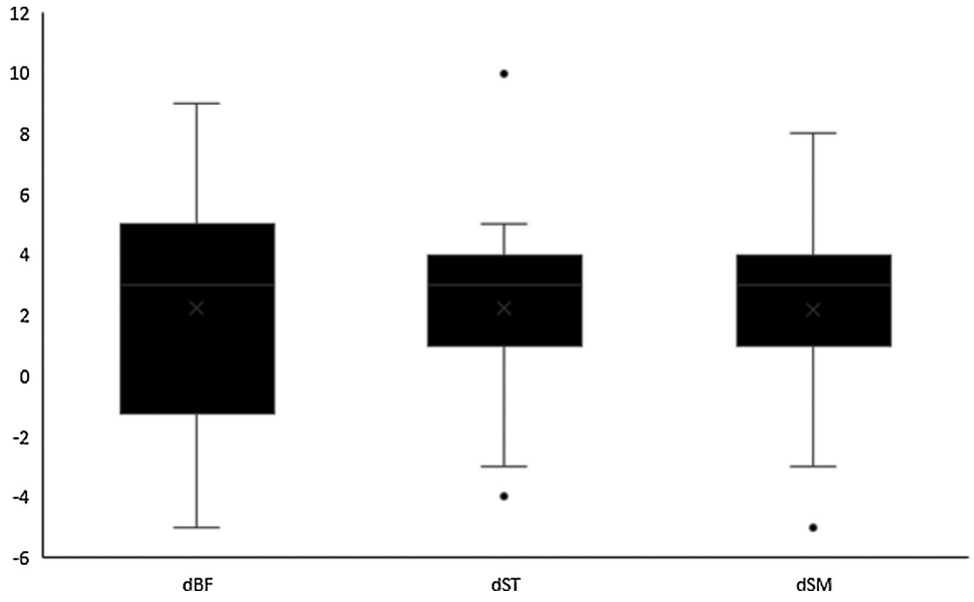

Fig. 3. Box plot representing the measured distances in centimetres. The zero distance corresponds to the centre of the lateral surface of the great trochanter, negative distance means that the nerve was located cranially to the great trochanter, whilst positive distance means that the nerve was located caudally to the great trochanter. The line in the box represent the median value and the cross the mean value. dBF, distance from the great trochanter to the emergence of the long head of the biceps femoris nerve; dST, distance from the great trochanter to the emergence of the ST semitendinosus nerve; dSM, distance from the great trochanter to the emergence of the semimembranosus nerve.

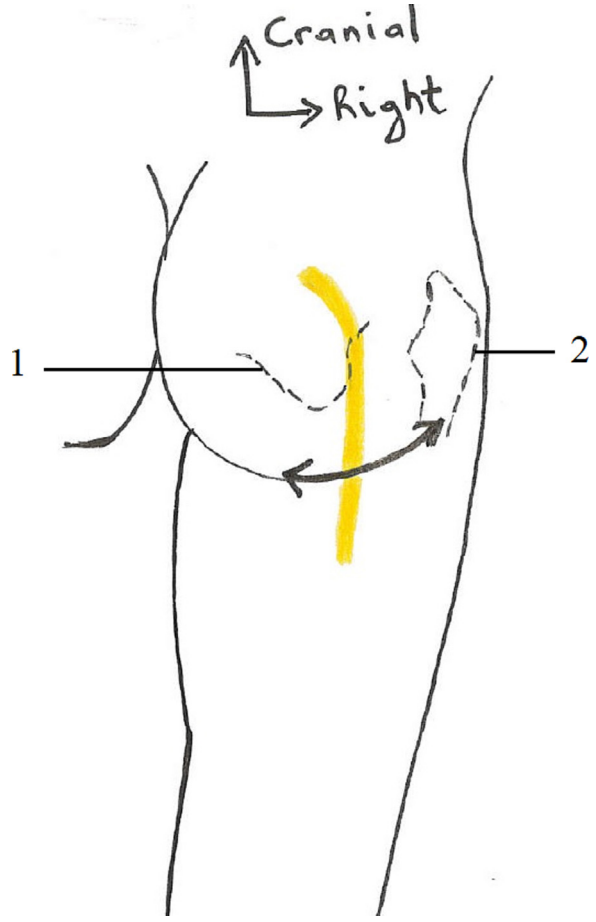

Fig. 4. Diagram showing the surgical incision to expose the branches of the sciatic nerve directed to the hamstring muscles. The arrow indicates the surgical incision. 1: ischial tuberosity; 2: greater trochanter; in yellow, the sciatic nerve.

