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REVIEW ARTICLE

EFFECTS OF SELECTIVE TIBIAL NERVE NEUROTOMY AS A TREATMENT FOR ADULTS PRESENTING WITH SPASTIC EQUINOVARUS FOOT: A SYSTEMATIC REVIEW

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Objective: **Spastic equinovarus foot is a major cause of disability for neurorehabilitation patients, impairing their daily activities, social participation and general quality of life. Selective tibial nerve neurotomy is a neurosurgical treatment for focal spasticity, whose acceptance as treatment for spastic equinovarus foot remains controversial. We performed a systematic review of the literature to assess the efficacy of tibial nerve neurotomy as a treatment for adult patients presenting with spastic equinovarus foot.**

Methods: **We queried PubMed, Science Direct, Trip Database and PEDro databases with the following keywords: "equinus deformity" OR "muscle spasticity" AND "neurotomy."**

Results: **We selected a total of 11 non-randomized and uncontrolled studies, suggesting that neurotomy could be an efficient treatment to reduce impairments in spastic equinovarus foot patients.**

Discussion: **Our conclusions are based primarily on case series studies. The effects of tibial nerve neurotomy had not been compared with a reference treatment through a randomized controlled trial, which would be necessary to increase the level of scientific evidence. Moreover, further studies using quantitative, validated and objective assessment tools are required to evaluate the efficacy of tibial nerve neurotomy accurately based on the International Classification of Functioning, Disability and Health from the World Health Organization.**

Key words: equinus deformity; muscle spasticity; neurotomy; adult.

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INTRODUCTION

Spastic equinovarus foot (SEF) includes equinus, varus and claw toe deformities. It constitutes a common disability for neurorehabilitation patients presenting with central nervous system disorders, such as stroke patients (estimated incidence of 18%) (1). SEF is primarily due to muscle overactivity of the calf muscles (triceps surae, tibialis posterior, flexor hallucis longus, flexor digitorum longus and brevis muscles), or weakness of the antagonist muscles (tibialis anterior, peroneus longus and brevis muscles), and is often complicated by muscle contracture.

Patients with SEF usually walk slowly, and frequently require supporting devices such as orthoses or crutches, which impairs their daily activities, social participation and general quality of life. When SEF clearly restricts the patient's daily abilities, various symptomatic treatments can be proposed together with the rehabilitation programme.

Oral or intrathecal medications are largely used to reduce diffuse spasticity (2). However, they are poorly effective for focal spasticity and often lead to adverse effects. Thus, these medications are not recommended for isolated SEF. In the case of focal spasticity, localized treatments should be used instead. Orthoses, chemodenervation (botulinum toxin, alcohol or phenol injections) and surgery (neurotomy, tendon lengthening and/or transfer) constitute good alternatives. Botulinum toxin injections were found to be an effective SEF treatment, based on two randomized, double-blind, placebo-controlled studies that assessed their effects on adult SEF patients (3, 4). One randomized, double-blind trial had also compared the effects of tibial nerve block with phenol to those of botulinum toxin injections into the triceps surae muscle (5). Both treatments rapidly reduce muscle spasticity, but also frequently lead to muscle weakening. They are reversible and have to be repeated frequently.

Tibial nerve neurotomy (TNN) is another treatment option for SEF. This surgical technique consists of a partial and selective section of the motor nerve branches that innervate spastic muscles. On one hand, sectioning of the afferent Ia and Ib fibres that lead to the spinal cord induces an immediate decrease in the myotatic reflex gain. On the other hand, sectioning of the efferent a fibres also results in extensive denervation of the corresponding muscle. However, motor reinnervation by collateral sprouting of residual axons occurs in the next months, leading to a widening of persisting motor units, and therefore to a recovery of pre-operative muscle strength. Conversely, fusorial reinnervation is anarchic and inefficient, allowing a permanent release of spasticity (6, 7).

Neurotomy was introduced in 1887 by Lorenz (8) for the treatment of hip adduction spasticity by sectioning the obturator nerve, and was first applied in 1912 by Stoffel (9) to the tibial nerve to treat SEF. Nevertheless, this surgical intervention was rapidly abandoned in favour of oral medications and chemodenervation because of the resulting adverse effects from surgery. Indeed, despite the introduction of intraoperative faradic stimulation to distinguish motor and sensitive nerves, neurotomy remained poorly selective and often resulted in sensory disorders and neuropathic pain. Gros et al. (10) renewed interest in neurotomy in the 1970s, when they were able to perform partial and fully selective section of the motor nerve branches by improving intraoperative electrical stimulation and using an operating microscope.

