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REVIEW ARTICLE

DOES CASTING AFTER BOTULINUM TOXIN INJECTION IMPROVE OUTCOMES IN ADULTS WITH LIMB SPASTICITY? A SYSTEMATIC REVIEW

Jordan FARAG, MD[1,2] Rajiv REEBYE, MD[1,2], Carl GANZERT, MSc[5] and Patricia MILLS, MD, MHSc[1–4]
From the [1]Department of Medicine, University of British Columbia, [2]GF Strong Rehabilitation Centre, [3]International Collaboration on Repair Discoveries (ICORD), [4]Rehabilitation Research Program, Vancouver Coastal Health Research Institute, Vancouver, and [5]Hodgson Orthopedic Group, Coquitlam, BC, Canada

Objective: **To determine current evidence for casting as an adjunct therapy following botulinum toxin injection for adult limb spasticity.**
Design: **The databases MEDLINE, EMBASE, CINAHL and Cochrane Central Register of Controlled Trials were searched for English language studies from 1990 to August 2018. Full-text studies using a casting protocol following botulinum toxin injection for adult participants for limb spasticity were included. Studies were graded according to Sackett's levels of evidence, and outcome measures were categorized using domains of the International Classification of Disability, Functioning and Health. The review was prepared and reported according to PRISMA guidelines.**
Results: **Five studies, involving a total of 98 participants, met the inclusion criteria (2 randomized controlled trials, 1 pre-post study, 1 case series and 1 case report). Casting protocols varied widely between studies; all were on casting of the lower limbs. There is level 1b evidence that casting following botulinum toxin injection improves spasticity outcomes compared with stretching and taping, and that casting after either botulinum toxin or saline injections is better than physical therapy alone.**
Conclusion: **The evidence suggests that adjunct casting of the lower limbs may improve outcomes following botulinum toxin injection. Casting protocols vary widely in the literature and priority needs to be given to future studies that determine which protocol yields the best results.**

Key words: spasticity; botulinum toxin; casting; rehabilitation.

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Correspondence address: Patricia Mills, GF Strong Rehabilitation Centre, 4255 Laurel St, Vancouver, BC, V5Z 2G9, Canada. E-mail: patricia.mills@vch.ca

LAY ABSTRACT

Spasticity is a common and problematic consequence of neurological conditions affecting the brain and spinal cord. It is characterized by intermittent or sustained involuntary muscle activation that can limit function and quality of life. Intramuscular injection with botulinum toxin is a useful treatment in such patients in order to weaken the spastic muscle. This study reviewed the published evidence for the use of casting after botulinum toxin injection for limb spasticity in adults. Casting of a limb after botulinum toxin injection shows promise in improving function in patients with spasticity, although further research is needed to determine the best method to use.

Spasticity, a sensori-motor disorder characterized by intermittent or sustained involuntary muscle activation, is a common and potentially problematic consequence of upper motor neurone disorders (1). A recent systematic review of 17 observational studies revealed that the presence of spasticity is associated with worse health status in patients with chronic neurological conditions (2). Spasticity may also reduce quality of life and heighten economic burden (2, 3).

There are various treatment approaches for spasticity, which differ based on the pattern of increased muscle tone, patient characteristics and functional goals. Botulinum toxin (BoNT) is an effective pharmacological treatment for focal muscle over-activity in a wide range of neurological conditions (4, 5). There is high-level evidence to suggest that adjunct therapies may improve outcomes after BoNT injection (6, 7). However, at present there are no systematic reviews in the literature describing the current evidence and protocols used for casting as an adjunct therapy to BoNT injection.

