Treating Benign Paroxysmal Positional Vertigo in the Patient With Traumatic Brain Injury: Effectiveness of the Canalith Repositioning Procedure

CE 2.5 ANCC Contact Hours

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ABSTRACT

Objective: The aim of this study was to determine the effectiveness of the canalith repositioning procedure (CRP) in the treatment of benign paroxysmal positional vertigo (BPPV) among patients after mild-to-moderate traumatic brain injury. **Methods:** An unblinded, nonrandomized, case comparison interventional study with repeated measures (1, 5, 9, and 12 weeks postenrollment) of three groups of patients with traumatic brain injury (BPPV, $n = 21$; nonspecific dizziness, $n = 23$; no dizziness, $n = 12$) was conducted. Patients in the BPPV group received the CRP at baseline and repeatedly until a negative Dix–Hallpike Maneuver was observed. Participants in the other two groups did not receive the CRP. **Results:** Symptom resolution at the 12-week follow-up was observed in 75% of patients in the BPPV group versus 8.3% in the nonspecific dizziness group ($p = .0006$). A significant Group × Time interaction was observed for the Dizziness Handicap Inventory ($F = 4.2$, $p = .003$) and 36-item Short Form Health Questionnaire physical component scores ($F = 2.16$, $p = .035$) with the BPPV group showing significantly improved scores by the 12-week follow-up. Although there were between-group differences on the 36-item Short Form Health Questionnaire mental health component scores ($F = 4.06$, $p = .022$), changes over time were not significant in the groups. **Conclusions:** Treatment with the CRP for posttraumatic BPPV resulted in significant symptom resolution and improvement in perceived physical health status.

Keywords: concussion, disability, health, outcome, therapy, traumatic brain injury

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Although most patients recover to previous levels of functioning after mild traumatic brain injury (TBI), a subset (estimated at 22%–36%) display persisting symptoms (Cassidy et al., 2014). The constellation of postconcussive symptoms (e.g., cognitive, behavioral, mental health, physical) varies substantially between patients because of the diverse nature of injuries (Maskell, Chiarelli, & Isles, 2006). Also complicating matters is the fact that symptoms often overlap and are interconnected (Lange, Iverson, & Rose, 2011). Dizziness is one of the most commonly reported physical symptoms after TBI with 25% of patients reporting dizziness 12 months postinjury (Hartvigsen, Boyle, Cassidy, & Carroll, 2014). Post-TBI dizziness can result in self-perceived impairment in functional tasks including self-care and community engagement, increased psychological distress, and poorer psychosocial functioning with a potentially extreme influence on quality of life (Chamelian & Feinstein, 2004; Maskell et al., 2006).

Benign paroxysmal positional vertigo (BPPV) is a form of dizziness characterized by short (typically lasting seconds) yet frequent attacks of vertigo associated with certain provocative movements (i.e., looking up, bending over, rolling over in bed to the affected side,

etc.; Bhattacharyya et al., 2008). It is the most common vestibular disorder in adults, with a lifetime prevalence of 2.4% in the general population (Bhattacharyya et al., 2008). BPPV is classified as either primary (idiopathic) BPPV or secondary (acquired) BPPV. Of those with BPPV, idiopathic BPPV has been observed in 50%–70% of the population (Parnes, Agrawal, & Atlas, 2003). Head trauma and inner ear disease are the most common causes of secondary BBPV, with head trauma accounting for approximately 7%–17% of all BPPV cases (Baloh, 1998; Bertholon, Chelikh, Tringali, Timoshenko, & Martin, 2005; Katsarkas, 1999). Posttraumatic BBPV has been reported to occur more often in younger individuals, with no difference in incidence between men and women (Katsarkas, 1999).

BPPV arising from the posterior semicircular canal (posterior canal BPPV) is the most common variant of BPPV, accounting for approximately 85%–95% of cases (Parnes et al., 2003; White, Coale, Catalano, & Oas, 2005). Posterior canal BPPV is diagnosed by (a) a patient's report of repeated episodes of vertigo after changes in head position related to gravity and (b) a characteristic nystagmus provoked by the Dix–Hallpike Maneuver (DHP-M; Bhattacharyya et al., 2008). With a positive diagnosis, posterior canal BPPV can often be successfully treated with a canalith repositioning procedure (CRP), also known as the Epley maneuver (Epley, 1992). The traditional CRP is performed with the patient sedated and uses mechanical skull vibration while the patient's head is moved sequentially through five separate positions (Parnes et al., 2003). For this study, a modified version of the CRP was performed, which did not use mechanical skull vibration or sedation. Studies have shown that a single session of CRP for idiopathic BPPV results in resolution of symptoms in 70%–90% of cases (Epley, 2001; Prokopakis et al., 2013).

