SHORT COMMUNICATION

IS THE OUTCOME OF DIAGNOSTIC NERVE BLOCK RELATED TO SPASTIC MUSCLE ECHO INTENSITY? A RETROSPECTIVE OBSERVATIONAL STUDY ON PATIENTS WITH SPASTIC EQUINOVARUS FOOT

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Objective: **To investigate the relationship between spastic calf muscles echo intensity and the outcome of tibial nerve motor branches selective block in patients with spastic equinovarus foot.**
Design: **Retrospective observational study.**
Patients: **Forty-eight patients with spastic equinovarus foot.**
Methods: **Each patient was given selective diagnostic nerve block (lidocaine 2% perineural injection) of the tibial nerve motor branches. All patients were evaluated before and after block. Outcomes were: spastic calf muscles echo intensity measured with the Heckmatt scale; affected ankle dorsiflexion passive range of motion; calf muscles spasticity measured with the modified Ashworth scale and the Tardieu scale (grade and angle).**
Results: **Regarding the outcome of tibial nerve selective diagnostic block (difference between pre- and post-block condition), Spearman's correlation showed a significant inverse association of the spastic calf muscles echo intensity with the affected ankle dorsiflexion passive range of motion ($p=0.045$; $\rho=$ 00–0.269), modified Ashworth scale score ($p=0.014$; $\rho=-0.327$), Tardieu grade ($p=0.008$; $\rho=-0.352$) and Tardieu angle ($p=0.043$; $\rho=-0.306$).**
Conclusion: **These findings support the hypothesis that patients with spastic equinovarus foot with higher spastic calf muscles echo intensity have a poor response to selective nerve block of the tibial nerve motor branches.**

Key words: muscle hypertonia; muscle spasticity; nerve block; rehabilitation; ultrasonography.

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LAY ABSTRACT

This study reviewed data from 48 patients with spastic equinovarus foot in order to investigate the relationship between spastic calf muscles echo intensity (which indicates the degree of muscular fibrosis) and the outcome of tibial nerve motor branches diagnostic block (which temporarily relieves focal muscle overactivity). Outcome was the response to nerve block as to passive motility of the affected ankle and overactivity of the calf muscles. All patients were evaluated before and after the nerve block. A significant inverse association was found for the outcome of selective diagnostic nerve block of the tibial nerve motor branches with their respectively supplied spastic calf muscles (i.e. gastrocnemius medialis and lateralis, soleus and tibialis posterior) echo intensity. These results support the hypothesis that the degree of spastic muscle fibrosis may reduce the response to selective diagnostic nerve block in patients with spastic equinovarus foot.

Spastic paresis is a main feature of upper motor neurone syndrome (UMNS) (1). Equinovarus foot is one of its most common patterns, which may be due to a combination of calf muscles overactivity, Achilles tendon/muscle shortening, weakness of ankle dorsiflexor muscles and imbalance between peroneal and tibialis anterior muscles (2, 3). According to its composite pathophysiology, spastic equinovarus foot requires interdisciplinary management (3, 4). In line with the guidance from the Mont-Godinne interdisciplinary group, diagnostic nerve block (DNB) of the tibial nerve and its motor nerve branches plays a key role in determining the most appropriate management of spastic equinovarus foot (3). This is because selective tibial nerve DNB allows differentiation of spastic muscle overactivity from contracture, also determining the respective role of different muscles in patterns of spastic paresis, and testing the strength of antagonist muscles (3).

Soft tissue contracture is a main disabling feature in patients with spastic paresis, which may occur over time, including degenerative changes at the myotendinous junction, muscle atrophy and loss of sarcomeres, accumulation of intramuscular connective tissue and increased fat content (5). Echo intensity is a parameter commonly used for grading pathological changes of the muscle due to fatty infiltration and fibrosis (6). Increased spastic gastrocnemius muscle echo intensity has been shown to correlate with a reduced response to botulinum toxin type A (BoNT-A) injection in chronic stroke patients with spastic equinus (7). Furthermore, the increased echo intensity has been found to be associated with reduced muscle thickness, posterior pennation angle, and compound muscle action potential amplitude (8).

In order to understand the clinical presentation of people with spastic equinovarus foot in more depth and to better define treatment goals, it would be useful to determine the role played by the development of changes in the spastic calf muscles on the outcome of DNB. However, to the best of our knowledge, no previous study has investigated this issue, despite the importance of selective tibial nerve DNB in the management of spastic equinovarus foot. Thus, the main aim of this study was to investigate the relationship between spastic calf muscles echo intensity and the outcome of tibial nerve motor branches selective DNB in patients with spastic equinovarus foot.

