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EFFECT OF THE NEURO-ORTHOPAEDIC SURGERY FOR SPASTIC EQUINOVARUS FOOT AFTER STROKE

A PROSPECTIVE LONGITUDINAL STUDY BASED ON A GOAL-CENTERED APPROACH

Thierry DELTOMBE*, Maxime GILLIAUX, François PERET, Mie LEEUWERCK, Delphine WAUTIER, Philippe HANSON, Thierry GUSTIN.

Short title: Spastic foot surgery among stroke patient

*Corresponding author: Thierry Deltombe Departments of Physical Medicine and Rehabilitation CHU UCL Namur (Université catholique de Louvain) site Mont-Godinne, B-5530 Yvoir, Belgium. E-mail: thierry.deltombe@uclouvain.be

ABSTRACT

Background: neuro-orthopaedic surgery is recognized as an effective treatment to improve walking capacity in case of spastic equinovarus foot. However, the effect of surgery on the 3 domains of the International Classification of Functioning, Disability and Health (ICF) has never been studied.

Aim: to assess the efficacy of the neuro-orthopaedic surgery for spastic equinovarus foot after stroke based on a goal-centered approach and on the 3 domains of the International Classification of Functioning, Disability and Health (ICF).

Design: prospective, single blind, case-series, intervention study (before-after trial) with a 1-year follow-up.

Population: eighteen hemiplegic patients with spastic equinovarus foot.

Methods: A selective tibial neurotomy and/or an Achille tendon lengthening and/or a tibialis anterior tendon transfer were performed to correct a disabling SEF. The primary outcome measure was the goal attainment scale. The secondary outcome measures included body function and structure (spasticity, strength, range of motion, pain, gait speed, ankle kinematics), activities (walking aids, functional ambulation category, functional walking category, ABILOCO) and social participation and quality of life (Satispart-Stroke, SF-36) assessment before and 2 months and 1 year after surgery.

Results: an increase in the goal attainment scale score, in the body function and activity/participation domains of the ICF, a decrease in triceps spasticity and pain, an increase in ankle range of motion and gait speed, an improvement in equinus and a reduction in walking aids were observed.

Conclusion: this study confirms the efficacy of the neuro-orthopaedic surgical treatment of spastic equinovarus foot after stroke to improve walking capacities and to achieve personal goals in the body function and activity/participation domains of the ICF.

Clinical Trial: NCT01265238

Key words: hemiplegia, muscle spasticity, neurotomy, tendon lengthening

(List of abbreviations: ICF (International Classification of Functioning, Disability and Health), SEF (spastic equinovarus foot), AFO (ankle foot orthosis), BoNT-A (botulinum toxin type A), STN (selective tibial neurotomy), SPLATT (split anterior tibial tendon transfer), GAS (goal attainment scale), SIAS (stroke impairment assessment set), MAS (Modified Ashworth scale), TS (Tardieu scale), ROM (range of motion), 10MWT (10 meters walking test), VAS (visual analogic scale), FWC (functional walking category), FAC (functional ambulatory classification).

INTRODUCTION

Spastic equinovarus foot (SEF) is a common deformity among hemiplegic patients, with an incidence estimated at 18% (1). SEF contributes to poor locomotor performance after stroke (2). The deformity is mainly caused by the spasticity and/or contracture of the ankle flexor muscles (soleus and/or gastrocnemius), of the foot invertor (tibialis posterior) and of the toes flexors (flexor hallucis and flexor digitorum longus and brevis) muscles, sometimes associated with weakness and/or imbalance of the peroneus and tibialis anterior muscles. Patients frequently need ankle-foot orthosis (AFO) and/or a crutch for walking. The first line treatment of SEF includes physical therapy, orthosis and orthopaedic footwear, functional electrical stimulation, chemical neurolysis with phenol or alcohol and botulinum toxin type A (BoNT-A) injections (3). When reversible treatments fail to correct SEF deformity, permanent surgical treatments such as selective tibial neurotomy (STN), tendon lengthening and tendon transfer are recommended (4,5,6). A recent systematic review supported that the surgical correction of equinovarus foot deformity was a safe and effective procedure in terms of re-obtaining a balanced foot position, improving walking capacity and diminishing the need for orthotic use (5). However, in this review, STN was not mentioned.

STN is a neurosurgical procedure that consists in a partial section of the motor nerve branches innervating the spastic muscles, resulting in a permanent reduction of the spasticity. A recent RCT has demonstrated that STN is an effective treatment of the SEF after stroke (7). Tendon lengthening (Achilles, tibialis posterior and/or toe flexors) and split anterior tibial tendon transfer (SPLATT) are well known surgical techniques leading to a better ankle kinematic and AFO discontinuation (8). However, no prospective study evaluated the efficacy of combined STN and tendon surgery in the treatment of the SEF nor used a personal goal-centered approach. Only Bollens et al used the International Classification of Functioning, Disability and Health (ICF) model (9) in a study comparing STN and BoNT-A (7).