Although there is a strong evidence base and clinical practice guidelines (Bhattacharyya et al., 2008) for the assessment and treatment of BPPV in the general population, there are only a handful of studies describing the characteristics and presentation of post-TBI BPPV (Davies & Luxon, 1995; Gordon, Levite, Joffe, & Gadoth, 2004; Katsarkas, 1999) and only two studies (Ahn et al., 2011; Motin, Keren, Groswasser, & Gordon, 2005) describing its treatment in this population. Motin et al. assessed 150 consecutive admissions to a rehabilitation facility after severe TBI (Motin et al., 2005). They identified 20 patients with complaints of vertigo, and 10 of these were diagnosed with posterior canal BPPV based on the DHP-M. Ahn et al. conducted a retrospective analysis of the records of 192 consecutive patients with head trauma and vertigo treated at their tertiary referral neurotology and dizziness clinic (Ahn et al., 2011). Twenty-three percent of their patients had posttraumatic BPPV. In both studies, complete symptom resolution was achieved with the CRP, most often after only one treatment. Although it was unclear how many of their sample of 965 patients had a history of TBI, Prokopakis et al. showed that BPPV recurrence was significantly more likely in patients who were greater than 70 years old or had a history of head trauma or vestibular neuropathy (Prokopakis et al., 2013).

In a post-TBI population, relying on symptom report alone may result in missed diagnosis.

Although these previous studies showed the effectiveness of the CRP for resolving posttraumatic BPPV, there is a lack of evidence regarding the quality of life or psychological distress associated with dizziness after TBI (Maskell et al., 2006). Moreover, there are no studies comparing the health-related status of patients with TBI with BPPV with those with nonspecific dizziness or no dizziness. The primary aim of this study was to examine the efficacy of the CRP for the treatment of posterior canal BPPV associated with TBI. The secondary aims were to (a) describe the incidence and presentation of posttraumatic BPPV in an outpatient head injury clinic population and (b) compare demographic and injury-related characteristics of patients with posttraumatic BBPV with those with nonspecific dizziness or no dizziness at all.

Method

The study was a based on a concurrent, cohort, prospective design, with repeated measures of three groups of patients: (a) those with TBI and posterior canal BPPV (BPPV group), (b) those with TBI and nonspecific dizziness (NSD group), and (c) those with TBI and no dizziness (no-dizziness group). The study was approved by the research ethics board at the participating hospital.

Study participants were recruited from an outpatient clinic specializing in the management of head injury at a level 1 trauma center. Patients were included if they had been diagnosed with a mild or moderate TBI, were 18 years old or older, were fluent in the English language (because the assessment tools were only available in English), and were available for the follow-up appointments. The criteria used to meet the minimal diagnosis of TBI were adapted from the World Health Organization task force operational definition of TBI. Mild and moderate TBIs were distinguished by post-injury Glasgow Coma Scale scores of 13–15 (mild TBI) versus 9–12 (moderate TBI). Patients were excluded if they had (a) concomitant ear disease or conditions

including chronic otitis media, Ménière disease, acute labyrinthitis, acute vestibular neuronitis, otosclerosis, perilymphatic fistula, cerebrovascular disease, or spontaneous nystagmus on physical examination (no consistent provoking factor) or (b) concomitant illness or injury prohibiting participation in DHP or CRP (e.g., cervical spine fracture, cervical pain).

Upon arrival to the clinic, patients completed a routine screening form, which queried various postconcussive symptoms including the presence of dizziness. Patients who endorsed experiencing dizziness were approached by the study coordinator and informed about the study. The coordinator then confirmed eligibility and obtained consent for participation. As a part of standard clinic practice, all patients with reported dizziness, regardless of their participation in the study, were administered the in-house created Dizziness Protocol. The Dizziness Protocol is made up of two components: the patient's subjective report of dizziness, associated symptoms, and medical history and the clinician's observations and examination of dizziness (e.g., DHP-M). The DHP-M was administered by one of the clinic's attending physicians or the nurse case manager. Patients with a positive DHP-M underwent treatment as described below.

Patients with dizziness who provided consent to participate in the study were placed into either the BPPV group (positive DHP-M) or the NSD group (negative DHP-M) and were asked to complete the 36-item Short Form Health Questionnaire (SF-36; Ware & Sherbourne, 1992), Dizziness Handicap Inventory (DHI; Jacobson & Newman, 1990), and Dizziness Protocol. Patients in the BPPV group underwent treatment as described below. A third group of patients who had no symptoms of dizziness (no-dizziness group) was also recruited and completed the SF-36.