In spastic muscle, the number of serial sarcomeres becomes reduced, which may contribute to more rapid development of contractures. Immobilization in the lengthened position may increase the length and number of serial sarcomeres (8). Casting with a non-removable external device theoretically provides a prolonged stretch of the muscle-tendon complex to prevent or correct soft-tissue contractures associated with spasticity. In addition to the soft-tissue changes that occur with prolonged muscle stretching, casting may also affect the neural circuits contributing to spasticity. Casts provide firm, consistent pressure distributed across the skin in a total-contact fashion. This may reduce the sensory input from cutaneous, muscle and joint receptors that contribute to spasticity (9, 10). Furthermore, prolonged stretch of the muscle-tendon complex may contribute to decreased alpha motor excitability, which could also improve spasticity (9).

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Casting is an attractive treatment option, as it can be done with relatively inexpensive and accessible materials, such as plaster, it does not require a significant amount of time for application, and can be applied either once or several times (serial casting). Potential downsides include soft-tissue injury and pain, requiring prompt removal of the cast. Since the cast cannot be applied or removed by the patient, frequent appointments may be required depending on the number of cast changes. This can be particularly inconvenient for patients with mobility impairments. Casting protocols vary widely between clinicians and it is not yet understood which approach yields the best outcomes. The systematic review by Mills et al. demonstrated that, at the time of publication, there were a limited number of randomized controlled trials (RCT) using casting following injections (6). It highlighted the need to explore this topic in greater depth, including understanding what treatment protocols have been used across all studies (not just RCTs) and with what degree of success.

The primary objective of this study is to synthesize the current evidence for casting in adults as an adjunct treatment following BoNT injection for limb spasticity resulting from various neurological conditions. The secondary objective of this study is to present casting protocols and outcome measures used in the literature for the purpose of informing future research in this area.

METHODS

Systematic review

This review was prepared and reported with reference to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (11). Details of the protocol for this systematic review were registered on PROSPERO (CRD42017073098).

A systematic search strategy, developed by the College of Physicians and Surgeons of British Columbia librarians, was conducted to identify relevant studies published between 1990 and August 2018 using electronic databases MEDLINE, EMBASE, CINAHL and Cochrane Central Register of Controlled Trials. Reference lists of systematic reviews and included studies were reviewed to expand the dataset. The search was restricted to the English language. The search strategy was based on 3 key concepts: spasticity, BoNT, and casting. An example of the search strategy, as applied in MEDLINE, is shown in Appendix SI[1].

Eligibility criteria

For this review, the study inclusion criteria were: (*i*) full-text studies of any design using a casting protocol following BoNT injection for spasticity management on any proportion of the participants; (*ii*) adult participants over the age of 18 years with limb spasticity from a neurological condition; (*iii*) clinical outcomes including spasticity, range of motion, pain, function and adverse events; and (*iv*) English language studies. As per the Lannin et al. systematic review of upper extremity casting in patients with central nervous system motor disorders, casts were defined as any non-removable, external device made from plaster or casting tape applied with the intention of modifying the structural or functional characteristics of the neuromuscular system (12).

Study selection

Two reviewers independently reviewed titles and abstracts of studies to determine eligibility for inclusion. Disagreement was resolved through consensus and, if necessary, by third-party resolution. Studies that clearly failed to meet the inclusion criteria were not reviewed further. Those that could not be excluded were retrieved and reviewed in full-text by the 2 reviewers. In all instances, differences of opinion were resolved by discussion. Studies that met criteria were retrieved and reviewed in detail.

Data collection

Data were extracted independently from all included studies and in duplicate into Excel spreadsheets, with the templates adapted from the Cochrane Collaboration (13). Data included a description of participants, intervention protocols, outcome measures and results. When BoNT injection or casting protocol information was missing or not available, the authors were contacted for additional information. Contact was made via email at 2 time-points separated by 2 weeks; contacted authors had 2 weeks to respond to each email, for a total of 4 weeks of response time following the first email contact. If no casting protocol information was available following paper abstraction or email contact, the study was excluded. If at least partial casting protocol information was available, the study was included. It was determined *a priori* by the study authors that casting protocols would be considered completely reported (100%) if the study methods described: timing of casting application post BoNT injection, casting material, position of patient during casting, casting angle, total duration of casting, frequency of cast change. Time that it took to cast per casting session was also documented when available, but did not contribute to the percentage of reporting calculation.

