

Functional outcome following Botulinum toxin A injection to reduce spastic equinus in adults with traumatic brain injury

JIMY FOCK[†], MARY P. GALEA[‡], BARRY
C. STILLMAN[‡], BARRY RAWICKI[†] and
MALCOLM CLARK[§]

[†]Brighton Rehabilitation Centre, Brighton, Victoria 3186, Australia

[‡]School of Physiotherapy, University of Melbourne, Parkville, Victoria 3010, Australia

[§]Department of Mathematics and Statistics, Monash University, Clayton, Victoria 3168, Australia

(Received 2 September 2002; accepted 5 May 2003)

Primary objective: The aim of this study was to assess the effect of Botulinum toxin A in the management of spastic equinus resulting from traumatic brain injury.

Research design: A before–after intervention design was used without controls.

Methods and procedures: Subjects were seven patients suffering from traumatic brain injury of average duration 14 (4–38) months as a result of motor vehicle trauma, who had spastic equinus interfering with gait.

Experimental intervention: The patients were treated with injections of Botulinum toxin A into the spastic calf muscles: gastrocnemius, soleus and tibialis posterior. Assessments were made pre-injection and at 2 weeks and 3 months post-injection.

Main outcome and results: At the end of the 3-month period, all patients showed a significant improvement in gait velocity, cadence and stride length.

Conclusions: The findings suggest that Botulinum toxin A may be useful in the management of spastic equinus following traumatic brain injury.

Introduction

Spastic equinus is a common problem limiting the mobility of patients following severe traumatic brain injury (TBI). The equinus posture of the foot causes difficulty in foot clearance during the swing phase and affects the postural alignment in the stance phase of the walking cycle. Management approaches have typically included oral anti-spasticity medication, nerve phenolization and splinting. Oral medication may be ineffective or inappropriate for localized spasticity and doses may be limited by side effects [1]. Nerve phenolization may produce side effects including neuropathic pain [1, 2]. Splinting may not be sufficient to control the foot position if the muscle tone is very high.

Correspondence to: Mary P. Galea, PhD, School of Physiotherapy, University of Melbourne, 200 Berkeley Street, Parkville, Victoria 3052, Australia. e-mail: m.galea@unimelb.edu.au

Botulinum toxin A (Allergan Australia Pty. Ltd., Sydney NSW) has been advocated as a more appropriate tool for the management of localized spasticity [3]. Published reports have suggested that the use of Botulinum toxin A could improve active and passive range of movement and improve function [4–16]. However, there has been significant variation in the effectiveness and the duration of effect, possibly because many of these studies have involved patients with various diagnoses. Patients with TBI frequently present with severe extensor tone in the lower limbs from the time of injury, unlike those with acquired brain injury from other causes such as stroke. In addition, these patients may spend many hours in non-weight-bearing positions because of prolonged bed rest due to coma or inability to walk, resulting in adaptive shortening of the triceps surae muscles. It is, therefore, important to evaluate options in a diagnostically homogenous group of subjects. While the use of Botulinum toxin A has been examined in upper limb spasticity following TBI [13, 14], its value for the management of dynamic equinus in this subject group does not appear to have been investigated, apart from a single case study by Wilson *et al.* [11].

The aim of this study was to evaluate both the effectiveness and functional outcome of the use of Botulinum toxin A in the management of spastic equinus in a group of patients following TBI.

Methods

Subjects

Seven adult patients with acquired TBI were recruited for this preliminary study, which was approved by the Human Research Ethics Committee at the University of Melbourne. Each patient had unilateral spastic equinus that had not been adequately managed by other physical treatments. No other localized interventions such as nerve block, surgical release or Botulinum toxin A injection of the spastic calf muscles had been used within the previous year. The average period post-injury was 14 months (range 4–38 months). All patients were able to walk with or without aids independently for at least 50 m.

Design

This study used a one-way repeated factor design. Walking speed, cadence, stride length and peak ankle dorsiflexion angle were measured during walking over a 10 m level track. Other measures were passive and active range of movement of the affected ankle using the American Academy of Orthopaedic Surgeons guidelines [17] and muscle tone in the plantarflexors of the affected ankle using the modified Ashworth Scale (MAS [18]). All measurements were recorded pre-injection and at 2 and 12 weeks post-injection.