Study participants were invited back to the clinic for in-person follow-up at 1, 5, 9, and 12 weeks postenrollment. Patients in the BPPV and NSD groups completed the SF-36, DHI, and Dizziness Protocol at each follow-up and underwent the DHP-M. The CRP was repeated for patients with positive DHP-M. Patients who were unable to attend any of the in-person follow-ups were contacted by telephone and administered the SF-36, DHI, and Dizziness Protocol. Participants in the no-dizziness group completed the SF-36 at each follow-up assessment, either in person or via telephone.

The clinic physicians and/or the nurse case manager performed the CRP as described by Parnes et al. (2003) as treatment for all patients with TBI diagnosed with BPPV. This was performed within 1 week of diagnosis. Resolution of BPPV symptoms has been reported as early as 48 hours to 1 week after a single session of the CRP in the general population. During this time, positional tests such as the DHP-M were not recommended to improve the efficacy of treatment (Gordon & Gadoth, 2004). The Head Injury Clinic adhered to this recommendation during the course of the study. For patients with bilateral BPPV, the most symptomatic ear (by patient subjective report) was treated first (Kaplan, Nash, Niv, & Kraus, 2005) followed by the second ear (during the same session) if the patient could tolerate the treatment. Three additional treatment sessions (1, 5, and 9 weeks postenrollment) were chosen as the maximum number based on work by Nunez, Cass, and Furman (2000). CRP treatment was considered to have failed if BPPV symptoms persisted at the 12-week follow-up; at which point, patients were referred to a specialized neurotology clinic.

Assessment Tools

Retrospective chart review and patient interviews were conducted to collect information regarding demographic characteristics (age, gender, marital status, highest grade of school completed, and employment status) and injury-related characteristics (date of injury, mechanism, severity, history of premorbid head trauma, imaging findings [if any]). The outcome measures below were also assessed.

Dizziness Handicap Inventory

This subjective scale was developed through case history reports of people with dizziness (Jacobson & Newman, 1990). The DHI measures perceived handicap after vestibular changes and has been applied to the measurement of many different balance disorders including BPPV (Maskell et al., 2006). It is composed of 25 items and three domains: emotional, physical, and functional. The maximal score is 100, with a higher score reflecting greater perceived handicap. The DHI was administered to patients in the BPPV and NSD groups.

Dizziness Protocol

This in-house developed tool was used by the clinic staff to document characteristics of dizziness reported by patients post-TBI. The Dizziness Protocol is made up of two components. Page 1 focuses on patient's subjective report of dizziness, associated symptoms, and medical history. Page 2 concentrates on objective clinician's observations and examination of dizziness.

Dix–Hallpike Maneuver

The DHP-M (Dix & Hallpike, 1952) is considered to be the gold standard for diagnosing posterior canal BPPV (Nunez et al., 2000; Viirre, Purcell, & Baloh, 2005) and was used in this study for that purpose. As described by Parnes et al. (2003), the procedure was administered as follows: the patient was seated on the end of the examination table. The head was turned 45° toward the side being tested. The patient was

quickly lowered into the supine position so that the head was hanging over the edge of the table reaching an angle of 30° to the horizontal. If symptomatic for BPPV, this maneuver would have reproduced symptoms of vertigo, and the patient's eyes were observed for nystagmus (involuntary rhythmic rotary oscillation of the eyes) in the direction of the affected side. The nystagmus in head down position (also called geotropic rotatory) would have beat toward the undermost ear and lasted for a duration of 10–30 seconds. The patient was then brought up to the seated position, and the eyes were observed for reversal of the nystagmus (ageotropic reversal) lasting a shorter duration. The response typically would fatigue with repetitive testing. Both symptomatic and nystagmus responses were recorded.

36-Item Short Form Health Survey

This tool (Ware & Sherbourne, 1992) has been used to determine the impact of the CRP on BPPV-related quality of life in non-TBI samples (Lopez-Escamez, Gamiz, Fernandez-Perez, Gomez-Fiñana, & Sanchez-Canet, 2003). It consists of 36 items grouped into eight scales including physical function, role-physical, bodily pain, general health, vitality, social functioning, role-emotional, and mental health. Physical health and mental health component scores can be derived from the scales. Raw scores were converted to norm-based scores, which range from 0 to 100 with a score of 50 being representative of the general U.S. population. Scores lower than 50 reflect poorer health status than that of the general population, whereas scores greater than 50 reflect better health status. The SF-36 was used to compare health status in patients with BPPV with the NSD and no-dizziness groups as well as within each group over time. The survey has been validated for use in the population with TBI (Findler, Cantor, Haddad, Gordon, & Ashman, 2001).