The aim of this study was to prospectively evaluate the effects of a neuro-orthopaedic surgery as a treatment of the SEF after stroke by using a goal-centered approach and the ICF model. Our hypothesis was that neuro-orthopaedic surgery can achieve concrete goal discussed with the patient before surgery in the different domains of the ICF classification.

MATERIAL AND METHODS

All participants gave written consent and the study protocol was approved by the institutional Ethic Committee. The trial was registered at ClinicalTrial.gov N° NCT01265238.

Patient selection

Adults with spastic equinovarus following stroke were recruited by an interdisciplinary spasticity group of a university hospital over the period the period March 2012 – April 2015. Inclusion criteria were a stroke history of more than 6 months, the presence of a disabling SEF resistant to a medical treatment, the ability to walk 10 meters with AFO and/or crutch if necessary and completion of a diagnostic tibial motor nerve branches block with anaesthetics. Exclusion criteria were a previous history of neuro-orthopaedic surgery, phenol denervation or BoNT-Ainjection in the past 6 months.

Surgery

Based on the clinical characteristics and the diagnostic tibial motor nerve branches block with anesthetics assessment, a surgical program was planned after an interdisciplinary discussion by several specialists (PRM specialist, neurosurgeon and orthopaedic surgeon) according to published guidance (4): STN in case of spasticity, Achilles tendon lengthening in case of contracture and SPLATT in case of imbalance between tibialis anterior and peroneus muscles. A tibialis anterior activation in the swing phase of gait is necessary to propose a SPLATT procedure. These treatments can be associated.

STN was performed under general anaesthesia without muscle relaxant drugs 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 knee fold. 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 5mm length under the microscope. The extent of the nerve section was determined according to the degree of spasticity. Patients were allowed to walk the day after the surgery and no immobilization or cast was used.

The Achilles tendon lengthening associated to a flexor hallucis and digitorum longus tenotomy was performed in order to be able to put the ankle in a 10° dorsal flexion position. For the SPLATT procedure, the distal tibialis anterior tendon was divided in 2 parts over 10 cm. The external part of the tendon was sutured on the short peroneus tendon. After tendon lengthening and/or transfer, a resin cast was placed for 6 weeks but the patient was authorized to walk immediately. After removing the cast, a daily rehabilitation program identical to the pre-operative program including triceps surae stretching to obtain and/or maintain a 10° ankle dorsal flexion, muscle strengthening and gait rehabilitation with kinematics correction and endurance training was conducted. After SPLATT procedure, the patients were educated to avoid ankle plantar flexion and varus in order to protect the tendon transfer. The use of oral antispastic medications was not monitored.

Outcome measurement

The outcome measures were undertaken by a blind assessor before surgery and 2 months and 1 year after surgery following the ICF framework.

Primary outcome The primary outcome measure was the achievement of individual goals using Goal Attainment Scale (GAS) (10). At baseline, patients identified with the rehab team up to 2 personal goals they expected to achieve with the treatment. Goal attainment was rated at 2 months and 1 year on a 5-point scale where “0” denotes the expected level of achievement, “+1” a little better than expected, “+2” a lot better than expected while “-1” and “-2” correspond to respectively a little and a lot less than expected. These attainment levels were combined in a single score by applying the formula recommended by Kiresuk & Sherman (11) This formula is designed to transform the sum of the attainment levels for each goal into a standardized measure or “T-score” normally distributed around a mean of 50 and standard deviation of 10 if the results exceed and fall short of expectation in roughly equal proportion.

Body function and structure Global neurological impairment was assessed using the Stroke Impairment Assessment Set (SIAS) (12). The clinical examination included the spasticity assessment of the soleus muscle (with the knee flexed) and gastrocnemius muscle (with the knee extended) using the Modified Ashworth scale (MAS; 0-4) (13) and the Tardieu scale at fast stretching speed (TS; 0-4 and angle of catch) (14), the evaluation of the tibialis anterior and triceps muscles strength in seated position with the MRC scale (Medical Research Council; 0-5) (15) and the measurement of the passive and active range of motion (ROM) of the ankle with extended knee. The spontaneous walking speed barefoot (when possible) and with the usual walking aids (shoes and/or orthosis and/or crutch) were measured using the 10-meters walk test (10MWT) (16). The knee and ankle segmental kinematics in the swing and stance phase of gait were measured on a video record using the Dartfish® program. Anatomical landmarks for angle measurement were the femur and the tibia for the knee and the tibia – center of the heel – fifth metatarsophalangeal joint for the equinus. The kinematics measurements were performed by 2 different blind assessors. The obtained results were the mean of the 2 measurements. Walking aids requirement such as ankle foot orthosis (AFO), orthotics footwear and/or crutch was monitored.

Pain. Foot pain at rest and during gait was assessed with a 100-mm visual analogic scale (VAS); 0 and 100 respectively indicating “no pain” and “unbearable pain”.