Instrumentation

A standard 10 m track for the walking trials was set up in the Movement Laboratory at the School of Physiotherapy, University of Melbourne. Light reflective markers were attached to the affected leg of the subjects on the following points: neck of fibula, prominence of the lateral malleolus, lateral aspect of the heel and head of the



Figure 1. Placement of markers for measurement of ankle dorsiflexion during walking.

fifth metatarsal. The markers on the heel and the fifth metatarsal were the same distance from the floor (figure 1). A fixed single video camera at floor level 6 m from the middle point of the track was used to record the walking parameters. The shutter speed of the camera was set at $1/250$ s in order to ensure there was no blurring of the foot, particularly at mid-swing, and to provide a sharp image of the foot at 'touch down' and 'lift-off' points. The videotape of the gait pattern was analysed using the PEAK 5 Motion Analysis System (Peak Performance Technologies, Inc. Englewood, CO) and a time code generator on the video recorder. The active and passive non-weight-bearing range of motion of the ankle were measured using a goniometer.

Test procedure

Measurement of range of movement and muscle tone on the affected ankle was performed with subjects lying in supine with both hips and knees supported in 45° flexion. For measurement of the walking parameters, subjects walked on the 10 m track in bare feet at their own comfortable pace. The subjects wore shorts so that the lower leg and foot were exposed. Three walking trials were recorded on each assessment and the averaged results were used for data analysis.

Following the initial physical assessment, the patients were injected with Botulinum toxin A. Both heads of gastrocnemius and soleus were each injected with 100 units of Botulinum toxin A, with a total of 300 units per patient. Tibialis posterior was also injected in some subjects. Motor point localization was performed using a Respond 2 (Medtronic) neuromuscular stimulator with a Stimuplex teflon coated needle (B. Braun, Melsungen, Germany).

Data analysis

Data were analysed using one-sample *t*-test and one-sample Wilcoxon test. In order to take account of the multiple significance tests and the discreteness of the Wilcoxon statistic in small samples, the significance level in all tests was set to 0.03. This value, although arbitrary to an extent, is a compromise between caution and power. Any results significant at the 0.03 level are necessarily significant at the 0.05 level as well. Changes in muscle tone were analysed using Wilcoxon's non-parametric tests.

Results

Subject attributes

Subject characteristics are summarized in table 1.

Gait

Six of the seven subjects showed an increase in walking speed 2 weeks post-injection, with the improvement continuing at 12 weeks after the injection ($p < 0.03$). Six subjects had a longer stride length at 12 weeks after injection ($p < 0.03$), although only four of them showed this improvement at 2 weeks post-injection. Six subjects had an increase in cadence at 12 weeks post-injection ($p < 0.03$), but only three showed improvement at 2 weeks post-injection.

Ankle dorsiflexion

Statistically non-significant improvement was shown in measurements of ankle position during walking. The improvement was greater at 12 weeks post-injection than at 2 weeks post-injection. Six subjects had a reduction in spastic equinus during

Table 1. Subject characteristics

Subject	Gender	Age (years)	Side of lesion	Time since lesion (months)
1	M	33	Left	38
2	F	35	Left	28
3	M	29	Right	11
4	F	27	Right	7
5	M	28	Left	4
6	M	22	Bilateral	7
7	M	35	Left	5

Table 2. Change in outcome measures

Variable	Pre-injection	2 weeks post-injection	12 weeks post-injection
Walking velocity (m/s)	0.28	0.33	0.46 ^{ab}
Stride length (m)	0.52	0.59	0.66 ^{ab}
Cadence (steps/min)	55.2	56.8	70.9 ^{ab}
Dorsiflexion on contact with the ground (°)*	-17.9	-17.2	-8.7 ^b
Dorsiflexion at mid-stance (°)*	-1.0	0.4	0.6
Active dorsiflexion in supine (°)*	-16.4	-14	-7
Passive dorsiflexion in supine (°)*	0.9	5.9	9.3 ^b
Muscle tone (MAS)	3	2.5	2.5

Numbers are mean values.

*Negative values indicate the angle of the ankle below the neutral position (0°).

^aStatistically significant at $p < 0.03$ on one-sample *t*-test.

^bStatistically significant at $p < 0.03$ on one-sample Wilcoxon test comparing the difference from pre-injection to 12 weeks post-injection.

walking, as measured by ankle dorsiflexion angle at the point of contact of the foot with the floor, at 12 weeks post-injection. Three showed this improvement at 2 weeks post-injection. There was an average increase in the angle of dorsiflexion at initial contact with the floor of 9.2° between the first and final assessments. Only one subject demonstrated an improved ankle position in mid-stance 2 weeks post-injection, but four subjects demonstrated this reduction of equinus in the mid-stance position 12 weeks after the injection. The results are summarized in table 2.

