Prognostic indicators for decrease in tinnitus severity after cervical physical therapy in patients with cervicogenic somatic tinnitus

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Abstract

Background: Tinnitus can be related to many different aetiologies such as hearing loss or a noise trauma, but it can also be related to the somatosensory system of the cervical spine, called cervicogenic somatic tinnitus(CST). Recently, a positive effect of multi-modal cervical physical therapy on tinnitus severity in patients with CST was demonstrated. To date however, the outcome of the intervention cannot be predicted.

Objective: To identify prognostic indicators for decrease in tinnitus severity after cervical physical therapy in patients with CST.

Patients: Patients with moderate to severe subjective tinnitus (Tinnitus Functional Index(TFI):25–90points) and neck complaints (Neck Bournemouth Questionnaire(NBQ)>14points).

Intervention: All patients received multimodal cervical physical therapy for 6 weeks (12 sessions). This physical therapy contained a combination of manual mobilizations and exercises of the cervical spine.

Measurements: TFI and NBQ-scores were documented at baseline, after treatment and after a 6-weeks follow-up period. Impairments in cervical spine mobility and muscle function were identified at baseline and after 6-weeks follow-up.

Results: Patients with co-varying (increasing or decreasing simultaneously) tinnitus and neck complaints had significantly lower TFI-scores after treatment ($p=0.001$) and follow-up ($p=0.03$). The presence of this co-variation and a combination of low pitched tinnitus and increasing tinnitus during inadequate cervical spine postures are prognostic indicators for a decrease in TFI-scores after cervical physical therapy (adjusted $R^2=0.357$).

Conclusion: Patients who experience a decrease in tinnitus annoyance from cervical physical therapy are those with co-varying tinnitus and neck complaints and those with a combination of low-pitched tinnitus and increasing tinnitus during inadequate cervical spine postures.

Introduction

Tinnitus is the phantom sensation of sound in the absence of overt acoustic stimulation (Landgrebe et al. , 2012). It occurs in 10 to 15% of adults and is experienced as severely annoying by 1.6% (Baguley et al. , 2013). Tinnitus is mostly subjective, as it is only experienced by the patient (Baguley, McFerran, 2013). Typically, tinnitus is related to hearing loss or a noise trauma, where cochlear abnormalities are the initial source and neural changes in the central auditory system maintain the tinnitus (Baguley, McFerran, 2013).

Apart from the well-known causes, tinnitus can also be related to the somatic system of the cervical spine, in which case it is called cervicogenic somatic tinnitus (CST). The physiological explanation for CST is offered by several animal studies that have found connections between the cervical somatosensory system and the cochlear nuclei (CN) (Pfaller and Arvidsson, 1988, Zhan X, 2006). Cervical somatosensory information is conveyed to the brain by afferent fibres, the cell bodies of which are located in the dorsal root ganglia or the trigeminal ganglion. Some of these fibres also project to the central auditory system. This enables the somatosensory system to influence the auditory system by altering spontaneous rates or synchrony of firing among neurons in the CN, inferior colliculus or auditory cortex. In this way, the somatosensory system is able to alter the intensity and character of tinnitus (Shore et al. , 2007).

To date however, no unambiguously accepted diagnostic criteria exist for CST. The criteria suggested by Sanchez et al. (Sanchez and Rocha, 2011) are currently used as a guidance for the diagnosis. Based on these criteria, the diagnosis of somatic tinnitus is suggested when at least one of the following criteria is present: (1) evident history of head or neck trauma, (2) tinnitus association with some manipulation of the teeth, jaw or cervical spine, (3) recurrent pain episodes in head, neck or shoulder girdle, (4) temporal coincidence of appearance or increase of both pain and tinnitus, (5) increase of tinnitus during inadequate postures during rest, walking, working or sleeping and (6) intense bruxism periods during the day or night.

Previous research has shown that CST is present in 36 to 43% of the overall tinnitus population (Abel and Levine, 2004, Fabijanska A., 2014, Michiels, 2015, Ostermann K., 2014). Patients with CST mainly suffer from restricted cervical spine rotation (Michiels, 2015, Reisshauer et al. , 2006), pain provocation during combined extension, lateral flexion and rotation (Michiels, 2015) of the cervical spine or sensitive trigger points (Michiels, 2015, Reisshauer, Mathiske-Schmidt, 2006) in the presence of a positive score (> 14/70) on the Neck Bournemouth Questionnaire (NBQ) (Michiels, 2015).

