Scandinavian Journal of Pain 8 (2015) 1–7

Contents lists available at ScienceDirect

Scandinavian Journal of Pain

journal homepage: www.ScandinavianJournalPain.com

Observational study

Treatment of chronic canalithiasis can be beneficial for patients with vertigo/dizziness and chronic musculoskeletal pain, including whiplash related pain

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HIGHLIGHTS

- Otolith repositioning manoeuvres in canalithiasis reduce pain and other symptoms.
- Chronic canalithiasis involves multiple semi-circular canals (CSCC).
- Trauma is a main cause of chronic canalithiasis.
- Anterior SCC canalithiasis is associated with temporo-mandibular joint region pain.
- The Dizziness Handicap Inventory identifies treatable painful balance disorders.

ARTICLE INFO

Article history:
Received 16 October 2014
Received in revised form 19 January 2015
Accepted 3 February 2015
Available online 20 March 2015

Keywords:
Pain
Vertigo
Chronic BPPV
Canalithiasis
Whiplash
Temporo-mandibular joint region pain

ABSTRACT

Background and aim: Chronic musculoskeletal pain, e.g. whiplash associated disorders (WAD), fibromyalgia and myalgia, causes significant burden on both the individual and on society as a whole. In a previous study, the authors concluded that there is a likely connection between chronic benign paroxysmal positional vertigo (BPPV)/canalithiasis and headache, neck pain, generalized pain, fatigue, cognitive dysfunctions as well as tinnitus. The balance dysfunction in BPPV/canalithiasis is dynamic and not static. This leads to a perpetual postural mismatch. The vicious cycle of a disturbed equilibrium control system may be the driving force behind the vicious cycle of pain. The aim of this study is to investigate if otolith-repositioning manoeuvres in patients with chronic BPPV/canalithiasis can be beneficial.

Methods: During a period of about two years a prospective observational study on patients with chronic musculoskeletal pain referred for physiotherapy was performed. Those with a Dizziness Handicap Inventory (DHI) inquiry score above 20 underwent further investigations to diagnose chronic BPPV/canalithiasis. *Diagnostic criteria*: (A) The diagnosis of BPPV/canalithiasis was confirmed with the following: (1) specific history of vertigo or dizziness provoked by acceleration/deceleration, AND (2) nystagmus and symptoms during at least one of the test positions; (B) the disorder had persisted for at least one year. Specific otolith repositioning manoeuvre for each semi-circular canal (SCC) was performed. Symptom questionnaire ("yes" or "no" answers during a personal interview) and a follow-up questionnaire were used.

Results: The responders of the follow-up questionnaire constituted the study group. Thirty-nine patients responded (i.e. 87%) (31 females, 8 males) with a median age of 44 years (17–65). The median duration of the disease was 5 years. Seventy-nine percent had a history of head or neck trauma. The DHI median score was 48 points (score >60 indicates a risk of fall). The video-oculography confirmed BPPV/canalithiasis in more than one semi-circular canal in all patients. In the present study the frequency of affected anterior semi-circular canal (SSC) was at a minimum of 26% and could be as high as 65%. Ninety-five percent suffered from headache, 92% from neck pain, 54% had generalized pain, and 56% had temporo-mandibular joint region pain. Fatigue (97%), aggravation by physical exertion (87%), decreased ability to concentrate (85%) as well as visual disturbances (85%) were the most frequently reported symptoms, and 49% suffered from tinnitus. The median number of otolith repositioning manoeuvres done was six (2–29). Median time span between finishing otolith repositioning manoeuvres and answering the questionnaire was 7 months.

