THE EFFECT OF TINNITUS ON HEARING-RELATED QUALITY OF LIFE OUTCOMES IN ADULT COCHLEAR IMPLANT RECIPIENTS

Elmien Opperman[1]

Talita le Roux[1]

Andries Masenge[2]

Robert H. Eikelboom[1,3,4]

[1]Department of Speech-Language Pathology and Audiology, University of Pretoria, South Africa

[2]Department of Statistics, University of Pretoria, South Africa

[3]Ear Science Institute Australia, Subiaco, Australia

[4]Ear Sciences Centre, Medical School, The University of Western Australia, Nedlands, Australia

Corresponding author: Elmien Opperman

Department of Speech-Language Pathology and Audiology, University of Pretoria, c/o Lynnwood and University Road, Hatfield, Pretoria, 0002, South Africa

elmieno@vodamail.co.za

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Abbreviations: QoL, Quality of Life; CI, Cochlear Implant; HL, Hearing Loss

ABSTRACT

Objective: To describe the effect of tinnitus distress on the hearing-related quality of life (QoL) outcomes over time in adult cochlear implant (CI) recipients.

Design*:* A retrospective, longitudinal study of adult CI recipients was conducted. Hearing-related QoL and tinnitus distress were assessed using the *Abbreviated Profile of Hearing Aid Benefit* (APHAB) and the *Tinnitus Reaction Questionnaire* (TRQ) preoperatively and at 6-months, 12-months and >24-month postoperatively. The association between tinnitus distress and hearing-related QoL outcomes over time was investigated. Furthermore, 13 potential predictive factors were identified from the retrospective dataset. Multiple regression analyses were performed to identify variables that influence hearing-related QoL outcomes over time.

Study sample: The study sample included 210 adult (≥18 years) CI recipients implanted between 2001 and 2017.

Results*:* Lower tinnitus distress and younger age at implantation were significant predictors of better hearing-related QoL in adult CI recipients. A significant reduction in tinnitus distress up to two years post-implantation was found, as well as greater tinnitus distress correlating with poorer hearing-related QoL outcomes.

Conclusion: Tinnitus distress negatively affects the hearing-related QoL outcomes of adult CI recipients. Tinnitus distress and age at implantation were found to be significant predictors of hearing-related QoL when controlling for other predictive factors.

Introduction

Subjective tinnitus can be defined as a sound sensation perceived in the head or ears in the absence of an external stimulus (Searchfield, 2014). Due to its heterogeneous nature there is still limited understanding of the complex mechanism of tinnitus (Chung & Lee, 2016; Aazh et al, 2019). In spite of being aware of this sound sensation, some people reporting tinnitus

are not bothered by it and subsequently do not seek medical assistance, whereas for others it can be associated with problems such as insomnia, frustration, depression and anxiety (McCormack et al, 2016; Nondhal et al, 2007).

In adult cochlear implant (CI) recipients, who present with severe to profound sensorineural hearing loss, the prevalence of preoperative range between 51% and 80% (Baguley & Atlas, 2007; Kloostra et al, 2015). The primary aim of cochlear implantation is to manage severe-profound hearing loss, however, tinnitus suppression is experienced as a beneficial secondary effect by 25%-72% of CI recipients (Quaranta et al, 2004; Baguley & Atlas, 2007; Ramakers et al, 2015; Knopke et al, 2016; Olze et al, 2016; Knopke et al, 2017). There is also a risk for newly induced tinnitus or for the worsening of existing tinnitus after cochlear implantation (Quaranta et al, 2004). Therefore, CI candidates should be made aware of the potential risk of negative tinnitus outcomes after implantation and this should be transparently included in the informed consent in order to manage patient expectations (Quaranta et al, 2004; Bovo et al, 2011).

A number of studies have found that cochlear implantation leads to the improvement of quality of life (QoL) (Knopke et al, 2017; Olze et al, 2011; Olze et al, 2016, 2012; Knopke et al, 2016). Various generic and disease specific QoL questionnaires have been used throughout literature to assess changes in QoL brought on by a CI (Loeffler et al, 2010). QoL is linked to the social, emotional and physical well-being of individuals, including their ability to partake in the ordinary tasks of everyday living (Loeffler et al, 2010). Therefore, QoL has become a standard outcome measure in assessing the impact a lasting hearing loss and its resultant management have on the personal well-being of CI recipients (Capretta & Moberly, 2016; King et al., 2014; Zaidman-Zait & Smith, 2010). Improved QoL outcomes in

adult CI recipients has been found to be associated with factors such as better speech understanding abilities (Sladen et al, 2017), shorter duration of deafness (Maillet et al, 1995; Hirschfelder et al, 2008), younger age at implantation (Chung et al, 2012; Farinetti et al, 2014), higher socio-economic status (Hawthorne et al, 2004), longer duration of CI use (Hirschfelder et al, 2008) and bilateral implantation (Härkönen et al, 2015; le Roux et al, 2017).

