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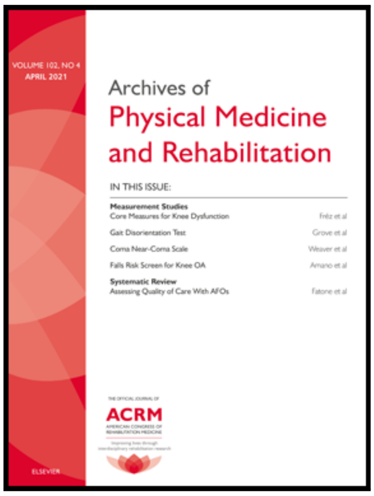


# International recommendations to manage post-stroke Equinovarus Foot deformity validated by a panel of experts using DELPHI

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**Running Head: Management of equinovarus foot deformity**

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**Abstract**

**Objective:** This study intended to establish international recommendations for the management of spastic equinovarus foot deformity.

**Design:** Delphi method

**Setting:** International study

**Participants**: 24 international experts in neuro-orthopedic deformities, from different specialties (Physical and Rehabilitation Medicine physicians, neurologists, geriatricians, orthopaedic surgeons, neurosurgeons, and plastic surgeons)

**Interventions:** Experts answered three rounds of questions related to important aspects of diagnosis, assessment and treatment of spastic equinovarus foot deformity.

**Main Outcome Measures:** A consensus was established when at least 80% of experts agreed on a statement

**Results:** A total of 52 items reached consensus. Experts recommend assessing impact of the deformity on functional activities before treatment. Before treatment, it is crucial to differentiate spastic muscle overactivity from soft tissue contractures, identify which muscles are involved in the deformity and evaluate the activity of antagonist muscles. Motor nerve blocks, two-dimensional video analysis and radiological exams are often required to complement a clinical exam. The treatment of equinovarus foot depends on the correctability of the deformity, but also the patient's ability to stand or walk. The preoperative assessment should include an interdisciplinary consultation that must finalize a formal agreement between doctors and the patient, which will define personalized attainable goals before surgery.

**Conclusion:** The establishment of guidelines on managing equinovarus foot will help physicians and surgeons, specialists, and non-specialists to diagnoses and assess the deformity and direct patients to a network of experts, in order to optimize patient functional recovery and improve their autonomy.

**Keywords:** equinovarus foot, muscle overactivity, spasticity, neuro-orthopedic deformity, DELPHI

**Abbreviations:**

BoNT: Botulinum toxin type A

CREDES: Conducting and REporting of DElphi Studies

EVF: Equinovarus foot

PRM**:** Physical and Rehabilitation Medicine

**Introduction**

Equinovarus foot (EVF) is a common neuro-orthopedic complication that occurs in approximately 18% of hemiplegic patients after stroke.[1] In these patients, EVF deformity is a major factor that limits the capacity to stand, transfer weight, and walk.[1,2] The goals for rehabilitation include preventing development of neuro-orthopedic deformities such as EVF.[3] However, despite completing rehabilitation, EVF may still negatively impact recovery and the acquisition of functional independence, leaving non-specialist physicians perplexed or feeling helpless.[4] Health care providers treating hemiplegic patients across the spectrum of care should be able to identify EVF deformity, ascertain how the EVF is interfering with their daily life activities, and recommend the patient to a team specialized in neuro-orthopedic deformities if needed.

EVF is a complex deformity of the foot.[5] An equinus foot is defined as a foot held in a plantar flexed position, whereas varus is an excessive inward angulation of the hindfoot. The equinovarus foot is a result of both neurological and orthopedic complications, which may be attributed to a variety of mechanisms.[6,7] A deformity is correctable when that can be returned to normal range of motion passively, with or without a diagnostic nerve block. In contrast, the deformity is considered not correctable when passive mobilization of the joint is impossible, with or without diagnostic nerve block. Careful examination of EVF allows physicians to determine causes of the deformity, and more precisely assess the deformities impact on patient function, in order to prescribe an appropriate treatment.[8] Occasionally, clinical exam may not be sufficient to fully characterize the deformity, and additional technical examinations are necessary.[5,9] Currently, no recommendations exist for guiding clinicians through the clinical and technical examinations required to assess EVF deformity. Therefore, current practice is determined by the decisions of individual physicians, and the availability of technical facilities present in the health center.

Management of EVF deformity usually combines several treatments, such as physical rehabilitation, anti-spastic medications, surgery and braces.[9,10] The sequence of treatments is not clearly established for EVF and depends on collaboration between different medical and surgical specialties.[7] Each discipline habitually works within its own area of expertise, and thus may be naive to how other disciplines approach treatment. Furthermore, patient concerns and functional goals are not always clearly identified by the physician prior to treatment. Unfortunately, there is currently no consensus on how to manage EVF deformity in hemiplegic patients. The literature is heterogeneous, and only encompasses some disciplines representing local team experiences.[6,11,12] For this reason, we conducted an international, interdisciplinary survey using the structured communication Delphi method, to converge towards consensus and achieve recommendations for specialist and non-specialist doctors to accurately assess and treat EVF deformity in hemiplegic patients.