DOI of refers to article: http://dx.doi.org/10.1016/j.sjpain.2015.02.005.
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http://dx.doi.org/10.1016/j.sjpain.2015.02.002

Effects of treatment and conclusion: The present study has shown that repositioning of otoliths in the SCCs in nearly all patients with chronic BPPV/canalithiasis ameliorated pain and other symptoms. The correlation between vertigo/dizziness and the majority of symptoms was significant. Therefore, there is strong evidence to suggest that there is a connection between chronic BPPV/canalithiasis and chronic pain as well as the above-mentioned symptoms.
Implications: Patients with unexplained pain conditions should be evaluated with the Dizziness Handicap Inventory-questionnaire, which can identify treatable balance disorders.

1. Introduction

Chronic muscular skeletal pain, whiplash associated disorders (WAD), fibromyalgia and myalgia, cause significant burden on both the individual and on society as a whole. Some of these patients have seen many medical specialists and have been through numerous inconclusive investigations. Based on the main symptom of pain, patients have received numerous diagnoses including WAD, fibromyalgia and myalgia. Many researchers have found balance-disturbance/dizziness in patients with WAD [1–3]. If these patients do not have attacks of rotatory vertigo they are usually not diagnosed with BPPV. The current accepted diagnosis of BPPV is brief attacks of rotatory vertigo and concomitant nystagmus elicited by rapid changes in head position relative to gravity [4,5]. However, other researchers have found that BPPV is not always characterized by rotatory vertigo [6–8]. The use of the term BPPV in this connection may seem problematic or even contradictory. Can a condition causing debilitating chronic health problems be called 'benign'? And can a chronic condition be called 'paroxysmal'? 'Canalithiasis' is an expression of the pathology. 'BPPV' is a description of one of more clinical signs and symptoms. Therefore we have chosen to call this condition chronic 'canalithiasis' and not chronic BPPV. In the following, only chronic 'canalithiasis' will be used.

In a previous study [9], the authors concluded that there is a likely connection between chronic canalithiasis and headache, neck pain, generalized pain, fatigue, cognitive dysfunctions as well as tinnitus. The balance dysfunction in canalithiasis is dynamic and not static. This leads to a perpetual postural mismatch. The vicious cycle of a disturbed equilibrium control system may be the driving force behind the vicious cycle of pain [9]. The aim of the present study is to investigate if otolith-repositioning manoeuvres in patients with chronic canalithiasis can be beneficial in ameliorating chronic pain and other symptoms.

2. Methods

This was a prospective observational study on patients with chronic pain referred for physiotherapy by general practitioners in Vennesla and Kristiansand in Southern Norway during the period October 2011–March 2014. Written informed consent was obtained from all patients. This study is in accordance with ethical standards on human experimentation and with the Helsinki Declaration of 1975, as revised in 1983. Formal approval was given by the Regional Ethical Committee (No. IRB 00001870).

The study group was selected from a cohort of patients referred with chronic musculo-skeletal pain. Individuals 17–65 years of age with on-going pain for more than one year and not caused by rheumatic diseases, migraine, CNS-disorders or cancer completed the Dizziness Handicap Inventory (DHI) inquiry [10,11]. Those with a score above 20 underwent further investigations to diagnose canalithiasis.

2.1. Diagnostic criteria

(A) The diagnosis of canalithiasis is confirmed with the following:

(1) Specific history of vertigo or dizziness provoked by acceleration or deceleration AND.
(2) Nystagmus and symptoms during at least one of the test positions.

(B) The disorder had persisted for at least one year.

2.2. Exclusion criteria

(1) Consequent smooth pursuit eye movement ataxia, i.e. uni- or bilateral ocular ataxia characteristic for a CNS disorder (pontine or cerebellar lesion).
(2) Saccadic eye movement test disturbance, especially hyper- or hypometric, which is characteristic for CNS disorders such as multiple sclerosis.
(3) Migraine (confirmed by positive effect of migraine specific medication).
(4) Active Ménière's disease.
(5) Severe eye disorders, i.e. conditions where optimal vision cannot be obtained by optical aids.
(6) Cardiovascular disorder.
(7) Pain caused by cancer or rheumatic diseases.
(8) Severe elevated body mass index.