Risk of bias assessment

Two reviewers independently assessed the methodological quality of the included studies. Differences in scores were resolved by a third party. Quality assessment was performed using the Physiotherapy Evidence Database (PEDro) scoring system for RCTs and a modified Downs and Black tool for non-RCTs (14–16). The PEDro scale is composed of 11 yes or no quality items, 10 of which are used to calculate the final PEDro score (0–10). The modified Downs and Black scale consists of 27 1-point questions and 1 2-point question, resulting in a final score ranging from 0 to 28 (16). For both tools, higher scores are indicative of greater methodological quality. To simplify interpretation of results, studies scoring 9 or 10 on the PEDro scale or $\geq$24 on the Downs and Black scale are considered methodologically to be of excellent quality; scores of 6–8 on the PEDro scale or 20–23 on the Downs and Black scale are considered of good quality; scores of 4–5 on the PEDro scale or 15–19 on the Downs and Black scale are of fair quality; and scores $<$4 on the PEDro scale or $\leq$14 on the Downs and Black scale are considered of poor quality (16). The level of evidence

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for study results was evaluated using a 5-level scale (simplified form of Sackett), where level 1 (the highest level of evidence) is an RCT with a PEDro score ≥ 6; level 2 is an RCT with a PEDro score ≤ 5, a non-randomized prospective-controlled study, or a cohort study; level 3 is a case-control study; level 4 is a pre- and post-test or a case series; and level 5 is an observational report or case report with only a single subject (14–16).

Outcome measures

Outcome measures from the studies included in this review were listed and classified according to the International Classification of Functioning, Disability and Health (ICF) domains. The ICF was published by the World Health Organization (WHO) in May 2001 to provide a common international language for describing health and disability in clinical and research settings (17). The ICF framework classifies function into 3 domains: body structure and function, activity, and participation. Outcome measures that did not fit within a domain were classified as "other".

Statistical analysis

Because of the paucity of studies for the primary objective and the differences in outcome measured used, a formal meta-analysis was not feasible. Therefore, the results of this review are presented in a narrative form. Description of pre-casting interventions, casting protocols and study results are shown in Table I. Description of outcome measures subcategorized by the ICF domains are presented in Table II. Levels of evidence are summarized in Table III.

RESULTS

Search strategy

Fig. 1 shows the flow of study selection. A total of 108 studies were identified through the electronic database search. After the removal of duplicate studies and screening of articles based on title and abstract, 10 studies were included for full review. Three of these studies did not meet the inclusion criteria. Two of these studies did not include casting protocol details and were excluded after telephone or email follow-up (23, 24).

Risk of bias assessment

The PEDro and Downs and Black scores for all included studies are recorded in Table I. PEDro values ranged between 7 and 8; Downs and Black scores ranged between 5 and 17.

Population

Characteristics of included studies are summarized in Table I. The 5 studies included a total of 98 participants. The number of participants ranged from 1 to 42 per study.

Casting protocols

Casting protocols varied widely between studies; all were on casting of the lower limb. Of the 5 studies included for full review, all had some degree of missing data. Completeness of reporting of casting methodology ranged from as low as 50% (3/6) to as high as 83% (5/6). Thus, all authors were contacted for missing data, with 3 of the 5 authors responding with information via email. Information acquired from authors is denoted in *italics* in Table I.

Outcome measures

A total of 10 distinctive outcome measures were used within the studies (see Table II). In all, 6 measurements were classified in the ICF Body Structure and Function domain and 4 in the Activity domain. None of the outcome measurements were classified in the Participation domain, and none of the studies used an outcome measurement for quality of life. The most commonly used outcome measure was ankle passive range of motion, which was used in all studies.