**Methods**This study utilized a Delphi process, which is a rigorous approach to define consensus when evidence is lacking.[15,16]

The questionnaire evolved over the course of the three rounds (see appendix 1). After obtaining answers from the first questionnaire (Appendix 2), members from the steering committee wrote a second questionnaire that had questions deleted, reformulated, or merged. This second questionnaire (Appendix 2) was reviewed and validated. The same procedure was applied for the third round questionnaire (Appendix 2).

A consensus was established when at least 80% of experts agreed on a statement [17].

To be considered as a neuro-orthopedic expert, medical doctors had to belong to one of the following disciplines: PRM, orthopedic surgery, neurosurgery, neurology, plastic surgery or geriatrics. An expert also needed to have published and/or communicated at an international congress regarding neuro-orthopedic deformities.

## Results

Results are presented following the usual process for the management of EVF.

### *DELPHI procedure*

Twenty-nine experts (18 PRM Physicians, 1 Neurologist, 7 Orthopedic Surgeons, and 3 Neurosurgeons) from 12 different countries were invited to participate in the study. Twenty-four experts answered the first questionnaire, 22 the second questionnaire, and 23 the third questionnaire (Figure 1). After three rounds, a total of 52 consensuses were found.

### *Identifying the causes of EVF deformity*

Experts identified the *Triceps surae* as the muscle group responsible for hindfoot equinus (Table 1).

Experts were unanimous in identifying the *Tibialis posterior* as the primary muscle responsible for hind foot varus deformity (80 %). Experts agreed that pronator muscles of the forefoot indirectly induce varus of the hindfoot (83.3 %). For the experts, the first muscle responsible for forefoot pronation deformity was the *Fibularis longus* (63.6 %) and the second was the *Abductor hallucis* (36.4 %), but no consensus was achieved (Table 1).

***Clinical evaluation of EVF deformity***

On a scale of having a major impact on determining a course of therapeutic treatment, from 0 (no impact) to 10 (major impact), assessing functional muscle contraction while performing tasks such as standing or walking, was ranked at 9.4 ± 0.87 (range 7-10). In contrast, muscle activation during analytical clinical exam involving the patient lying or sitting on an exam table was less important, ranking 6.8 ± 2.14 (range 2-10). Thus, functional muscle activation should have a higher influence on determining a course of therapeutic intervention than analytic muscle activation (Table 1).

There was 100% consensus that it is important to differentiate spastic muscle overactivity from soft tissue contracture before considering surgery as a treatment for EVF. Furthermore, to avoid overcorrection after surgery, the consensus (95.8%) was that assessment of co-contractions and antagonist muscle overactivity is essential before surgery.

There was 91.3% consensus that to better assess EVF deformity, total and/or selective *Tibialis* motor nerve blocks using local anesthetics are useful. Before considering a tendon to transfer, it is important to assess its muscle contraction strength during the movement desired for correction and analyze the impact of motor nerve blocks targeting the muscle for 72.7 % of the experts (Table 1).

***Instrumental examinations to assess EVF deformity.***

Radiological exam was recommended by all experts, for providing assistance with preoperative assessment of EVF (complex deformity of the foot, quality of joint surfaces, ankle pain) (Table 1).

Two-dimensional video analysis is considered to be helpful when deciding upon the best course of action to treat EVF with a consensus of 87.5%.

However, no consensus was reached when concerning quantitative gait analysis (69.6%) and dynamic multi-channel electroneuromyography (52.2%).

***Treatment sequences***

In the case of fully correctable EVF deformity, experts recommend Botulinum toxin type A (BoNT) injections (81.8%) and physical therapy (95.8%) as a first line medical treatment for correcting muscles involved in the deformity (Figure 2). Surgery was not recommended as first line (83.3%) (Table 2). However, 36.4% of the participants believed that sometimes partially- or un-correctable EVF deformities may require surgery as a primary treatment. This was in light of the availability of BoNT injection (91.7%) and physical therapy (83.3%) treatment options. In contrast, for all cases of EVF deformity (correctable, partially- and un-correctable), there was a 90.9% consensus that oral baclofen should not be used as a first intention treatment.

When establishing the indication for performing surgical procedures to correct EVF, preoperative clinical assessment by a PRM physician was considered mandatory (90.9%). Furthermore, the outcome of previous BoNT injections targeting overactive muscles is helpful (81.8%) (Table 1).