Although TNN is widely used in daily clinical practice by several European rehabilitation centres, its acceptance as treatment for SEF remains controversial. On one hand, based on promising results from several case series studies (6, 7, 11–19), TNN can be considered as a safe and effective SEF treatment. Because this technique is invasive and irreversible, it should be required only when other more conservative treatments, such as physiotherapy or orthoses, fail, and when SEF significantly limits the patient's routine activities and social participation. However, it should also be performed before the development of musculo-tendinous contractures, which requires additional orthopaedic surgery (20). On the other hand, some authors have described cases of equinovarus recurrence after TNN, challenging the long-term efficacy of neurotomy as an SEF treatment. (21). Based on those elements, we performed a systematic review of the existing literature to assess the efficacy of TNN in treating adult patients presenting with SEF.

METHODS

We searched PubMed, Science Direct, Trip Database and PEDro databases using the following 3 keywords: "equinus deformity" OR "muscle spasticity" AND "neurotomy". Articles were first selected based on titles and abstracts, and a second screening was conducted after reading selected papers. Bibliographic references of articles were also inspected to include additional studies in this review.

The following inclusion criteria were applied:

- full papers published after 1985 in peer-reviewed journals (case reports were excluded);
- papers written in English, German or French;
- study populations consisting primarily of adult patients;
- clearly defined experimental protocols (descriptive articles were excluded);
- studies assessing the efficacy of tibial nerve neurotomy applied exclusively (with no additional neurosurgical or orthopaedic treatments).

When multiple papers were published by the same group, the one with the most patients was selected. If the number of subjects was the same, only the most recent study was included.

Due to the lack of randomized controlled trials, meta-analyses were not possible, and the use of reference reading grids was not applicable. Articles were analysed following the International Classification of Functioning, Disability and Health (ICF) from the World Health Organization (WHO) (available from: www.who.int/icidh, 2001), which describes how a disease can influence body structure and function, activity and participation. This model also serves as the framework for Physical and Rehabilitation Medicine.

RESULTS

Of 56 articles found in the various databases, 31 were excluded immediately based on titles and abstracts and 14 did not meet the inclusion criteria after reading of the entire paper. No supplementary article was added after inspection of the different bibliographic references. In total, 11 studies were included in our systematic review.

The methodological characteristics of the selected articles are presented in Table I, which highlights two major limitations. First, all the papers described uncontrolled and unblinded case series studies, while only one was multicentre (15). Secondly, inclusion criteria were poorly defined among the papers and the aetiology of SEF in patients was variable.

The assessment methods of the 11 studies and their main outcomes are presented in Table II following the ICF framework. Impairments were largely assessed, and considered as the primary outcome in all the studies. However, many assessment tools were qualitative, unvalidated and even designed by the authors of the study. Activity limitations were evaluated in only two papers (16, 18), while participation restriction and quality of life were not addressed at all.

All the selected studies showed an effect of TNN on patient impairments. Muscle tone was clinically reduced in all cases. However, one study highlighted a resurgence of ankle clonus with knee flexed in 1 of 7 patients and a recurrence of an exaggerated ankle stretch reflex with knee extended in 3 other cases (13), while another described a discrete increase of resistance to passive movement in 8 patients (18). A significant decrease of the myotatic reflex was also observed by electrophysiology. Indeed, a reduction of the excitable fraction of the spinal cord motoneurons pool that participates in the myotatic reflex, measured by the ratio of the maximum amplitude of the H reflex response over the maximum amplitude of the motor response, was noted in 3 studies (7, 12, 13). In 10 studies, TNN also increased passive range of motion in dorsal flexion, but this improvement was no longer statistically significant at the end of the follow-up (2 years) in 1 study (19). TNN improved voluntary motricity of the foot in dorsal flexion (i.e. muscular strength, active range of motion or quality of movement) in 6 studies (11–13, 16, 18, 19). Finally, it was reported to reduce pain or cutaneous lesions when present, and improved foot position (11, 13, 16–18) or balance (15, 18) during standing in 6 studies.