2.3. Procedure

2.3.1. Dizziness Handicap Inventory (DHI) [10,11]

The Dizziness Handicap Inventory (DHI) is validated for individuals with vestibular dysfunction. The tool consists of 25 items that are scored as *always* (4 points), *sometimes* (2 points), and *never* (0 point) for a maximal score of 100. A score >60 indicates an increased likelihood of having a fall.

2.3.2. Symptom questionnaire

"Yes" or "no" answers during a personal interview (shown in Table 1).

Stedman's Medical Dictionary (26th edition) [12] defines vertigo as

(1) "The sensation of spinning or whirling motion. Vertigo implies a definite sensation of rotation of the subject or of objects about the subject in any plane.
(2) Imprecisely used as a general term to describe *dizziness* commonly used by patients in an attempt to describe various symptoms such as faintness, giddiness, light-headedness, or unsteadiness".

We chose to operate with either *rotatory vertigo* or *nautical vertigo* (=sensory illusion reminding of movements experienced on board a ship in waves) and *dizziness*.

The visual disturbances the patients report were blurred vision, seeing "stars" of different colours even in darkness, episodes of tunnel vision lasting for a few minutes, all evoked by movements of the head (Table 2).

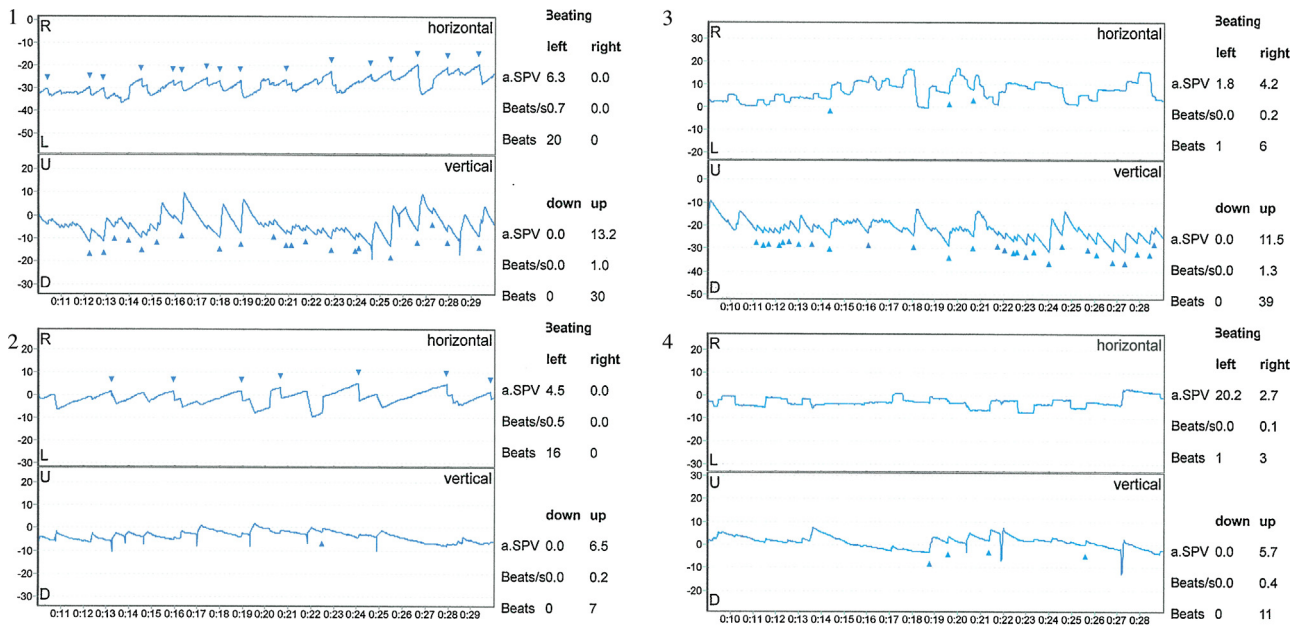

Fig. 1. Video-oculographic documentations of BPPV. (1) Demonstrates an affection of the posterior SCC in the left labyrinth. The patient is lying on his left side; his head turned 45° up. The rectangle shows the last 20 s of a 30 s sequence. At the right side of each rectangle the quantitative details are given, i.e., the counts of nystagmus and their orientation (left, right, down and up) during a 30 s period, beats per second, and SPV, i.e., Slow Phase Velocity of nystagmus beats. This patient had 20 left-directed horizontal nystagmus beats and 30 up-right vertical nystagmus beats. (2) Demonstrates the nystagmus appearance after coming back into an upright position. Now the horizontal nystagmus beats are dominant and this is interpreted as a possible horizontal SCC affection. (3) Demonstrates an affection of the anterior SCC in the left labyrinth. The patient is lying on his right side; his head turned 45° up. The patient had 39 up-right directed vertical nystagmus beats and six right horizontal directed nystagmus beats. (4) Demonstrates the nystagmus appearance after returning into an upright position. There are now very few nystagmus beats. The video-oculographic picture was interpreted as a multicanalicular canalithiasis with an affection of the anterior and posterior SCCs as well as a possible affection of the horizontal SCC in the left labyrinth. The recordings are from a 52 year old man with a 2 year history of neck pain and fatigue after a road traffic accident. The patient received repositioning of otoliths in all three SCCs, left side, and he improved significantly.