Interdisciplinary consultations or meetings are required to determine if surgery is needed, by 91.7% of participants, to specify the kind of surgical procedure to perform and to organize perioperative care. For 81.8%, patient presence during this consultation is necessary. A formal agreement between doctors and the patient (or power of attorney and relatives) must be established (90.1% consensus), to define therapeutic goals before surgery.

It was generally accepted (81.8%) that surgery for EVF can be performed within the first year after central nervous system damage.

***Surgical treatment***

When surgical treatment is required to rebalance the foot and restore movement for fully correctable EVF, the tendons were indicated as the targets, to reduce foot positioning. Surgery could be used to exploit functioning muscles (analytic muscle contraction, muscle overactivity or global synkinesis movement) (91.6 % agreement), or to eliminate their influence by targeting the tendon to correct equinovarus (100%).

When a patient can walk and the EVF deformity is fully correctable, 91.7% of the experts proposed surgery on nerves only (neurotomy) (Table 2). Experts recommend neurotomy when BoNT is contraindicated (71.4%), or to replace BoNT injections (95.2%) upon a patient request. 18.2% of experts could also propose neurotomy as first-line treatment.

When the patient can walk and EVF is fully correctable, 87% recommend a surgical procedure combining neurotomy of the selective branch of the tibial nerve to stop *soleus* overactivity, and a partial tendon transfer of the *Tibialis anterior* (SPLATT)[8]. This type of surgery can be performed when troublesome spasticity of the *soleus* (equinus) and synkinetic contraction of the *Tibialis anterior* (varus) are present. Under these conditions, 80 % of the experts recommend performing the neurotomy and the tendon transfer in a single surgery.

When the patient presents a fully correctable deformity, and can walk, all experts agreed that complete tenotomy is not recommended (Table 2).

In the case of a patient unable to walk and presenting with totally correctable EVF and the failure of conservative treatments, experts believed that neurotomy could be combined with tendon or intramuscular lengthening (50%), tenotomy (50%) or tendon transfer (36.4%) (Figure 2).

For rebalancing a foot and restoring movement when partially- or uncorrectable EVF is present, 95.8% of experts believed that a procedure on tendons (tenotomy, transfer, lengthening) could be beneficial. Tendon transfer is considered as an adjunct technique by 90.9% of experts, when correcting partially correctable or uncorrectable EVF caused by both overactivity and retraction. Furthermore, 95.5% would combine a neurotomy with tendon lengthening, and/or tendon transfers to treat a partially correctable EVF. In contrast, 60.9 % of the experts would recommend neurotomy alone, in specific cases (deformity correctable after nerve block, useful equine) (Table 2).

Musculo-tendinous lengthening and tenotomy could be possible, using an open surgery approach or percutaneous procedure using needles (95.8%). PRM physicians are qualified to perform simple percutaneous tenotomies after undergoing structured and specific training (81.8 %).

Experts recommended soft tissue surgery, preferentially (81.8 %), in comparison with surgical procedures involving bones and joints. A consensus was not reached when considering performing a double arthrodesis of the foot (subtalar, Chopart) in adults with EVF. Among the experts proposing double arthrodesis as a second line procedure, 85.7% recommend it after soft tissue surgery, when there is persistence of foot and ankle instability, but also in the case of uncontrolled pain with osteoarthritis (86.4 %).

Osteotomy and arthrodesis should be reserved for fixed EVF involving the joint (83.3 % consensus), or when a foot and ankle stabilization deficiency is present during activity (paresis, overactivity, etc...) (66.7%).

Experts did not recommend multiple procedures in a single surgery when a patient presents with bilateral, or multiple joint deformities (91.7%).

***Risk management:***

Arterial insufficiency is a contraindication for bone and joint surgery (82.6%) (Table 2). Tendon surgery (52.2%) and neurotomy (73.9%) may be performed even when patient is suffering from arterial insufficiency. No consensus was met for management of active smokers before surgery.

Experts agreed that bone surgery (arthrodesis, osteotomy…) should not be carried out on patients with a documented urinary tract infection. However, consensus was not reached (78.3%). Furthermore, no consensus was found concerning tendon surgery or neurotomy in a situation of documented urinary tract infection or arterial insufficiency.

***Post-surgical management***

Consensus was not achieved regarding the timing of post-surgical immobilization depending on the type of surgery.

For 83.3% of experts, post-surgical care (convalescent home, rehabilitation center, outdoor physiotherapy…) should be organized as soon as the surgery for EVF is validated (Table 2).

For cast removal (90.9 %), a PRM physician can perform the consultation with consent of the surgeon, while there was some disagreement that a PRM can also perform follow-up until the 3rd month post-surgery (75.0 %), even if in contact with the surgeon. Follow-up by PRM specialist should be systematically established, or continuous after surgery (87.5 %).

