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SHORT COMMUNICATION

MANAGEMENT OF SPASTIC EQUINOVARUS FOOT IN CHILDREN WITH CEREBRAL PALSY: AN EVALUATION OF ANATOMICAL LANDMARKS FOR SELECTIVE NERVE BLOCKS OF THE TIBIAL NERVE MOTOR BRANCHES

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Objective: **To define the anatomical landmarks of tibial motor nerve branches for selective motor nerve blocks of the gastrocnemii, soleus and tibialis posterior muscles in the management of spastic equinovarus foot.**

Design: **Observational study.**

Patients: **Twenty-four children with cerebral palsy with spastic equinovarus foot.**

Methods: **Considering the affected leg length, motor nerve branches to the gastrocnemii, soleus and tibialis posterior muscles were tracked using ultrasonography, and located in the space (vertical, horizontal, deep) according to the position of fibular head (proximal/distal) and a virtual line from the middle of popliteal fossa to the Achilles tendon insertion (medial/lateral).**

Results: **Location of motor branches was defined as percentage of the affected leg length. Mean coordinates were: for the gastrocnemius medialis 2.5 ± 1.2% vertical (proximal), 1.0 ± 0.7% horizontal (medial), 1.5 ± 0.4% deep; for the gastrocnemius lateralis 2.3 ± 1.4% vertical (proximal), 1.1 ± 0.9% horizontal (lateral), 1.6 ± 0.4% deep; for the soleus 2.1 ± 0.9% vertical (distal), 0.9 ± 0.7% horizontal (lateral), 2.2 ± 0.6% deep; for the tibialis posterior 2.6 ± 1.2% vertical (distal), 1.3 ± 1.1% horizontal (lateral), 3.0 ± 0.7% deep.**

Conclusion: **These findings may help the identification of tibial motor nerve branches to perform selective nerve blocks in patients with cerebral palsy with spastic equinovarus foot.**

Key words: equinus deformity; muscle spasticity; nerve block; ultrasonography.

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LAY ABSTRACT

This observational study was performed on a sample of 24 children with cerebral palsy in order to identify the motor nerve branches to the main calf muscles for assisting the management of spastic foot. All patients were evaluated with ultrasonography. The nerve branches to the gastrocnemii, soleus and tibialis posterior muscles were located in space (vertical, horizontal, deep), based on the position of the fibular head (proximal/distal) and a posterior line in the middle of the leg (medial/lateral). Location of motor branches was defined as percentage of the affected leg length. The mean coordinates for the gastrocnemius medialis motor branch were 2.5% proximal, 1.0% medial, 1.5% deep; for the gastrocnemius lateralis: 2.3% proximal, 1.1% lateral, 1.6% deep; for the soleus: 2.1% distal, 0.9% lateral, 2.2% deep; for the tibialis posterior: 2.6% distal, 1.3% lateral, 3.0% deep. These findings may help the management of spastic foot in children with cerebral palsy.

Cerebral palsy (CP) is the most common cause of disability in childhood, presenting with an estimated prevalence of 1.5–4/1,000 live births (1). It refers to a group of permanent activity-limiting disorders in the development of movement and posture attributed to non-progressive disturbances that occur in the developing foetal or infant brain (2). Up to 80% of children with CP have spastic muscle overactivity, defined as a velocity-dependent increase in muscle resistance arising from the chronic loss of supraspinal inhibitory inputs onto a motor neurones accompanied by exaggerated spinal H-reflexes (3). Children with spastic CP usually need clinical interventions for muscle overactivity, including drugs, rehabilitation, surgery and other combined procedures also in order to reduce pain and muscle spasms, facilitate brace use, improve posture, minimize muscle contractures and deformity, facilitate mobility and dexterity, improve patient ease of care and hygiene/self-care (4).

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Nerve blocks involve the injection of medications near to peripheral nerves in order to obtain a reduction/abolition of conduction. Diagnostic nerve block (DNB) consists of injecting local anaesthetic (e.g. lidocaine, bupivacaine) near to the motor nerve branches for spastic muscles in order to temporarily suppress their overactivity allowing determination of their role in spastic overactivity patterns and differentiation from contracture (5). Therapeutic nerve block (TNB) consists of perineural injection of phenol or alcohol to obtain chemical neurolysis and, consequently, a long-term reduction in muscle overactivity (5). The nerve block technique is commonly based on the use of needles for conduction anaesthesia (delivering electrical stimulation) positioned according to surface anatomical landmarks (5, 6). Electromyography (EMG) may be used to help target the appropriate nerve branch by monitoring the H-reflex (7). Likewise ultrasonography (US) may be coupled with needle electrical stimulation and EMG for performing nerve blocks in order to maximize their precision and safety also increasing patient compliance by making the procedure faster and easier.

