Comparison between tibial nerve block with anaesthetics and neurotomy in hemiplegic adults with spastic equinovarus foot

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ABSTRACT

Objective: The aim of the study was to compare the effect of diagnostic motor nerve block with anaesthetics and of selective tibial neurotomy in the treatment of spastic equinovarus foot in hemiplegic adults.

Methods: In this prospective observational study, 30 hemiplegic adults with spastic equinovarus foot benefited from a diagnostic nerve block with anaesthetics followed by a selective tibial neurotomy performed at the level of the same motor nerve branches of the tibial nerve. Spasticity (Ashworth scale), muscle strength (Medical Research Council scale), passive ankle dorsiflexion (ROM), gait parameters (10 meters walking test) and gait kinematics (video assessment) were assessed before and after the nerve block and two months and two years after selective tibial neurotomy.

Results: The decrease in spasticity and the improvement in gait kinematics were similar after the diagnostic nerve block and two months and two years after neurotomy. The diagnostic nerve block did not reveal the slight increase in gait speed and in tibialis anterior muscle strength that was observed two years after neurotomy.

Conclusion: This study suggests that diagnostic nerve block with anaesthetics and selective neurotomy equally reduce spasticity and improve gait in case of spastic equinovarus foot in hemiplegic adults. Diagnostic nerve block can be used as a valuable screening tool before neurotomy.

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1. Introduction

Spastic equinovarus foot (SEF) is a common deformity among hemiplegic patients, with an incidence estimated at 18% of the stroke survivors [1]. The deformity is mainly caused by spasticity of the triceps surae (soleus and gastrocnemius muscles) and tibialis posterior muscles, sometimes associated with Achilles' tendon shortening and weakness and/or imbalance of the peronei and tibialis anterior muscles. SEF contributes to poor locomotor performance after stroke [2]. Moreover, SEF is frequently associated with other gait disturbances such as knee recurvatum [3]. Patients frequently need ankle-foot orthosis and/or crutch for walking. Treatment of SEF includes physical therapy, muscle stretching, orthosis, functional electrical stimulation, chemical neuromyotaxis with phenol or alcohol, botulinum toxin (BTXa) injections, tendon transfers and lengthening, and selective tibial neurotomy (STN) [4]. Several randomized, double-blind, placebo-controlled studies have demonstrated that BTXa injections can reduce spasticity, pain and use of walking aids, and increase active ankle dorsiflexion, whereas the effect on gait velocity has been more equivocal [5–8]. However, BTXa has a reversible effect necessitating repeated injections every four to six months. In such cases, permanent surgical treatment, such as STN, is indicated in order to definitively correct the SEF [9].

STN is a neurosurgical procedure in which the motor nerve branches innervating the spastic muscles are partially sectioned. This old technique has been reintroduced by French and Belgian neurosurgical teams over the last few decades and was improved by use of intraoperative electrical stimulation and operating microscopes [9–16]. Partial section of the motor nerve branches results in a permanent reduction of spasticity by interrupting afferent (Ia) and efferent (α and γ) fibers mediating the spastic monosynaptic reflex arc. The surgeon carefully spares sensory fibers to avoid sensory deficit and neuropathic pain. STN is indicated in case of disabling SEF caused by spasticity of the gastrocnemius, soleus, tibialis posterior and flexor hallucis longus.
muscles without associated musculo-tendinous shortening. The motor nerve branches innervating the flexor digitorum longus muscle are spared in order to avoid sensory deficits because these branches are frequently very close to the sensory fibers innervating the sole of the foot. The most frequently reported complaints that may justify STN were foot instability with repetitive ankle sprains, pain related to excessive pressure on the toes, and difficulties tolerating ankle foot orthosis. The long-lasting beneficial effect of STN on spasticity, gait speed and equinovarus deformity in patients with SEF has been suggested in several longitudinal studies [10–12,14,16–18]. A recent randomized controlled trial evaluating the effect of BTXa and STN in the SEF confirms the efficacy of the STN to reduce spasticity and to improve the ankle kinematics [9].

