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Serial casting versus positioning for the treatment of elbow contractures in adults with traumatic brain injury: a randomized controlled trial

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Objective: To compare the effects of serial casting with positioning for 1 hour per day for the treatment of elbow flexion contracture in adults with traumatic brain injury.
Design: Pragmatic randomized controlled trial with concealed allocation and assessor blinding.
Setting: Four brain injury rehabilitation units.
Subjects: Twenty-six adults with elbow flexion contracture after traumatic brain injury participating in multidisciplinary inpatient rehabilitation.
Interventions: Subjects were randomized to receive either serial casting or positioning for two weeks. In the subsequent four weeks subjects could be positioned for up to 1 hour/day.
Main measures: Torque-controlled passive elbow extension was measured at baseline, post-intervention (two weeks), post-intervention plus one day, and at follow-up (four weeks post-intervention).
Results: All 26 subjects completed the study. Post-intervention, serial casting reduced contracture by an average of 22 degrees (95% confidence interval (CI) 13 to 31; $P < 0.001$) compared with the positioning group. One day later this effect had decreased to 11 degrees (95% CI 0 to 21 degrees; $P = 0.052$). The effect had almost completely disappeared at the four-week follow-up (mean 2 degrees, 95% CI −13 to 17; $P = 0.782$).
Conclusions: Serial casting induces transient increases in range of motion. These effects are not maintained.

Introduction

Contracture, or loss of joint mobility, is a common complication of traumatic brain injury. The prevalence of elbow flexion contracture has been estimated at 44% of people with traumatic brain injury admitted to a rehabilitation service.[1] Loss of joint mobility can impede the performance of everyday tasks and cause significant activity limitation.[1]

Physiotherapists commonly treat contracture with passive stretch.[2] The duration of passive stretch applied is variable. Some physiotherapists apply

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very brief stretches with their hands,[3] others apply longer stretches by positioning using equipment (e.g. standing on a wedge for 30 minutes to stretch calf muscles),[4] and others use casts to apply continuous stretch for days or weeks.[5] With *serial* casting the limb is held in a stretched position for 24 hours/day and the casts are changed regularly to maintain the stretch as the joint becomes more mobile.[5]

Stretch can increase joint mobility through a number of mechanisms. When applied for minutes or hours, stretch induces viscous deformation of soft tissues.[6,7] If applied regularly over days or weeks, stretch may also produce adaptations of tissue structure.[8–12] It is also possible that stretch causes neurophysiological changes, thereby reducing spasticity.[13] Lastly, apparent increases in range of motion may result from increased tolerance to stretch.[14] Viscous and neurophysiological effects are likely to be transient. Sustained changes in joint mobility are most likely to occur if stretch can induce structural adaptations.

The effects of stretch have been investigated in two systematic reviews and a modest number of randomized controlled trials, but the results of these trials and reviews are not conclusive. One systematic review concluded that passive stretch can produce lasting increases in range of motion in able-bodied subjects with less than normal joint range,[15] but it is not clear whether this result reflects real changes in tissue extensibility or just changes in tolerance to uncomfortable stretch sensations.[14] A series of recent randomized trials suggest that 30 minutes of daily stretch does not have a sustained effect on joint mobility compared with no stretch in people with spinal cord injury.[16–18] Some trials have performed head-to-head comparisons of different stretch protocols, but provide conflicting evidence of the superiority of long-duration stretch (e.g. 1 hour per day) over short-duration stretch (e.g. 15 minutes per day) for treatment of pathological contracture.[3,19–22] In addition, these trials do not differentiate between the transient and lasting effects of stretch.

A second systematic review specifically evaluated the effectiveness of serial casting in the management of contracture in adults with acquired brain injury.[13] While the review suggests that serial casting can prevent or reverse contracture, only two of the 13 studies included in the review were randomized controlled trials. Both trials were small ($n<15$), of poor quality, and compared serial casting to a no-stretch condition. Serial casting (i.e. 24 hour stretch) has not been compared with stretch of shorter duration (e.g. positioning). This comparison is of importance because clinicians are often faced with a choice between these alternatives.