Activity. The walking activity was assessed using 2 standard ordinal scales: the Functional Walking category (FWC; 0-6) (16) and the Functional Ambulation categories (FAC; 0-5) (17). A linear and unidimensional scale validated by Rasch analysis (the 13-

item ABILOCO questionnaire) was also used to assess the locomotion ability in stroke patients (18).

Participation and Quality of Life. Another linear and unidimensional questionnaire validated by Rasch analysis called Satispart-Stroke was used to assess the satisfaction in participation (19). The general quality of life was evaluated with norm-based scoring (NBS) of the 36-item Short-Form Health Survey (20). Side effects were monitored.

Statistics

For parametric data, a 2-way repeated-measures analysis of variance (ANOVA) was computed to study the effect of time and treatment. A post hoc test completed the analysis to determine significant differences ($p<0.05$).

For non-parametric data, a Friedman test was used to assess the effect of time and treatment. A Tukey test completed the analysis to determine significant differences ($p<0.05$).

Sigmastat 3.5 software was used for all statistical analysis.

RESULTS

Participants

A total of 46 patients were screened; 26 patients fulfilled the selection criteria and were proposed for surgery; 22 patients agreed to participate to the study; 18 patients (81%) completed the study. Four patients were lost for follow-up.

(Figure 1 : flow chart)

Table 1 describes patient characteristics and the details of performed surgery.

(Table 1: Patients characteristics and type of surgery)

Primary outcome

Table 2 presents the goals to reach chosen after discussion with patients and the GAS results. Each goal was classified according to the body function and activity/participation domains of the ICF with corresponding code. Thirteen of the eighteen patients obtained a GAS score superior or equal to 50. It means that the goals were reached at least “as expected”.

(Table 2: GAS, presentation of the patients goals according to the body functions and activity/participation domains of the ICF)

Table 3 shows the global GAS score obtained at T1 and T2. Table 3 presents the global GAS score (median [quartile 1-quartile 3]) observed at T1 (52.3 [46.6-59.1]) and T2 (52.3 [46.6-66.0]) .

(Table 3 : For the primary outcome GAS, results of Friedman repetitive measures comparing these data before (T0) two months (T1) and one year (T2) after neuro-orthopaedic surgery)

Body function, activity and participation

Table 4 and 5 describe the results obtained in the 3 domains of the ICF classification. We identified statistical improvement in global neurological impairment (SIAS) and barefoot walking speed, in triceps spasticity, in equinus in swing phase, in pain during gait and in passive ankle dorsiflexion at T1 and T2 assessment. The 5 patients who were unable to walk barefoot before surgery were able to do it after. No differences were found between T1 and T2 assessment. In contrast, no changes were observed in the activities and participation domains.

(Table 4 - Results of One way repetitive ANOVA comparing parametric data before (T0), two months (T1) and one year (T2) after neuro-orthopaedic surgery)

(Table 5 Results of Friedman repetitive measures comparing non-parametric data before (T0), two months (T1) and one year (T2) after neuro-orthopaedic surgery.)

Adverse events

Early postoperative complications were reported in 8 cases. A calf edema (6 cases), a transient meralgic paresthesia (1 case) and painful scar (1 case) were reported. No serious adverse effects were reported.

DISCUSSION

As pointed out by Fuller, the reasons leading to SEF were shown to be varied and complex, due to a variety of deforming forces explaining why a single procedure does not exist to correct all deformities (21). As the respective responsibility of the factors contributing to SEF (spasticity, contracture and imbalance) varied between patients, the treatment (surgical or non-surgical) should be determined according to the patient's characteristics after clinical examination, gait analysis, diagnostic nerve block with anaesthetics and/or botulinum toxin injections assessment. In complex and severe cases, the combination of treatments is sometimes necessary in order to target spasticity (by means of STN), contracture (by means of tendon lengthening) and imbalance (by means of tendon transfer) that are responsible for the SEF deformity. For the first time, a prospective single blind case-series study demonstrates the ability of a neuro-orthopaedic surgical program combining STN, tendon lengthening and/or transfer to improve walking capacity and to achieve personal goals in stroke patients suffering from SEF. Until now, studies only focused on the effect of an isolated STN (7,21) or orthopaedic surgical procedure (5,8). This study demonstrates that a combined surgical treatment is able to suppress triceps spasticity and to correct triceps surae – Achilles tendon complex contracture allowing stroke patients with SEF to walk faster with reduced equinus deformity, less pain and less AFO requirement. No serious adverse events occurred. The post-operative rehabilitation program was never limited by any complications. In particular, a 6 weeks immobilization in a resin cast followed by an immediate rehabilitation program including strengthening, stretching and gait didn't lead to rupture of the lengthened or transferred tendons. The use of an orthosis-assisted immediate rehabilitation seems to be also safe (22). Therefore, this study supports the fact that targeting all these factors during the same surgical neuro-orthopaedic procedure is safe and effective. The outcome measures assess the body function, activities and participation domains of the ICF framework. While the ICF framework is largely used in rehabilitation field, only Bollens et al used it to assess STN as a treatment of SEF without identifying modifications in activity and participation. In our study, the focal (spasticity, ROM) and global (SIAS, gait speed) neurological impairment were improved after surgery while the activities (FWC, FAC, Abiloco) and participation (SF-36, Satispart-stroke) domains remained unchanged. However, the GAS also allows us to evaluate the achievement of personal centered goals in the three domains of the ICF. The goals defined with the patients before surgery were reached in the body function domain (gait kinematic, pain) as well as in the activity and participation (foot stability, AFO release). For the first time, this study shows an improvement in the activity and participation domains of the ICF after SEF surgery. The contrast between the lack of improvement in the activities and participation observed by using scales like SF-36 in comparison with GAS can be explained by the fact that usual scales assess many factors such as neuropathic pain, cognitive deficit and depression that cannot be improved by a focal treatment. We, therefore, strongly suggest using GAS as a systematic assessment tool when treating focal spasticity.