Study results and levels of evidence

Study results are summarized in Table I. There were no RCTs that compared BoNT alone with BoNT and

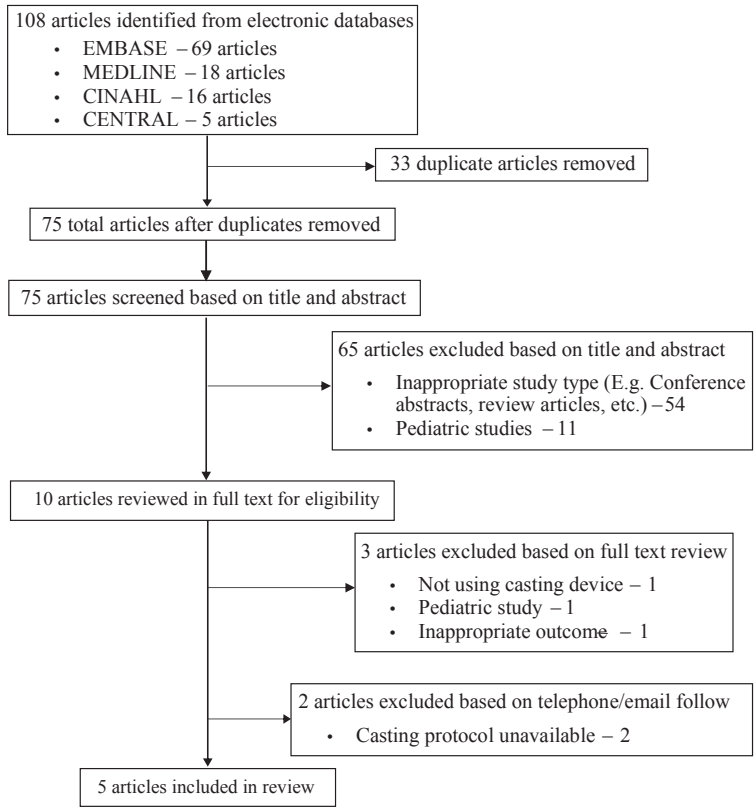

Fig. 1. Study selection flowchart.