The aim of this pragmatic randomized controlled trial was to compare the effectiveness of serial casting (stretch for 24 hours per day) and a positioning programme (stretch for 1 hour per day) for the treatment of elbow flexion contracture after traumatic brain injury.

Methods

Subjects

Subjects were recruited between June 2002 and October 2005 from three inpatient rehabilitation units for adults with traumatic brain injury in Sydney, Australia (Liverpool Health Service, Royal Rehabilitation Centre Sydney and Westmead Hospital). An inpatient unit providing rehabilitation for adults with traumatic brain injury in Brisbane, Australia (Princess Alexandra Hospital) was added as a fourth site from November 2004. All patients admitted for inpatient rehabilitation who fulfilled the following criteria were invited to participate:

1) sustained a traumatic brain injury;
2) participating in an inpatient physiotherapy programme for at least two weeks;
3) elbow flexion contracture of at least 15 degrees;
4) no orthopaedic or other injuries which would preclude serial casting of the elbow;
5) no clinical evidence of active heterotopic bone growth;
6) able to actively participate in physiotherapy; and
7) able to comply with both interventions.

Criterion 6 was amended in mid-2003 to allow recruitment of subjects who were minimally responsive.

Subjects were randomly allocated to receive either serial casting or positioning. The allocation sequence was unrestricted. Allocations were concealed using consecutively numbered, sealed, opaque envelopes. The envelopes were generated by the first author, who was not involved in the recruitment or allocation of subjects, thus ensuring concealment.

Subjects or their legal guardians provided informed consent to participate. The trial adhered to principles of the World Medical Association Declaration of Helsinki and was approved by the participating institutions' ethics committees.

Interventions

All subjects participated in a multidisciplinary inpatient rehabilitation programme designed to address their specific needs. This included an individually designed therapy programme to improve motor skills. Both groups performed exercises with the study arm for 15 minutes/day, five days/week. These exercises were designed to elicit activity of paralysed muscles and improve voluntary control of the upper limb muscles. Training included repetitive exercise to activate weak muscles, task-related training to improve strength and co-ordination, forced use of the affected limb with constraint of the unaffected limb, and the opportunity to practise intensively. For subjects who were minimally responsive, treatment focused on following simple commands to elicit muscle activity. Training was also provided for the non-study arm and for other tasks (e.g. walking and standing up from sitting), but this was not mandated in the study protocol.

Subjects in the serial casting group had long arm synthetic casts applied for two weeks with the elbow in a stretched position. The position was determined by either the subjects' perception of a strong stretch or the physiotherapists' perception of significant passive tension in the elbow flexor muscles. The cast was changed after seven days, or earlier if indicated, in order to progress the stretch. Consequently each subject had two or more casts applied to his or her arm over a two-week period. All subjects were monitored closely for sensation, movement, circulation, skin breakdown and the presence of swelling.

Subjects in the positioning group had passive stretch applied to the elbow flexor muscles for 1 hour each day, five days per week. Some subjects also received the same intensity and duration of stretch on the weekend if it could be implemented by family members. Stretch was administered in either a single 1-hour session or two 30-minute sessions. Stretch was applied by extending the elbow until the subject reported experiencing a strong stretch or until the physiotherapist judged the presence of significant passive tension. The stretch position was maintained using sandbags, slings or splints.

After two weeks, the cast was removed from the experimental subjects and positioning ceased in the control subjects. During the four-week follow-up phase, passive stretch for the elbow flexor muscles could be applied with positioning for up to 1 hour per day for subjects in either group, at the discretion of the treating physiotherapist. For the six weeks that subjects participated in the study, no other treatments for elbow flexion contracture (e.g. splinting, electrotherapy, botulinum toxin injections) were implemented.

Process variables

The treating physiotherapists and occupational therapists completed diaries detailing the duration of passive stretch for the elbow flexors and time spent practising with the study arm as well as the time spent practising other tasks. These were analysed to ascertain compliance with the protocol.