All experts agreed that BoNT injections can be proposed postoperatively. Once surgery enables achievement of a patient's goal, there was 95.5 % agreement that pursuing BoNT injections in other muscles, to treat new objectives, is recommended. BoNT injections could be used to treat overactive muscles that are newly identified in the foot or the ankle after EVF-corrective surgery, but also to target overactive muscles in other parts of the body that are implicated in other troublesome deformities, to determine new objectives of treatment (91.7 % and 79.2%, respectively).



**Discussion**

Currently, no international recommendations exist describing the management of EVF, in patients suffering from spastic paresis hemiplegia, after stroke and/or after central nervous system injury. Since the first international Symposium of Neuro-Orthopedics in Versailles (2017), the experts in the field of neuro-orthopaedic have been gathered together bi-annually, to share the knowledge of their clinical experience across disciplines. From this collaboration, we embarked on creating recommendations for the management of EVF, to facilitate cross-discipline clinical practice, which addresses both specialist and non-specialist physicians.

The Delphi method is considered to be the best scientific technique to establish guidelines, by forming a consensus of knowledge between international and interdisciplinary experts'.[13,14] Therefore, we exploited this technique to determine recommendations for management of EVF. Using this approach, we uncovered key points that form the basis of our recommendations during this process.

Preoperative assessment should include an interdisciplinary consultation, and in the least should include physicians, surgeons, and the patient, family, and sometimes personal caregivers or physiotherapists.[8] Patients are usually referred for interdisciplinary consultation by non-specialist doctors, who together have outlined the patients complaints and a desired outcome for treatment.[8,15,16] Discussion between the interdisciplinary team, the patient, and their family, is important to precisely identify treatable problems affecting quality of life. Patient expectations should be focused towards goals of resolving symptoms, or improving function. Goals and objectives may be different between patients presenting with the same deformity, as the impact of the deformity on daily life activities varies greatly. Interdisciplinary consultations assess the characteristics of the deformity, ascertain the impact of the treatment of the deformity on daily life activities, and can also be used to propose complementary strategies. In addition, an interdisciplinary consultation enables surgeons, physicians and the rehabilitation team to discuss various therapeutic strategies in the presence of the patient, to find the best therapeutic option to achieve the patient's goal, which is then formalized as an agreement between patient and caregivers, in order to avoid misunderstanding and disappointment. Improvement can only result from a coordinated EVF management strategy, which depends on the quality of the medico-surgical network. While an interdisciplinary framework has been lacking until now, our Delphi-defined position lays the foundations for the interdisciplinary management of EVF.

Thorough clinical evaluation of the affected limb is essential to maximize patient outcome. Clinical examination of the lower limb must be carried out with the patient lying or sitting on an exam table and more importantly, with static loading. Then, assessing the impact of the deformity in functional activities is crucial to clarify discomfort sensed by the patient during daily life activities. Caregivers, family, but also physiotherapists and the family doctor, usually play an important role maintaining and improving patient comfort levels, and autonomy in daily life. Their contributions in concert with patient complaints help specialists to determine potential and realistic achievable goals, and to help select the appropriate course of treatment.[15,16]

It is crucial to differentiate spastic muscle overactivity from soft tissue contractures, as well as to identify which muscles are involved in the deformity. Evaluating the activity of antagonistic muscles helps to avoid over correction.[17] Thus, motor nerve blocks are often quite useful in assessing muscle involvement.[12,18] Following the French clinical guidelines for peripheral motor nerve blocks, injection of local anesthetic is safe, easy to perform, and the effect may last for a few hours.[18] Selective motor nerve blocks targeting a specific distal motor branch can help to better assess an individual muscles contribution to the deformity, without inducing sensory deficit that may hamper the interpretation of the result by the patient.[19] Successive nerve blocks can be performed if the total dose administrated does not exceed the total recommended dose.[18] Motor nerve blocks also assist in predicting the outcomes of BoNT injections or neurotomy[20,21] and help to establish attainable therapeutic goals with the patient.[22]

In addition to the clinical exam, additional investigations are frequently necessary to better assess EVF. During the swing and stance phases of gait, two-dimensional video analysis is useful to explore dynamic components of muscle overactivity implicated in EVF. Filming patients in 2 dimensions is also helpful in complex multi-joint deformity situations, or when a deformity changes overtime (dystonia). Radiological exams (X-ray and CT-scan) are required as a complement to clinical exam if a patient presents with a complex foot deformity, joint pain, or to assess the quality of the joint. According to the experts of our study, dynamic multi-channel electroneuromyography and gait analysis are not necessary before EVF treatment. However, more than half of the experts did not have access to the machines required for this assessment or lacked competence to perform this assessment.