Spastic equinus/equinovarus foot is one of the most common patterns in children with CP, especially those with hemiparesis (8). It may be due to the spastic overactivity of calf muscles (e.g. gastrocnemii, soleus and tibialis posterior), calf muscles contracture/shortening, drop-foot during the swing phase of gait due to muscle weakness (e.g. tibialis anterior, extensor digitorum/hallucis), imbalance between the tibialis anterior and peroneus muscles leading to hindfoot varus in the swing phase of gait (7). Tibial nerve motor branches DNB is recommended to determine the causes of spastic equinovarus foot and define its most appropriate therapeutic management, which may include also TNB (7). Anatomical landmarks of the tibial nerve motor branches for managing spastic equinovarus foot have been identified using US in adults with stroke (6). To the best of our knowledge, no previous study has dealt with a similar issue in children. Thus, the main aim of this study was to identify by means of US the anatomical landmarks of tibial motor nerve branches to the gastrocnemii, soleus and tibialis posterior muscles for selective motor nerve blocks for the management of spastic equinovarus foot in children with CP. In our view, determining these anatomical landmarks might be useful in particular for those clinicians who perform nerve blocks by means of EMG guidance in order to facilitate the procedure of nerve targeting in a paediatric setting as well as for those physicians who are beginners as to the US-guided nerve block technique in paediatric patients in order to ease nerve recognition.

METHODS

This was a single-centre observational study. Inclusion criteria were: age 6–16 years; spastic equinovarus foot due to CP; calf muscles overactivity grade of at least 1 on the Modified Ashworth Scale (MAS) (9); no previous treatment with botulinum toxin for spastic equinovarus foot. Exclusion criteria were: participation in other trials; bony deformities of the affected lower limb; previous treatments of spastic equinovarus foot with neurolytic or surgical procedures; other neurological or orthopaedic conditions involving the affected lower limb. All participants were outpatients scheduled to receive selective DNB of tibial motor nerve branches according to our daily clinical practice. Informed consent was obtained from all children's parents. The study was carried out according to the Declaration of Helsinki and approved (study i.d. 4139CESC) by the local Ethics Committee (Comitato Etico per la Sperimentazione Clinica delle Province di Verona e Rovigo).

Clinical evaluation

Children remained in the supine position with their knees extended during the evaluation. The affected leg length was measured by means of a meter tape considering the medial spino-malleolar distance (i.e. distance from the antero-superior iliac spine up to the apex of the medial malleolus). The affected ankle passive dorsiflexion range of motion (PROM) was measured using a handheld goniometer. The sensitivity of the measurement was set at 5°. The dorsiflexion angle was defined as positive and the plantar flexion angle as negative, taking 0° as the neutral position of the joint (10). The MAS was used to evaluate spastic calf muscles overactivity. It is a 6-point scale grading the resistance of a relaxed limb to rapid passive stretch (0 = no increase in muscle tone; 1 = slight increase in muscle tone at the end of the range of motion (ROM); 1+ = slight increase in muscle tone through less than half of the ROM; 2 = more marked increase in muscle tone through most of the ROM; 3 = considerable increase in muscle tone; 4 = joint is rigid) (9). For statistical purposes, a score of 1 was considered as 1, and a score of 1+ was considered as 2, and so on, up to a score of 4, which was considered as 5 (9, 10). Also, the Tardieu scale (TS) was used to evaluate spastic calf muscles overactivity according to the TS grade, which measured the gain of the muscle reaction to fast stretch in dorsiflexion (0: no resistance throughout passive movement; 1: slight resistance throughout passive movement; 2: clear catch at a precise angle, interruption of the passive movement, followed by release; 3: fatigable clonus occurring at a precise angle; 4: unfatigable clonus occurring at a precise angle), and the TS angle, which measured the difference between the angle of catch-and release/clonus at fast stretch in dorsiflexion and the ankle PROM (10).

Ultrasonographic evaluation

Children were examined in the prone position with their legs outstretched. The sonographic examination consisted of real-time B-mode US performed using a MyLab 70 XVision system (Esaote SpA, Genoa, Italy) interfaced with a linear probe (scanning frequency 15–18 MHz). The US assessment aimed at identifying the tibial nerve as it emerges from the sciatic nerve in the lower third of the thigh and distally tracking its motor nerve branches to the gastrocnemii, soleus and tibialis posterior muscles by means of the so-called "elevator technique" (6). The tibial nerve motor branches were located in the space (vertical, horizontal and deep) according to the position of the fibular head (upper end) and a virtual line extending from the middle of the popliteal fossa to the Achilles tendon insertion (6, 11). See Fig. 1 for a graphical explanation of this system of coordinates.