In the assessment of SEF, especially before STN, a selective diagnostic nerve block (DNB) with anaesthetics of the motor nerve branches of the tibial nerve innervating the soleus, gastrocnemius and tibialis posterior muscles is recommended and preferred to a non-selective tibial nerve block [13,19–22]. The DNB involves injecting a small dose (usually 1 mL) of local anaesthetics at the level of the motor nerve. The nerve block eliminates spasticity after few minutes and for some hours, allowing assessment of the respective contribution of the different spinal muscles, the degree of Achilles’ tendon shortening, and the weakness of the antagonist muscles. Before proposing STN, it is necessary that a reduction in the equinovarus deformity following a DNB with anaesthetics and/or botulinum toxin injections can be demonstrated [9,11–13,15,16,23]. However, the necessity to perform DNB before proposing STN was suggested only by three studies which have compared the effect of DNB and STN in respectively two, seven and 11 patients, supporting the need for larger studies [13,20,24].

The aim of the present study was to prospectively evaluate the effect of DNB with anaesthetics of the motor nerve branches of the tibial nerve and of STN in the treatment of SEF in hemiplegic adults. Our research hypothesis was that the DNB would provide an identical decrease in spasticity and in equinovarus deformity as STN and therefore predicts the improvement obtained after STN.

2. Methods

2.1. Participants

The patients were consecutively recruited by an interdisciplin ary specialist group in a referral center of a university hospital from 1997 to 2005. All the patients benefited from a selective DNB with anaesthetics of the motor nerve branches of the tibial nerve innervating the soleus, tibialis posterior ± gastrocnemius muscles and from a STN performed at the same nerves. Inclusion criteria were a stroke history or trauma of more than one year, an age over 18 years, an ability to walk without shoes, the presence of a disabling SEF improved by DNB with anaesthetics and a passive ankle dorsal range of motion with flexed knee at neutral angle after DNB. Exclusion criteria were a previous history of surgery or injection with phenol and injection with BTXa in the last 6 months and the need for a tendon surgery in addition to neurotomy. Our institutional review board approved the study and informed consent was obtained from all the patients.

2.2. Diagnostic nerve block with anaesthetics

The DNB with anaesthetics was performed at the level of the different motor nerve branches of the tibial nerve until the triceps spasticity had disappeared. If possible, a selective DNB was preferred to a global tibial nerve block, which induces a non-selective decrease of the spasticity of all the muscles of the calf and sensory disturbances which may interfere with gait. The DNB was performed by means of a disposable needle for conduction anaesthesia, gauge 23 and 100 mm in length (Top Corp., Japan), coupled to an EMG apparatus (Nicolet Viking, Nicolet Biomedical, Inc., Madison, WI). The motor nerve branches were located according to coordinates previously determined in relation to anatomic landmarks [21]. A 1 mL dose of lidocaine 2% (Xylocaine® 2%) was injected on each motor nerve branch when a clinical muscular contraction and an EMG detection response (for the soleus and gastrocnemius muscles) were still obtained with a low stimulation intensity (0.01 ms and 4 mA). The local anaesthetics usually act after few minutes allowing to assess the effect on the spasticity of the targeted muscles. The DNB was performed first at the superior motor nerve branch to the soleus muscle followed, if necessary, by the motor nerve branch to the tibialis posterior and to the gastrocnemius muscles. If necessary, the DNB was finally performed at the tibial nerve. The effect of the DNB lasts for several hours.

2.3. Surgical treatment

STN was performed under general anaesthesia according to previous description [9,12,14,16,23]. Muscle relaxant drugs were not used in order to prevent any interference with the intraoperative electrical stimulation. The patient was placed in a prone position and a vertical cutaneous incision was made below the crease of flexion of the popliteal fossa. The tibial nerve was dissected and the motor nerve branches to the soleus, gastrocnemius, tibialis posterior and flexor hallucis longus were identified with intraoperative tripolar electrical stimulation (Newmedic, France). The selected motor nerve branches were partially sectioned over a 5 mm length under the microscope. The extent of nerve section was determined according to the degree of spasticity and to the peroperative residual muscular contraction under electrical stimulation. Patients were allowed to walk the day after surgery and no immobilization or cast was used. During the two years period of the study, patients continued to benefit from a 30 minutes daily rehabilitation program including personal triceps stretching in load, muscle strengthening and gait rehabilitation. This rehabilitation program was the same as performed before the inclusion in the study. Use of oral antispastic medications was not monitored.