Interestingly, the clinical improvement and the goals achievement observed 2 months after surgery remained unchanged at the 1 year assessment supporting the permanent long lasting effect of surgery. This is of importance as the main interest of surgery is to provide a permanent solution that cannot be obtained by a reversible treatment such as BoNT-A.

This study has several limitations. First, there was no control group. However, as most of our patients (14/18) suffered from a triceps surae – Achilles tendon complex shortening, a surgical lengthening was necessary. As muscle lengthening cannot be obtained by any other treatment, a control group seems not ethical. Secondly, as the patients were operated, a double-blind study was impossible. However, the assessments were performed in a single blind manner as the assessors were not informed about the surgical procedure. Last, gait kinematics was assessed by a video analysis and not by an instrumented gait analysis known as the “gold standard” for gait assessment.

CONCLUSIONS

This study confirms that neuro-orthopaedic surgery seems effective to decrease triceps spasticity, to increase gait speed and to reduce walking aids. Furthermore, a goal-centered approach using GAS tends to demonstrate an improvement in the activities and participation domains of the ICF. We suggest using GAS as an assessment tool when treating focal spasticity.

CONFLICT OF INTEREST STATEMENTS

None of the authors has any conflicts of interest

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Table 1 **Patients characteristics and type of surgery**

Patients	Sex	Age (years)	Side	Surgery
1	M	56	R	STN (sol, tp, fhl) + L (gastroc, fdl)
2	M	63	L	STN (sol, tp, fhl)
3	M	61	R	STN (sol, fhl) + L (Achille, fdl)
4	M	72	L	L (gastroc, fdl) + SPLATT
5	F	65	L	L (Achille, fdl)
6	F	44	R	STN (sol, tp, fhl) + L (Achilles, fdl)
7	F	41	L	STN (sol, fhl) + L (gastroc, fdl)
8	M	62	R	STN (sol, tp, fhl) + L (gastroc, fdl)
9	M	45	R	STN (sol, tp, fhl)
10	M	51	R	L (Achille, fhl,fdl)
11	M	58	L	STN (sol) + L (gastroc)
12	F	45	R	L (Achille, fhl,fdl)
13	M	48	L	STN (sol, tp, fhl)
14	M	78	R	L (Achille, fhl, fdl) + SPLATT
15	M	52	L	L (Achille, fhl, fdl)
16	F	48	R	STN (sol, fhl) + L (gastroc, fdl)
17	F	61	R	STN (sol, tp, fhl)
18	M	52	L	STN (sol, fhl) + L (gastroc, fdl)
	M/F, n	Mean ± SD	R/L, n	
	12/6	55,7 ± 10,2)	10/8	

Abbreviations: STN (selective tibial neurotomy), sol (soleus), tp (tibialis posterior), fhl (flexor hallucis longus), L (lengthening procedure), gastroc (gastrocnemius), fdl (flexor digitorum longus), Achille (Achilles tendon), SPLATT (split anterior tibial tendon transfer)

Table 2: GAS, presentation of the patients goals according to the body functions and activity/participation domains of the ICF. For each goal, the ICF corresponding code is provided