Outcomes

Outcomes of all randomized subjects were assessed regardless of the subjects' compliance with the experimental protocols. The primary outcome was assessed at baseline, post-intervention (two weeks), post-intervention plus one day, and at follow-up (four weeks post-intervention). The secondary outcomes were assessed at baseline, post-intervention (two weeks), and at follow-up (four weeks post-intervention).

Primary outcome

The primary outcome was passive elbow extension with the application of a standardized torque. The subject lay in the supine position with his or her shoulder slightly abducted and the upper arm supported on a plinth. Forearm position was standardized. Subjects were instructed to relax as much as possible during testing. A force was applied perpendicular to the distal end of the forearm to extend the elbow. The force was quantified using a spring balance. The amount of force was standardized within subjects. It was either the maximum amount of force that could be tolerated by the subject or, for minimally conscious subjects, the force judged by the assessor to produce significant passive tension at the baseline assessment. The passive force was maintained for 20 seconds then the inclination of the upper arm and forearm segments with respect to the horizontal were measured using a digital inclinometer; the difference in these inclinations gave the elbow angle. Elbow angle was calculated as degrees from full extension, so a larger angle denotes more contracture. Torque-controlled procedures for the measurement of passive range of motion have excellent inter-rater reliability.[23] We evaluated the test–retest reliability of our procedure by measuring the passive elbow extension of nine people with traumatic brain injury twice on the same day. The intraclass correlation coefficient was 0.98 (95% confidence interval 0.93 to 1.00).

Secondary outcomes

Secondary outcomes were: (1) spasticity, (2) maximum reach, (3) upper limb function, (4) pain, (5) global perceived effect of treatment, (6) perceived adverse effects of treatment, (7) degree of difficulty of treatment, (8) amount of pain during treatment, and (9) satisfaction with treatment. Spasticity of the elbow flexor muscles was quantified using the modified Tardieu Scale.[24] Two variables were recorded: quality of the muscle reaction when the forearm was rotated at a rate faster than the natural drop of the forearm under gravity (i.e. 'V3'), and the angle of catch (measured using the digital inclinometer). Maximum seated forward reach was measured by marking the position of the fingertips during a maximum forward reach on a table top, then measuring the distance between the sternum and table marker with a tape measure.[25] Upper limb function was measured using the Test Évaluant la Performance des Membres Supérieurs des Personnes Âgées (TEMPA).[26] Functional ratings were recorded for the 13 TEMPA reaching tasks (four unilateral tasks assessed on both arms plus five bilateral tasks) and added to produce a single total functional rating score (range −39 (severe upper limb dysfunction) to 0 (no or minimal upper limb dysfunction)). The TEMPA has excellent inter-rater reliability for the traumatic brain injury population.[27] Pain during assessment of passive elbow extension was measured on a 10-cm horizontal visual analogue scale labelled 'no pain' and 'worst pain I have ever had' at its extremes.[28] The global perceived effect of treatment was measured using a five-point scale ranging from 1 ('completely recovered') to 5 ('worsened')[29]; where possible both the subject and a relative provided ratings and the highest score was used for analysis. Outcomes (6) to (9) were measured at the post-intervention assessment only. Both the treating physiotherapists and the subjects (or a relative if subjects were minimally responsive) were asked if treatment had any negative effects and, if so, the nature of the effects. Subjects (or a relative) were asked to rate the degree of difficulty of the treatment on a five-point scale (very easy, easy, average, difficult, very difficult) and how painful the treatment was on a four-point scale (not at all, a little, a moderate amount, very painful). Subjects (or a relative) were also asked to rate satisfaction with treatment using a 10-cm horizontal visual analogue scale labelled 'physiotherapy was completely unsatisfactory' and 'physiotherapy was best possible' at its extremes.

Assessors blinded to group allocation made all measurements. The adequacy of assessor blinding was evaluated after each assessment by asking the assessor if he or she had been unblinded. If assessors indicated they were blinded, they were asked to guess the allocation for the subject. On the occasions that an assessor indicated he or she was unblinded to the allocation of a particular subject, a different blinded assessor performed subsequent assessments on that subject.