Recently we demonstrated the effect of a multimodal cervical physical therapy treatment on tinnitus severity (Michiels et al. , 2016). This RCT showed a decrease in tinnitus severity in 53% of the treated patients. These results are promising, however, to date identification of patients who are most likely to benefit from this intervention is impossible.

Therefore, the aim of this study was to investigate prognostic indicators that can predict a positive outcome after multi-modal cervical physical therapy treatment in patient with CST.

Methods

Patients

Patients were recruited from the Antwerp University Hospital at the tertiary tinnitus clinic. During consult, patients were thoroughly examined by a multidisciplinary team to exclude any objective causes of tinnitus. Patients were included in the study when suffering from moderate to severe chronic non-fluctuating subjective tinnitus that had been stable for at least three months combined with neck complaints. The severity of the tinnitus was evaluated using the TFI (Meikle et al. , 2012). Moderate to severe tinnitus is defined as a score between 25 and 90 on the TFI (Meikle, Henry, 2012). Neck complaints were considered to be significant with a score of > 14 points on the NBQ (Bolton and Humphreys, 2002, De Hertogh et al. , 2007). Patients suffering from vertigo, objective tinnitus, subjective tinnitus with etiologies such as hearing loss or Meniere's disease, severe depression (diagnosed by a psychologist), progressive middle ear pathology, intracranial pathology, traumatic cervical spine injury, tumors, cervical spine surgery or any cervical spine condition in which physical therapy treatment is contraindicated were excluded from the study. Patients were also excluded if they had received physical therapy treatment for the cervical spine in the past two months.

Intervention

The intervention, a physical therapy treatment for the cervical spine, consisted of multimodal care containing manual mobilizations, exercise therapy and home exercises. This multimodal physical therapy treatment was based on recent insights of cervical spine therapy (Gross et al. , 2004, Miller et al. , 2010). For the home exercises, a booklet established by Castien et al. (Castien et al. , 2009) was adjusted for the tinnitus patients, implementing exercises for the deep neck flexor muscles (Jull et al. , 2002) and self-mobilizing exercises (Reid et al. , 2008). Treatment was applied by a selected group of physical therapists, all of whom had obtained a master's degree in physical therapy and an additional master's degree in manual therapy. Prior to the start of the study, all therapists participated in a training session about the treatment protocol, which was organized by the research group. Patients included in the trial were referred for treatment to one of the selected therapists (guided referral). The treatment protocol provided 12 standardized cervical physical therapy sessions during a 6-week treatment program. The therapists were free to adapt the mobilization techniques and exercises to the current situation of the patient. No spinal manipulation techniques were allowed.

No changes were made to the patients' drug use during the study, but no additional treatments, such as neuromodulation were allowed.

Assessment

During medical history taking at baseline, the items of the diagnostic criteria for CST (Sanchez and Rocha, 2011) were questioned. The following information was inventoried: (1) evident history of head or neck trauma, (2) tinnitus association with some manipulation of the teeth, jaw or cervical spine, (3) recurrent pain episodes in head, neck or shoulder girdle, (4) temporal coincidence of appearance or increase of both pain and tinnitus, (5) increase of tinnitus during inadequate postures during rest, walking, working or sleeping and (6) intense bruxism periods during the day or night.

The TFI (Meikle, Henry, 2012) was used to assess tinnitus annoyance in eight different domains: the unpleasantness of the tinnitus, reduced sense of control, cognitive interference, sleep disturbance, auditory difficulties attributed to the tinnitus, interference with relaxation, reduction in quality of life and emotional distress. The test-retest reliability of the TFI is good (r: 0.78). The convergent validity with the Tinnitus Handicap Inventory (Newman et al. , 1996) (r: 0.86) and 10 cm visual analogue scale for tinnitus (VAS) (r: 0.75) is good, as well as the discriminant validity with the Beck Depression Inventory-Primary Care (Beck et al. , 1961) (r: 0.56) (Meikle, Henry, 2012). A reduction of 13 points is considered to be clinically relevant (Meikle, Henry, 2012).

Additionally the NBQ (Bolton and Humphreys, 2002) and global perceived effect (GPE) were registered.

The NBQ consists of seven questions on the severity of the neck complaints and its interference with the patient's wellbeing and professional and daily activities. The test-retest reliability of the NBQ is moderate (ICC: 0.65). The construct validity is acceptable with both the Neck Disability Index (Vernon and Mior, 1991) (r: 0.50) and the Copenhagen Neck Functional Index (Jordan et al. , 1998) (r: 0.44). The effect size was high (Cohen's d: 1.67), which indicates that the NBQ is highly responsive to changes in cervical spine complaints. Changes in NBQ-score are clinically significant in case of a change of 13 or more points, percentage change scores of 36% or more, and individual effect sizes of 1.0 or more (Bolton, 2004).