Data Analyses

A repeated measures analysis was performed for each measure using linear mixed model methodology across each time point. A Kruskal–Wallis test was conducted to test age and time since injury variables because they were not normally distributed. Chi-squared analyses were used to compare other baseline demographic variables between groups. SPSS software was used to perform the analyses (Version 20.0; Armonk, NY), and statistical significance was measured at $p < .05$ (two sided).

Results

Patient Screening, Enrollment, and Follow-Up

Between October 2008 and December 2010, 240 patients were screened for the study, and 56 participants were enrolled as follows: BPPV group ($n = 21$), NSD group ($n = 23$), and no-dizziness group ($n = 12$; Fig 1).

Table 1 summarizes the demographic and injury characteristics of the study participants. Participants in the three groups had comparable demographic characteristics. The BPPV group had significantly more individuals with moderate TBI (23.8%) than the NSD and no-dizziness groups (all mild TBI) and more patients (76.2%) with positive finding on neuroimaging compared with the NSD (4.6%) and no-dizziness (25.0%) groups.

Of the 44 study participants with dizziness (both BPPV and NSD) at baseline, 21 (47.7%) had a positive DHP-M and were diagnosed with BPPV: four (23.8%) bilaterally and 16 (76.1%) unilaterally. Five of the BPPV group participants withdrew ($n = 2$, too busy to continue) or were lost to follow-up ($n = 3$, reasons unknown). Only over half ($n = 12$, 52.2%) of the participants in the NSD group completed the 12-week study, with five participants withdrawing ($n = 3$, too busy to continue; $n = 1$, lives too far to come for follow-up assessments; $n = 1$, did not want to undergo the DHP-M) and six participants being lost to follow-up (reasons unknown). Eight (66.7%) of the 12 no-dizziness group patients completed the study, with two lost to follow-up (reasons unknown) and two withdrawing (too busy).

Dizziness Symptoms, Treatments, and Resolution

As summarized in Table 2, 90.5% of participants in the BPPV group and 76.2% in the NSD group reported spinning associated with their dizziness. Most participants in both groups also reported lightheadedness and that the dizziness was affected by position.

Of the 16 BPPV group participants who completed the study, 12 (75%) had no symptoms of dizziness at