Patients	Body functions	Activity/participation	GAS T1	GAS T2
1	↓ foot Pain (B280)	↑ foot stability (D415) AFO release (D450)	54.6	68.3
2		↑ foot stability (D415) AFO release (D450)	50.0	50.0
3	↓ painful toe claw (B280)	↑ foot stability (D415) AFO release (D450)	54.6	54.6
4	↓ painful toe claw (B280) ↓ varus (B755)	AFO release (D450)	45.4	40.9
5	↓ painful toe claw (B280)	↑ foot stability (D415) Orthotic shoes release (D450)	45.4	45.4
6		↑ foot stability (D415) AFO release (D450)	68.3	68.3
7		↑ foot stability (D415)	50.0	50.0
8		↑ foot stability (D415) Cane release (D450)	36.3	50.0
9		↑ foot stability (D415)	50.0	45.4
10	↓ foot Pain (B280)	↑ foot stability (D415)	59.1	59.1
11	↓ genu recurvatum (B755)	AFO release (D450)	59.1	59.1
12		↑ foot stability (D415) AFO release (D450)	68.3	68.3
13	↓ spasticity (B735)	↑ foot stability (D415)	50.0	50.0
14		↑ foot stability (D415) AFO release (D450) Orthotic shoes release (D450)	54.6	54.6
15		↑ foot stability (D415) AFO release (D450)	68.3	68.3
16	↓ hip adduction(B755)	↑ foot stability (D415) AFO release (D450)	63.7	72.8
17		↑ foot stability (D415)	45.4	45.4
18	↓ genu recurvatum (B755)	↑ foot stability (D415)	45.4	45.4

Furthermore, presentation of the GAS data two months (T1) and one year (T2) after neuro-orthopaedic surgery.
Definition of ICF codes: B280 = Pain; D415 = Maintaining body position; D450 = Walking; B735 = Muscle tone; B755 = Involuntary movement reactions to position

Table 3 : For the primary outcome GAS, results of Friedman repetitive measures comparing these data before (T0) tw,o months (T1) and one year (T2) after neuro-orthopaedic surgery.

	T0 Median [Q1;Q2] (n=18)	T1 Median [Q1;Q2] (n=18)	T2 Median [Q1;Q2] (n=18)	T2-T1
GAS	37.6 [36.3;37.6]	52.3 [46.6;59.1]*	52.3 [46.6;66]*	0.0 [0.0;0.0]

* indicates a significant difference (p<0.05).

Table 4 - Results of One way repetitive ANOVA comparing parametric data before (T0), two months (T1) and one year (T2) after neuro-orthopaedic surgery.

	T0 Mean (SD) (n=18)	T1-T0	T2-T0 Mean difference (SD) (n=18)	T2-T1
Impairments				
Walking speed (m/s)				
Barefoot	0.27 (0.19)	0.18 (0.17)*	0.21 (0.25)*	0.08 (0.10)
With walking aids	0.49 (0.28)	0.10 (0.16)	0.19 (0.24)	0.08 (0.11)
Gait equinus (°)				
Swing phase	116.3 (10.3)	-10.0 (10.7)*	-9.4 (10.7)*	1.0 (12.5)
Stance phase	106.5 (10.5)	-4.2 (11.3)	-7.1 (17.4)*	-3.1 (13.2)
Ankle ROM (°)				
Active	-19.4 (12.5)	-0.8 (13.6)	5.9 (20.5)	6.8 (16.1)
Passive	-8.7 (11.7)	17.6 (14.7)*	13.6 (16.0)*	-4.0 (8.6)
Tardieu catch angle (°)				
Soleus	-7.2 (5.7)	18.1 (7.3)*	15.6 (11.5)*	-2.5 (7.5)
Triceps Surae	-14.2 (8.6)	17.5 (12.9)*	16.4 (16.3)*	-1.1 (10.8)
Activities				
Abiloco (Logits)	2.5 (2.7)	0.5 (1.8)	0.4 (1.9)	-0.1 (1.6)
Participation				
Satispart-stroke (Logits)	0.5 (0.5)	-0.1 (1.6)	0.8 (1.1)	0.9 (2.3)

Abbreviation: ROM=Range of motion; SD=Standard deviation.

* indicates a significant difference (p<0.05).

Table 5 Results of Friedman repetitive measures comparing non-parametric data before (T0), two months (T1) and one year (T2) after neuro-orthopaedic surgery.