On commencement of this study, all subjects were striking the ground with their ankle in an equinus position (mean equinus = 17.9°). In mid-stance, five subjects maintained the equinus position, even though they had a passive range of dorsiflexion at least to the neutral position.

Of the seven subjects recruited for the study, three were at least 11 months post-head-injury, while the other four were 7 months or less post-head injury. The average angle of equinus on foot strike in these two groups was the same. At 12 weeks post-injection, the chronic subjects showed an average improvement in ankle dorsiflexion range of 19% (3.3°), while the subjects who had their injury more recently improved by an average of 41% (7.4°).

Discussion

Among the positive signs of the upper motor neuron syndrome, spastic ankle equinus in severely head-injured patients is one of the most common problems challenging rehabilitation clinicians. An equinus position of the foot causes difficulty in clearing the ground in swing phase and the forefoot hits the ground first instead of the heel. In severe cases, the fixed equinus ankle position can persist during the stance phase, which forces the stance leg into hyperextension at the knee and flexion at the hip. Gait laboratory data collected from studies of young healthy adults have shown that foot clearance, a major function of the dorsiflexors of the swing leg, is quite sensitive to small angular changes at the ankle [19], so that even a small change in ankle angle could lead to clinically significant changes in gait pattern. This preliminary study has demonstrated that Botulinum toxin A to the

spastic calf muscles in patients following TBI may assist in restoring the ability to clear the foot during walking.

Many studies, mainly on stroke patients, have shown that Botulinum toxin A injections to spastic muscles have led to reduced muscle tone and improved range of movement, as well as improvement in gait parameters [7, 8, 10, 15, 16]. Reductions in electromyographic activity in the calf muscles at the end phase of swing and in mid-stance have also been demonstrated following Botulinum toxin A injections [9]. However, these effects have been relatively short-lived. Hesse *et al.* [7], in a study of stroke patients, and Pierson *et al.* [15], who investigated 38 subjects with various diagnoses, reported that while walking speed and stride length were improved at 2 weeks, the effect was less pronounced at 8 weeks following Botulinum toxin A injection. Wilson *et al.* [11], in a single case study of a head-injured subject 2 years following injury, reported that improvements in walking speed and stride length had started to fade at 4 weeks following Botulinum toxin A injection.

In this pilot study of seven head-injured subjects, walking speed, stride length and cadence were improved 12 weeks after the Botulinum toxin A injection to the spastic calf muscles. Ankle dorsiflexion angle was also improved at foot strike, as well as in tests of active and passive range of movement in supine. Although all subjects showed similar degrees of equinus on foot strike, improvements were not uniform across the subjects. Subjects whose injury was more recent appeared to demonstrate larger improvements (41%) in ankle dorsiflexion following Botulinum toxin A injection than chronic subjects (19%). These results suggest that subjects who had the more recent injury might derive more benefit from the injection and are in accord with the findings of Burbaud *et al.* [10], who reported that Botulinum toxin A was less effective in patients with longer duration of spasticity. The number of subjects in this study was too small to clarify this issue, which should be investigated further in a larger sample of subjects.

The cost/benefit of Botulinum toxin A was not evaluated in this study and, clearly, the high cost of this drug necessitates a careful examination of its effectiveness. Radensky *et al.* [20], in a study of physicians' practice patterns in the management of focal spasticity, concluded that median cost for management of spasticity using Botulinum toxin A was lower than using baclofen in patients following CVA. There did not appear to be a cost benefit for the use of Botulinum toxin A in patients following TBI. Another study by Wallesch *et al.* [21] reported that Botulinum toxin A plus physiotherapy was ten times more effective in reducing spasticity than physiotherapy alone and three times more effective than physiotherapy plus baclofen for about the same total cost. However, the degree of improvement was measured using the Ashworth scale, which provides little indication of changes in function. Future studies of the cost-effectiveness of Botulinum toxin A following TBI should ensure that objective measures are used to determine functional outcome and should take into account the time since injury.

Conclusion

Spasticity in patients with acquired brain damage has long been a major concern for rehabilitation clinicians. Localized spasticity management using agents such as Botulinum toxin A has been advocated as it can offer selective management of

spasticity. The results of this study suggest that Botulinum toxin A is effective in improving gait in head-injured subjects with spastic equinus.