2.4. Test protocol

Before and after DNB and two months and two years after STN, the degree of spasticity, muscle strength, passive range of ankle motion, gait parameters and gait kinematics were assessed by the same unblinded therapist. The degree of spasticity was measured at the triceps surae, tibialis posterior, quadriceps and hamstring muscles by using the modified Ashworth scale [25]. The muscle strength was measured at the quadriceps, hamstring, tibialis anterior, peronei and triceps muscles by using the MRC (Medical Research Council graded 0–5) scale in sitting position. The passive range of ankle motion (ROM in degrees) was measured with a goniometer with the knee in the flexed (soleus) and extended (soleus and gastrocnemius) position taking the tibia, the center of the heel and the first metatarsophalangeal joint as landmarks. Gait parameters (gait speed, step cadence and step length) were obtained during a 10-meter walking test. Gait kinematics (equinus, varus and knee flexion both in swing and stance phase) was measured using video analysis and expressed in degrees; the gait was recorded with a digital camera recorder and analysed on a 20 inches screen. The following landmarks were used: the trunk and the femur for the hip, the femur and the tibia for the knee, the
tibia – center of the heel – first metatarsophalangeal joint for equinus and the tibia and the calcaneus for varus. Adverse effects of DNB and STN were monitored and recorded.

3. Statistical analysis

Numerical parameters are expressed as medians with first and third quartiles into brackets and as mean ± standard deviations for some selected parameters. Differences in the parameters at the various time points were compared globally by a Friedman test, followed by Wilcoxon signed rank tests for two by two selected comparisons in case of significant heterogeneity. All tests were two-tailed and were performed by SPSS 15.0 statistical software (SPSS Inc., Chicago, USA). As correction for multiple tests, a p value less than 0.01 was considered as statistically significant.

4. Results

Out of a population of 144 consecutive hemiplegic patients with SEF who benefited from a DNB 49 patients met the inclusion and exclusion criteria and were operated from STN. Thirty of the 49 patients completed the study with a 2-year follow-up: 1 patient died from a cause unrelated to surgery, eight patients underwent a split anterior tibialis tendon transfer (SPLATT procedure) to correct a varus in swing phase related to imbalance between tibialis anterior and peroneus muscles and 10 patients were lost for follow-up. The population included 17 males and 13 females. Hemiplegia affected the right side in 13 patients and the left side in 17 patients. The etiology of hemiplegia was ischemic in 18 cases, haemorrhagic in seven cases and traumatic in five cases. Mean age at enrolment was 45 ± 14 years (range 20–69 years) and time from stroke or trauma to enrolment was 48 ± 56 months (range, 15–218 months).

The DNB was performed selectively at the level of the motor nerve branch of the soleus in 28 cases, of the tibialis posterior in 25 cases, of the flexor hallucis longus in 10 cases and of the gastrocnemius in two cases. The DNB was performed at the level of the tibial nerve (innervating the soleus, gastrocnemius, tibialis posterior and flexor digitordus muscles) as a first procedure in two cases and after selective motor nerve branch block in 10 cases. STN was performed at the same motor nerve branches as those selected during the DNB. In six cases, the neurotomy involved the motor nerve branch innervating the flexor hallucis longus while it was not blocked by means of a selective or tibial nerve block. STN involved the soleus nerve in all cases (median percentage of section 75 [75;80]), the medial and lateral gastrocnemius nerves in 16 cases (median percentage of section 75 [52;75]), the tibialis posterior nerve in 26 cases (median percentage of section 70 [50;80]), and the flexor hallucis longus nerve in 22 cases (100% section in all cases).

Tables 1–3 show spasticity, muscle strength, passive ankle range of motion, gait parameters and kinematic parameters before and after the DNB, and two months and two years after STN.

There was a statistically significant and similar decrease in triceps and tibialis posterior spasticity, in triceps clonus and in equinus and varus in swing and stance phase after DNB and two months and two years after STN. In contrast, there were no changes in quadriceps and hamstring spasticity and in hip and knee flexion during gait. There was statistically significant decrease in triceps muscle strength and increase in passive ankle dorsiflexion after DNB and two months after STN while both parameters returned to baseline values two years after STN. Finally, the gait speed and the tibialis anterior strength were unchanged after DNB but were increased two months and two years after STN and two years after STN, respectively.