	T0 Median [Q1;Q2] (n=18)	T1-T0	T2-T0 Difference of results Median [Q1;Q2] (n=18)	T2-T1
Impairments				
SIAS (76)	40.5 [35.0;46.3]	5.5 [2.0;8.8]*	6.0[3.0;8.8]*	-1.0[-2.0;2.8]
MAS (/4)				
Soleus	2.5 [2.0;3.0]	-2.5 [-3.0;-2.0]*	-2.0[-3.0;-2.0]*	0.0[0.0;0.8]
Triceps Surae	3.0 [2.0;4.0]	-2.5 [-3.0;-1.3]*	-2.0 [-3.0;-1.3]*	0.0 [0.0;0.8]
Tardieu (/4)				
Soleus	3.0 [1.0;3.8]	-3.0 [-3.0;-0.3]*	-2.0 [-3.0;-0.3]*	0.0 [0.0;0.8]
Triceps Surae	2.5 [1.0;4.0]	-1.0 [-3.0;0.0]*	-1.0 [-3.0;0.0]*	0.0 [0.0;0.0]
MRC (/5)				
Tibial anterior	0.5 [0.0;3.0]	0.0 [0.0;1.0]	1.0 [0.0;1.8]	0.0 [0.0;0.8]
Triceps Surae	0.5 [0.0;3.0]	0.0 [-1.0;0.0]	0.0 [-0.8;0.0]	0.0 [0.0;0.0]
Pain (/100)				
Rest	0.0 [0.0;7.5]	0.0 [-7.5;0.0]	0.0 [0.0;7.5]	0.0 [0.0;0.0]
Walking	20.0 [0.0;50.0]	-10.0 [-30.0;0.0]*	-10.0 [-30.0;0.0]	0.0 [0.0;0.0]
Activities				
FWC (/6)	3.0 [2.3;5.0]	0.0 [0.0;1.0]	0.5 [0.0;1.0]	0.0 [0.0;1.0]
FAC (/5)	4.0 [3.0;4.8]	0.0 [0.0;0.8]	0.0 [0.0;1.0]	0.0[0.0;0.0]
Participation				
SF-36				
Mental Health	78.0 [71.0;89.0]	4.0 [-2.0;18.0]	12.0[-3.0;24.0]	0.0 [-4.0;8.0]
Physical Health	40.4 [36.3;45.1]	0.4 [-6.3;7.9]	2.0 [-4.1;11.5]	5.9 [-4.8;8.8]

Abbreviations: GAS= Goal attainment scale; SIAS= Stroke Impairment Assessment Set; MAS=Modified Ashword Scale; MRC=Medical research council; FWC=Fonctional walking category; FAC= Functional Ambulation categories; SF=Short Form.

* indicates a significant difference ($p<0.05$).

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Table 1 Patients characteristics and type of surgery

Patients	Sex	Age (years)	Side	Surgery
1	M	56	R	STN (sol, tp, fhl) + L (gastroc, fdl)
2	M	63	L	STN (sol, tp, fhl)
3	M	61	R	STN (sol, fhl) + L (Achille, fdl)
4	M	72	L	L (gastroc, fdl) + SPLATT
5	F	65	L	L (Achille, fdl)
6	F	44	R	STN (sol, tp, fhl) + L (Achilles, fdl)
7	F	41	L	STN (sol, fhl) + L (gastroc, fdl)
8	M	62	R	STN (sol, tp, fhl) + L (gastroc, fdl)
9	M	45	R	STN (sol, tp, fhl)
10	M	51	R	L (Achille, fhl,fdl)
11	M	58	L	STN (sol) + L (gastroc)
12	F	45	R	L (Achille, fhl,fdl)
13	M	48	L	STN (sol, tp, fhl)
14	M	78	R	L (Achille, fhl, fdl) + SPLATT
15	M	52	L	L (Achille, fhl, fdl)
16	F	48	R	STN (sol, fhl) + L (gastroc, fdl)
17	F	61	R	STN (sol, tp, fhl)
18	M	52	L	STN (sol, fhl) + L (gastroc, fdl)
	M/F, n	Mean ± SD	R/L, n	
	12/6	55,7 ± 10,2)	10/8	

Abbreviations: STN (selective tibial neurotomy), sol (soleus), tp (tibialis posterior), fhl (flexor hallucis longus), L (lengthening procedure), gastroc (gastrocnemius), fdl (flexor digitorum longus), Achille (Achilles tendon), SPLATT (split anterior tibial tendon transfer)

Table 2: GAS, presentation of the patients goals according to the body functions and activity/participation domains of the ICF. For each goal, the ICF corresponding code is provided

Patients	Body functions	Activity/participation	GAS T1	GAS T2
1	↓ foot Pain (B280)	↑ foot stability (D415) AFO release (D450)	54.6	68.3
2		↑ foot stability (D415) AFO release (D450)	50.0	50.0
3	↓ painful toe claw (B280)	↑ foot stability (D415) AFO release (D450)	54.6	54.6
4	↓ painful toe claw (B280) ↓ varus (B755)	AFO release (D450)	45.4	40.9
5	↓ painful toe claw (B280)	↑ foot stability (D415) Orthotic shoes release (D450)	45.4	45.4
6		↑ foot stability (D415) AFO release (D450)	68.3	68.3
7		↑ foot stability (D415)	50.0	50.0
8		↑ foot stability (D415) Cane release (D450)	36.3	50.0
9		↑ foot stability (D415)	50.0	45.4
10	↓ foot Pain (B280)	↑ foot stability (D415)	59.1	59.1
11	↓ genu recurvatum (B755)	AFO release (D450)	59.1	59.1
12		↑ foot stability (D415) AFO release (D450)	68.3	68.3
13	↓ spasticity (B735)	↑ foot stability (D415)	50.0	50.0
14		↑ foot stability (D415) AFO release (D450) Orthotic shoes release (D450)	54.6	54.6
15		↑ foot stability (D415) AFO release (D450)	68.3	68.3
16	↓ hip adduction(B755)	↑ foot stability (D415) AFO release (D450)	63.7	72.8
17		↑ foot stability (D415)	45.4	45.4
18	↓ genu recurvatum (B755)	↑ foot stability (D415)	45.4	45.4

Furthermore, presentation of the GAS data two months (T1) and one year (T2) after neuro-orthopaedic surgery.
Definition of ICF codes: B280 = Pain; D415 = Maintaining body position; D450 = Walking; B735 = Muscle tone; B755 = Involuntary movement reactions to position

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Table 3 : For the primary outcome GAS, results of Friedman repetitive measures comparing these data before (T0) tw,o months (T1) and one year (T2) after neuro-orthopaedic surgery.