The first-line treatment for correctable EVF relies on BoNT injections and rehabilitation. However, when the deformity is no longer correctable, a surgical approach can sometimes be performed as a first line treatment. In general, oral medication for muscle overactivity is not useful, due to side effects and meagre clinical benefit. For equivalent results, soft tissue surgery (muscle, tendon and nerve) should always be favored over bone and joint surgery (arthrodesis). As arthrodesis outcomes the overuse of adjacent joints by transferring mechanical forces, concomitant treatment of muscle overactivity and/or retraction of muscles involved in the deformity must also be performed. In contrast, soft tissue surgery is considered as less risky, more reversible, easier to perform, has less post-operative immobilization and enables earlier rehabilitation (Figures 2). Recently, historical soft tissue surgery techniques that preserve joints have been revisited, and preferred by teams specialized in neuro-orthopedic deformities.[8] Percutaneous needle tenotomies were performed during the 18$^{th}$ century, to lengthen tendons when retracted.[23,24] This technique is less invasive than open surgery, and can be conducted on fragile patients under local or general anesthesia.[25] Therefore, doctors of today must not think about compromising hope of functional recovery in younger patients. In parallel with percutaneous tenotomy, new and innovate techniques are emerging, like cryoneurotomy,[26] and laser surgery, to treat hemiplegic patients suffering for neuro-orthopedic deformities. These techniques are promising but have not yet been evaluated in randomized trials.

**Study Limitations**

The main limitation of this study was the selection of the experts who are rare in the field of neuro-orthopedic. Experts were selected if they have at least one publication peer reviewed specifically regarding the following topics: muscle overactivity, neuro-orthopedic deformities, heterotopic ossification; and/or have presented in international congresses on the same topics and continue to work in this field. Years of experience was not considered as a pre-requisite as neuro-orthopedic is a quite young sub-specialty in PMR specialty.

**Conclusion**

This study was performed to address the absence of recommendations for the management of EVF. We developed these first guidelines using a Delphi process to provide unanimity on the process of diagnosing, assessing and treating EVF. The establishment and dissemination of this information to physicians, specialists, and also non-specialists should make it possible to direct these specific patients to a network of experts, in order to optimize patient functional recovery and improve their autonomy to facilitate social integration.

**Author contribution:**

Conception and design of the study: FG

Steering committee: FG, EA, FD, LG

Experts who answer questionnaires: MS, LG, TD, TG, SC, PM, PW, RR, TW, AE, MAK, FM, PZ, AP, FC, BC, NSN, CF, AY, BP, PH, SV, PR, RD, PD, AS, EA, FG

Acquisition and analysis of data: MS, FG

Drafting a significant portion of the manuscript or figures: MS, FG

**References**


1. Verdié C, Daviet JC, Borie MJ, et al. [Epidemiology of pes varus and/or equinus one year after a first cerebral hemisphere stroke: apropos of a cohort of 86 patients]. *Ann Readaptation Med Phys Rev Sci Soc Francaise Reeducation Fonct Readaptation Med Phys*. 2004;47(2):81-86. doi:10.1016/j.annrmp.2003.10.005

2. Kerrigan DC, Burke DT, Nieto TJ, Riley PO. Can toe-walking contribute to stiff-legged gait? *Am J Phys Med Rehabil*. 2001;80(1):33-37. doi:10.1097/00002060-200101000-00009

3. Cieza A, Causey K, Kamenov K, Hanson SW, Chatterji S, Vos T. Global estimates of the need for rehabilitation based on the Global Burden of Disease study 2019: a systematic analysis for the Global Burden of Disease Study 2019. *Lancet Lond Engl*. December 2020. doi:10.1016/S0140-6736(20)32340-0

4. Lin JA, Liao CC, Chang CC, Chang H, Chen TL. Postoperative adverse outcomes in intellectually disabled surgical patients: a nationwide population-based study. *PloS One*. 2011;6(10):e26977. doi:10.1371/journal.pone.0026977

5. Fuller DA, Keenan MAE, Esquenazi A, Whyte J, Mayer NH, Fidler-Sheppard R. The impact of instrumented gait analysis on surgical planning: treatment of spastic equinovarus deformity of the foot and ankle. *Foot Ankle Int*. 2002;23(8):738-743. doi:10.1177/107110070202300810

6. Deltombe T, Wautier D, De Cloedt P, Fostier M, Gustin T. Assessment and treatment of spastic equinovarus foot after stroke: Guidance from the Mont-Godinne interdisciplinary group. *J Rehabil Med*. 2017;49(6):461-468. doi:10.2340/16501977-2226

7. Allart E, Sturbois-Nachef N, Salga M, Rosselin C, Gatin L, Genêt F. Neuro-Orthopedic Surgery for Equinovarus Foot Deformity in Adults: A Narrative Review. *J Foot Ankle Surg Off Publ Am Coll Foot Ankle Surg*. November 2021:S1067-2516(21)00476-2. doi:10.1053/j.jfas.2021.11.012