Table I. Botulinum toxin (BoNT) and casting protocols

Study details Authors (year) Country Study design Risk of bias Sample size Population	Pre-casting intervention BoNT type Method (of injection site localization) Dilution BoNT dosing Muscle selection Other (e.g. pre-casting nerve block)	Casting protocol Timing of casting application post BoNT injection Casting material Position of patient (during casting) Casting angle Duration of casting (total) Cast change (frequency) Time to cast (per casting session)	Results
Carda et al. (18) (2011) Italy SB RCT PEDro = 7 *n* = 69 (23 analysed in casting group) P: ≥6 months post-stroke with spastic equinovarus foot	Type: Xeomin™ Method: EStim Dilution: 50 U/1.0ml 0.9% NS Dosing: 50–140 U; Mean (SD): 242 U (48) Muscles: GM, GL, soleus	Timing: *Immediate* Material: Fibreglass cast with stockinette lining, synthetic undercast padding and wooden foot support; bony prominences protected with gel pads. Position of patient: *seated* Casting angle: neutral Duration of casting: 1 week Cast change: twice per week Time to cast: 30 min	1. MAS: ↓ at 20 and 90 days ($p < 0.02$); greater reduction compared with taping and stretching groups only at 20 and 90 days ($p < 0.02$). 2. 6MinWT: ↑ at 20 and 90 days ($p < 0.02$); greater in casting vs stretching group at 90 days ($p < 0.02$). 3. 10MetWT: ↑ in casting group only at 20 and 90 days compared with baseline ($p < 0.02$); no difference between groups. 4. Ankle PROM: casting > stretching group at all time points and taping group at 90 days ($p < 0.02$). 5. Strength of ankle dorsiflexors, functional ambulation: no significant differences between groups. AE: discomfort and pain causing treatment interruption ($n = 1$), skin blisters ($n = 2$) and oedema ($n = 1$).
Verplancke et al. (19) (2005) UK DB RCT PEDro = 8 *n* = 35 P: Adults post-ABI with spastic equinovarus ankle deformity	Type: Botox™ Method: *Anatomical landmarking* Dilution: 50 U/0.5 ml 0.9% NS Dosing: 100 U split between GM/GL, 100 U to soleus Muscles: GM, GL, soleus	Timing: *within 10 days of event* Material: "Combicast" made up of Soft Cast and Scotchcast™ (supplied by 3M™ Health Care Ltd) with a double layer of polyester stockinette and Microfoam™ to protect bony prominences Position of patient: *supine* Casting angle: neutral Duration of casting: 12 weeks Cast change: when there was a 10° change in dorsiflexion Time to cast: *35–40 min*	1. Ankle PROM: ↑ mean change in ankle dorsiflexion in BoNT injection plus casting (13.59°) vs saline injection plus casting (11.69°) vs PT only (4.59°). 2. MAS: ↓ in BoNT injection plus casting ($p = 0.04$) vs saline injection plus casting ($p < 0.03$), but not in PT only group ($p > 0.05$). AE: soft-tissue contracture at subtalar joint ($n = 1$), transient "flu-like" symptoms post-BoNT injection ($n = 1$), skin damage (mostly partial thickness breakdown) in casting plus saline injection ($n = 6$), skin damage (mostly discoloration only) in casting plus BoNT injection ($n = 5$).
Singer et al. (20) (2003) Australia Mixed RCT and pre-post study: 5 of the 10 participants enrolled in an RCT to examine the effect of serial casting plus BoNT vs placebo injection. The other 5 received casting only. Results combined as RCT did not show between-group difference D&B = 17 *n* = 10 P: Adults post-ABI with spastic equinovarus ankle deformity	Type: BoNT A (unspecified) Method: *EMG* Dilution: *20U/1.0 ml* Dosing: *70–125 U* Muscles: *GM, soleus, TP, FDL*	Timing: *minimum 7 days post-injection* Material: below-knee plaster cast with silicone gel segments to cover potential pressure areas, plaster back-slab and bandages applied circumferentially, covered in a fiberglass-impregnated wrap Position of patient: prone Casting angle: initial cast applied in dorsiflexed position of minimal tension to soft tissues; subsequent casts applied in dorsiflexed position of maximal achievable tension Duration of casting: mean of 5 weeks (Range= 3–10 weeks). Cast change: weekly re-casting until 10° of dorsiflexion was achieved with an extended knee, or no measurable gain (<5°) was obtained for 3 consecutive weeks Time to cast: *30 min*	Data were analysed according to "casting" or "casting plus adjunctive treatment" sub- groups; as no differences were found for any outcome measures, data were pooled for both groups. Results for RCT $n = 5$ not reported Pooled results ($n = 10$): 1. Ankle PROM: ↑ median change in dorsiflexion of 30° and 15° with the knee flexed ($p < 0.001$), and extended ($p < 0.021$), respectively. 2. AnDT10: ↑ median change of 4.3° of dorsiflexion ($p < 0.0001$). In $n = 4$, who demonstrated consistent soleus stretch reflex responses on EMG, "reflex threshold angle" (the angle of visually detected EMG onset in response to stretch) increased into the available ROM. AE: not reported
Yasar et al. (21) (2010) Turkey Case series D&B = 15 *n* = 10 P: Chronic (>1 year) ambulatory hemiplegic stroke patients with spastic equinovarus deformity (MAS 3–4)	Type: Botox™ Method: *No response* Dilution: *No response* Dosing: 2–4 U/kg for GM/GL, 1–2 U/kg for soleus Muscles: GM, GL, soleus	Timing: *no response* Material: *no response* Position of patient: prone with knee flexed to 90° Casting angle: maximal achievable dorsiflexion Duration of casting application: 24 days Cast change: every 6 days (4 total casting sessions) Time to cast: *no response*	1. Ankle PROM: ↑ dorsiflexion from −12.90±2.33 pre-injection to −4.50±3.68 post-casting ($p = 0.004$). 2. FIM: significant improvement ($p = 0.025$). 3. PRS Knee and Foot contact scores: significant improvement ($p = 0.014$ and $p = 0.014$, respectively) AE: none observed
Xu et al. (22) (2015) China Case report D&B = 5 *n* = 1 P: 27-year-old female with recurrent peroneal spastic flatfoot	Type: Botox™ Method: US Dilution: 100 U/1.0ml 0.9% NS Dosing: 6 U/kg per muscle Muscles: peroneal muscles Other: Common peroneal nerve block with 3 ml of 2% lidocaine and subsequent casting was trialled as treatment before BoNT injection with casting	Timing: *no response* Material: arch sole made of silica; T-strap affixed to the foot at night in case of spasms. Position of patient: *no response* Casting angle: neutral Duration of casting: 6 weeks Cast change: *no response* Time to cast: *no response*	1. MAS: ↓ from 4/4 to 0/4 after BoNT and casting. 2. Ankle PROM: Exact degrees not reported. Authors report improvement from a position of foot eversion, valgus deformity of calcaneus and minimal peri-talar motion to "normal" after treatment AE: none observed