FIGURE 1 Patient Screening and Enrollment

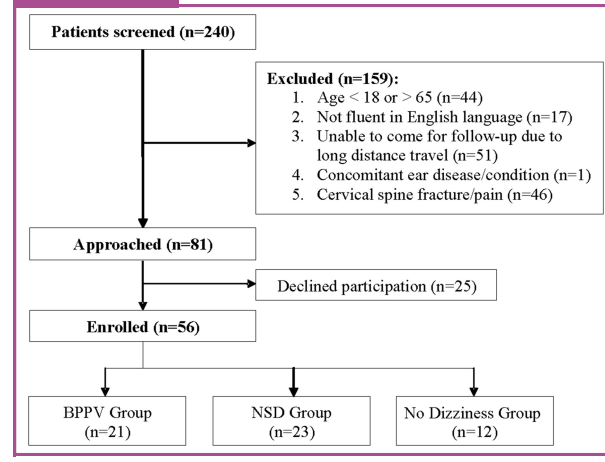


TABLE 1. Demographic and Injury Characteristics Across Study Groups

Characteristic	BPPV (*n* = 21)	NSD (*n* = 23)	No Dizziness (*n* = 12)	*p* Value[a]
Demographic characteristics				
Age (median years, IQR)	32.0 ± 21.0	36.0 ± 26.0	43.0 ± 26.25	$H(2) = 1.59$, $p = .452$
Gender, male	15 (71.4)	12 (52.2)	7 (58.3)	$\chi^2(2) = 1.74$, $p = .418$
Education				$\chi^2(6) = 7.85$
High school or less	5 (23.4)	7 (30.4)	4 (33.3)	$p = .249$
Postsecondary education[a]	12 (57.1)	11 (47.8)	8 (66.7)	
Graduate degree	4 (19.0)	2 (8.7)	0	
Unknown	0	3 (13.0)	0	
Marital status				$\chi^2(4) = 2.09$
Single	10 (47.6)	10 (43.4)	5 (41.6)	$p = .719$
Married/common law	10 (47.6)	8 (34.8)	5 (41.6)	
Separated/divorced/widowed	1 (4.8)	4 (17.4)	2 (16.7)	
Employment status				$\chi^2(8) = 5.64$
Student	2 (9.5)	1 (4.3)	0	$p = .687$
Employed (full or part time)	11 (52.4)	15 (65.2)	10 (83.3)	
Retired	1 (4.8)	2 (8.7)	0	
Unemployed	3 (14.3)	2 (8.7)	0	
Other/unknown	4 (19.0)	3 (13.0)	12 (16.7)	
Injury characteristics				
Time since injury (median days, IQR)	50.0 ± 72.5	65.0 ± 151.0	61.0 ± 50.0	$H(2) = 0.73$, $p = .690$
TBI severity				$\chi^2(2) = 9.15$
Mild	16 (76.2)	23 (100)	12 (100)	$p = .010$
Moderate	5 (23.8)	0	0	
Mechanism of injury				$\chi^2(8) = 14.5$
Vehicular/pedestrian	8 (38.1)	10 (43.5)	5 (41.7)	$p = .070$
Fall	11 (52.4)	9 (39.1)	3 (25)	
Violence	0	3 (13.0)	0	
Sports	2 (9.5)	1 (4.3)	2 (16.7)	
Other	0	0	2 (16.7)	
History of TBI before index TBI				$\chi^2(2) = 4.00$
Yes	4 (19.4)	10 (43.4)	2 (16.7)	$p = .135$
No	16 (76.2)	13 (56.5)	10 (83.3)	
Unknown	1 (4.8)	0	0	
Presence of pathology on CT scan				$\chi^2(2) = 27.0$
Yes	16 (76.2)	1 (4.3)	3 (25.0)	$p < .001$
No	4 (19.0)	14 (60.9)	4 (33.3)	
Unknown	1 (4.8)	8 (34.8)	5 (41.7)	

Note. Data presented as *n* (%) unless otherwise indicated. BPPV = benign paroxysmal positional vertigo; CT = computed tomography; IQR = interquartile range; NSD = nonspecific dizziness; TBI = traumatic brain injury.
[a]Postsecondary education includes associate degree, trade school, bachelor's degree, and college.

the 12-week follow-up. Most of these participants with resolved BPPV required only one ($n = 7$) or two ($n = 3$) treatments (Table 3). Of the five patients with bilateral BPPV at baseline, two resolved with one treatment, two resolved with two treatments, and one did not resolve (although they only received treatment at baseline and 9-week assessments). Of the four participants with unresolved BPPV, two had unilateral

TABLE 2. Patient Report of Dizziness Symptoms

Dizziness Symptom	BPV (*n* = 21)	NSD (*n* = 21)	*p* Value[a]
Spinning			
None	2 (9.5%)	5 (23.8%)	.164
Lasts seconds	14 (66.7%)	8 (38.1%)	
Lasts minutes to hours, or days	5 (23.8%)	8 (38.1%)	
Lightheadedness			
None	4 (19.0%)	3 (14.2%)	.196
Lasts seconds	11 (52.4%)	7 (33.3%)	
Lasts minutes to hours, or days	5 (23.8%)	11 (52.4%)	
Affected by position	21 (100.0%)	17 (80.1%)	.107

Note. BPPV = benign paroxysmal positional vertigo; NSD = nonspecific dizziness.
[a]Dizziness protocol not completed at baseline by two participants.

BPPV, one of which was identified to have bilateral BPPV at the 5-week session, and two missed the 1- and 5-week sessions and thus received only two treatments raising the possibility that they may have resolved had they adhered to the entire treatment protocol. Comparatively, dizziness symptoms resolved in only 1 of the 12 (8.3%, $p = .0006$, Fisher's exact test) participants in the NSD group who completed the study.

Participants in both BPPV and NSD groups showed high levels of impairment on the DHI at baseline with mean ± *SEM* scores of 42.9 ± 5.7 and 51.0 ± 5.6, respectively (Fig 2). A significant Group × Time interaction was observed for the DHI ($F = 4.2$, $p = .003$), with the BPPV group showing significantly improved scores at the 12-week follow-up (BPPV mean score = 17.8 ± 5.9 vs. NSD mean score = 47.0 ± 6.2; $p = .001$).

Participants in the no-dizziness group had significantly higher SF-36 physical component scores at baseline (mean = 43.6 ± 2.8) as compared with the NSD group (mean = 34.9 ± 1.8, $p = .03$) but not the BPPV group (mean = 37.1 ± 1.9, $p = .161$). There was a significant Group × Time interaction ($F = 2.16$, $p = .035$), with participants in the BPPV group having significantly higher scores (mean = 44.5 ± 1.9) as compared with the NSD group (mean = 36.4 ± 2.1, $p = .017$) at the 12-week follow-up (Fig 3).