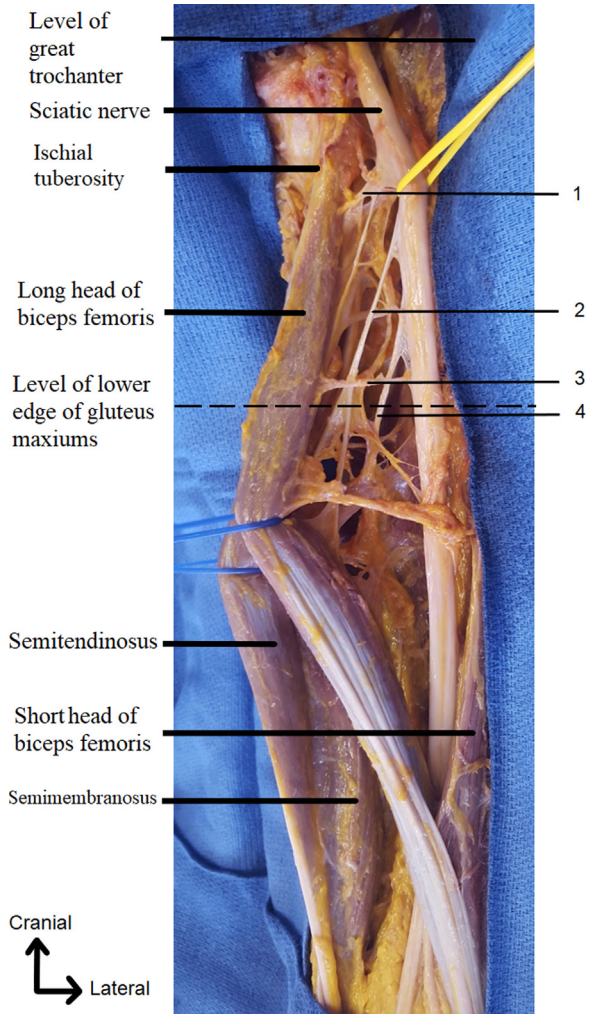

Fig. 5. Right posterior view of a dissected thigh and buttock. The gluteus maximus is sectioned on its medial and superior insertions and retracted laterally. The semitendinosus, semimembranosus and the long head of the biceps femoris muscles are medially retracted. The sciatic nerve is reclined laterally. The branches leading to the hamstring muscle are identified; 1,3: branches for the long head of the biceps femoris; 2: branch for the semitendinosus muscle; 4: branch for the semimembranosus muscle.

any surgeon wishing to perform a selective neurotomy of the SN to treat a disabling spasticity of the hamstring muscles. To the best of our knowledge, there is no anatomical article describing the innervation of the hamstring muscles by the SN which would make it possible to guide a selective neurotomy for a spastic knee. Seidel et al. [15] described the origin of motor branches along a line from the ischial tuberosity to the lateral femoral condyle. As in our results, they found that branches to the long head of the biceps femoris and semitendinosus were more proximal than those for the semimembranosus; however, their study had the objective of guiding percutaneous neurolytic procedures, and they did not provide anatomical landmarks to guide a surgical approach to performing a selective neurotomy of the SN. Succinct descriptions of the surgical procedure for hamstring spasticity exist in the literature. Abdennebi and Bougatene reported their experience of selective neurotomy of the SN for a spastic knee in 15 patients [7]. They performed an S-shaped incision on the buttock between the GT and the ischium, then split the gluteus maximus fibers and used bipolar stimulation to identify nerves leading to the hamstring muscles. No accurate data about the origin of the hamstring branches was provided. Sitthinamsuwan et al. [4] reported their experience concerning 9 patients, the operative procedure was performed in a similar way, and no precise anatomical data was given. Our approach to the SN proximally would not be impacted by the anatomical variation of the hamstring, because the motor branches are exposed just after they branch off the SN.