Statistical analysis

Statistical analysis was performed using the Statistical Package for Social Science for Macintosh, version 26.0 (SPSS Inc., Chicago, IL, USA). Descriptive statistics were used to define the tibial nerve motor branches spatial location in proportion to the affected leg length (%) and by itself (mm). Spearman's rank correlation test was used to assess the association between anatomical landmarks of the tibial nerve motor branches and other US and clinical features of patients. The alpha level for significance was set at $p < 0.05$.

RESULTS

A total of 24 children with CP with spastic equinovarus were recruited from among 51 consecutive outpatients. The study enrolment period was from November 2020 to May 2021. The patients' demographic and clinical features are shown in Table I.

The mean coordinates ± standard deviation (SD) for the gastrocnemius medialis motor branch were 2.5 ± 1.2% of the affected lower limb length (20 ± 10.9 mm) vertical (proximal to the fibular head), 1.0 ± 0.7% of the affected lower limb length (7.7 ± 5.6 mm) horizontal (medial to the virtual line extending from the middle of popliteal fossa to the Achilles tendon insertion), and 1.5 ± 0.4% of the affected lower limb length (11.5 ± 3.6 mm) deep (distance from the skin). The mean coordinates ± SD for the gastrocnemius lateralis motor branch were 2.3 ± 1.4% of the affected lower limb length (17.9 ± 11.2 mm) vertical (proximal to the fibular head), 1.1 ± 0.9% of the affected lower limb length (8.4 ± 6.7 mm) horizontal (lateral to the virtual line extending from the middle of popliteal fossa to the Achilles tendon insertion), and 1.6 ± 0.4% of the affected lower limb length (12.4 ± 4 mm) deep (distance from the skin). The mean coordinates ± SD for the soleus motor branch were 2.1 ± 0.9% of the affected lower limb length (16.5 ± 6.5 mm) vertical (distal to the fibular head), 0.9 ± 0.7% of the affected lower limb length (7.2 ± 5.5 mm) horizontal (lateral to the virtual line extending from the middle of popliteal fossa to the Achilles tendon insertion), and 2.2 ± 0.6% of the affected lower limb length (17 ± 5.1 mm) deep (distance from the skin). The mean coordinates ± SD for the tibialis posterior motor branch were 2.6 ± 1.2% of the affected lower limb length (19.8 ± 7.8 mm) vertical (distal to the fibular head), 1.3 ± 1.1% of the affected lower limb length (10.2 ± 8.9 mm) horizontal (lateral to the virtual line extending from the middle of popliteal fossa to the Achilles tendon insertion), and 3.0 ± 0.7% of the affected lower limb length (23.3 ± 6.3 mm) deep (distance from the skin).

No significant correlation was found between anatomical landmarks of the tibial nerve motor branches and other US and clinical features (Spearman's rank

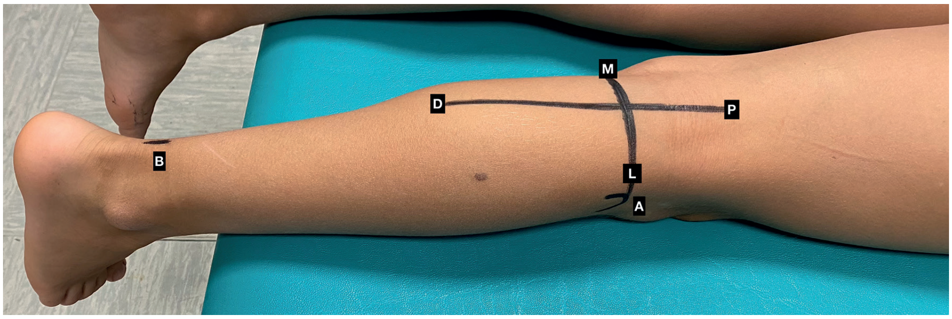

Fig. 1. System of coordinates used for locating the tibial nerve motor branches. A: fibular head (upper end); B: Achilles tendon; P: proximal; D: distal; L: lateral; M: medial.

Table I. Demographic and clinical features of patients

Characteristics	
Age, years, mean (SD)	10.9 (4.4)
Sex, male/female, *n*	13/11
Affected lower limb trochanter length, cm, mean (SD)	78.2 (11.2)
Affected ankle dorsiflexion PROM (°), mean (SD)	1.3 (10.9)
Calf muscles spasticity	
MAS (0–4), median (SD)	2.0 (1.0)
TS grade (0–4), median (SD)	2.0 (1.0)
TS angle (°), mean (SD)	16.3 (9.9)

SD: standard deviation; PROM: passive range of motion; °: degrees; MAS: Modified Ashworth scale; TS: Tardieu Scale.

correlation test) except for the association between ankle dorsiflexion PROM and the vertical coordinate for gastrocnemius lateralis motor nerve branch ($p=0.524$).