There were no serious adverse effects after DNB or STN and no patient suffered from any permanent additional sensory loss and/or neuropathic pain.

5. Discussion

In the assessment of SEF, a tibial DNB (or, if possible, a DNB of selective motor nerve branches of the tibial nerve) represents the best practice before a permanent treatment of spasticity, such as STN, should be proposed [9,11–16,23]. Firstly, the DNB, by inducing a transient suppression of the spasticity, helps to determine the contribution of the triceps surae–Achilles' tendon complex shortening and/or of the dorsiflexor weakness to the SEF deformity. For instance, if the SEF in stance phase remains unchanged after DNB, we can conclude that the deformity is related to muscle contracture rather than to spasticity. If the SEF in swing phase is improved after DNB, this indicates that dorsiflexor muscles activation was limited by the calf spasticity and could, therefore, be improved by an

<p>| Table 1  |
|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Spasticity (Ashworth scale), muscle strength (MRC scale) and passive ankle range of motion (ROM) (median) before and after diagnostic nerve block (DNB) and two months and two years after selective tibial neurotomy (STN). |</p>
<table>
<thead>
<tr>
<th>Baseline</th>
<th>DNB</th>
<th>STN 2 months</th>
<th>STN 2 years</th>
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</thead>
<tbody>
<tr>
<td><strong>Spasticity (Ashworth)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triceps surae</td>
<td>3 [3;4]</td>
<td>1 [0;1]</td>
<td>0 [0;1]</td>
</tr>
<tr>
<td>Tibialis posterior</td>
<td>1 [0;2]</td>
<td>0 [0;1]</td>
<td>0 [0;0]</td>
</tr>
<tr>
<td>Quadriceps</td>
<td>2 [1;2]</td>
<td>2 [1;2]</td>
<td>2 [1;2]</td>
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<tr>
<td><strong>Muscle strength (MRC)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triceps surae</td>
<td>3 [2;4]</td>
<td>1 [0;3]</td>
<td>1 [1;2]</td>
</tr>
<tr>
<td><strong>Passive ankle dorsiflexion (degrees)</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Extended knee</td>
<td>0 [-10; 5]</td>
<td>0 [0;10]</td>
<td>5 [0;10]</td>
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</tbody>
</table>

P values not shown are not significant.

* Significant difference versus pretreatment values.

** Significant difference months versus post block values.
appropriate spasticity treatment. Secondly, a selective DNB helps to differentiate the respective contribution of the different spastic muscles (soleus, gastrocnemius, tibialis posterior, flexor digitorum and less frequently the fibularis muscles) to the SEF [26]. For example, if the triceps clonus and SEF deformity disappear after a selective DNB of the soleus motor nerve branch, this means that the soleus spasticity only is responsible for the SEF. Decq et al. showed that soleus spasticity was exclusively responsible for the SEF in 75% of cases [27]. Buffenoir et al. have also shown that the triceps stretch reflex and Achilles’ tendon reflex were reduced after soleus DNB but not after gastrocnemius DNB and Bleyenheuft et al. noted a normalization of the elastic and viscous stiffness of the ankle plantar flexor muscles after soleus DNB confirming the predominant role of soleus spasticity in SEF [19,24]. Such an improvement after soleus DNB indicates that only the soleus spasticity has to be treated with BTXa injection or STN while sparing the gastrocnemius muscles may help to keep sufficient triceps strength and to preserve propulsion during the push-off phase of gait. In contrast, a global tibial DNB induces a decrease in spasticity of all the muscles innervated by the tibial nerve (gastrocnemius, soleus, tibialis posterior and flexor digitorum muscles), which does not permit to determine the responsibility of these different muscles in the SEF deformity. Furthermore, a tibial DNB also involves the sensory fibers innervating the sole of the feet leading to a sensory deficit, which may interfere with gait [28]. Lastly and most importantly, the DNB can predict the functional improvement that can be expected from treatment of spasticity. This aspect is crucial for the patient as it allows him/her to see and to feel what could be achieved with surgery.