At baseline, SF-36 mental health component scores were comparable across the three groups (BPPV group mean = 39.9 ± 2.7, NSD group mean = 37.5 ± 2.7, no-dizziness group mean = 46.7 ± 4.1). Although there were between-group differences on the SF-36 mental health component scores ($F = 4.06$, $p = .022$), the changes over time within each group were not significant.

Discussion

We have shown that the CRP is an effective treatment for posttraumatic posterior canal BPPV with 75% of patients showing symptom resolution, most of which (83%) were after only one or two treatments. This is in line with other investigations: Ahn et al. (2011) reported resolution of symptoms in 82% of their sample with one or two treatments, and Motin et al. (2005) reported that 60% of their sample had symptom resolution after one treatment.

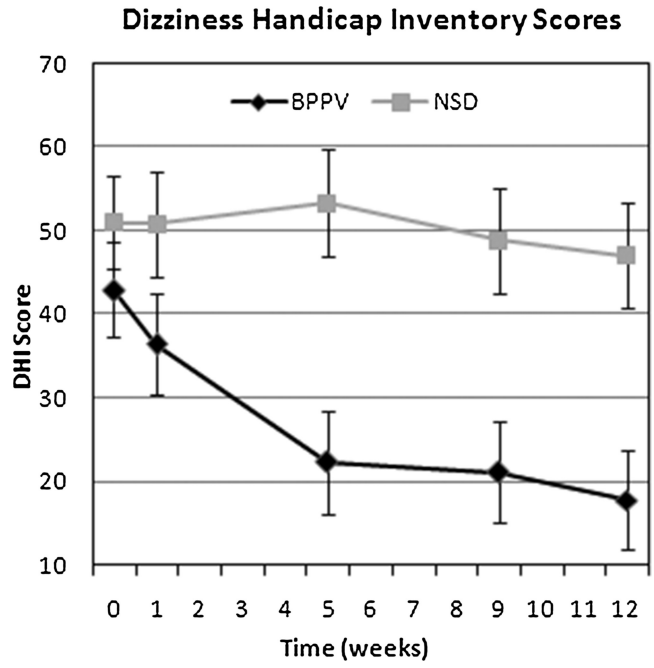
In our study, we evaluated the efficacy of the CRP both on BPPV symptom resolution and health-related quality of life. Both the BPPV and NSD groups had high dizziness handicap scores at baseline with scores significantly dropping for only the BPPV group participants by the 12-week follow-up. Patients in both the BPPV and NSD groups had worse physical component scores on the SF-36 than the no-dizziness group at baseline; these scores significantly improved in the BPPV group after treatment, to be comparable with the no-dizziness group at the 12-week follow-up. Interestingly, mental health component scores did not change after treatment for patients in the BPPV group. One would hypothesize that mental health component scores would improve with physical component scores. However, recovery from TBI can be complex and multifactorial. Patients were, on average, less than 3 months postinjury upon enrollment into the study and still experiencing persistent symptoms related to their injury, which may have been additional to their reports of dizziness. Greater severity of mental health issues is common in this population.

TABLE 3. Number of BPPV Group Participants (*N* = 21) Undergoing One, Two, Three, or Four CRP Treatments

	Number of CRP Treatments			
BPPV Status	1	2	3	4
Resolved (*n* = 12)	7	3	2	
Unresolved (*n* = 4)		2		2
Withdrawn/lost to follow-up (*n* = 5)	3	2		

Note. BPPV = benign paroxysmal positional vertigo; CRP = canalith repositioning procedure.

FIGURE 2 Estimated Marginal Means of the Dizziness Handicap Inventory (DHI) Scores Over Time for the Nonspecific Dizziness (NSD, Squares) and Benign Paroxysmal Positional Vertigo (BPPV, Diamonds) Groups