Italicized information denotes injection or casting details obtained after telephone or email correspondence with study authors. 6MinWT: 6-min walk test; 10MetWT: 10-m walk test; ABI: acquired brain injury; AE: adverse events; AnDT10: angle achieved at displacing torque of 10 Newton meters; DB: double-blind; D&B: Downs and Black assessment scale; EMG: electromyography; EStim: electrical stimulation; FDL: flexor digitorum longus; FIM: Functional Independence Measure; GL: lateral head of gastrocnemius; GM: medial head of gastrocnemius; MAS: Modified Ashworth scale; min: minutes; n: number; NS: normal saline; P: population; PROM: passive range of motion; PRS: Physician Rating Scale; PT: physiotherapy; SB: single-blind; TP: tibialis posterior; U: units; US: ultrasound.

Table II. Outcome measures categorized by International Classification of Functioning, Disability and Health (ICF) domains

Outcome	Number of studies	Studies, ref no.
Structure/function		
PROM of ankle	5	18, 19, 20, 21, 22
MAS	3	18, 19, 22
Strength of ankle dorsiflexors	1	18
PRS for knee and foot contact	1	21
AnDT10	1	20
EMG reflex threshold angle	1	20
Activity		
6MinWT	1	18
10MetWT	1	18
FAC	1	18
FIM	1	21

PROM: passive range of motion; MAS: Modified Ashworth scale; PRS: Physician Rating Scale; AnDT10: angle achieved at displacing torque of 10 Newton meters: EMG: electromyography; 6MinWT: 6-min walk test; 10MetWT: 10-m walk test; FIM: Functional Independence Measure; FAC: Functional Ambulation Category.

casting. In general, use of casting and BoNT improved spasticity outcomes compared with baseline status. Carda et al. (18) compared 3 adjunct therapies (casting, taping and stretching) after BoNT injection. Verplancke et al. also compared 3 groups: casting post BoNT injection, casting post saline injection, physical therapy only. In Singer et al., 5 of the 10 participants were enrolled in an RCT to examine the effect of serial casting plus BoNT vs placebo injection. The other 5 received casting only. Results were combined (pre-post study methodology) as the RCT did not show between group differences. Adverse events as a result of casting were reported in 4 studies, providing an adverse event profile in 58 participants (18–21). A total of 16 adverse events were reported for the 58 participants, all of which were related to soft-tissue injury. Only one treatment discontinuation due to pain as a result of casting was reported. Levels of evidence are summarized in Table III.