METHODS

This single-centre retrospective (chart review), observational study analysed data from 48 patients with spastic paresis due to UMNS with equinovarus foot, who had undergone selective DNB of the tibial nerve motor branches at the Neurorehabilitation Unit of the University Hospital of Verona, Italy, from January 2019 to December 2020.

Inclusion criteria were: age >18 years; spastic equinovarus foot consequent to UMNS documented by neurological consultation; calf muscles spasticity graded at least 1 on the Modified Ashworth Scale (MAS) (9); clinical pattern involving at least 1 of the following muscles: soleus, tibialis posterior (TP), gastrocnemius medialis (GM) and gastrocnemius lateralis (GL); no previous BoNT-A treatment for lower limb spasticity. Exclusion criteria were as follows: participation in other trials; clinical pattern involving the following muscles: flexor digitorum longus, flexor digitorum brevis, flexor hallucis longus and extensor hallucis longus; previous treatment of spastic equinovarus foot with neurolytic or surgical procedures; other neurological or orthopaedic conditions involving the affected lower limb. All participants were outpatients. All patients provided informed consent, which included consent for data extraction from chart review, as needed. The study was carried out according to the principles of the Declaration of Helsinki and was approved by the local Review Board.

Treatment procedures

According to the current literature (3), in our clinical practice the DNB is a mandatory procedure for patients with spastic equinovarus in order to define their management. Thus, before making any therapeutic decision (e.g. BoNT-A, surgery) all patients were evaluated by serial selective DNB of the tibial nerve motor branches (the DNB was performed first at the soleus motor nerve branch, followed, in the case of no or scant relief of muscle overactivity, by the motor nerve branch to the TP, to the GM and GL muscles). Patients lay in the prone position during the whole procedure. A 22-gauge, 80-mm, ultrasound faceted tip echogenic needle for nerve block (SonoPlex STIM, Pajunk, Geisingen, Germany) was guided to the motor branches of tibial nerve by means of ultrasound (MyLab 70 XVision, Esaote, Genoa, Italy) and electrical nerve stimulation (Plexygon, Vygon, Padua, Italy). Anatomical landmarks were used for linear transducer (scanning frequency 15 MHz) and needle-tip positions (10). Once the tibial nerve motor branches were identified by ultrasound, following elicitation of appropriate muscular response to a 1 Hz, 100 μs, 0.5 mA electrical stimulus, 1–2 mL lidocaine 2% was injected (gentle aspiration was performed before injection to ensure the absence of vessels at the needle tip).

Ultrasonographic evaluation procedures

As usual in our clinical practice, before DNB all patients performed real-time B-mode ultrasonography by means of a MyLab 70 XVision system (Esaote SpA, Genoa, Italy) interfaced with a linear probe (scanning frequency 13 MHz), which was positioned perpendicular to the affected calf surface in order to scan it up and down using the "elevator technique" (7, 11). The highest degree of echo intensity was chosen for each muscle (i.e. GM, GL, soleus and TP). The probe was placed gently over the skin using water-soluble transmission gel in order to avoid pressure alterations of the muscle tissue. The spastic calf muscles echo intensity found at these points was graded on the Heckmatt scale (grade 1 = normal; grade 2 = increase in muscle echo intensity; grade 3 = marked increase in muscle echo intensity; grade 4 = very high muscle echo intensity) (6). The same experienced operator performed all the ultrasonographic evaluations.

Clinical evaluation procedures

According to our routine practice, all patients were clinically evaluated before and after DNB. During evaluations patients remained in the supine position with their knees extended. The affected ankle dorsiflexion passive 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 (7). The MAS was used to evaluate spastic calf muscles tone. 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; 1+=slight increase in muscle tone through less than half of the range of motion; 2=more marked increase in muscle tone through most of the range of motion; 3=considerable increase in muscle tone; 4=joint is rigid). The Tardieu Scale (TS) was used to evaluate spastic calf muscle tone according to the spasticity grade, which measured the gain in muscle reaction to fast stretch in dorsiflexion from (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: unsustained clonus occurring at a precise angle; 4: sustained clonus occurring at a precise angle), and spasticity angle, which measured the difference (a – b) between the ankle dorsiflexion angle at which the reaction to fastest stretch (i.e. catch-and release/clonus) occurs (b) and ankle dorsiflexion PROM (a) (12).