Table 1
Frequency of symptoms reported before treatment.

	N = 39	%
Isolated rotatory vertigo	2	5
Combined rotatory- and nautical vertigo/dizziness	16	41
Nautical vertigo/dizziness	21	54
Headache	37	95
Neck pain	36	92
Peri-/retroorbithal pressure/pain	31	79
Temporo-mandibular region pain	22	56
Generalized pain	21	54
Involuntary movements	14	36
Visual disturbance	33	85
Phonophobia/hyperacousis	10	26
Tinnitus	19	49
Fatigue	38	97
Aggravation by physical exertion	34	87
Sleep disturbances	33	85
Sensation of globus	11	28
Nausea	28	72
Temperature disturbances	24	62
Impaired short term memory	32	82
Concentration problems	34	87

The cypher indicates the number of individuals reporting the specific symptom. The percent expresses the frequency of each symptom.

2.3.3. Diagnosing procedure

The two first authors performed the diagnosing procedure simultaneously. The tests were developed by the authors and based on their clinical experience. The nystagmus registration was done consecutively: (1) in sitting position; (2) in side-lying position, head turned 45° upwards; (3) in sitting position again. Two minutes were spent in each position. We refrained from using the Dix-Halpike test, since the majority of the patients in this study group suffered from severe neck pain. We wanted to avoid exacerbation of their pain. The nystagmus was registered by video-oculography (Interacoustics A/S, Assens, Denmark). Oculography is superior to oculoscopy as it is able to register the lowest amplitude nystagmus. The cause of canalithiasis is believed to be otoliths or debris, which have loosened from macula utriculi and moved into one or more semicircular canals (SCCs) in the vestibule of the inner ear. It can be difficult to move solid floating particles in liquid by rapid movements; therefore the repositioning manoeuvres were done in slow motion. Because of the possible long latency before nystagmus was evoked in some patients, they were kept for 2 min in each position during the diagnostic procedure (Stoke's law). Otoliths in one SSC give a specific nystagmus pattern. Otoliths in more than one SSC give various nystagmus patterns depending on how many SSCs are activated and the amount of debris present.

Table 2
Painrelieving drugs before and after otolith repositioning manoeuvres.

	Before treatment	After treatment Unchanged	After treatment Reduced	After treatment No medication
Tramadol	6	1	3	2
NSAID	19	3	6	10
Paracetamol	21	7	7	7
No medication	13			21

The cypher indicates the number of individuals who reported the use of specific medications before and after otolith repositioning.