Muscle weakening was noted in 5 studies during the weeks following TNN (7, 12, 16, 18, 19), which was directly due to muscle denervation. However, patients rarely complained about this loss of strength during gait, as other calf muscles were able to compensate (22) and motor reinnervation developed within a few months to restore function (7, 13, 16, 18, 19). However, there remains some controversy over the delay of reinnervation. By electrophysiology, Roujeau et al. (13) had already reported a return of the motor response values to baseline after 8 months,

Table I. *Methodological characteristics of the different selected articles*

		Patients				
Authors	Study design	Number	Age, years Mean [Min–Max]	Aetiology of SEF	Delay after incident, months Mean [Min–Max]	Follow-up after treatment, months Mean [Min–Max]
Sindou et al. (1988) Neurosurgery (11)	Case series; uncontrolled; retrospective; unicentre; unblinded	53 (62 TNN)	36 [6–68]	41 cerebral lesions, 12 SCI	48 [24–204]	36 [15–120]
Fève et al. (1997) J Neurol Neurosurg Psychiatry (12)	Case series; uncontrolled; prospective; unicentre; unblinded	12 (12 TNN)	35.8 [6–70]	6 strokes, 5 TBI, 1 SCI	52.7 [18–96]	4.9 [1–12]
Decq et al. (2000) Neurosurgery (6)	Case series; uncontrolled; prospective; unicentre; unblinded	46 (46 TNN)	36 [8–79]	18 strokes, 15 TBI, 8 Little diseases, 5 MS	96	15 [8–28]
Roujeau et al. (2003) J Neurol Neurosurg Psychiatry (13)	Case series; uncontrolled; prospective; unicentre; unblinded	6 (7 TNN)	28 [SD: 13]	1 stroke, 2 TBI, 1 prematurity, 1 Strumpell-Lorrain, 1 Arnold-Chiari	67 [8–144]	29 [10–48]
Caillet et al. (2003) Ann Readapt Med Phys (14)	Case series; uncontrolled; prospective; unicentre; unblinded	9 (9 TNN)	47 [25–69]	9 strokes	78 [36–180]	6 [constant]
Buffenoir et al. (2004) Neurosurgery (15)	Case series; uncontrolled; prospective; multicentre; unblinded	55 (57 TNN)	43.5 [12–74]	34 strokes, 8 TBI, 7 SCI, 4 CP, 2 others	64 [3–320]	10 [4–22]
Deltombe et al. (2008) Clin Neurphysiol (7)	Case series; uncontrolled; prospective; unicentre; unblinded	11 (11 TNN)	51 [38–57]	10 strokes, 1 TBI	Not specified	12 [constant]
Rousseaux et al. (2008) Eur J Neurol (16)	Case series; uncontrolled; prospective; unicentre; unblinded	34 (34 TNN)	50.4 [20–80]	34 strokes	44.9 [7–293]	12 [constant]
Buffenoir et al. (2008) Am J Phys Med Rehabil (17)	Case series; uncontrolled; prospective; unicentre; unblinded	7 (7 TNN)	41 [19–71]	4 strokes, 2 TBI, 1 CP	37 [10–45]	1 [constant]
Rousseaux et al. (2009) J Neurol Sci (18)	Case series; uncontrolled; prospective; unicentre; unblinded	51 (51 TNN)	51.1 [20–80]	51 strokes	44.3 [11–304]	24 [constant]
Deltombe el al. (2010) Arch Phys Med Rehabil (19)	Case series; uncontrolled; prospective; unicentre; unblinded	30 (30 TNN)	45 [20–69]	25 strokes, 5 TBI	48 [15–218]	24 [constant]

SEF: spastic equinovarus foot; TNN: tibial nerve neurotomy; SD: standard deviation; SCI: spinal cord injury; TBI: traumatic brain injury; MS: multiple sclerosis; CP: cerebral palsy.

while Deltombe et al. (7) only noted an improvement, but still remaining non-significant, after 1 year.

The outcomes listed in Table III suggest that TNN does improve gait in patients. Walking was evaluated subjectively, either through clinical observation or video recordings in 9 studies, and was assessed quantitatively by instrumented gait analysis in only 2 studies (14, 17). Equinus and varus deformities were reduced, rather during the stance phase, in the 9 studies assessing kinematic parameters. Conversely, spatio-temporal gait parameters (stride or step length, cadence and relative duration of stance and swing phases) were not much modified. Finally, 9 studies reported variable effects on knee recurvatum and gait speed. Four studies reported increased walking velocity, but 5 reported no change; genu recurvatum was reduced in 5 studies and unchanged in 4 others.