8. Genêt F, Denormandie P, Keenan MA. Orthopaedic surgery for patients with central nervous system lesions: Concepts and techniques. *Ann Phys Rehabil Med*. October 2018. doi:10.1016/j.rehab.2018.09.004

9. Keenan MA. The management of spastic equinovarus deformity following stroke and head injury. *Foot Ankle Clin*. 2011;16(3):499-514. doi:10.1016/j.fcl.2011.07.002

10. Ward AB. Managing spastic foot drop after stroke. *Eur J Neurol*. 2014;21(8):1053-1054. doi:10.1111/ene.12404

11. Wissel J, Ward AB, Erztgaard P, et al. European consensus table on the use of botulinum toxin type A in adult spasticity. *J Rehabil Med*. 2009;41(1):13-25. doi:10.2340/16501977-0303

12. Yelnik AP, Simon O, Parratte B, Gracies JM. How to clinically assess and treat muscle overactivity in spastic paresis. *J Rehabil Med*. 2010;42(9):801-807. doi:10.2340/16501977-0613

13. Mullen PM. Delphi: myths and reality. *J Health Organ Manag*. 2003;17(1):37-52. doi:10.1108/14777260310469319

14. Powell C. The Delphi technique: myths and realities. *J Adv Nurs*. 2003;41(4):376-382. doi:10.1046/j.1365-2648.2003.02537.x

15. Deltombe T, Gilliaux M, Peret F, et al. Effect of the neuro-orthopedic surgery for spastic equinovarus foot after stroke: a prospective longitudinal study based on a goal-centered approach. *Eur J Phys Rehabil Med*. 2018;54(6):853-859. doi:10.23736/S1973-9087.18.04993-6

16. Ambrose AF, Verghese T, Dohle C, Russo J. Muscle Overactivity in the Upper Motor Neuron Syndrome: Conceptualizing a Treatment Plan and Establishing Meaningful Goals. *Phys Med Rehabil Clin N Am*. 2018;29(3):483-500. doi:10.1016/j.pmr.2018.03.004

17. Gracies JM, Bayle N, Vinti M, et al. Five-step clinical assessment in spastic paresis. *Eur J Phys Rehabil Med*. 2010;46(3):411-421.

18. Yelnik AP, Hentzen C, Cuvillon P, et al. French clinical guidelines for peripheral motor nerve blocks in a PRM setting. *Ann Phys Rehabil Med*. 2019;62(4):252-264. doi:10.1016/j.rehab.2019.06.001

19. Picelli A, Chemello E, Verzini E, et al. Anatomical landmarks for tibial nerve motor branches in the management of spastic equinovarus foot after stroke: An ultrasonographic study. *J Rehabil Med*. 2019;51(5):380-384. doi:10.2340/16501977-2543

20. Picelli A, Battistuzzi E, Filippetti M, et al. Diagnostic nerve block in prediction of outcome of botulinum toxin treatment for spastic equinovarus foot after stroke: A retrospective observational study. *J Rehabil Med*. 2020;52(6):jrm00069. doi:10.2340/16501977-2693

21. Deltombe T, Bleyenheuft C, Gustin T. Comparison between tibial nerve block with anaesthetics and neurotomy in hemiplegic adults with spastic equinovarus foot. *Ann Phys Rehabil Med*. 2015;58(2):54-59. doi:10.1016/j.rehab.2014.12.003

22. Filipetti P, Decq P. [Interest of anesthetic blocks for assessment of the spastic patient. A series of 815 motor blocks]. *Neurochirurgie*. 2003;49(2-3 Pt 2):226-238.

23. Coroian F, Jourdan C, Froger J, et al. Percutaneous Needle Tenotomy for the Treatment of Muscle and Tendon Contractures in Adults With Brain Damage: Results and Complications. *Arch Phys Med Rehabil*. 2017;98(5):915-922. doi:10.1016/j.apmr.2016.11.014

24. Boffeli TJ, Collier RC. Minimally invasive soft tissue release of foot and ankle contracture secondary to stroke. *J Foot Ankle Surg Off Publ Am Coll Foot Ankle Surg*. 2014;53(3):369-375. doi:10.1053/j.jfas.2013.06.008

25. Gatin L, Schnitzler A, Calé F, Genêt G, Denormandie P, Genêt F. Soft Tissue Surgery for Adults With Nonfunctional, Spastic Hands Following Central Nervous System

Lesions: A Retrospective Study. *J Hand Surg*. 2017;42(12):1035.e1-1035.e7. doi:10.1016/j.jhsa.2017.08.003