Statistical analysis

Statistical analysis was carried out with the Statistical Package for Social Science for Macintosh, version 26.0 (SPSS Inc., Armonk, NY, USA). Descriptive statistics were used for demographic, ultrasonographic and clinical features of our sample. Spearman's rank correlation test was performed to assess the association between echo intensity and spasticity of the calf muscles before DNB. Furthermore, it was performed to assess the association between echo intensity of the spastic calf muscles (i.e. GM, GL, soleus and TP) and clinical outcome of their respective tibial nerve motor branches supply selective DNB (difference between post- and pre-DNB condition). The alpha level for significance was set at $p<0.05$.

RESULTS

Demographic and clinical features of patients are reported in Tables I and II.

Regarding the relationship between the Heckmatt grade and calf muscles spasticity at baseline (before DNB condition), Spearman's correlation showed a significant inverse association of the spastic calf muscles echo intensity with the MAS score ($p=0.044$; $\rho=-0.342$), the TS grade ($p=0.049$; $\rho=-0.336$) and the TS angle ($p=0.033$; $\rho=-0.362$).

Regarding the outcome of tibial nerve selective DNB (difference between post- and pre-block condition), Spearman's correlation showed a significant inverse association of the spastic calf muscles echo intensity with the affected ankle dorsiflexion PROM ($p=0.045$; $\rho=-0.269$), MAS score ($p=0.014$; $\rho=-0.327$), TS grade ($p=0.008$; $\rho=-0.352$) and TS angle ($p=0.043$; $\rho=-0.306$).

DISCUSSION

This observational study based on a chart review aimed to retrospectively investigate whether the clinical outcome of DNB might be related to the development of changes in muscles of patients with spastic paresis. The results showed that patients with spastic equinovarus due to UMNS with higher spastic calf muscle echo intensity (i.e. GM, GL, soleus and TP) had a reduced response to the tibial nerve selective DNB.

Spastic paresis is due to lesions of the central nervous system involving corticospinal pathways and consists of 2 main disorders: a muscle disorder (called "spastic myopathy", which refers to a combination of muscle shortening and loss of extensibility) and a neurological disorder (comprising spastic dystonia, spastic co-contraction, spasticity and stretch-sensitive paresis) (1). Neural blockade with anaesthetics (e.g. lidocaine 2% or bupivacaine 0.5%) is a diagnostic tool to obtain a transient suppression of muscle overactivity (i.e. the neurological disorder of spastic paresis) as a consequence of drug action on Ia fibres (which mediates the myotatic reflex) and alpha motor fibres (which mediates voluntary contraction) (3, 13). In particular, the effect of anaesthetics is based on the block of depolarization by acting on the voltage-gated sodium channel, which determines a lack of calcium ions entry at the neuromuscular junction and, consequently, the

Table I. Demographic features of patients

Characteristics	
Age (years), mean (SD)	52.3 (16.9)
Sex (*n*), male/female	31/17
Aetiology of spastic equinovarus foot (*n*)	
Stroke	22
Multiple sclerosis	9
Brain injury	7
Spinal cord injury	6
Chiari malformation type 1	2
Hereditary spastic paraparesis	2
Tibial nerve motor branches DNB (*n*)	
Gastrocnemius medialis	8
Gastrocnemius lateralis	7
Soleus	34
Tibialis posterior	15

SD: standard deviation; *n*, number; DNB: diagnostic nerve block.

Table II. Clinical features of spastic equinovarus foot

	Before tibial nerve selective DNB	After tibial nerve selective DNB
Spastic muscles echo intensity (Heckmatt grade) median (IQR)	2.0 (2.0; 3.0)	
Ankle dorsiflexion PROM (degrees) mean (SD)	–1.6 (7.0)	5.7 (7.4)
Calf muscles spasticity (MAS score) median (IQR)	3.0 (3.0; 4.0)	2.0 (1.0; 3.0)
Calf muscles spasticity (TS grade) median (IQR)	3.0 (2.0; 4.0)	2.0 (1.0; 2.0)
Calf muscle spasticity (TS angle) mean (SD)	16.1 (6.5)	5.8 (8.3)

DNB: diagnostic nerve block; PROM: passive range of motion; MAS: modified Ashworth scale; TS: Tardieu scale; SD: standard deviation; IQR: interquartile range.

impossibility of triggering the acetylcholine release process. Therefore, the effect of DNB is due to its action on the contractile component of muscles.