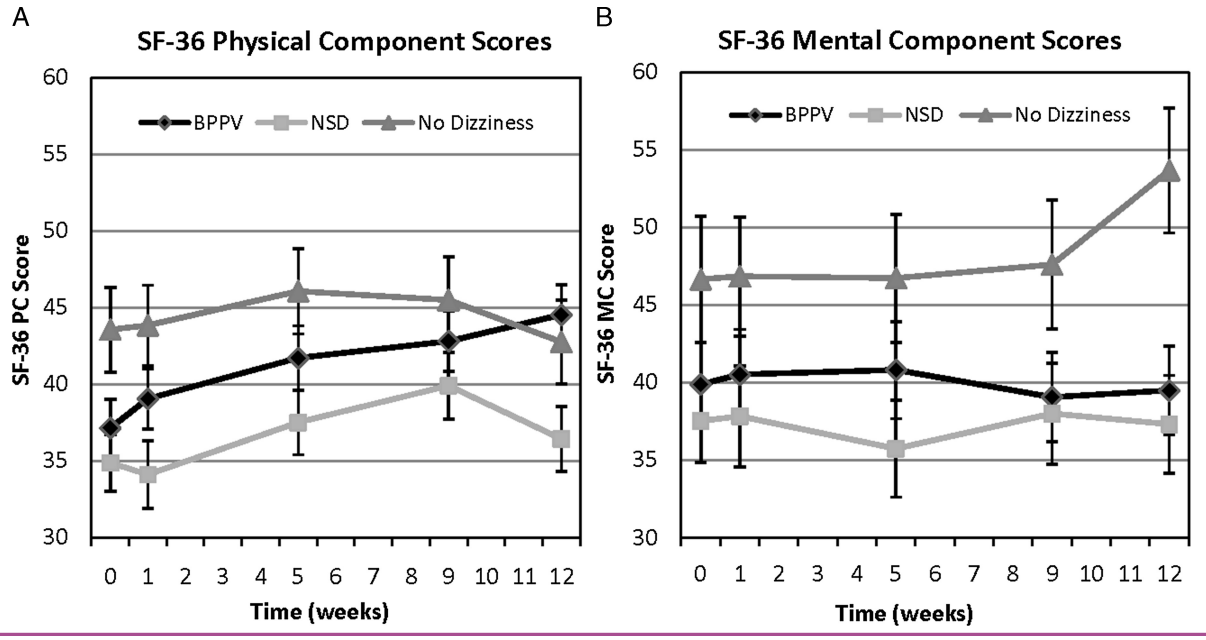


Almost half of our study patients with complaints of dizziness upon enrollment were subsequently diagnosed with posterior canal BPPV. This is comparable with the rate of 50% reported by Motin et al. (2005) among their patients with severe TBI but higher than the 25% reported by Davies and Luxon (1995) and 23% reported by Ahn et al. (2011). Our higher proportion of positive BPPV may be attributed to the fact that we administered the DHP-M to all patients presenting with dizziness, not only those who presented with the classical symptoms of BPPV (e.g., vertigo that is brief and elicited on positional changes, such as looking up, rolling over in bed, etc.).

Seven participants (33%) in the BPPV group did not present with the classical symptom of brief vertigo lasting seconds, with two of these participants reporting no spinning at all yet testing positive for BPPV according to the DHP-M. In the NSD group, 38.1% reported the classical symptom of brief vertigo, and 80.1% reported that their dizziness was positional in nature. These findings underscore the point that, in a post-TBI population, relying on symptom report alone may result in missed diagnosis. Postinjury cognitive deficits, or psychological sequelae such as depression, may influence the patients' ability to perceive and report symptoms. We, as well as others, suggest that, even after a mild TBI, physicians should test for BPPV if a patient complains of dizziness (Ahn et al., 2011).

We conducted our study in an ambulatory head injury outpatient setting. Ahn et al. (2011) reported data from patients treated in a neurotology and dizziness clinic, whereas Motin et al. (2005) included patients admitted to a rehabilitation facility with resources related to neurotology. One of our study team members (JR) is an otolaryngology and neurotology specialist who trained members of the clinic team on the conduct of the CRP in this setting, which did not otherwise have specialization in neurotology. For the patients in our head injury clinic, including those in this study, the CRP was predominantly conducted by a trained nurse (AM). We would recommend that clinicians including neuroscience nurses in settings where patients with TBIs or concussions would be seen be trained on these simple techniques to assess for and treat BPPV in their patients after head trauma (Bhattacharyya et al., 2008). Such settings could include emergency departments, acute care inpatient units, primary care settings, and concussion care clinics. Patients with complaints of posttraumatic dizziness should also be prioritized for treatment: patients who are referred to our clinic with such symptoms are often scheduled for an earlier appointment than those without dizziness. In the emergency department, nurse practitioners or bedside nurses could be trained to test for BPPV and administer the CRP. Future research could determine where the treatment of BPPV in the emergency department shortly after a concussion or mild TBI could reduce the persistence of postconcussive symptoms by providing early resolution of symptoms for patients.