The GPE consists of the patient's subjective opinion on changes in his or her tinnitus complaints. Figures for the GPE were obtained by asking whether or not (dichotomous) the patient experienced a substantial improvement of their tinnitus complaints compared to baseline. The test-retest reliability of the GPE was excellent (ICC: 0.90-0.99) in patients with musculoskeletal disorders, but the patients' current status strongly influenced the rating (Kamper et al. , 2010). Therefore, in our study we only compared the current status to baseline.

TFI, NBQ and GPE were used as measures for the effectiveness of the therapy and were therefore measured at baseline, after treatment and after 6 weeks follow-up.

Impairments in cervical spine mobility and muscle function were identified using manual investigation of the cervical spine and tenderness of trigger points.

First, the passive rotation movement of the cervical spine was investigated using the manual rotation test (De Hertogh, Vaes, 2007). This test rates the quality of passive rotation movement on C0-C2 and C2-C7 levels based on three parameters: range of motion (hyper- /normal/hypomobility), end feel (hard/normal/soft/empty) and pain provocation (VAS > 2 cm (max. 10 cm))(De Hertogh, Vaes, 2007).

Second, the adapted Spurling test, a segmental pain provocation test using a combination of cervical extension, lateral flexion and rotation, was used(De Hertogh, Vaes, 2007). Both the manual rotation and adapted Spurling test have shown high sensitivity (77.8%) and specificity (77.3%) in discriminating patients with neck dysfunction from asymptomatic controls (De Hertogh, Vaes, 2007).

Finally, the tenderness of sixteen myofascial trigger points was tested by applying manual pressure. A trigger point was identified as active when a hyperirritable spot could be identified in a palpable taut band in the muscle and stimulation/palpation of this spot elicited a familiar referred pain (Gerwin et al. , 1997, Simons, 1999). The test was positive when at least one active trigger point was found. The locations of the trigger points were determined according to the findings of Teachey et al. (Teachey et al. , 2012).

Tinnitus characteristics, such as localization (unilateral, bilateral, central), type of tinnitus, pitch and loudness were measured during a multidisciplinary assessment.

The type of tinnitus was identified, by asking whether one perceives a pulsatile or non-pulsatile tinnitus, whether the tinnitus is perceived constantly or not and whether the tinnitus sound is a pure tone, a noise or a mixture of different sounds (polyphonic).

The tinnitus pitch is the psychoacoustic equivalent of the physical parameter frequency and was obtained by use of a pitch matching technique. By this technique, an attempt is made to identify the pitch of the tinnitus. Each time a pair of pure tones (or noises in case of noise-like tinnitus), differing by one or more octaves, is presented to the subject who has to indicate which of the tones resembles his/ her tinnitus the most. This procedure is repeated and finer adjustments are made to obtain a match of tinnitus pitch as exact as possible. (Gilles, 2014)

Afterwards, a tinnitus loudness matching is performed. Loudness is the perceptual correlate of the sound intensity. The tone (or noise) defined as the pitch math is presented to the ipsilateral ear (when appropriate) and a loudness match is made by use of an alternating procedure. (Gilles, 2014)

The questions of the medical history, the cervical spine tests and the tinnitus characteristics were inventoried as potential prognostic indicators. Therefore, they were only measured at baseline.

Statistics

The relationship between TFI decrease after treatment and potential prognostic indicators was evaluated using linear regression analysis. As potential prognostic indicators, the different items of the diagnostic criteria for CST (Sanchez and Rocha, 2011) were used, as well as the baseline results of the cervical spine tests and the tinnitus analysis (type, pitch and loudness). Adjusted regression coefficients and 95% confidence intervals were calculated. Additionally, standardized regression coefficients were reported to compare the strength of the influence of the different prognostic indicators. A multivariate model for the prediction of TFI decrease was created using a multiple linear regression analysis retaining only the strongest predictors ($p < 0.05$) from the individual linear regression analysis.

In addition, a binary logistic regression analysis was performed. For this analysis, the change in TFI-scores for each patient was dichotomized, based on the clinically relevant reduction of 13 points (Meikle, Henry, 2012). The same potential prognostic indicators as before were entered in the model as independent variables using the forward stepwise method. Afterwards, the multicollinearity of the included independent variables was assessed, using correlation coefficients.