As STN is a surgical and permanent treatment for SEF, it is important to determine if the improvements obtained after DNB and STN are similar. This is essential to promote the use of DNB as a mandatory screening tool before performing STN. A few studies, with limited follow-up and numbers of patients, have been conducted to compare the effect of DNB and STN. In 7 patients, Buffenoir et al. showed a similar reduction in the triceps surae stretch reflex score and in the mean walking time during the 10-meter walking test after soleus DNB and one month after STN. In contrast, kinematic parameters (equinus and varus) and passive ankle dorsiflexion were improved after STN but not after DNB [20]. In two patients, Bleyenheuft et al. noted a similar near-normalization of elastic and viscous stiffness of ankle plantar flexor muscles after soleus DNB and seven months after STN [24]. In a series of 11 patients, Deltombe et al. showed that the triceps spasticity and equinovarus in swing and stance phase were similarly improved after DNB and one year after STN, suggesting the predictive value of DNB before STN in terms of improvement in spasticity and ankle kinematics parameters [13].

In this study, the decrease in triceps and tibialis posterior spasticity and the reduction in equinus and varus in swing and stance phase were similarly observed after DNB and two months and two years after STN. This confirms the results obtained in previous study with shorter follow-up [13,20]. No changes were observed in quadriceps or hamstring spasticity or in hip and knee flexion during gait. In this cohort, a distal treatment of the spasticity does not seem to have any proximal effect. DNB failed to predict the slight improvement in tibialis anterior muscle strength and gait speed that was observed two years after STN. We attribute this to the fact that improvement in these parameters requires a prolonged neurological rehabilitation program. This hypothesis is reinforced by the observation that tibialis anterior muscle strength was not improved two months after STN. As the proximal (quadriceps and hamstrings) spasticity stay unchanged all along the study, a proximal reduction of the spasticity consecutive to a distal treatment cannot explain the gait speed improvement observed.

BTXa injection can be used instead of DNB as a long-lasting block before performing STN. However, as the effect of BTXa is not immediate and occurs after several days or weeks, assessment will be delayed. Moreover, Rousseaux et al. showed that STN was more effective than BTXa injection to decrease spasticity [15].

Several studies have shown that the reduction in spasticity observed after soleus DNB and STN was correlated to the soleus

| Table 2 | Gait parameters (10 meters walking test) (means ± SD and median) before and after diagnostic nerve block (DNB) and two months and two years after selective tibial neurotomy (STN). |
|-------------------|-------------------|-------------------|-------------------|-------------------|
|                  | Baseline          | DNB              | STN 2 months      | STN 2 years       |
| Gait speed (m/s)  | 0.5 ± 0.3         | 0.6 ± 0.3        | 0.6 ± 0.3         | 0.7 ± 0.3         |
|                  | [0.5; 0.7]        | [0.5; 0.9]       | [0.6; 0.8]        | [0.7; 0.8]        |
|                  | *P = 0.001        | *P = 0.001       | *P = 0.001        | *P = 0.001        |

P values not shown are not significant.

* Significant difference versus pretreatment values.

~ Significant difference versus block values.

Table 3 | Kinematic parameters (video analysis) in swing (SwP) and stance (StP) phases (median) before and after diagnostic nerve block (DNB) and two months and two years after selective tibial neurotomy (STN). |
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<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>DNB</td>
<td>STN 2 months</td>
<td>STN 2 years</td>
</tr>
<tr>
<td></td>
<td>*P = 0.01</td>
<td>*P = 0.001</td>
<td>*P = 0.001</td>
<td>*P = 0.001</td>
</tr>
<tr>
<td>Equinus (StP)</td>
<td>−5 [−10;10]</td>
<td>−10 [−15;0]</td>
<td>−10 [−15;0]</td>
<td>−5 [−10;10]</td>
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<td></td>
<td>*P &lt; 0.001</td>
<td>*P &lt; 0.001</td>
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<td>*P &lt; 0.001</td>
<td>*P &lt; 0.001</td>
<td>*P &lt; 0.001</td>
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<tr>
<td>Varus (StP)</td>
<td>10 [0;20]</td>
<td>0 [−5;0]</td>
<td>0 [−5;0]</td>
<td>0 [−5;5]</td>
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<td></td>
<td>*P &lt; 0.001</td>
<td>*P &lt; 0.001</td>
<td>*P &lt; 0.001</td>
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P values not shown are not significant.