DISCUSSION

Nerve blocks are a useful procedure for the management of focal spasticity in adults and children (5). From a diagnostic point of view, DNB of the tibial nerve main trunk with local anaesthetics, which consists of a mixed sensorimotor nerve block, is used to temporarily abolish calf muscles spastic overactivity in order to differentiate it from soft tissues contracture (5, 7). Furthermore, selective DNB of the tibial nerve motor branches enables the clinician to define the respective role of different calf muscles (e.g. soleus, gastrocnemii and tibialis posterior) as contributors to the spastic equinovarus pattern (6, 7). From a therapeutic perspective, DNB permits the clinician to determine if botulinum toxin treatment is appropriate and which muscles should be targeted during injection. Furthermore, it may also be useful to define the dosage of botulinum toxin to inject. Indeed, DNB had been found to provide a significantly greater reduction in muscle overactivity than "on label" botulinum toxin treatment (12). Based on this information, one might infer about the dosage of botulinum toxin to administer, considering, for example, the injection of low doses in the case of weakness after DNB or the use of high doses in the case of good outcome after DNB (also higher than the labelled ones if the outcome of DNB is difficult to obtain). The use of DNB should also be considered mandatory before TNB and other interventional procedures, such as selective neurotomy and cryoneurolysis (5, 11, 13, 14).

With regard to the management of spasticity, US guidance for diagnostic and therapeutic procedures has gained a widespread use in the last decade. However, even if the use of US was initially suggested, in particular, for the paediatric population in order to improve therapeutic compliance, to the best of our knowledge no previous study has investigated, by means of US, the location of tibial nerve motor branches in children with CP with spastic equinovarus foot. Hence, the current results must be discussed in light of the literature about adults. In this regard, a seminal study was published by Deltombe and colleagues in 2004, which used computed tomography to identify the anatomical landmarks for the soleus and tibialis posterior motor nerve branches in 12 stroke patients with spastic equinovarus foot according to a system of coordinates based mainly on the fibular head and a vertical line extending from the middle of the popliteal fossa to the Achilles tendon insertion (11). Using the same system of coordinates, a more recent study by Picelli and collaborators further investigated this issue by means of US and enlarged the information provided by Deltombe about the anatomical landmarks of tibial nerve motor branches, including those for the gastrocnemius (medialis and lateralis) muscle and substantially confirming the ones for the soleus and tibialis posterior muscles (6). The current study not only adds some new information about children with CP, but also overcomes methodological limitations of previous literature, which did not consider the variability given by lower limb length when defining spatial coordinates for the motor branches of tibial nerve. This issue is very important in the paediatric population. This study included patients between 6 and 16 years old. Normative data about this population report a mean height between 115.5 cm and 162.5 cm for females and between 115.5 cm and 173.4 cm for males (15). On this basis it was decided to describe the anatomical landmarks (location in the space) of the tibial nerve motor branches in proportion to the affected leg length (%) and not only by itself in terms of distance (mm). From a clinical and procedural point of view, this information represents an important added value, because not only it may further support the use of US guidance for nerve blocks in children with CP (especially for clinicians who are inexperienced in the use of US), but also it might improve "blind" nerve blocks performed using needle electrical stimulation/EMG guidance in terms of speed, precision and compliance. In the same way, high frequency US is important for enabling the physician to scan peripheral nerves and their branches in order to perform US-guided selective peripheral nerve blocks in patients with spasticity (16).

Spastic muscle overactivity may affect limb anatomy as a consequence of disrupted muscle architecture (i.e. contracture) (10). Thus, the development of changes in surrounding muscles might influence the spatial location of nerve branches. Interestingly, the secondary findings of the current study are in keeping with previous ones about adults with stroke and do not support this hypothesis (6).

Study limitations

This study has several limitations. First, the sample size was small. Secondly, the study did not consider healthy controls for evaluating potential differences as to the anatomical landmarks of tibial motor nerve branches to the gastrocnemii, soleus and tibialis posterior muscles due to spastic CP. This was because the main aim of the study was not to evaluate anatomical modifications consequent to spastic muscle overactivity, but to provide information for selective motor nerve blocks in the management of spastic equinovarus foot due to CP. Thirdly, the study did not perform US evaluation of other tibial nerve motor branches (e.g. the motor nerve branches to the flexor digitorum longus and flexor hallucis longus muscles) that might be a target for selective blocks in the management of spastic equinovarus foot.

CONCLUSION

Nerve blocks in children with CP should be considered as an advanced procedure that requires some expertise on the field of paediatric spasticity. In particular, the information provided by this study may help those clinicians who usually perform nerve blocks using only EMG guidance or are inexperienced in the use of US guidance to help and improve their ability in targeting the motor branches of tibialis nerve in children with CP. Of course, for the experts in the field of nerve US, this information might be less useful due to their visual ability to see the target without the support of anatomical landmarks. To further validate these findings, larger scale studies are required, taking into account the limitations reported above.

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The authors have no conflicts of interest to declare.

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