Divergence from one-SSC pattern was interpreted as a canalithiasis with otoliths in more than one SSC [13]. The criterion for diagnosing otoliths in the anterior SCC is a downbeat/torsio or eventually an isolated downbeat nystagmus in one of the test positions [14]. However, in patients with unilateral canalithiasis involving all three SCCs, we observed torsio/upbeat in the ipsilateral position and up or downbeating nystagmus in the contralateral position (Fig. 1). An analytic nystagmus study as well as a smooth pursuit eye movement study on this material of patients with chronic canalithiasis will follow in a separate publication.

Polensek and Tusa in 2009 found the caloric test unnecessary for diagnosing BPPV [15]. The caloric test and the head impulse test were excluded in this study because they do not give reproducible results in patients with BPPV. This is because the otoliths in the SCC are influenced by the slightest movement and the latency and nystagmus duration are variable. The oculomotor test battery (i.e. smooth pursuit eye movement test and saccadic eye movement test) has been applied to exclude patients with CNS disorders.

2.3.4. Repositioning manoeuvres

The repositioning of otoliths in the posterior SCC was accomplished by using Epley's manoeuvre [16,17]. The repositioning of the otoliths in the horizontal SCCs was developed and described by the authors [9].

In patients with otoliths in the anterior SCC it can be difficult to determine which side is mostly affected. Using an anatomical specimen, a new manoeuvre was established. By doing a summersault (360°) in a forward movable chair it is possible to treat both sides simultaneously. Both the chair and the manoeuvre were developed by the authors.

(1) Relax in sitting position in a forwardly movable chair (0°) for 5 min before start. The head is in neutral position.
(2) The chair is turned slowly forward until the patient is sitting in an upside-down position (180°).
(3) After three minutes the summersault continues for an additional 45° (225°).
(4) Return to the starting sitting position (360°).

The patient is kept in position (2) for three minutes followed by position (3) for an additional three minutes. The procedure is done in slow motion.

If there was a lack of success by repositioning the otoliths in posterior and horizontal SCCs we took into consideration a possibility of an anterior SCC affection. They were treated for an anterior canalithiasis, even without having a vertical nystagmus.

The order of otolith repositioning out of the SCCs was (1) anterior, (2) posterior and (3) horizontal with one week between each treatment. In patients with bilateral canalithiasis the repositioning starts out with the most affected side.

Home exercises recommended were walking on uneven surfaces (i.e. non-asphalt) with the purpose to integrate the different balance components, i.e. vision, vestibular function and proprioception.

2.3.5. Follow-up questionnaire

The patients in the study group received a follow-up questionnaire (Table 3). Five answer alternatives for each symptom or condition were given. The quantification value of each is given in parenthesis: symptom free (4); much improved (3); some improvement (2); unchanged (1); worse (−4). These values were used for the correlation study.

2.3.6. Statistical analysis

The StatSoft-statistical program, copyright 2004 (Tulsa, OK 74104) was used for the analyses. Non-parametric analyses were applied. Kruskal–Wallis ANOVA test was used as well as Spearman Rank Order Correlation test.

3. Results

3.1. Patients with the diagnosis of chronic canalithiasis and chronic pain

Forty-seven patients with chronic pain (WAD, fibromyalgia, myalgia etc.) who suffered from a chronic canalithiasis fulfilled the diagnostic criteria. Two patients were excluded, one with multiple sclerosis and one due to parallel treatment at another institution. Forty-five patients received the follow-up questionnaire. The responders constituted the study group. Thirty-nine responded (87%) (8 males and 31 females) with a median age of 44 years (range 17–65; quartiles 39–52). The median duration of the disease was 5 years (range 1–36; quartiles 4–16). The median number of otolith repositioning manoeuvres done was six (range from 2 to 29; quartiles 4–9.5). Median time span between finishing the otolith repositioning manoeuvres and answering the questionnaire was 7 months (range 1–31; quartiles 3–15).