Sample size

Prior to the initiation of the trial it was estimated that a sample of 60 subjects (30 in each group) would provide an 80% probability of detecting differences between group means of 5 degrees of passive elbow extension, assuming a standard deviation of 7 degrees. These calculations assumed, probably conservatively, a correlation of 0.6 between pre- and post-test measures, an alpha of 0.05, a loss to follow-up of 10% and 20% non-compliance. The rate of subject recruitment was lower than expected and, therefore, after recruiting 16 subjects, a second power calculation was performed using the available data. This sample size calculation assumed follow-up and compliance was complete, and used the observed standard deviation of 13.1 degrees. It was estimated that a sample of 26 subjects (13 in each group) would provide an 80% probability of detecting differences between group means of 15 degrees of passive elbow extension. This sample size was used in the study.

Statistical analyses

All analyses were by intention-to-treat.[30] To test the effects of treatment, between-group differences were examined with analysis of covariance using a linear regression approach. Separate analyses were performed on data obtained post-intervention (two weeks), post-intervention plus one day, and at follow-up (four weeks post-intervention). The primary analysis was based on passive elbow extension measured in the post-intervention plus one day assessment. For each outcome, the pretest score of that outcome was entered into the regression model as a covariate to maximize precision. For variables with highly skewed distributions we used the Kruskal–Wallis test plus estimated between-group differences in medians and their 95% confidence intervals using a bootstrapping procedure.[31] Odds ratios were calculated for adverse events.

Results

Subjects

The flow of subjects through the trial is illustrated in Figure 1. Of 798 screened admissions, 724 had sustained traumatic brain injuries and 78 had elbow flexion contractures, so the prevalence of elbow flexion contracture amongst

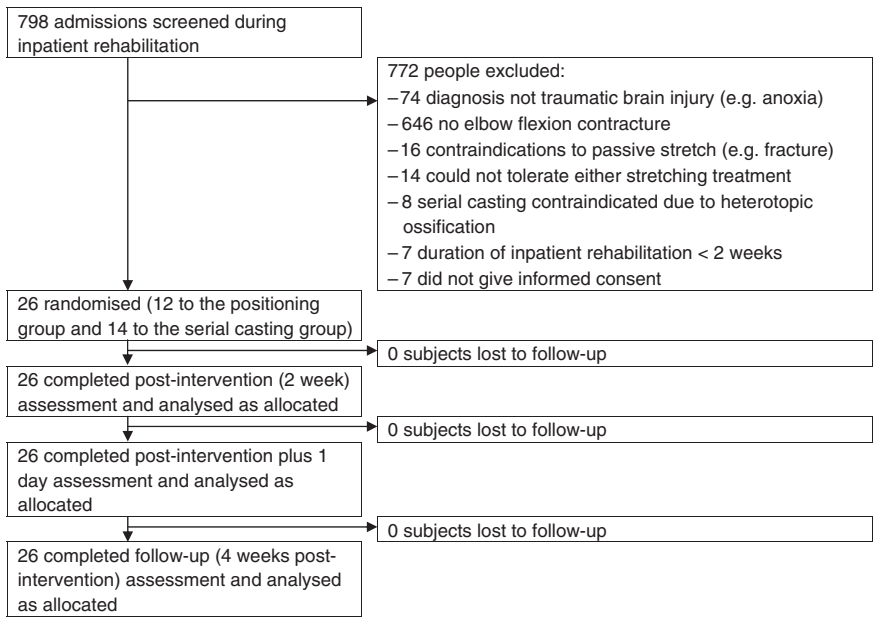

Figure 1 Recruitment and flow of subjects through the trial.