26. Rubenstein J, Harvey AW, Vincent D, Winston P. Cryoneurotomy to reduce spasticity and improve range of motion in spastic flexed elbow. A visual vignette. *Am J Phys Med Rehabil*. October 2020. doi:10.1097/PHM.0000000000001624

**Figure 1. Delphi process**

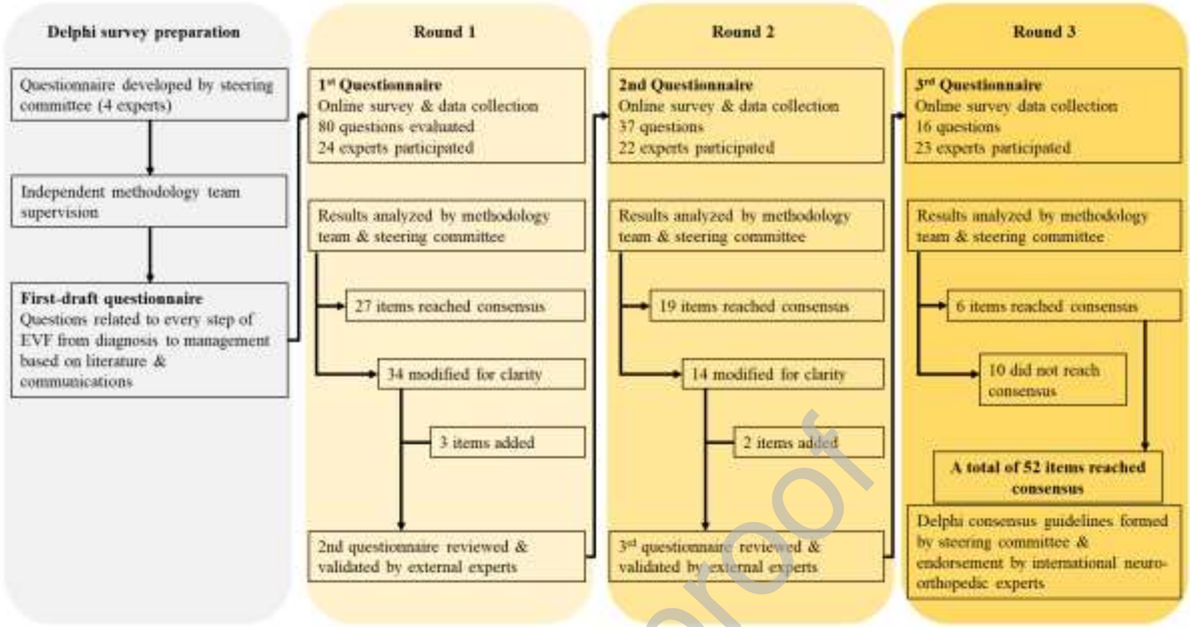


**Figure 2. Evaluation and treatment of spastic equinovarus foot deformity**

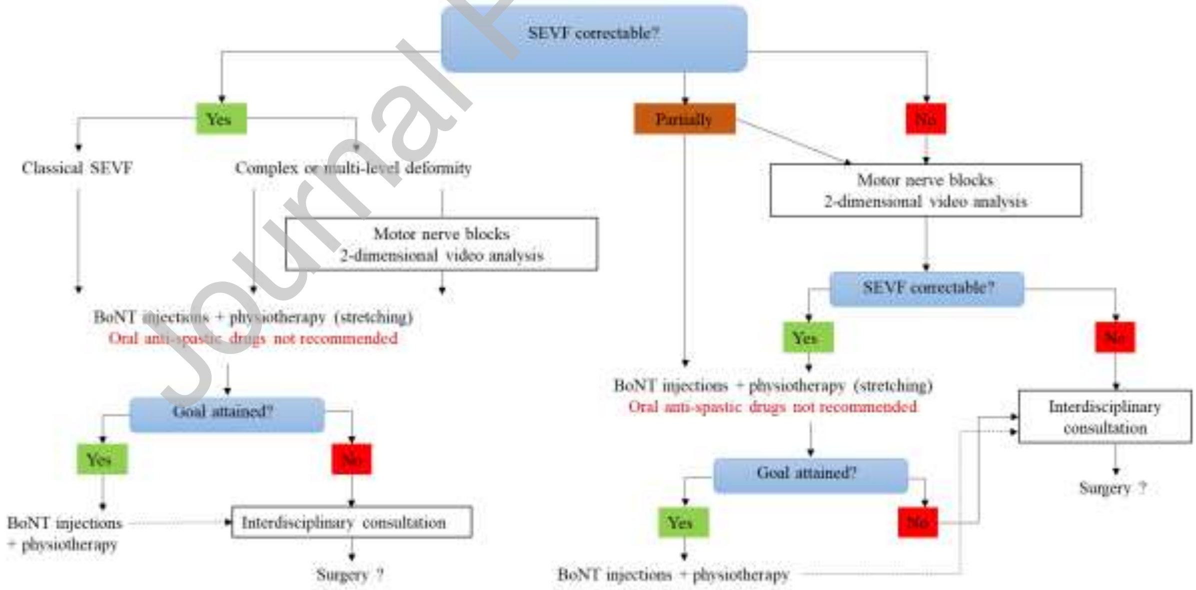


**Table 1: Anatomical considerations, clinical and instrumental assessment: summary of strong consensus (>80% agreement)**