3.2. Trauma

Thirty-one patients (79%) had a history of head or neck trauma resulting from road traffic accidents, fall accidents, or sports injuries. Sixteen patients (41%) fulfilled the Quebec Task Force criteria for the diagnosis of whiplash associated disorders (WAD) [18]. Fifteen individuals (38%) had a history of trauma without continuous symptoms for a period of time after the accident. The majority of these believed that their disorder was a result of the previous trauma. Eight (21%) could not recall any trauma. There was no difference in age, gender and duration of illness among those with and without trauma. There was also no difference in DHI-score, frequency of symptoms, number of otolith repositioning manoeuvres or treatment results.

3.3. Vertigo

Twenty-one (54%) individuals suffered from nautical vertigo and dizziness, two (5%) from isolated rotatory vertigo, and sixteen (41%) from combined rotatory vertigo and nautical vertigo/dizziness see Table 1.

The Dizziness Handicap Inventory (DHI) median score was 48 points (range 20–72; quartiles 38–60).

3.4. Nystagmus

The video-oculography confirmed canalithiasis in more than one semicircular canal in all patients. Ten patients (26%) had isolated upbeat- or downbeat vertical nystagmus. In the present study more patients had upbeat nystagmus than downbeat (Fig. 1). Nineteen individuals (49%) had minimal improvement after repositioning of otoliths in posterior and horizontal SCCs. These nineteen patients had no isolated vertical nystagmus, but were treated for an anterior SCC canalithiasis.

There were no differences in treatment outcome between patients with and without isolated vertical nystagmus. Thus, in this study the frequency of affected anterior SCC was at a minimum of 26% and could be as high as 65%.

3.5. Pain

Thirty-seven patients (95%) suffered from headache, thirty-six (92%) from neck pain, twenty-one (54%) from generalized pain, and twenty-two (56%) from temporo-mandibular joint (TMJ) region

Table 3
Effects of otolith repositioning manoeuvres on pain and other symptoms.

	N	Free of symptom	Much improved	Some improvement	Unchanged	Percentage of patients improved	Correlation value
Vertigo/dizziness	39	6	25	7	1	97	1.000
		15%	64%	18%	3%		
Visual disturbance	33	8	15	6	4	88	0.666
		24%	46%	18%	12%		
Headache	37	7	14	10	6	84	0.571*
		19%	38%	27%	16%		
Neck pain	36	6	12	9	9	75	0.501*
		17%	33%	25%	25%		
Widespread pain	21	4	6	3	8	62	0.524*
		19%	29%	14%	38%		
TMJ pain	21	12	2	2	5	76	0.395[a]
		57%	10%	10%	24%		
Nausea	28	11	10	4	3	89	0.397*
		39%	36%	14%	11%		
Fatigue	38	6	14	12	6	84	0.691*
		16%	36%	32%	16%		
Sleep disturbance	33	5	15	8	5	85	0.529*
		15%	46%	24%	15%		
Concentrat. difficulty	33	4	14	9	6	82	0.600*
		12%	43%	27%	18%		
Involuntary movements	14	4	5	1	4	72	0.446[a]
		29%	36%	7%	29%		
Temperature disturbance	24	10	5	4	5	80	0.357[a]
		42%	21%	17%	21%		
Tinnitus	19	4	3	7	5	74	0.475*
		21%	16%	37%	26%		
Work capacity	39	4	15	14	6	85	0.418*
		10%	39%	36%	15%		

The cypher indicates the number of individuals who has reported the specific effect on the specific symptom. The percentage expresses the frequency of each symptom. Correlation value: vertigo/dizziness at one side and pain and other symptoms on the other side: Spearman Rank Order Correlations.

* $p < 0.05$.