	T0	T1	T2	T2-T1
	Median [Q1;Q2] (n=18)	Median [Q1;Q2] (n=18)	Median [Q1;Q2] (n=18)	
GAS	37.6 [36.3;37.6]	52.3 [46.6;59.1]*	52.3 [46.6;66]*	0.0 [0.0;0.0]

* indicates a significant difference ($p<0.05$).

Table 4 - Results of One way repetitive ANOVA comparing parametric data before (T0), two months (T1) and one year (T2) after neuro-orthopaedic surgery.

	T0 Mean (SD) (n=18)	T1-T0	T2-T0 Mean difference (SD) (n=18)	T2-T1
Impairments				
Walking speed (m/s)				
Barefoot	0.27 (0.19)	0.18 (0.17)*	0.21 (0.25)*	0.08 (0.10)
With walking aids	0.49 (0.28)	0.10 (0.16)	0.19 (0.24)	0.08 (0.11)
Gait equinus (°)				
Swing phase	116.3 (10.3)	-10.0 (10.7)*	-9.4 (10.7)*	1.0 (12.5)
Stance phase	106.5 (10.5)	-4.2 (11.3)	-7.1 (17.4)*	-3.1 (13.2)
Ankle ROM (°)				
Active	-19.4 (12.5)	-0.8 (13.6)	5.9 (20.5)	6.8 (16.1)
Passive	-8.7 (11.7)	17.6 (14.7)*	13.6 (16.0)*	-4.0 (8.6)
Tardieu catch angle (°)				
Soleus	-7.2 (5.7)	18.1 (7.3)*	15.6 (11.5)*	-2.5 (7.5)
Triceps Surae	-14.2 (8.6)	17.5 (12.9)*	16.4 (16.3)*	-1.1 (10.8)
Activities				
Abiloco (Logits)	2.5 (2.7)	0.5 (1.8)	0.4 (1.9)	-0.1 (1.6)
Participation				
Satispart-stroke (Logits)	0.5 (0.5)	-0.1 (1.6)	0.8 (1.1)	0.9 (2.3)

Abbreviation: ROM=Range of motion; SD=Standard deviation.

* indicates a significant difference (p<0.05).

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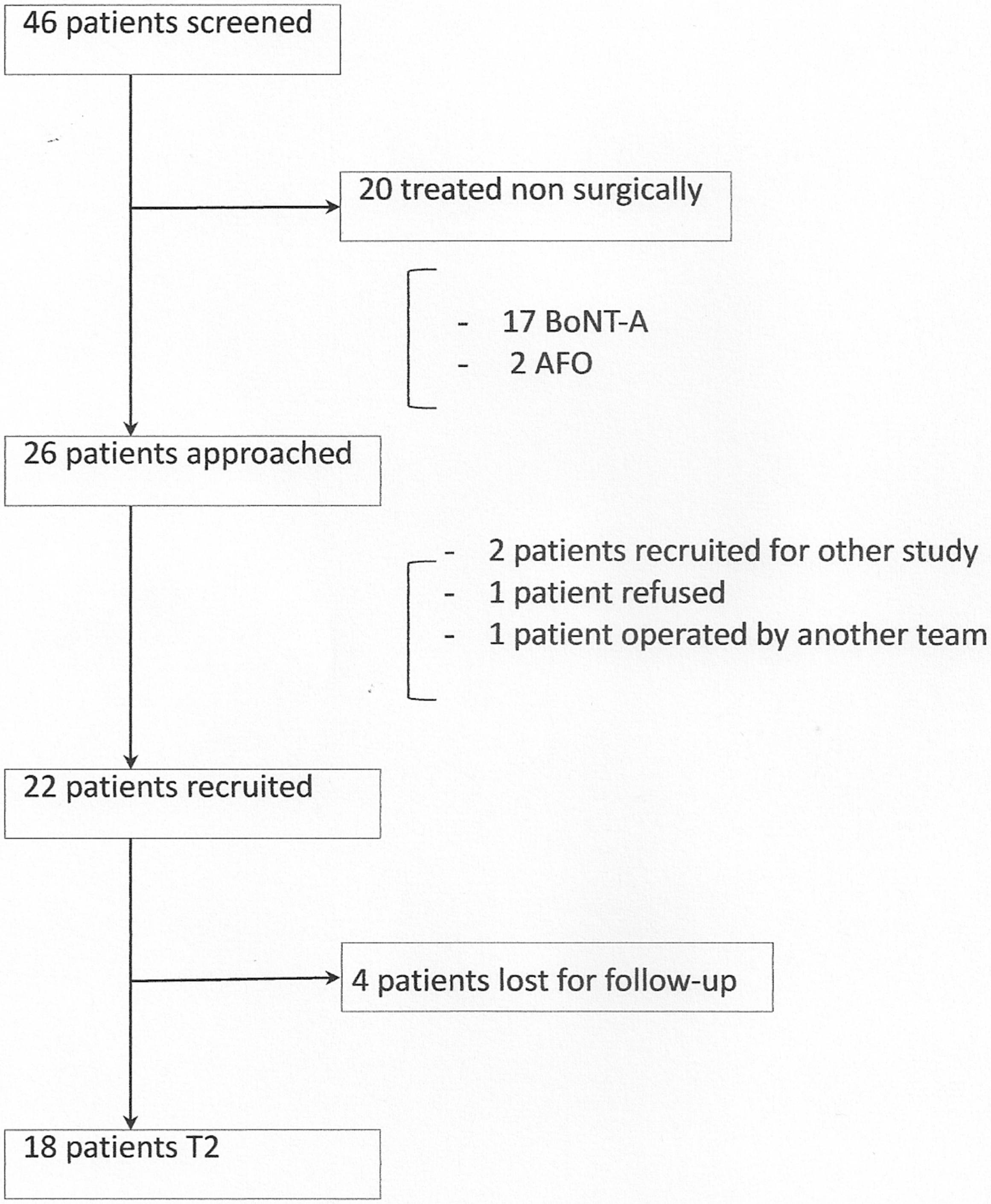
Table 5 Results of Friedman repetitive measures comparing non-parametric data before (T0), two months (T1) and one year (T2) after neuro-orthopaedic surgery.