References

1. GLENN, M.: Nerve block. In: M. Glenn and J. Whyte (editors) *The Practical Management of Spasticity in Children and Adults* (London: Lea and Febiger), pp. 227–259, 1990.
2. BRAUN, R., HOFFER, M., MOONEY, V. *et al.*: Phenol nerve block in the treatment of acquired spastic hemiplegia in the upper limb. *The Journal of Bone and Joint Surgery*, **55-A**: 580–585, 1973.
3. SHEEAN, G.: The management of spasticity with botulinum toxin. *European Journal of Neurology*, **4** (suppl 2): S41–S45, 1997.
4. DAS, T. and PARK, D.: Effect of treatment with Botulinum toxin on spasticity. *Postgraduate Medical Journal*, **65**: 208–210, 1989.
5. SNOW, B., TSUI, J., BHATT, M. *et al.*: Treatment of spasticity with Botulinum toxin: a double-blind study. *Annals of Neurology*, **28**: 512–515, 1990.
6. YOSHIMURA, D., ADMINOFF, M. and OLNEY, R.: Botulinum toxin therapy for limb dystonias. *Neurology*, **42**: 627–630, 1992.
7. HESSE, S., LUECKE, D., MALEZIC, M. *et al.*: Botulinum toxin treatment for lower limb extensor spasticity in chronic hemiparetic patients. *Journal of Neurology, Neurosurgery and Psychiatry*, **57**: 1321–1324, 1994.
8. DUNNE, J., HEYE, N. and DUNNE, S.: Treatment of chronic limb spasticity with Botulinum toxin A. *Journal of Neurology, Neurosurgery and Psychiatry*, **58**: 232–235, 1995.
9. HESSE, S., KRAJNIK, J., LUECKE, D. *et al.*: Ankle muscle activity before & after Botulinum toxin therapy for lower limb extensor spasticity in chronic hemiparetic patients. *Stroke*, **27**: 455–460, 1996.
10. BURBAUD, P., WIART, L., DUBOS, J. *et al.*: A randomised, double blind, placebo controlled trial of Botulinum toxin in the treatment of spastic foot in hemiparetic patients. *Journal of Neurology, Neurosurgery and Psychiatry*, **61**: 265–269, 1996.
11. WILSON, D., CHILDERS, M., COOKE, D. *et al.*: Kinematic changes following Botulinum toxin injection after traumatic brain injury. *Brain Injury*, **11**: 157–167, 1997.
12. WILSON, D., CHILDERS, M., SMITH, B. *et al.*: Ground reaction force changes in hemiparetic gait following Botulinum toxin injection. *Journal of Neurological Rehabilitation*, **11**: 81–89, 1997.
13. SIMPSON, D. M., ALEXANDER, D. N., O'BRIEN, C. F. *et al.*: Botulinum toxin type A in the treatment of upper extremity spasticity: a randomised, double-blind, placebo controlled trial. *Neurology*, **46**: 1306–1310, 1996.
14. YABLON, S. A., AGANA, B. T., IVANHOE, C. B. *et al.*: Botulinum toxin in severe upper extremity spasticity among patients with traumatic brain injury: an open labelled trial. *Neurology*, **47**: 939–944, 1996.
15. PIERSON, S., KATZ, D. and TARSY, D.: Botulinum toxin A in the treatment of spasticity: functional implications & patient selection. *Archives of Physical Medicine & Rehabilitation*, **77**: 717–721, 1996.
16. REITER, F., DANNI, M., LAGALLA, G. *et al.*: Low dose Botulinum toxin with ankle taping for treatment of spastic equinovarus foot after stroke. *Archives of Physical Medicine & Rehabilitation*, **79**: 532–535, 1998.
17. AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS: *Joint Motion—Method of Measuring and Recording* (Edinburgh: Churchill), pp. 68–69, 1965.
18. BOHANNON, R. and SMITH, M.: Interrater reliability of a modified Ashworth scale of muscle spasticity. *Physical Therapy*, **67**: 206–207, 1987.
19. WINTER, D.: Foot trajectory in human gait: a precise and multifactorial motor control task. *Physical Therapy*, **72**: 45–53, 1992.
20. RADENSKY, P. W., ARCHER, J. W., DOURNAUX, S. F. *et al.*: The estimated cost of managing focal spasticity: a physician practice patterns survey. *Neurorehabilitation and Neural Repair*, **15**: 57–68, 2001.
21. WALLECH, C.-W., MAES, E., LECOMTE, P. *et al.*: Cost effectiveness of botulinum toxin type A in patients with spasticity following stroke: a German perspective. *European Journal of Neurology*, **4** (Suppl 2): S53–S57, 1997.