FIGURE 3 Estimated Marginal Means of the SF-36 (a) Physical and (b) Mental Health Component Scores Over Time Across the Three Study Groups (Benign Paroxysmal Positional Vertigo [BPPV, Diamonds], Nonspecific Dizziness [NSD, Squares], and No Dizziness [Triangles])



Moreover, having such a treatment approach available in emergency and primary care settings could decrease the need for referral to specialized clinics.

Although comparable on all demographics variables (age, gender, educational level, marital and employment status) and on most injury-related variables (time since injury, mechanism of injury, past history of head trauma), participants with BPPV were more likely to have had (a) a moderate versus mild diagnosis of TBI (according to their Glasgow Coma Scale score) and (b) positive findings on computed tomography scan. It is interesting that, although the BPPV group had more cases of moderate TBI than the NSD group (all mild TBI), the BPPV group is the one in which the most improvements were seen on symptoms (although the two groups were comparable at baseline on both the DHI and SF-36 scores). There are no studies available that have examined the specific relationship with TBI severity and BPPV onset or severity. However, our findings suggest that the clinician should be particularly diligent about screening for BPPV among patients with more serious injuries who complain of postconcussive dizziness.

Study Limitations

There are several limitations to our study including the lack of a longer-term follow-up and the fact that the research team members were not blinded to the participant's study group. We were unable to conduct the study using a randomized, controlled approach because the members of the study team did not possess clinical equipoise and felt that denying or delaying a treatment that they felt was effective would be unethical.

It is important to note that the study participants across all three groups were, on average, about 2 months postinjury. Previous research has suggested that postconcussive symptoms naturally resolve in most cases within approximately 3 months to 1 year postinjury (Cassidy et al., 2014). It is thus possible that BPPV symptoms resolved spontaneously in this group, as a part of the natural recovery post-TBI, rather than because of the CRP. However, the BPPV group improved in their scores on the DHI and the SF-36 physical component score, whereas the NSD group did not. SF-36 mental health component scores remained relatively unchanged in both groups. Given that the NSD group had "milder" cases of TBI, if spontaneous recovery were to have been a factor in the study, we would have expected to observe more of an improvement in these measures for the NSD group.

It is also important to note that the BPPV symptom resolution, which was observed in the BPPV group, was often quite dramatic and almost immediate in one third of the cases (e.g., after only one treatment) and within two treatments in an additional 14% of cases. So, for almost half of the patients who presented with BPPV, which was associated with significant impact

on their daily functioning and quality of life, they achieved resolution of symptoms within a 1-week period. For an individual to live with this condition even for an additional day, when such a simple, noninvasive treatment option is available to them, is unacceptable. Thus, although they may have recovered spontaneously, we were able to show that the CRP can halt the symptoms much faster than which may have occurred as per natural recovery.

An additional limitation in our study was the use of the DHP-M as our sole diagnostic tool for BPPV. Although DHP-M is the standard, accepted procedure for the diagnosis of BPPV in the general population, it is only able to positively diagnose BPPV 83% of the time (Labuguen, 2006). For example, a positive test may be recognized as a variable sign of the condition, whereas a negative response on any given examination may not invalidate the diagnosis. This is of significance because there may be a subset of patients with TBI who present atypically, confounding diagnosis and treatment of BPPV. Still, although the DHP-M may fail in a small percentage of cases, it still has the potential to reduce the number of patients with posttraumatic BPPV who remain undiagnosed and untreated.

Finally, 240 clinic patients were screened to identify 81 eligible study participants, of which 56 (69%) consented to participate, with 36 of those completing the 12-week follow-up. The high degree of dropout and moderate consent refusal were predominantly because of the time demands of participating in the study for which patients were asked to come to the clinic for four additional visits over a 12-week period. As a tertiary referral center, the clinic receives patients from a wide geographical area, and most participants did not qualify for the study or withdrew from the study because of travel and time demands. However, even with the follow-up rates, which we were able to achieve, effectiveness of the CRP for posttraumatic BPPV was shown.

Conclusions

Posttraumatic dizziness presents an additional obstacle to recovery, perpetuating the healthcare burden related to the management of TBI. The CRP is noninvasive and easily administered at the bedside and may be an economical treatment procedure for BPPV. Results from this study indicate that the CRP is an effective intervention for TBI-associated BPPV as documented by significant improvements on the DHI and SF-36 physical component scores at 12-week follow-up. Early diagnosis and accessible treatment for BPPV has implications for improving the quality of life after a brain injury and may reduce the time needed to return to daily activities such as work and school. Ultimately, we aim to capture these patients for assessment and treatment in a primary care setting or TBI clinic much earlier than later, leading to reduced patient disability and expenses and alleviating the need for referrals to specialized clinics.

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