	T0 Median [Q1;Q2] (n=18)	T1-T0	T2-T0	T2-T1
		Difference of results Median [Q1;Q2] (n=18)		
Impairments				
SIAS (76)	40.5 [35.0;46.3]	5.5 [2.0;8.8]*	6.0[3.0;8.8]*	-1.0[-2.0;2.8]
MAS (/4)				
Soleus	2.5 [2.0;3.0]	-2.5 [-3.0;-2.0]*	-2.0[-3.0;-2.0]*	0.0[0.0;0.8]
Triceps Surae	3.0 [2.0;4.0]	-2.5 [-3.0;-1.3]*	-2.0 [-3.0;-1.3]*	0.0 [0.0;0.8]
Tardieu (/4)				
Soleus	3.0 [1.0;3.8]	-3.0 [-3.0;-0.3]*	-2.0 [-3.0;-0.3]*	0.0 [0.0;0.8]
Triceps Surae	2.5 [1.0;4.0]	-1.0 [-3.0;0.0]*	-1.0 [-3.0;0.0]*	0.0 [0.0;0.0]
MRC (/5)				
Tibial anterior	0.5 [0.0;3.0]	0.0 [0.0;1.0]	1.0 [0.0;1.8]	0.0 [0.0;0.8]
Triceps Surae	0.5 [0.0;3.0]	0.0 [-1.0;0.0]	0.0 [-0.8;0.0]	0.0 [0.0;0.0]
Pain (/100)				
Rest	0.0 [0.0;7.5]	0.0 [-7.5;0.0]	0.0 [0.0;7.5]	0.0 [0.0;0.0]
Walking	20.0 [0.0;50.0]	-10.0 [-30.0;0.0]*	-10.0 [-30.0;0.0]	0.0 [0.0;0.0]
Activities				
FWC (/6)	3.0 [2.3;5.0]	0.0 [0.0;1.0]	0.5 [0.0;1.0]	0.0 [0.0;1.0]
FAC (/5)	4.0 [3.0;4.8]	0.0 [0.0;0.8]	0.0 [0.0;1.0]	0.0[0.0;0.0]
Participation				
SF-36				
Mental Health	78.0 [71.0;89.0]	4.0 [-2.0;18.0]	12.0[-3.0;24.0]	0.0 [-4.0;8.0]
Physical Health	40.4 [36.3;45.1]	0.4 [-6.3;7.9]	2.0 [-4.1;11.5]	5.9 [-4.8;8.8]

Abbreviations: GAS= Goal attainment scale; SIAS= Stroke Impairment Assessment Set; MAS=Modified Ashword Scale; MRC=Medical research council; FWC=Fonctional walking category; FAC= Functional Ambulation categories; SF=Short Form.

* indicates a significant difference ($p<0.05$).


46 patients screened
20 treated non surgically
- 17 BoNT-A
- 2 AFO
26 patients approached
- 2 patients recruited for other study
- 1 patient refused
- 1 patient operated by another team
22 patients recruited
4 patients lost for follow-up
18 patients T2