Journal of the Neurological Sciences 366 (2016) 158–163

Contents lists available at ScienceDirect

Journal of the Neurological Sciences

journal homepage: www.elsevier.com/locate/jns

Effects of tibial nerve neurotomy on posture and gait in stroke patients: A focus on patient-perceived benefits in daily life

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ARTICLE INFO

Article history:
Received 20 February 2016
Received in revised form 7 April 2016
Accepted 28 April 2016
Available online 07 May 2016

Keywords:
Spasticity
Gait
Posture
Stroke
Neurotomy
Equinovarus foot

ABSTRACT

Objective: To evaluate the objective and subjective functional effectiveness of tibial nerve neurotomy (TNN) in post-stroke spastic equinovarus foot (SEF).
Methods: In an open study, 23 hemiplegic patients were assessed immediately before TNN and then 5 months after TNN. The main outcome measure was the Lower Limb Function Assessment Scale (LL-FAS), which provided an ecologic assessment of impairments in standing and walking (i.e. kinematic abnormalities) and their impacts on activities of daily living. Patients were also assessed for global clinical impression of change, fear of falling, neuromotor impairments, spatiotemporal and video gait parameters and walking capacities.
Results: TNN had a very marked effect on the level of spasticity and the range of motion in dorsiflexion ($p < 10^{-3}$). These changes resulted in better foot positioning when standing and walking (particularly in stance), which was perceived very favorably by the patients. There was a clear, patient-perceived improvement in activities performed when standing and walking (LL-FAS ($p < 0.01$)), the global clinical impression of change ($p < 10^{-3}$) and the fear of falling ($p = 0.022$) that was not revealed by conventional, objective measurements (New Functional Ambulation Classification, Rivermead Mobility Index).
Conclusion: TNN is an effective treatment for post-stroke SEF; it is associated with a patient-reported improvement in standing and walking abilities during activities of daily living. Further research must now assess the long-term subjective efficacy of TNN.

1. Introduction

Spastic equinovarus foot (SEF) occurs in almost 18% of hemiplegic post-stroke patients [1]. The condition is mainly caused by spasticity and/or contracture of the triceps surae and tibialis posterior on the one hand, and weakness or imbalance of the tibialis anterior and peronei muscles on the other. When the patient stands or walks, SEF interferes with the foot's weight-bearing function during the stance phase; in turn, this causes instability and limits foot clearance during the swing phase. The deformity leads also to kinematic abnormalities in neighboring joints, and is involved in the genesis of knee recurvatum in the stance phase, and stiff-knee gait and limb circumduction in the swing phase [2–4]. Consequently, SEF can result in severe functional limitations (especially in activities of daily living performed in the upright position or when walking), activity limitations and restriction of participation.

When combined with physical therapy and orthotics, botulinum toxin (BT) injections are widely used to treat focal spasticity. Although BT is quite effective in relieving muscle spasticity, its functional impact is less evident - especially when the spasticity is severe [5–8]. Moreover, BT's effects are reversible, and so the injections must be repeated on a regular basis. Neuro-orthopedic surgery aims at avoiding these limitations. In particular, tibial nerve neurotomy (TNN) can be performed on the nerve branches leading to the gastrocnemius, soleus and/or tibialis posterior muscles. It has been demonstrated that TNN has a strong, long-lasting effect on the level of spasticity and thus improves ankle kinematics and most of the time gait speed in test situations [9–21]. However, the technique's impact on activities of daily living has not been extensively studied. Although Rousseaux et al. [14,15] observed a significant increase in gait capacities (as evaluated with the Functional Ambulation Classification (FAC) and the leg and trunk part of the Rivermead Motor Assessment), Bollens et al. [18] did not find any improvements in activities (using the ABILOCO questionnaire), participation or quality of life. However, functional improvement may

Abbreviations: BT, botulinum toxin; NFAC, New functional ambulation classification; GAIT, Gait Assessment and Intervention Tool; GAS, global assessment scale; LL-FAS, lower limb function assessment scale; MAS, modified Ashworth scale; MRC, Medical Research Council; RMI, Rivermead Mobility Index; SEF, spastic equinovarus foot; TNN, tibial nerve neurotomy.

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http://dx.doi.org/10.1016/j.jns.2016.04.055
0022-510X/

concern more subjective aspects as well as better performance in objective tests.

Hence, we performed a multilevel study of the effectiveness of TNN in hemiplegic stroke patients presenting with SEF. We notably compared a patient-reported (subjective) assessment of standing and walking activities with a clinical (objective) assessment of gait and posture.

2. Patients and methods

2.1. Patients

Post-stroke outpatients consulting in the Neurorehabilitation Unit at Lille University Medical Center (Lille, France) were prospectively included in an open study between July 2012 and May 2014. The main inclusion criterion was the presence of post-stroke SEF that was due (at least in part) to spasticity of the triceps surae and/or tibialis posterior, leading to impairments in posture and gait. All patients had to be aged 18 or over, with a time since stroke of 6 months or more. Patients who were unable to understand the study procedure (due to cognitive or psychiatric disorders) were excluded, as were patients with disabling aphasia (i.e. a Boston Diagnostic Aphasia Examination global severity score ≤ 4), those presenting with postural and walking disorders unrelated to stroke and those having received BT injections in the preceding 6 months.