Selective DNB of the tibial nerve motor branches may be considered mandatory to evaluate and define the management of patients with spastic paresis with equinovarus foot (3). A relevant change in clinical pattern after DNB indicates muscle overactivity as the "main problem" (13, 14). On the other hand, the development of spastic myopathy may lead to the progressive loss of response to myorelaxant procedure/treatments, such as selective DNB or BoNT-A injection (4, 7).

Spastic myopathy is mainly due to atrophy (i.e. loss of muscle mass), loss of sarcomeres (i.e. muscle shortening) and accumulation of connective tissue and fat (5). Ultrasonography may be used to detect some of its features by evaluating muscle thickness and cross-sectional area, fascicle length, pennation angle, muscle echo intensity and elasticity (15). In particular, the increase in intramuscular connective tissue and fat content has been reported to increase reflections of the ultrasound beam, resulting in an increased echo intensity of spastic muscles (6, 7, 16).

The findings of a significant inverse association between spastic calf muscles echo intensity and the outcome of tibial nerve selective DNB in UMNS patients are in line with previous ones about chronic stroke patients showing a reduced response to BoNT-A injection of spastic gastrocnemius muscle with higher echo intensity (7). From this perspective, one may argue that ultrasonography (and in particular the evaluation of muscle echo intensity by means of the Heckmatt scale) might differentiate spastic myopathy from the neurological components of spastic paresis. Considering its retrospective design, this study cannot draw definitive conclusions about this issue. However, in our view, to differentiate muscle and neurological disorders, the clinical evaluation of spastic paresis should include not only the ultrasound features of spastic myopathy (e.g. reduced muscle thickness and cross-sectional area; increased muscle echo intensity; reduced pennation angle; shortened fascicle length; reduced muscle elasticity), but also the DNB evaluation and its outcome. This is because spastic paresis comprises deeply related muscular and nervous components, which influence and potentiate each other over time. Hence, recording ultrasound parameters should be useful to follow-up the patient over time, starting from the first assessment (e.g. before DNB and or BoNT-A injection). On the other hand, for example, indications about surgical procedures (e.g. tendon lengthening) should be based on clinical, ultrasound and DNB evaluation.

In addition, the current observations further confirm the relationship previously observed between spastic calf muscles echo intensity and some outcome measures used to evaluated the features of spastic equinus/equinovarus foot (i.e. ankle PROM, MAS and TS) (7, 8). From a clinical point of view, the TS has been reported to differentiate spasticity from contracture, whereas the MAS grades the resistance to rapid passive movement without differentiating stretch reflex hyperactivity from non-reflex biomechanical changes in spastic muscles (12). From this perspective, the similar results obtained by this study as to the MAS and the TS might seem quite unexpected, particularly with regard to to the TS performed at V3 (maximum speed stretch to evaluate muscle overactivity), which evaluates not only the resistance to passive movement, but also clonus and its duration (12). Based on previous findings, this is probably because the reduced extensibility of spastic fibrotic muscles in a shortened position may produce a more ready transmission of any pulling force to the muscle spindles, thus enhancing stretch reflexes (7).

This study has several limitations. First, the design of the study was retrospective. In our view, the findings should be considered preparatory for larger, future, prospective studies on the same field. Furthermore, due to the retrospective design, the patients were not standardized and we did not provide information about the ankle dorsiflexion active range of motion because the database was incomplete with respect to this outcome. Similarly, the current study did not collect data about the non-affected limbs. Secondly, no neurophysiological (e.g. electromyography) evaluation was performed to assess spastic muscles condition/activity before and after DNB. Thirdly, to assess the spastic muscle echo intensity we used the Heckmatt scale (6) and not its modified version (16). This was because the validation of the modified Heckmatt scale was published after the current study data collection. Unfortunately, we are unable to update our evaluation in light of the current literature because in our database we usually record only the Heckmatt grade and do not store the ultrasound images of each patient. Fourthly, we considered some different aetiologies of UMNS, which might have played a role in spastic muscle structure (17). Fifthly, no other evaluation of muscle tissue (e.g. MRI muscle composition analysis) was considered.