Table 1 Characteristics of the positioning and serial casting groups at baseline

Variable	Positioning group ($N=12$)	Serial casting group ($N=14$)
Gender (male : female)	11 : 1	12 : 2
Dominant arm (left : right)	0 : 12	0 : 14
Mean (SD) age at injury, years	30.8 (11.1)	32.2 (11.3)
Cause of injury motor vehicle accident : fall : assault : other	7 : 2 : 2 : 1	10 : 2 : 1 : 1
Median (IQR) initial Glasgow Coma Scale score	3 (3–4)	4.5 (3–6)
Median (IQR) length of post-traumatic amnesia, days[a]	182 (128–182)[b]	160 (91–182)
Median (IQR) length of inpatient rehabilitation, days	234 (137–342)	219 (116–417)
Upper limb trauma (yes : no)	1 : 11	7 : 7
Median (IQR) time from injury to baseline assessment, days	71 (51–173)	59 (52–79)
Arm used in study (left : right)	3 : 9	7 : 7
Median (IQR) Motor Assessment Scale score for upper arm function: 0–6 scale	0 (0–1)	0 (0–0)
Mean (SD) force used to measure passive elbow extension, kg	3.7 (1.9)	2.6 (1.0)

[a]If the duration of post-traumatic amnesia exceeded six months, a value of 182 days was used.
[b]$N=11$.

people admitted to the units with traumatic brain injury was 11%. On average, subjects had moderate or severe contracture at baseline (mean elbow angle of 39 degrees, SD 19). There were no clinically important differences between the groups at baseline (Table 1).

Compliance with the trial protocol

Compliance with the protocol was excellent. Subjects in the positioning group received an average of 13.0 hours (SD 2.1) of stretch during the two weeks of intervention, compared with the target value of 14 hours. Subjects in the serial casting group had stretch applied for an average of 13.6 days (SD 0.7) compared with the target value of 14 days. Both groups had similar training times for the study arm and other physiotherapy training. During the four-week follow-up the groups were given similar amounts of stretch (median of 26.5 hours, interquartile range (IQR) 13.9 to 27.6 for the positioning group and 27.0 hours, IQR 24.5 to 28.0 for the serial casting group). All subjects completed all of the assessments (Figure 1).

Attempts at assessor blinding were not always successful. The assessors reported being unblinded in six of the 26 post-intervention assessments, three of the post-intervention plus one day assessments, and six of the follow-up (four weeks post-intervention) assessments. All unblinding was for subjects in the serial casting group. For the remaining assessments, assessor's guesses at group allocation were better than chance at the post-intervention assessment ($\kappa=0.53$, $P=0.007$) but not at the post-intervention plus one day ($\kappa=0.33$, $P=0.098$) or follow-up ($\kappa=0.00$, $P=1.000$) assessments.

Outcomes and effects of serial casting

On average, subjects experienced small reductions in contracture over the six weeks of the trial (Table 2 and Figure 2). The casting group experienced greater reductions in contracture in the short term. After two weeks of treatment, serial casting reduced contracture by an average of 22 degrees (95% CI 13 to 31; $P<0.001$) compared to the positioning group. One day after this post-intervention assessment (at the primary trial end-point) much of the effect had disappeared, although it was still marginally significant (mean effect 11 degrees, 95% CI 0 to 21 degrees; $P=0.052$). There was no statistically significant or clinically worthwhile difference between the groups at the follow-up assessment (mean effect 2 degrees, 95% CI −13 to 17 degrees; $P=0.782$).

The secondary outcomes are listed in Tables 2 and 3. There were two significant between-group differences in these secondary outcomes. At the post-intervention assessment the serial casting group had slightly lower spasticity (Table 2) and

Table 2 Group data, difference within groups and difference between groups for the positioning group ($n=12$ unless otherwise specified) and the serial casting group ($n=14$ unless otherwise specified) for the interval and ordinal scale outcomes