Further, differences in baseline characteristics were calculated between patients with co-varying (increasing or decreasing simultaneously) tinnitus and neck complaints and patients without this co-variation. This analysis of baseline measures, such as: age, TFI-score, NBQ-score and tinnitus analysis, was made, using an independent samples T-test. The analysis was made, because co-variation of tinnitus and neck complaints underpins the concept of somatic tinnitus.

Results

Patients

In total, 38 patients completed the treatment and follow-up phases. All patients suffered from severe tinnitus at baseline with an average TFI-score of 49 (SD: 21). The average NBQ-score at baseline was 33 points (SD: 12). In table 1 an overview of the patient's characteristics can be found.

PLEASE INSERT TABLE 1

Co-variation between tinnitus and neck complaints

Co-variation between TFI and NBQ-scores—meaning that tinnitus and neck complaints decrease or increase together—could be noted in 49% of the study population. At baseline, no significant differences between the co-varying and non-co-varying groups were present. Directly after treatment and after the 6 week follow-up period, significantly lower TFI values could be noted in the co-varying group ($p = 0.001$ and $p = 0.03$ respectively). Directly after treatment, the TFI-scores were 23.45 points (SD: 6.50) lower in the co-varying group than in the non-co-varying group. At the 6-week follow-up, the TFI-scores were averagely 16.64 points (SD: 7.23) lower in the co-varying group. No significant differences between the co-varying and non-co-varying groups were found for the neck related parameters (such as: adapted Spurling test) at baseline and after follow-up.

PLEASE INSERT TABLE 2

Prognostic indicators for outcome after therapy

Table 3 shows the prognostic indicators for decrease in TFI-score after treatment, their regression coefficients and 95% confidence intervals. A statistically significant association was found for the co-variation of tinnitus and neck complaints and for the presence of a low-pitched tinnitus in combination with an 'increase of tinnitus during inadequate postures while resting, walking, working or sleeping.' The multiple regression analysis showed that the combination of these variables explained 35% of the TFI decrease after cervical physical therapy.

PLEASE INSERT TABLE 3

Another model was created, using the 13-point reduction in TFI-score as a dependent variable. In this model only one variable cloud be identified as prognostic indicator, which is too little for a logistic model. This variable (co-variation of tinnitus and neck complaints) however, correlates strongly to the 13-points reduction, since it predicts the improvement in 86% of the cases.

Discussion

The aim of this study was to investigate prognostic indicators that can predict a positive outcome after multi-modal cervical physical therapy treatment in patient with CST. The applied physical therapy treatment was a noninvasive, approachable and easily available treatment option.

In our study, 53% of the patients experienced substantial improvement (on GPE) of tinnitus immediately after a 6-week treatment period. This effect was maintained after the follow-up period in 24% of the patients. This success rate is relatively high, given the chronicity and the therapy resistance of the tinnitus complaints in our tertiary referral center population. Despite the difference in outcome measures, our results match the results of a study performed by Bakker (Bakker, 2012) that found a significant decrease of tinnitus after 12 sessions of physical therapy in 62.9% of the patients. This effect was not maintained in any of the patients after 6 weeks follow-up.

Patients were included in this study based on the diagnostic criteria for CST (Sanchez and Rocha, 2011). After exclusion of other causes of tinnitus, the criterion 'recurrent pain episodes in head, neck or shoulder girdle' was used as the main criterion for inclusion, as patients without recurrent pain episodes are not likely to benefit from a cervical spine treatment. The other criteria were also questioned during the medical history and were taken into account as potential prognostic indicators.

The presence of both an 'increase of tinnitus during inadequate postures while resting, walking, working or sleeping' and co-variation of tinnitus and neck complaints combined with low-pitched tinnitus resulted in a multivariate model predicting 35% of the decrease in TFI-score. All patients meeting these criteria experienced substantial improvement of tinnitus directly after treatment and after the 6 week follow-up period. Although these conclusions are based on small numbers, the co-variation and low-pitched tinnitus with an 'increase of tinnitus during inadequate postures while resting, walking, working or sleeping' seem to be suitable criteria for referring patients for cervical spine treatment. Larger RCT's, specifically including patients who meet these criteria, are however needed.

Low-pitched tinnitus as a prognostic indicator for a positive outcome after therapy, as mentioned above, is in accordance with a study of Won et al. (Won et al. , 2013) that investigated tinnitus modulation. These authors described a unilateral buzzing and low-pitched tinnitus as the most optimal criteria for treatment. Our study could not confirm the influence of a unilateral or buzzing nature of tinnitus on the treatment outcome.