Parameters such as gait speed and walking balance were sometimes previously considered as activities. However, we felt that these parameters were more accurately defined as a part of the body structures and functions domain and were thus considered as such in our analysis. Rousseaux et al. (16) were the only group to assess the efficacy of TNN on activities using validated assessment scales: the Functional Ambulation Categories and the leg and trunk subscale of the Rivermead Motor Assessment (16, 18). Their presentation of mean results with those ordinal scales remains questionable, but after 2 years of follow-up, they showed a significant improvement on both scales (18). In the 2 papers, patients also had to self-evaluate their evolution in daily life (on a scale from –4 for very marked worsening to +4 for very marked improvement). All the selected items (lower limb position, forward propulsion of the affected limb, and balance during transfers, standing and gait) were significantly improved after treatment, but were not categorized as activities in this review.

Finally, achievement of predefined goals was assessed in 3 studies (6, 15, 17). Pre-operative objectives primarily concerning walking ability were reported to be achieved more than 90% of

Table II. *Assessment of tibial nerve neurotomy efficacy following International Classificaton of Functioning, Disability and Health in the different selected articles*

	Body structures and functions										
			Voluntary motricity								
Authors	Muscle tone	Passive ROM	Dorsal flexors	Plantar flexors	Electro-physiology	Pain	Cutaneous lesions	Standing	Gait	Activities	Participation and Quality of life
Sindou & Mertens (1988) (11)	AS ↑	↑	Lovett score ↑	NT	NT	QA ↑	NT	QA ↑	QA	NT	NT
Fève et al. (1997) (12)	SRS ↑	Ø	Active ROM ↑	MRC ↓	Hm/Mm ↑*; Mm ↓*	NT	NT	NT	Video	NT	NT
Decq et al. (2000) (6)	MAS ↑; SRS ↑	↑	NT	NT	NT	NT	NT	NT	Video	NT	NT
Roujeau et al. (2003) (13)	SRS ↑	Ø	QA ↑	NT	Hm/Mm ↑*; Mm ↓*	NT	NT	QA ↑	QA	NT	NT
Caillet et al. (2003) (14)	MAS ↑	↑	QA Ø	NT	NT	QA ↑	QA ↑	NT	Instrumented gait analysis	NT	NT
Buffenoir et al. (2004) (15)	SRS ↑*	↑*	QA Ø	NT	NT	NT	QA ↑	QA ↑*	QA	NT	NT
Deltombe et al. (2008) (7)	AS ↑*	↑*	NT	MRC ↓*	Hm/Mm ↑*; Mm ↓*	NT	NT	NT	Video	NT	NT
Rousseaux et al. (2008) (16)	MAS ↑*; SRS ↑*	↑*	MRC ↑*	MRC ↓*	NT	NT	NT	QA ↑*	QA	FAC ↑*; RMA ↑*	NT
Buffenoir et al. (2008) (17)	SRS ↑*	↑*	QA Ø	NT	NT	NT	NT	QA ↑*	Instrumented gait analysis	NT	NT
Rousseaux et al. (2009) (18)	MAS ↑*	↑*	MRC ↑*; active ROM ↑*	MRC ↓*; active ROM ↓*	NT	NT	NT	QA ↑*	QA	FAC ↑*; RMA ↑*	NT
Deltombe & Gustin (2010) (19)	AS ↑*	↑*	MRC ↑*	MRC ↓*	NT	NT	NT	NT	Video	NT	NT

↑*: statistically significant improvement; ↓*: statistically significant deterioration.
↑: improvement for more than 50% of the patients, in absence of statistical analysis; ↓: deterioration for more than 50% of the patients, in absence of statistical analysis.
Ø: no statistical difference, or modification for less than 50% of the patients in absence of statistical analysis.
ROM: range of motion; AS: Ashworth Scale; MAS: Modified Ashworth Scale; SRS: Stretch Reflex Scale; NT: not tested; QA: Qualitative assessment; MRC: Medical Research Council; Hm: maximum amplitude of H reflex; Mm: maximum amplitude of motor response; FAC: Functional Ambulation Categories; RMA: Rivermead Motor Assessment.