**Table 1: Anatomical considerations, clinical and instrumental assessment: summary of strong consensus (>80% agreement)**

| Anatomical considerations | Clinical Assessments | Instrumental assessment |
|---|---|---|
| *Tibialis posterioris* induces varus of the hind foot (80%) | Functional muscle activation is more important rather than analytic muscle activation | Two-dimensional video analysis is helpful but not necessary before treatment (87.5%) |
| *Triceps surae* (95.8%), and more specifically *soleus* (63.6%), are responsible for equinus of the hind foot. | Before treatment, differentiate muscle overactivity from soft tissue contracture (100%) | X-ray and CT Scan are required to assess complex equinovarus foot deformity (100%) |
| Muscles inducing a pronation of the forefoot in open chain are responsible for a varus of the hind foot in close chain (83.3%) (*Fibularis Longus)* | Before surgery, assessment of antagonist muscles is essential (to avoid over correction and to select the surgical technique) (95.8%) | |
| | Tibial motor nerve blocks are often necessary before surgery (91.3%) | |
| | Preoperative clinical assessment by a Physical and Rehabilitation medicine physician is necessary (90.9%) | |
| | Outcome of previous botulinum toxin injections in overactive muscles helps to establish the indication for surgery (81.8%) | |
| | Preoperative interdisciplinary consultation with the patient is needed (formal agreement to define personalized and attainable therapeutic goals) (91.7%) | |

**Table 2: Management of an equinovarus foot deformity: summary of strong consensus (>80% agreement)**

**Table 2: Management of an equinovarus foot deformity: summary of strong consensus (>80% agreement)**

| | Correctable deformity | Uncorrectable deformity |
|---|---|---|
| **Sequence of treatment:** | | |
| - 1st line of treatment | Botulinum toxin injections<br>Physical therapy | Botulinum toxin injections<br>Physical therapy<br>Surgery in specific cases |
| - 2nd line of treatment | Surgery | |
| - Not recommended | Oral anti-spastic drugs | |
| **Surgical procedure depends on patient ability to walk:** | | |
| - Patient able to walk | | |
| 1st line | Surgical procedure involving tendons (transfer, lengthening) and/or nerves (neurotomy) | Surgical procedure involving tendons: tendon transfer (to exploit functioning muscles) and/or tenotomy (to eliminate their influence) |
| 2nd line | | Neurotomy combine to surgical procedure involving tendons (transfer, lengthening)<br>Neurotomy alone can be proposed if :<br>1/ deformity partially correctable and deformity correctable after nerve block,<br>2/ useful equine |
| Not recommended | Tenotomy | Arthrodesis if tenotomy of the tendon involved in the deformity is not performed in the same time |
| - Patient unable to walk | | |

| | | |
|---|---|---|
| 1st intention | Surgical procedure involving tendons (tenotomy, transfer, lengthening) or/and nerves (neurotomy) | Surgical procedure involving tendons: tendon transfer (to exploit functioning muscles) and/or tenotomy (to eliminate their influence) |
| 2cd intention | Neurotomy can be combined with tendon or intramuscular lengthening (50%), tenotomy (50%) and tendon transfer | Neurotomy combine to surgical procedure involving tendons (transfer, lengthening)<br>Neurotomy alone can be proposed if :<br>1/ deformity partially correctable and deformity correctable after nerve block,<br>2/ useful equine |
| Not recommended | | Arthrodesis if tenotomy of the tendon involved in the deformity is not performed in the same time |
| **Surgery:** | Within the 1st year after central nervous system damage | |
| | Exploit functioning muscles or eliminate their influence | |
| | Musculo-tendenous lengthening and tenotomy can be performed using open surgery but also by a percutaneous technique | |
| | Percutaneous tenotomy can be performed by a Physical and Rehabilitation Medicine (PRM) physician whether he has been trained | |
| | Soft tissue surgery must be firstly preferred to bone or joint surgery | |
| | Arterial insufficiency contraindicates bony surgery | |
| **Post-surgery management:** | Organize post-surgical management as soon as the surgery is validated | |
| | Trained PRM physician can perform the consultation for cast removal and after 3 months post-surgery | |
| | Follow-up by PRM specialist should be established or continues after surgery | |
| | There is some indication for botulinum toxin injections after surgery (new goals) | |