DISCUSSION

This is the first systematic review that has been conducted with an in-depth look at casting as an adjunct to BoNT injections for limb spasticity in the adult population. The included studies provide important insights into the use of casting for treatment of lower limb spasticity that can be applied to clinical practice and guide future research in this area.

It is important to note that currently there are no studies published that address whether casting improves spasticity outcomes when used as an adjunct compared with BoNT injection alone; the 3 prospective controlled studies on casting and BoNT lacked a control group with BoNT only, which is needed in order to answer this clinical question. It is also notable that there were no studies identified on casting of the upper limb. It would be worthwhile for clinicians to report their experiences with the upper limb, even as case reports, as this would be a valuable contribution to the literature.

Currently, for the lower limb, there is level 1b evidence that casting as an adjunct is more effective than stretching and taping, and that casting after either BoNT or saline injections is better than physical therapy alone. Interestingly, with respect to adverse events captured by Verplanke et al. (19), casting with BoNT injection resulted in less severe soft-tissue injury (mainly skin discolouration) compared with casting with saline injection (mainly partial skin breakdown). This is presumably as a result of the decrease in muscle tone from the BoNT resulting in less generation of pressure of the limb against the cast. These preliminary results suggest that casting probably is useful as an adjunct to BoNT injection for improving outcomes in the treatment of lower limb spasticity, especially passive range of motion and Modified Ashworth Scale. If there is a goal of minimizing the risk of casting-related soft-tissue injury, then the cast should be administered

Table III. Levels of evidence

Level of evidence	Study	Recommendations
Level 1	RCT Carda et al. (18) (2011) Italy	In stroke patients with spastic equinovarus foot deformity, casting as an adjunct to BoNT injection to the ankle plantar flexors improves outcomes compared with the adjuncts stretching (for MAS, Ankle PROM, 6MinWT) and taping (for MAS, Ankle PROM).
Level 1	RCT Verplancke et al. (19) (2005) UK	In severely brain injured patients with lower limb spasticity, casting with or without BoNT injection prevents the development of equinovarus foot deformity compared with physical therapy alone. Casting with BoNT injection may result in less significant soft-tissue injury compared with casting with saline injection.
Level 4	Prospective pre-post study Singer et al. (20) (2003) Australia	In brain-injured patients with spastic equinovarus foot deformity, serial casting improved PROM and AnDT10. In a subset of patients who received BoNT in addition to casting, similar improvements were seen.
Level 4	Case series Yasar et al. (21) (2010) Turkey	In stroke patients with spastic equinovarus foot deformity, serial casting following BoNT improves ankle PROM, FIM and PRS.
Level 5	Case report Xu et al. (22) (2015) China	In one patient with recurrent peroneal spastic flatfoot, casting following BoNT improved MAS and PROM.

PROM: passive range of motion; MAS: Modified Ashworth scale; PRS: Physician Rating Scale; AnDT10: angle achieved at displacing torque of 10 Newton meters: EMG: electromyography; 6MinWT: 6-min walk test; 10MetWT: 10-m walk test; FIM: Functional Independence Measure.

in conjunction with BoNT injection; however, further research is required to confirm these findings.

This review demonstrates that there is wide variation in casting protocols of the lower limb post BoNT injection, and highlights the need for studies that lead to the development of a standardized casting protocol. This standardized protocol can then be uniformly applied across future studies and in clinical practice. Use of a standardized casting protocol will allow future meta-analyses (comparison and pooling) of data across studies, thus increasing power and confidence in study results. Notably, studies are needed to determine whether better outcomes result with: immediate vs delayed cast application; keeping the knee flexed vs extended during casting; starting with the ankle at neutral vs at maximum dorsiflexion; and shorter (e.g. 1 week) vs longer (e.g. 12 weeks) cast application.

Given that the method of BoNT injection has been shown to affect spasticity-related outcomes (5), future studies should standardize BoNT injection protocols including muscle localization techniques and BoNT dilutions. Which muscle is being injected needs to be considered; for example, use of ultrasound has been shown to be superior to other methods of injection localization (e.g. anatomical localization, electrical stimulation) when injecting the soleus and gastrocnemius muscles (5).