Peripheral selective neurotomies consist of a fine microsurgical dissection of a portion of the fibers, with mapping by intraoperative electrical nerve stimulation to achieve partial section of both

Table 2
Number and locations of motor roots originating from the sciatic nerve for each muscle.

Muscle	Mean number of branches of the sciatic nerve (± Standard deviation) (minimum–maximum)		Localization of penetrating point in the muscle (percentage of the total of branch subdivisions)		
			Superior part	Middle part	Inferior part
Long head of biceps femoris	1.8 (± 0.68)	(1–3)	43	51	6
Semitendinosus	1.5 (± 0.50)	(1–2)	56	44	0
Semimembranosus	1.4 (± 0.49)	(1–2)	37	55	8

afferent and efferent fibers of the stretch reflex at the level of the muscular nerve targeted [8,16]. The efficiency of partial nerve section is established at the end of the procedure by recording weaker muscular response to nerve stimulation above the section, and by assessing the spastic component below the section [16]. Neurotomy of the identified hamstring nerve to 75% permits the conservation of motor action, resection of the nerve 1 cm avoids nerve regrowth, as recommended in publications [8,16]. The aim of such functional surgery is to reduce harmful hypertonia without suppression of useful muscular tone or impairment of residual motor and sensory functions.

We also described the number of branches for each hamstring muscle and the point of penetration into each muscle. We found that the most frequent pattern of hamstring innervation was 2 branches for the lhBF, 1 for the semitendinosus and 1 for the semimembranosus. The majority of penetrating points were found in the superior and middle parts of the hamstring muscles. Fenzl et al. [17] found that the motor branches for the hamstring originated from the tibial component of the SN and were situated anteriorly on the SN. Similarly to us, Seidel et al. [15] showed that all the penetrating point of the motor branches were in the superior part of the femur length, they also found that the long head of the biceps femoris had 2 motor branches in 66% of cases, the semitendinosus had 2 motor branches in 77% of cases and 1 motor branch for the semimembranosus in all specimens.

The main limitation of our study was the limited sample size, and larger studies should be undertaken to verify our findings. However, we observed that the origin of nerves leading to the hamstrings branched off from a constant part of the sciatic nerve, permitting us to define a surgical approach. Another limitation is that we did not correlate our findings with imaging techniques such as MRI or echography which could have increased the level of evidence of our study, However, we consider it possible to describe anatomical structures based on dissection data only. We did not study the branches of the short head of the femoral biceps because the motor branches of this muscle are not interrupted during neurotomy, since this head not being involved in case of spasticity of the hamstrings.

6. Conclusion

In this anatomical study in which we performed twenty posterior thigh dissections, we described the origin and termination of the innervation of the hamstrings by the SN. We propose an approach to expose the SN for the purpose of a selective neurotomy: horizontal cutaneous incision on the gluteal fold, incision of the lower edge of the gluteus maximus, exposure of the SN to a distance of 10 cm below the great trochanter, and visualization of the nerve branches to the hamstring muscles (Fig. 4).

Disclosure of interest

The authors declare that they have no competing interest. Outside the submitted work, J.-M. Lemée declares supports from Depuy, Boehringer Ingelheim, LDR Medical, Vexim and Medtronic; X. Morandi declares support from UCB Pharma, Integra LifeSciences Service, Ethicon, Medtronic and Depuy; J.-E. Berton declares support from Medartis; M. Bretonnier declares supports from Medtronic, Integra LifeSciences Services, Depuy and Johnson and Johnson, and C. Haegelen declares supports from Boston Scientific, Medtronic, Depuy, LivaNova and UCB Pharma.

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Contribution of each author

M. Bretonnier: data collection, data analysis, manuscript writing; J.M. Lemee: data collection, manuscript writing; J.E. Berton: data collection, X. Morandi: protocol development, data analysis, manuscript writing; C. Haegelen: protocol development, data analysis, manuscript writing.

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