Variable	Groups		Difference within groups (change from baseline)[a]		Differences between groups[b]
	P	S	P	S	
Contracture, degrees, mean (SD)					
Baseline	39.4 (19.9)	38.1 (19.9)			
Post-intervention	32.7 (17.5)	10.2 (12.2)	6.8 (13.9)	27.9 (15.1)	22 (13–31)[†]
Post-intervention + 1 day	34.7 (24.4)	23.1 (15.8)	4.8 (14.1)	15.0 (12.8)	11 (0–21)[†]
Follow-up	29.6 (17.1)	26.9 (22.5)	9.8 (15.7)	11.1 (23.0)	2 (−13–17)
Spasticity, median (IQR)					
Baseline	1 (1–2)	1 (1–1)			
Post-intervention	1 (0–2)	1 (0–1)	0 (−1–1)	0 (0–1)	0.5 (0–2)[†]
Follow-up	1 (1–2)	1 (1–1)	0 (0–0)	0 (0–0)	0 (0–0.5)
Pain (0 to 100), *N*, median (IQR)					
Baseline	59 (13–71), 4	69 (21–75), 8			
Post-intervention	54 (21–61), 5	27 (10–57), 9	11 (3–13)	21 (0–33)	27 (−27–48)
Follow-up	51 (6–64), 7	17 (0–60), 11	28 (0–60)	22 (2–49)	34 (−46–55)
Maximum reach, cm, median (IQR)					
Baseline	0 (0–0)	0 (0–46)			
Post-intervention	0 (0–26)	0 (0–54)	0 (0–0)	0 (0–4)	0 (−18–47)
Follow-up	18 (0–54)	28 (0–67)	15 (0–46)	16 (0–24)	11 (−34–52)
TEMPA (−39 to 0), mean (SD)					
Baseline	−35 (7)	−28 (9)			
Post-intervention	−31 (9)	−25 (10)	3 (4)	3 (3)	−1 (−5–2)
Follow-up	−29 (10)	−23 (11)	6 (8)	5 (6)	0 (−7–6)
Satisfaction (0 to 100), *N*, mean (SD)					
Post-intervention	80 (20), 6	78 (24), 9			−2 (−28–24)

[a]Positive changes indicate less contracture, spasticity and pain, or higher maximum reach and TEMPA at post-intervention or follow-up.
[b]Positive differences indicate that the serial casting group is better (less contracture, spasticity and pain, or higher maximum reach, TEMPA and satisfaction) compared with the positioning group. Data are ANCOVA adjusted mean difference and 95% confidence intervals for elbow extension, TEMPA and satisfaction, and bootstrapped median and 95% confidence intervals for spasticity, maximum reach and pain.
[†]Indicates statistically significant between-group differences ($P<0.05$).
TEMPA, total functional rating score on the Test Évaluant la Performance des Membres Supérieurs des Personnes Âgées; P, positioning group; S, serial casting group.

better perceived effect of treatment (Table 3), compared with the positioning group. Angle of catch from the modified Tardieu Scale has not been reported or analysed because it could not be quantified for the majority of the spasticity assessments (in 67 of the 78 spasticity assessments the muscle reaction score was 0 or 1, so the angle of catch could not be measured).

Treating physiotherapists, but not subjects, reported more adverse effects in the serial casting group than in the positioning group (Table 3). Most adverse events in the serial casting group were swelling, skin irritation or breakdown, and pain. There were no between-group differences in subjects' ratings of the degree of difficulty of treatment or the amount of pain during treatment. As there were no differences between groups in satisfaction with treatment the two stretching programmes were deemed to be of equal credibility.

Discussion

The main finding of this trial was that serial casting (24 hours of stretch per day) produces greater *short-term* reductions in elbow flexion contractures than positioning (1 hour of stretch per day)

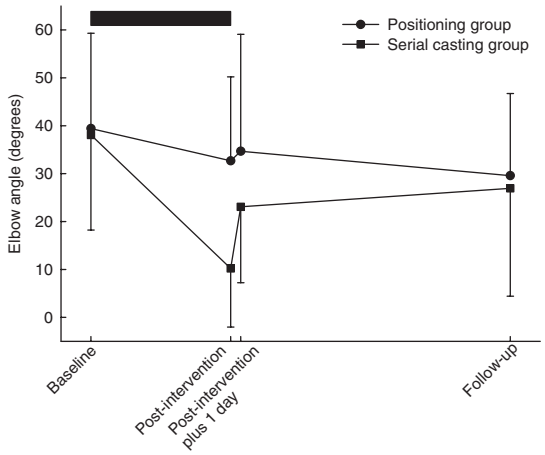

Figure 2 Passive elbow extension at baseline, post-intervention (two weeks), post-intervention plus one day, and follow-up (four weeks post-intervention), by group. Data are means and standard deviations. The shaded bar indicates when the intervention (serial casting or positioning) occurred.

in adults with traumatic brain injury. Large effects of casting were apparent after two weeks of intervention (22 degrees, on average). However the effect had diminished by half just one day post-intervention, and had completely disappeared at the end of the four-week follow-up.