Table III. *Effects of tibial nerve neurotomy on gait in the different selected articles*

		Foot position					
Authors	Assessment methods	Stance	Swing	Knee recurvatum in stance	Walking speed	Spatio-temporal parameters	Others
Sindou & Mertens (1988) (11)	QA	↑	NT	NT	NT	NT	NT
Fève et al. (1997) (12)	Video	NT	NT	NT	Ø	Ø	NT
Decq et al. (2000) (6)	Video	↑*	Ø	↑	Ø	Ø	NT
Roujeau et al. (2003) (13)	QA	↑	NT	Ø	NT	NT	NT
Caillet et al. (2003) (14)	Instrumented gait analysis	↑	Ø	↑	Ø	Ø	Gait discomfort (VAS) ↑*; gait difficulty ↑
Buffenoir et al. (2004) (15)	QA	NT	NT	↑*	↑*	NT	Walking time and distance ↑*; gait ability ↑*
Deltombe et al. (2008) (7)	Video	↑*	Ø	Ø	Ø	Ø	NT
Rousseaux et al. (2008) (16)	QA	↑*	NT	↑*	↑*	Ø	Gait balance ↑*
Buffenoir et al. (2008) (17)	Instrumented gait analysis	↑*	↑*	Ø	↑*	↑*	Walking distance Ø
Rousseaux et al. (2009) (18)	QA	↑*	NT	↑*	Ø	Ø	Gait balance ↑*
Deltombe & Gustin (2010) (19)	Video	↑*	↑*	Ø	↑*	Ø	NT

↑*: statistically significant improvement; ↓*: statistically significant deterioration.
↑: improvement for more than 50% of the patients, in absence of statistical analysis; ↓: deterioration for more than 50% of the patients, in absence of statistical analysis.
Ø: no statistical difference, or modification for less than 50% of the patients in absence of statistical analysis.
QA: qualitative assessment; NT: not tested; VAS: visual analogue scale.

the time. However, goal attainment could not be classified by one of the ICF domains and was thus not included in Table II.

DISCUSSION

As selective tibial nerve neurotomy is increasingly used to treat spastic equinovarus foot, we chose to take a systematic review of the current literature. In 2006, Collado et al. (21) had performed a similar assessment, but the aim of their review was to illustrate 4 clinical cases that suggested the possible reappearance of equinus deformity within a few months after TNN. In 2007, Deltombe et al. (20) had presented a general overview of various SEF treatments for stroke patients, but did not focus on the efficacy of TNN. As both articles date to several years ago, an updated review of the literature following the ICF framework was of interest. We highlight that 5 of the 11 articles included in our systematic review were published after 2007.

First, our results suggest that TNN is an efficient treatment for SEF impairments. However, this observation is based only on case series studies (designated level III or level II-3 according to the Preventive Services Task Force). Of the 11 studies, only 1 reported on the comparative effects of botulinum toxin injection and TNN applied successively to a population of stroke patients (16). However, botulinum toxin could not be strictly considered as a control treatment in that study, as the affected spastic muscles concerned by both consecutive treatments were different in some patients.

Randomized controlled trials are sometimes difficult to perform in neurorehabilitation patients, but they are required to demonstrate the efficacy of a treatment with a high level of proof. They remain feasible even when the treatment is individually adapted to each patient or requires an invasive intervention (23). In the case of TNN, a reference treatment of focal spasticity should be used as control, and the investigator should at least be blinded in order to prevent bias (24). Moreover, the design of clinical studies assessing the efficacy of TNN as an SEF treatment could be improved in future investigations. Impairments should also be assessed using quantitative, validated and objective tools. For example, resistance to passive sinusoidal displacement imposed to the ankle joint can be measured quantitatively to assess reduction in muscle stiffness after TNN, as described by Bleyenheuft et al. (25). Similarly, instrumented gait analysis should be regarded as the gold standard in clinical research studies, although it was only used in 2 of the 11 studies selected in this review (14, 17). Finally, the effects of TNN should also be evaluated in more detail according to all the predefined ICF domains. Activity, social participation and quality of life can, for instance, be assessed using validated questionnaires (26).