It is also important to investigate pre-casting protocols that optimize intervention outcomes and improve study results. For example, Xu et al. (22). used a peroneal nerve block to determine available foot and ankle range prior to BoNT injection and casting. Clinicians are increasingly using nerve blocks as part of spasticity treatment algorithms to help select who would be most likely to benefit from what treatment, and determining available range prior to casting would allow for sub-analysis of patient groups according to pre-intervention range of motion (25).

Ideally future studies will also standardize the use of outcome measures. In the lower limb, we suggest that, at minimum, passive range of motion and Modified Ashworth Scale be used as outcome measures within the Body Structure and Function domain. The Modified Ashworth Scale is widely used by spasticity clinicians, and has moderate intra- and inter-rater reliability (26). There will have to be consensus on which Activity domain outcome measure should be included; the 10-m walk test is easier to administer in terms of training and time; however, it may not be sufficiently sensitive to detect differences compared with other measures, such as the 6-min walk test, as demonstrated by Carda et al. (18). These outcomes should be measured at multiple time-points post-intervention (e.g. 3 weeks and 3 months) to determine both short- and long-term effects. Consideration should also be given to including an outcome measure within the Participation domain of the ICF, such as Goal Attainment Scaling. With this tool, patient-specific goals, such as returning to work or recreational pursuits, could be measured. Lastly, future studies should include quality of life outcomes, as these are often most important to the patient. There also needs to be systematic collection and reporting of the burden on the patient and the payer in the form of time to cast, costs related to casting and costs related to adverse events, as these factors are important when fully assessing the risk to benefit ratio of an intervention. For example, skin breakdown could require significant interventions (e.g. pain medication, surgery, time off recreational pursuits or work) that can increase direct and indirect costs. Currently it appears as though casting is a relatively well-tolerated intervention, although care needs to be taken to monitor the skin for potential injury.

Conclusion

Casting as an adjunct to BoNT injection appears to improve spasticity-related outcomes compared with other adjunct therapies, and probably results in less significant soft tissue injury when used following BoNT injection compared with a stand-alone intervention. Currently there are no studies that address whether casting in addition to BoNT is more effective compared with BoNT alone. Addressing this clinical question is important given the extra time, costs and potential adverse events that can be incurred with casting. Casting protocols and outcome measures reported in the literature vary widely and need to be standardized for future studies. Results of this systematic review can be used to inform the development of an international consensus on casting protocols and outcome measures so as to increase the quality, power and confidence in results of future studies for the purpose of determining best practice guidelines for casting in the setting of spasticity.

The authors have no conflicts of interest to declare.

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Appendix SI. Search strategy: MEDLINE 1990 to August 2018

Number	Search	Results
1	exp muscle spasticity/	4,158
2	spastic*.mp.	26,048
3	1 or 2	26,048
4	exp botulinum toxins/	14,635
5	(botulinum or botox or onabotulinum* or abobotulinum* or incobotulinum* or rimabotulinum* or bont-a or meditoxin* or neuronox* or oculinum* or dysport* or myobloc* or xeomin*).mp.	21,359
6	4 or 5	21,359
7	exp casts, surgical/	8,396
8	(cast or casts or casting).mp.	53,142
9	7 or 8	53,142
10	3 and 6 and 9	78
11	exp adult/	6,582,111
12	10 and 11	14
13	exp age groups/	8,333,765
14	10 not 13	20
15	(child* or pediatr* or paediatri* or juvenile* or adolesc* or teen* or youth or boy or girl or infan* or newborn* or neonat* or toddler* or preschool* or pre-school*).mp.	4,018,067
16	14 not 15	10
17	12 or 16	24
18	remove duplicates from 17	23
19	Limit 18 to yr = "1990-current"	23
20	Limit 19 to English language	18