The results of this trial provide an unbiased estimate of the effect of serial casting. The trial incorporated features designed to minimize bias such as true random (concealed) allocation to groups, adequate follow-up, prior specification of primary outcomes, and analysis by intention-to-treat. However, it was not possible to blind subjects or physiotherapists to the intervention. Moreover, while we intended to blind assessors it became apparent that assessors were able to identify subjects in the serial casting group. This is unlikely to be a serious source of bias because the primary outcome (i.e. passive elbow extension) was measured using a standardized torque, which reduced the reliance on assessor judgement of range of motion.

Sustained stretch of soft tissues (of the order of minutes) produces viscous deformation. Viscous deformation is a reversible mechanical phenomenon. In human calf muscles subjected to a 20-minute stretch, the recovery is an exponential function of time and half of the recovery occurs within 7 minutes of the release of stretch.[6] This may explain why much of the effect of casting disappears in the day following intervention. Interestingly, however, a residual effect of casting is apparent one day post-intervention, when the effects from viscous deformation would have dissipated.[6] This suggests that casting produces lasting changes in tissue properties. Lasting changes may indicate that the stretch applied by the casts induces adaptations (growth) of soft tissues.

The finding of a short-term effect of serial casting is consistent with the other randomized trials of serial casting after traumatic brain injury.[5,32] The more recent of these trials, which compared one week of serial casting to no stretch for ankle plantarflexor contractures, found a mean effect of casting of 15 degrees on the day of cast removal.[5] Two other randomized trials that compared four weeks of 30 minutes per day of stretch to no stretch after spinal cord injury found that stretching did not increase joint range of motion,[17,18] and a third trial by the same authors found that 12 weeks of an intense weight-bearing stretch to the calf muscles produced an average of just 4 degrees increase in ankle dorsiflexion range of motion (95% CI 2 to 6 degrees) compared with no stretch.[16] Together these studies suggest that stretch for 24 hours per day can produce short-term increases in range, but 30–60 minutes per day of stretch has little or no effect.

While casting appears to reduce spasticity, there was no effect on functional performance. There were no between-group differences in the TEMPA total functional rating score or maximum seated forward reaching distance post-intervention or at follow-up. This was probably because participants had very low levels of physical function – one-third of subjects scored the lowest possible score on the TEMPA (i.e. −39) and only three subjects had sufficient triceps activity to extend the elbow against gravity at baseline. Perhaps this sample may have benefited more from passive stretch combined with treatment to elicit activity in and strengthen the elbow extensor muscles (e.g. electrical stimulation[33]). The short-term effects of casting on passive elbow extension observed in our study may have been sustained

Table 3 Group data and difference between groups for the positioning group and the serial casting group for the categorical outcomes

Variable	Groups				Differences between groups[a]	
	Post-intervention		Follow-up		Post-intervention	Follow-up
	P	S	P	S		
Global perceived effect					0 (0–1)[†]	0 (0–1)
Unable to be assessed	1/12	0/14	1/12	0/14		
Completely recovered	0/12	0/14	0/12	0/14		
Improved a lot	1/12	2/14	0/12	2/14		
Improved a little	5/12	12/14	6/12	9/14		
Stayed the same	4/12	0/14	5/12	1/14		
Worsened	1/12	0/14	0/12	2/14		
Adverse effects – physiotherapists			NA	NA	14.7 (1.5–147.0)[†]	NA
None	11/12	6/14				
Skin irritation	0/12	1/14				
Skin breakdown	0/12	1/14				
Pain	0/12	1/14				
Swelling	0/12	3/14				
Triggered dysautonomia	1/12	0/14				
>2 adverse effects	0/12	2/14				
Adverse effects – subjects			NA	NA	4.3 (0.4–47.6)	NA
Unable to be assessed	5/12	2/14				
None	6/12	7/14				
Skin irritation	1/12	1/14				
Pain	0/12	2/14				
Swelling	0/12	1/14				
Numbness	0/12	0/14				
Inconvenience	0/12	1/14				
>2 adverse effects	0/12	0/14				
Degree of difficulty of treatment			NA	NA	0 (−3–2)	NA
Unable to be assessed	7/12	3/14				
Very easy	2/12	0/14				
Easy	0/12	1/14				
Average	2/12	6/14				
Difficult	0/12	4/14				
Very difficult	1/12	0/14				
Amount of pain during treatment			NA	NA	0 (−1.5–1)	NA
Unable to be assessed	7/12	4/14				
Not at all	2/12	0/14				
A little	1/12	7/14				
A moderate amount	2/12	1/14				
Very painful	0/12	2/14				