* Significant difference versus pretreatment values.

~ Significant difference versus block values.
Hmax/Mmax ratio, suggesting that local anaesthetics and neurotomy also affect the la fibres mediating the myotatic reflex and not only the α motor fibres mediating voluntary contraction [13,18,29]. Indeed, if DNB and STN affected α motor fibres only, Hmax and Mmax amplitudes should be similarly decreased and the Hmax/Mmax ratio should remain unchanged. The permanent reduction in spasticity observed after STN is due to the section of the afferent la fibres, and is correlated to a decrease in the Hmax/Mmax ratio. As the la fibres are not able to sprout and reconnect at the level of the spinal cord, the spasticity reduction is permanent. This phenomenon also explains the permanent disappearance of clonus after STN. Partial interruption of the γ efferent fibres also participates to the weakening of the hyperactive myotactic reflex arc. On the other hand, section of the α motor fibres during STN induces a transient decrease in triceps muscle strength correlated to a reduction in the motor unit number estimation (MUNE). Reduction in triceps strength was similar after DNB and two months after STN so that the effect of triceps muscle strength reduction on gait (talus in stance phase, lack of propulsion during toe-off phase of gait) can be predicted. Moreover, a collateral reinervation process occurs after STN, explaining a recovery in triceps muscle strength correlated to a return of the Mmax amplitude to baseline values after eight to 12 months [13,18]. Importantly, thanks to the persistent rehabilitation program including triceps stretching, STN does not induce muscular contractions or the passive ankle dorsiflexion stay unchanged before and two years after STN. As spasticity and equinovarus were reduced at a similar degree after DNB and STN, whereas the Hmax/Mmax ratio decreased more after STN than after DNB, Deltombe et al. suggested that a 50% section during STN may be enough to correct the SEF [13]. This hypothesis must however be confirmed by a prospective study.

DNB can be performed in an outpatient. It takes approximately 30 minutes to perform DNB and clinical assessment. The only equipment necessary is a needle for conduction-anaesthesia coupled to a portable electrical stimulator or to an EMG apparatus. The precise anatomical location of the motor nerve branches of the tibial nerve has been previously described using CT scanner and cadaver studies [21,30]. DNB is also a safe technique. Filippetti et al. reported five painful procedures and two haematomas in a study of 815 blocks [22]. Parziale et al. reported development of a compartment syndrome in the volar forearm after a median DNB performed under anticoagulant therapy [31]; anticoagulant therapy should, therefore, be discontinued before performing DNB. Finally, in a series of 110 tibial DNBS, Deltombe et al. reported one avulsion of the calcaneus at the insertion of the Achilles' tendon attributed to overstretching [32]. In our study, no serious adverse effect and, in particular, additional permanent sensory deficit and/or neuropathic pain were observed.

This study has several limitations. Firstly, the patient and the investigator were not blinded. Secondly, in six cases, STN was performed at the level of the motor nerve branch innervating the flexor hallucis longus without previous selective DNB on this branch. Thirdly, we used video as a gait kinematics analysis tool, but the reliability of this procedure in stroke patients has never been published. Finally, our study mainly focused on the body function and structure level (spasticity, strength, gait kinematics) of the International Classification of Functioning (ICF) and did not investigate activity and participation domains [33].

In conclusion, when performed at the same motor nerve branches, tibial DNB with anaesthetics and STN equally decrease triceps spasticity and correct equinovarus deformity. Therefore, using DNB prior to STN can be described as a valuable screening tool before STN. DNB helps us to determine the respective responsibility of several spastic muscles and of contracture in the deformity and to allow the patient to feel what could be achieved with STN. DNB fails to demonstrate the gait speed improvement observed two years after STN. STN is an effective and persistent treatment for SEF considered as an appropriate alternative to BTXa, which is the only treatment for SEF for which efficacy has been proved in a double blind randomized controlled trial versus placebo. Unfortunately, BTX is a reversible and costly treatment that has to be repeated in order to maintain functional benefit, supporting the need for a permanent surgical solution, such as STN.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

Financial disclosure statements have been obtained.

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