[a] Correlation-value: $0.05 < p < 0.10$.

pain. Nineteen out of the twenty-two patients with TMJ region pain underwent treatment for otoliths in the anterior SCC, and thirteen out of these nineteen patients reported resolution of TMJ region pain after treatment.

A report from a patient with TMJ region pain: "After you turned me upside down in the chair my life changed. The TMJ region pain and the headache disappeared and so did the hard pressure around my head. I got very tired for some days. After treatment my life went from night to day. I really appreciate the help I got. I was told at the neurological department at the hospital that my pain and other symptoms were of psychological origin and psychopharmaca were prescribed, which I did not take. Instead I contacted you".

This patient had no isolated vertical nystagmus, but it was a lack of success by repositioning the otoliths in posterior and horizontal SCCs. Therefore, she was treated with a summersault manoeuvre.

3.6. Analgesic drugs used before and after otolith repositioning

Thirteen patients used no pain medication before treatment due to lack of amelioration or fear of addiction.

3.7. Other associated symptoms

Fatigue (97%), aggravation by physical exertion (87%), decreased ability to concentrate (85%) as well as visual disturbances (85%) was the most frequent reported symptoms. Nausea was reported among 28 individuals, i.e. 72%. Twenty-four patients (62%) (5 males and 19 females) suffered from temperature disturbances (i.e. heat flush, profuse sweating or chills). Six females were below forty years of age. Nineteen (49%) suffered from tinnitus. Fourteen (36%) reported involuntary movements.

3.8. Follow-up

The answers from the patients are given in Table 3. Thirty-five patients (i.e. 90%) had some improvement or more. Four patients did not benefit from the treatment, although one reported initial substantial improvement, but relapsed after a couple of weeks. No patient reported disimprovement after treatment. Twenty-seven individuals, i.e. 59%, suffered at least one relapse.

Age, duration of sickness, DHI-score and follow-up time had no significant influence on the results.

4. Discussion

4.1. Nautical vertigo, dizziness, pain and other associated symptoms

In the present study, patients with musculoskeletal pain were referred for physical therapy. Another group of patients with vertigo/dizziness were referred for otoneurologic investigations [9]. All patients in both groups had a DHI-score above 20 and were diagnosed with a multiple-canal involvement chronic canalithiasis. The frequency of symptoms was similar in both series.

Due to the high response on the follow-up questionnaire, it is likely that the given answers are representative. The median time span between completed otolith repositioning manoeuvres and answering the questionnaire was 7 months. Half of the patients responded in the period of 3–15 months. Therefore, the possible placebo effect of treatment has probably been minimized. This assumption is supported by lack of correlation between the follow-up time span and the given answers.

The present study has shown that repositioning of otoliths in the SCCs on patients with chronic canalithiasis ameliorates pain and other symptoms. The correlation between vertigo/dizziness

and the majority of symptoms was significant. Temperature disturbance, involuntary movements and TMJ-pain had a tendency to be statistically correlated. Therefore, the present study supports the former statement [9] that there is a likely connection between chronic canalithiasis and the following symptoms: nautical vertigo/dizziness, neck pain, headache, generalized pain, fatigue, visual disturbances, cognitive dysfunctions, nausea, and tinnitus.

4.2. Dynamic- and not static balance disturbance

Patients with BPPV and Ménière's disease, who have a dynamic balance disturbance, do not improve by exercises to compensate like patients with a static balance disturbance, e.g. vestibular neuritis [19–21]. It is impossible to compensate in the same way within a canalithiasis with its dislocated free-floating otoliths and debris, because the affected labyrinth(s) transmit(s) varying abnormal signals from time to time to the same stimuli. This is possibly why their symptoms are ongoing [9].

4.3. Trauma

Trauma seems to be a main cause of chronic canalithiasis. The frequency of patients with a history of trauma was the same in both study groups, i.e. the present pain-related- and the former vertigo-related study group [9]. Ernst et al. (2005) [2] documented that there could be a time span between the trauma and the onset of symptoms. In both study groups all patients suffered from a multiple-canal involvement canalithiasis. Many studies have documented that traumatic chronic BPPV patients can be relative resistant to treatment [22–28]. We raise the question: is this because of an affection of the anterior SCC [14,27].