Secondly, we found that TNN might be a safe and long-lasting treatment for calf muscles spasticity. However, the efficiency of this treatment depends highly on adequate selection of patients, thoroughness of pre-operative evaluations, determination of the spastic muscles involved in the SEF deformity and precision of the surgical procedure performed. Due to the inescapable motor denervation following TNN and the potential risk of consecutive musculo-tendinous shortening, a specific rehabilitation programme adapted to each patient (including intensive daily stretching of the triceps surae for at least 2 years) is also recommended after surgery (19, 27). However, due to the lack of well-conducted studies with really long-term follow-up, this risk of post-operative contracture must still be taken into consideration, and each patient should be informed prior to intervention.

Despite the precarious health status of some SEF patients, general complications have never been reported. Adverse effects such as healing delay had been described previously in several studies (11, 15), but they were exceptional (less than 10% in both papers) and are in fact common to all peripheral surgeries (22). Largely depending on the surgeon's expertise, sensory disorders were absent in 6 studies, and rare in 3 others (11, 14, 15). In only 2 studies, they concerned a majority of the patients (16, 18). In both papers, neuropathic pain, dysesthesia or hypoesthesia appeared almost exclusively when the patient was operated for tibialis posterior or flexor digitorum longus spasticity, due to excessive manipulation of sensory fascicles in the tibial nerve trunk. Fortunately, these complications were often discrete, temporary or treatable with medication.

Several authors reported cases of equinovarus deformity persistence or recurrence a few months after TNN treatment (11, 21). Others described an increase of resistance to passive ankle dorsal flexion (13, 18, 19). However, a constant decrease of the myotatic reflex gain was measured by electrophysiology after 1 and 2 years (7, 13), suggesting a permanent release of spasticity after neurotomy. Musculo-tendinous shortening is probably the main explanation for those casual SEF resurgences (6, 11, 18, 27). This hypothesis is confirmed in one paper by the failure of lidocaine hyperselective motor nerve blocks of the triceps surae in cases of SEF recurrence (18). Musculo-tendinous shortening may be a consequence of motor denervation caused by TNN (21). However, even if the clinical link between muscle denervation and muscle shortening (in peripheral neuropathy for instance) is evoked, there have been no publications to support this hypothesis.

Finally, to avoid the recurrence of deformity, the patient selection is crucial and must always result from a multidisciplinary assessment. Pre-operative muscle contracture should be considered as a relative contra-indication to TNN (27), and neurotomy has also to be avoided in the case of dystonic movement patterns, that are unrelated to an increase of the stretch reflex. Several studies included non-walking patients with bilateral SEF (11, 13, 15), while others even mixed adult patients with children (6, 11–13, 15). However, the long-term efficacy of TNN is probably dramatically different in hemiplegic walking patients who constantly stretch their calf muscles during gait, than in paraplegic patients permanently moving in a wheelchair. Similarly, children with growth potential present a higher risk of muscle shortening than do adults (20, 28).

TNN treatment must always result from conscientious assessments and thoroughly reviewed clinical examinations. Since motor nerve block with lidocaine predicts whether functional improvement will be seen after TNN treatment (7, 17), this test should also be systematically performed prior to surgery. Moreover, by determining the degree of Achilles tendon shortening and the strength of antagonist muscles, it further confirms the indication of neurotomy and the need for a possible combined orthopaedic surgery. Finally, motor nerve block allows identifying the respective contribution of the different spastic muscles to the foot deformity and indicates to the surgeon the tibial nerve collaterals that need to be sectioned.

The percentage of motor nerve that should be sectioned during TNN has not been defined precisely. It is currently based on the personal expertise of the medical team and constrained either by the fear of undertreating spasticity (if the section is insufficient) (11, 13) or inducing excessive muscle weakness or talus/valgus deformation (if the section is too large) (14, 16, 18). Among the 11 selected papers in this review, the section percentage was quite variable, ranging from 50% to 90% of the motor nerve. Based on electrophysiological observations, Deltombe had suggested that a section of about half the fibres would be sufficient to completely release spasticity without causing excessive muscle weakness (20), although this hypothesis requires further validation.

In conclusion, this systematic review suggests that TNN may be a safe and efficient treatment for patients presenting with SEF. Efficiency of this surgical procedure depends highly on good selection of patients, thoroughness of the pre-operative assessment, identification of the different spastic muscles involved in the SEF deformity and precision of the surgery. However, our conclusions are based primarily on case series studies, since TNN has not been compared with a reference treatment through a randomized controlled trial. Further studies using quantitative, validated and objective assessment tools are expected to evaluate the efficiency of TNN according to the ICF framework with a higher level of scientific evidence.

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