In conclusion, the results of this study about the relationship between spastic calf muscle intensity and the outcome of tibialis nerve motor branches selective DNB might be useful for clinicians during the management of spastic equinovarus, in order to guide the choice of which spastic muscles to block by DNB, and to improve understanding of its outcome.

The authors have no conflicts of interest to declare.

REFERENCES

1. Baude M, Nielsen JB, Gracies JM. The neurophysiology of deforming spastic paresis: a revised taxonomy. Ann Phys Rehabil Med 2019; 62: 426–430.
2. Li S. Ankle and foot spasticity patterns in chronic stroke survivors with abnormal gait. Toxins (Basel) 2020; 12: 646.
3. Deltombe T, Wautier D, De Cloedt P, Fostier M, Gustin T. Assessment and treatment of spastic equinovarus foot after stroke: guidance from the Mont-Godinne interdisciplinary group. J Rehabil Med 2017; 49: 461–468.
4. Picelli A, Santamato A, Chemello E, Cinone N, Cisari C, Gandolfi M, et al. Adjuvant treatments associated with botulinum toxin injection for managing spasticity: an overview of the literature. Ann Phys Rehabil Med 2019; 62: 291–296.
5. Gracies JM. Pathophysiology of spastic paresis. I: Paresis and soft tissue changes. Muscle Nerve 2005; 31: 535–551.
6. Pillen S, van Keimpema M, Nievelstein RA, Verrips A, van Kruijsbergen-Raijmann W, Zwarts MJ. Skeletal muscle ultrasonography: visual versus quantitative evaluation. Ultrasound Med Biol 2006; 32: 1315–1321.
7. Picelli A, Bonetti P, Fontana C, Barausse M, Dambruoso F, Gajofatto F, et al. Is spastic muscle echo intensity related to the response to botulinum toxin type A in patients with stroke? A cohort study. Arch Phys Med Rehabil. 2012; 93: 1253–1258.
8. Picelli A, Tamburin S, Cavazza S, Scampoli C, Manca M, Cosma M, et al. Relationship between ultrasonographic, electromyographic, and clinical parameters in adult stroke patients with spastic equinus: an observational study. Arch Phys Med Rehabil 2014; 95: 1564–1570.
9. Bohannon RW, Smith MB. Interrater reliability of a modified Ashworth scale of muscle spasticity. Phys Ther 1987; 67: 206–207.
10. Picelli A, Chemello E, Verzini E, Ferrari F, Brugnera A, Gandolfi M, et al. Anatomical landmarks for tibial nerve motor branches in the management of spastic equinovarus foot after stroke: an ultrasonographic study. J Rehabil Med 2019; 51: 380–384.
11. Picelli A, Baricich A, Chemello E, Smania N, Cisari C, Gandolfi M, et al. Ultrasonographic evaluation of botulinum toxin injection site for the medial approach to tibialis posterior muscle in chronic stroke patients with spastic equinovarus foot: an observational study. Toxins (Basel) 2017; 9: 375.
12. Patrick E, Ada L. The Tardieu scale differentiates contracture from spasticity whereas the Ashworth scale is confounded by it. Clin Rehabil 2006; 20: 173–182.
13. Picelli A, Battistuzzi E, Filippetti M, Modenese A, Gandolfi M, Munari D, et al. Diagnostic nerve block in prediction of outcome of botulinum toxin treatment for spastic equinovarus foot after stroke: a retrospective observational study. J Rehabil Med 2020; 52: jrm00069.
14. Deltombe T, Lejeune T, Gustin T. Botulinum toxin type A or selective neurotomy for treating focal spastic muscle overactivity? Ann Phys Rehabil Med 2019; 62: 220–224.
15. Özçakar L, Ata AM, Kaymak B, Kara M, Kumbhare D. Ultrasound imaging for sarcopenia, spasticity and painful muscle syndromes. Curr Opin Support Palliat Care 2018; 12: 373–381.
16. Moreta MC, Fleet A, Reebye R, McKernan G, Berger M, Farag J, et al. Reliability and validity of the modified Heckmatt scale in evaluating muscle changes with ultrasound in spasticity. Arch Rehabil Res Clin Transl 2020; 2: 100071.
17. Picelli A, Vallies G, Chemello E, Castellazzi P, Brugnera A, Gandolfi M, et al. Is spasticity always the same? An observational study comparing the features of spastic equinus foot in patients with chronic stroke and multiple sclerosis. J Neurol Sci 2017; 380: 132–136.