In order to document the role of spasticity in SEF and its influence on upright standing and walking abilities, all patients had to show a significant improvement in both analytical parameters (spasticity, ankle range of motion) and posture/gait-related parameters after a tibial nerve block with lidocaine. In particular, patients who showed a fixed contracture of the triceps surae muscle were excluded. Both patient- and physician-reported functional assessments were taken into account. The nerve block was performed at the nerve trunk (behind the knee). The tibial nerve was detected using a block needle (Locoplex, 50 mm, Vygon, Ecouen, France) coupled to a stimulator (Stimuplex HNS12 SENSe, B Braun, Melsungen, Germany). Three ml of 2% lidocaine were injected. The nerve branches to be treated were chosen on the basis of the clinical examination and the results of the tibial nerve block.

The present study was performed in accordance with the tenets of the Declaration of Helsinki and was approved by the French National Data Protection Authority (CNIL). In accordance with French legislation, approval by an investigational review board was not required for this non-interventional study. Patients gave their written informed consent to participation prior to inclusion in the study.

2.2. Treatment

In all cases, TNN had been recommended during a multidisciplinary team meeting that included physical and rehabilitation medicine physicians, orthopedic surgeons and a neuro-surgeon. This consultation allowed us to select the neurotomy targets, agree on formal treatment goals with the patient and to obtain his/her informed consent.

TNN was carried out according to a previously described technique, under general anesthesia [20,21]. The patient was placed in the prone position. A vertical skin incision was made in the upper part of calf. The motor branches of the tibial nerve innervating the soleus, the gastrocnemius (medial and lateral heads) and (when necessary) the tibialis posterior were then dissected. Selective fascicular neurostimulation was used to identify motor branches and avoid sensory branches. The selected nerve branches were resected over a distance of 1 cm in a sufficient amount to result in a marked decrease in the motor response after perioperative neurostimulation (generally between three and four fifths of the motor branch was resected). Spasticity level and results of the nerve block did not influence the amount of resection. Immobilization was not implemented and patients were allowed to walk the day after surgery. The patients were then referred to a rehabilitation center for a 4- to 6-week outpatient rehabilitation program that included triceps stretches, muscle strengthening, and gait and posture training.

2.3. Assessments

Patients were evaluated by two experienced, unblinded and trained investigators (CLB and EA, who were not members of the surgical team) before TNN and then 5 months after TNN. Assessments addressed the “impairment” and the “activity” levels of the International Classification of Functioning.

The range of motion during passive ankle dorsiflexion was assessed goniometrically in the supine position, with the knee extended and the knee flexed. Spasticity of the triceps surae, tibialis posterior, quadriceps and hamstring muscles was measured using the modified Ashworth scale (MAS) [22]. We also rated the muscle strength of the plantar flexors and plantar dorsiflexors, using the Medical Research Council (MRC) classification (0 to 5).

Gait kinematics were assessed with an orthogonal, two-dimensional video recording system and the Gait Assessment and Intervention Tool (GAIT) [23]. The latter has been validated in stroke patients and enables a kinematic evaluation of all components of the paretic lower limb in both phases of the gait cycle. Spatiotemporal gait parameters were evaluated using an 8-meter GAITRite® mat (CIR Systems Inc., Sparta, NJ, USA). Two trials (each over a total distance of 10 m, i.e. starting about a meter before the mat and finishing about a meter afterwards) were performed at a comfortable speed and then averaged. Likewise, two trials were performed at maximum speed and then averaged. Resting periods between trials were allowed when necessary. We took into account gait speed and cadence, non-paretic and paretic step lengths, gait asymmetry (as defined by Patterson et al.: non-paretic step length/paretic step length) [24], and paretic swing, total stance and single support phase durations (as a percentage of the gait cycle). These two objective gait measurements were performed bare-feet, and assistive device was authorized when needed.

We then used a force platform (FDM-System, Zebris Medical GmbH, Germany) to measure paretic plantar foot pressure (i.e. the weight bearing on the paretic limb as a percentage of body mass, and the weight placed on the heel relative to the forefoot) and the center of pressure (COP) trajectory. Patients were instructed to stand upright on the platform (barefoot, with their eyes open) and move as little as possible.

The Lower Limb Function Assessment Scale (LL-FAS) is a newly developed tool for evaluating posture and gait [25]. It can address the patient's perception (in a 30-item questionnaire) and/or the examiner's perception (in a practical test using the same 30 items) of impairments in upright stance and walking (i.e. kinematic abnormalities) and the latter's impact on activities of daily living in an ecological point of view. Items are divided into two parts: standing (9 items) and walking (21 items). In each part, the initial items explore kinematic parameters in a proximal-to-distal order (trunk, hip, knee, heel, and then foot); the remaining items explore the patient's ability to perform activities when standing (5 items) or walking (7 items). Items are presented in order of increasing difficulty (i.e. starting with unconstrained activities, such as walking indoors, and moving on to more difficult activities, such as walking outdoors and climbing stairs). In stroke patients, the LL-FAS displayed a fair degree of psychometric validity (especially when compared with functional assessments and gait assessments) and good reliability [25]. In the present study, only the LL-FAS questionnaire (i.e. the patient's point of view) was considered because two other objective gait assessments were performed.

Gait capacities were assessed objectively by applying the New Functional Ambulation Classification (NFAC) [26]; this modified version of the Functional Ambulation Classification (FAC) is validated in French in hemiplegic patients and more precise in terms of the patient's ability to climb stairs unaided and thus limits the FAC's known ceiling effect. We also measured the Rivermead Mobility Index (RMI), a 15-item questionnaire that explores overall aspects of transfers and gait (from