4.4. Anterior SCC and TMJ region pain

In the upright resting position, the anterior SCC is the only SCC where otoliths and debris will be placed on top of the cupula. Even the slightest movement of the head, e.g. walking, talking, eating, the cupula is affected. In the present study a high frequency of possible anterior SCC affection was found. The majority did not have the isolated vertical nystagmus, but they responded positively on the forward summersault manoeuvre used for treating the anterior SCC. Since all the patients suffered from a multicanalicular canalithiasis the observed nystagmus pattern differed from the ordinary findings in uni-canalicular canalithiasis. The most affected SCC dominates the nystagmus pattern, but the nystagmus pattern is also influenced from other affected SCCs. The huge difference between the observed frequency of affected anterior SCC in the present study compared to other studies may be explained by the fact that we studied patients with multi-canalicular canalithiasis while the other studies are based on uni-canalicular canalithiasis [13,14].

Half of the patients in the present study suffered from TMJ region pain, nearly all of them were treated for an anterior SCC BPPV. The majority responded positively. TMJ region pain is a common and unsolved problem among many patients with WAD [29,30]. The most common explanation is that the TMJ pain is due to the tension of the ligaments in the temporo-mandibular joint caused by translational force during the initial impact on the vehicle.

The relative high frequency of WAD in these series might be explained through the characteristic whiplash trauma, i.e. acceleration/deceleration. Otoliths are slung through a natural trajectory from the macula utriculi to the crus commune and further into the posterior and anterior SCCs.

During repositioning of otoliths in the anterior SCC, pain in the TMJ region (including otalgia) often occurred in the first position and then declined in the next. The motor root of the trigeminal nerve innervates the muscles of mastication (the masseter, temporalis, and pterygoides and a few muscles of the palate (tensor veli palatine), middle ear (tensor tympani), and upper neck (mylohyoid and anterior belly of digastric muscle) [31]. Nearly two thirds of the patients in the present study had resolution of pain in the TMJ region after otolith repositioning.

4.5. Vestibulo-cranial nerve reflexes

The mentioned symptoms (Table 1) can be explained through inappropriate activity in the vestibular reflexes [9]. Symptoms associated with the cranial nerves are observed appearing and disappearing during otolith repositioning manoeuvres like the TMJ region pain related to the trigeminal nerve [32]. Therefore, it is not out of the question that there are reflexes from the vestibular nuclear complex to other cranial nerves than the oculomotor nerves (III, IV, VI). Together with nystagmus during otolith repositioning, many patients have periorbital clonic spasms, which we have interpreted as facial nerve activity. We have as well observed and palpated clonic spasms in the sternocleidomastoid and trapezius muscle innervated by the accessory nerve.

5. Conclusion

There is strong evidence to suggest that there is a connection between chronic canalithiasis and the following symptoms: nautical vertigo and dizziness, neck pain, headache, widespread pain, fatigue, visual disturbances, cognitive dysfunctions, nausea, and tinnitus.

The balance dysfunction in canalithiasis is dynamic and not static. This leads to a perpetual postural mismatch. Thus, the vicious cycle of the equilibrium control system may be the driving force behind the vicious cycle of pain.

Conflict of interests

The authors declare that they have no conflict of interest.

Authors' contributions

The first two authors have equally been involved in examination and treatment of all patients. Both authors have equally contributed to conception, design, and acquisition of data, analysis and interpretation of data. Moreover, both of the two first authors have equally been involved in drafting the manuscript and have given final approval of the version to be published. The third author has contributed to design and discussion. He has given the final approval of the version to be published.

Acknowledgement

The investigations that comprise this study were supported by grant from the Norwegian Medical Association (July 2014).

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