P, positioning group; S, serial casting group; NA, not assessed at this time point.
[a]Data are bootstrapped median differences and 95% confidence intervals for global perceived effect, degree of difficulty with treatment, and amount of pain during treatment, and odds ratios and 95% confidence intervals for adverse effects.
[†]Indicates statistically significant between-group differences ($P<0.05$).

had recruitment been restricted to subjects who exhibited some active control of the elbow extensors.

Subjects in the casting group had a higher perceived effect of treatment (i.e. all reported that they had improved a little or a lot) compared with those in the positioning group, but the treating physiotherapists reported more adverse effects in the casting group. The adverse effects reported were swelling, skin irritation or breakdown, and pain. Swelling and pain can be alleviated by elevating the limb, applying the

cast with the elbow under less stretch, and analgesia. Skin irritation and breakdown are of more concern. To avoid these complications it is important to carefully select patients, monitor pain, and change the cast regularly (i.e. once or twice each week). Another issue with casting is that it interferes with therapy. However, short-term disruptions to therapy can be justified in patients with disabling contractures. Extended periods of casting are probably best avoided.

The upper limb training for the two groups was slightly different, although both groups received the same overall time of upper limb training during the two-week intervention period. Training for the casting group involved eliciting activity or increasing the strength and control of the shoulder and hand muscles, while training for the positioning group involved this as well as exercises for the elbow muscles and practice of reaching tasks.

It is surprising that effects of serial casting evident the day after intervention had dissipated four weeks later. This is despite the fact that subjects in both groups received a similar programme of stretch over that period. There may be little value in serial casting if the effects of casting cannot be maintained. It would be interesting to know if a more aggressive stretching protocol in the period following cast removal could maintain the increase in joint range (e.g. splints worn for 8 hours per day or overnight).

The prevalence of elbow flexion contracture in people with traumatic brain injuries screened during recruitment for this trial was 11%, considerably lower than the 44% prevalence reported previously.[1] Both prevalence figures were established using cohorts of people with traumatic brain injury severe enough to warrant admission to an inpatient rehabilitation service. Our cohort of consecutive admissions was screened between 2002 and 2005, while Yarkony and Sahgal's cohort was recruited during the mid-1980s.[1] One possible explanation for the lower prevalence in our sample is the improvements in acute management (i.e. prior to admission to inpatient rehabilitation) that have occurred over this 20-year time span.

Clinical messages

- Serial casting produces short-term increases in elbow range of motion in adults with traumatic brain injury who have elbow flexion contracture.
- These effects are short-lived and are not maintained by positioning for up to 1 hour per day.

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Competing interests

None declared.

Contributors

AMM initiated the study. AMM, RDH, LAH, LMH, JL and JSC designed the study. AMM, LMH, JL, JSC, RDH and LAH acquired funding. AMM managed the project. LMH, JL and JSC assisted with recruitment and provided treatment. RDH provided statistical advice. AMM wrote the first draft of this manuscript. AMM, RDH, LAH, LMH, JL and JSC revised the manuscript for important intellectual content and gave approval of the version to be published. AMM takes ultimate responsibility for the accuracy and honesty of the report and the morality of the study.

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