None of the other outcome measures showed prognostic value on positive outcome after therapy. It was to be expected however, that the cervical spine mobility and muscle function measures would have an influence on the treatment outcome. Patients that benefited from our treatment did not show differences in cervical spine dysfunction at baseline or after treatment compared to patients that did not benefit from the treatment. Possibly, a large heterogeneity of the type and degree of cervical spine dysfunction is present in tinnitus patients. In some patients the somatosensory afference is altered due to muscle dysfunction and in other patients due to articular dysfunction. This would explain why, for instance, the degree of cervical spine mobility has no predictive value.

Patients with co-variation of tinnitus and neck complaints benefited significantly more from cervical spine treatment than patients without this co-variation. These findings indicate the somatosensory influence on the intensity and the character of tinnitus. Complementary, this can contribute to the discussion on a causal relation between tinnitus and neck complaints. This causal relation can be presumed in the specific group of patients with low-pitched tinnitus, co-varying with neck complaints and increasing during inadequate cervical spine postures, who all experienced a decrease of their tinnitus both after treatment and after follow-up.

The predictive power of the presented multivariate model is rather weak, which indicates the need for further examination of other factors that can influence tinnitus decrease. In future research, larger RCT's, including only patients suffering from low-pitched tinnitus that co-varies with neck complaints and increases during 'inadequate postures while at rest, walking, working or sleeping', are needed to investigate the short and long-term effects of cervical physical therapy on CST.

The other binary logistic model could not be created, due to the limited number of patients that reached the 13-points reduction threshold on the TFI. Only 7 out of 38 patients reached this threshold, while 21 out of 38 patients did have a decrease in TFI-score and also indicate a substantial improvement of their tinnitus on GPE. These findings indicate some limitations regarding the responsiveness of the TFI, which has been confirmed by Fackrell et al.(Fackrell et al. , 2015) who point out important floor effects of the TFI, which makes it hard to reach the 13 points decrease in many patients.

Conclusion

Prognostic indicators to predict a positive outcome after multi-modal cervical physical therapy treatment in patients with CST could be identified. The group of patients that benefited most from cervical physical therapy was patients with low-pitched tinnitus, co-varying with neck complaints and increasing during inadequate cervical spine postures. To prove the efficacy of cervical physical therapy in these patients, a large RCT, including only the described subgroup is needed.

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Characteristic	Total	Co-varying	Non-co-varying
Number of subjects	38	17	21
Age (SD)	50(13)	49 (15)	49 (13))
TFI (SD)	49(21)	47 (20)	53 (20)
NBQ (SD)	32(12)	30 (9)	36 (13)
VAS tinnitus	5(2)	5 (2)	6 (3)
Hyperacusis	19(9)	22 (9)	18 (8)
Manual rotation + AST	53%	53%	61%
AST	63%	65%	67%
Trigger points	82%	94%	72%
Provocation of tinnitus	11%	6%	17%

Table 1: Baseline characteristics, comparison of patients with co-varying and non-co-varying tinnitus

SD: standard deviation

TFI: Tinnitus Functional Index

NBQ: Neck Bournemouth Questionnaire

VAS: Visual analogue scale

AST: adapted Spurling test

Outcome	Co-varying	Non-co-varying	p
Number of subjects	17	21	
Change in TFI baseline versus post-treatment (SD)	- 15 (21)	+ 3 (7)	0.002
Change in TFI baseline versus follow-up (SD)	- 7 (21)	+ 3 (9)	0.06
Change in NBQ baseline versus post-treatment (SD)	- 16 (16)	-17 (16)	0.834
Change in NBQ baseline versus follow-up (SD)	- 10 (17)	-13 (22)	0.747

Table 2: Outcome after therapy in the co-varying and non-co-varying group

SD: standard deviation

Variable	Regression analysis individual			Multiple regression model						
	B	**95%CI**	**p**	**β**	**B**	**95%CI**	**p**	**SSE**	**SSTO**	**MSE**
Co-varying	-17.38	-38.83 – (-6.94)	0.002	-0.50	-17.63	-27.86 – (-7.40)	0.001			
Low-pitch +Postures	-26.62	-50.88 – (-2.37)	0.032	-0.37	-27.21	-48.64 – (-5.78)	0.015			
Adjusted R^2						35%	0.001	6206	10129	206.9

Table 3: Prognostic indicators of Tinnitus Functional Index decrease post-treatment: adjusted regression coefficients

B: regression coefficient

β: standardized regression coefficient

CI: confidence interval

SSE: Sum of squared errors

SSTO: Total sum of squares

MSE: Mean squared error