Even though pre- and post-implantation data on QoL outcomes of patients with tinnitus is limited (Olze et al, 2011), evidence suggests that the health-related QoL of CI recipients is affected by tinnitus. Olze et al. (2011) specifically suggested the association between a high level of tinnitus and lower health-related QoL outcomes. Both le Roux et al. (2017) and Lenarz et al. (2017) found that tinnitus presence before implantation was significantly predictive of reduced health-related QoL outcomes in adult CI recipients. A significant correlation was also found between higher tinnitus-related distress and poorer health-related QoL at the 6-, 12- and 24-months post-implantation intervals in a study by Knopke et al. (2017). Tinnitus distress was found to be significantly associated with anxiety and depression symptoms and was still present after implantation in 25% of unilaterally implanted adults who reported preoperative tinnitus (Andersson et al, 2009). Furthermore, the experience of residual tinnitus after cochlear implantation can also be linked to higher levels of perceived stress, poorer coping strategies, more prominent depressive symptoms and anxiety (Andersson et al, 2009; Olze et al, 2012). Considering this, it is important not to underestimate the significant effect that tinnitus may have on the auditory rehabilitation of CI recipients (Knopke et al, 2017).

CI performance and outcomes vary among adult CI recipients and are influenced by various individual and interacting factors (le Roux et al, 2017). Therefore, the ability to predict outcomes for individual CI candidates will arise from a better understanding of the factors influencing this variation (Brüggemann et al, 2017). The role of tinnitus as a predictive factor for QoL outcomes should therefore be investigated as available evidence has suggested that the effects of tinnitus negatively influence QoL and can even counterbalance the positive effects of cochlear implantation (Brüggemann et al, 2017; Olze et al, 2016; Knopke et al, 2016; Olze et al, 2011; le Roux et al, 2017; Summerfield et al, 2006; Ramos et al, 2013; Lenarz et al, 2017; Knopke et al, 2017). What also needs further exploration is the longitudinal sustainability of the tinnitus supressing effect of a CI and the effect of it on hearing-related QoL over time. Therefore, this study, aimed to describe the influence of tinnitus distress on hearing-related QoL outcomes in adult CI recipients who experience tinnitus, and to investigate the prognostic significance of tinnitus distress over time.

Method

Study population

Institutional ethical clearance was obtained prior to the analyses of retrospective data. A retrospective dataset of 345 adult (≥18 years) CI recipients, implanted between 2001 and 2017 at the *Ear Science Institute Australia (ESIA) – Ear Science Clinic*, was reviewed for the purpose of this study. During the reference period, hearing-related QoL, tinnitus distress, and speech perception outcome data were routinely captured for all adult CI recipients preoperatively, as well as at fixed postoperative intervals. The availability of preoperative hearing-related QoL and tinnitus distress outcome data were prerequisites for inclusion. The final study sample comprised of 210 adult CI recipient preoperatively and decreased to 161,

127 and 104 CI recipients at the 6-, 12- and >24- months postoperative intervals respectively. Demographic characteristics of the study population are described in Table 1.

Table 1. Characteristics of study population

Demographical characteristics	*% (n)*	*Clinical characteristics*	*% (n)*
Gender		Onset of hearing loss	
Male	49.5 (104/210)	Prelingual	18.1 (38/210)
Female	50.5 (106/210)	Postlingual	90.5 (172/210)
Chronological age at data interval (years)		Course of hearing loss	
6 months postoperatively (n=160)		Sudden	7.8 (16/206)
Mean (SD)	65.4 (14.2)	Progressive	92.23 (190/206)
Range	25.5 - 94.2		
		Laterality of hearing loss	
12 months postoperatively (n=126)		Unilateral HL	4.8 (10/210)
Mean (SD)	66.3 (13.3)	Bilateral HL	95.2 (200/210)
Range	26.3 - 92.2		
		Duration of hearing loss prior to implant (years) (n=200)	
>24 months postoperatively (n=104)		Mean (SD)	30.4 (19.07)
Mean (SD)	67.9 (13.28)	Range	0.0 - 79.0
Range	27.7 - 92.3		
		First ear implanted	
		Left	49.5 (104/210)
		Right	50.5 (106/210)
		Age at (first) implant (years) (*n*=210)	
		Mean (SD)	62.9 (15.6)
		Range	20.6 - 93.8
		Bilateral implantation	
		12 months postoperatively	2.9 (6/210)
		>24 months postoperatively	15.2 (32/210)
		Balance concerns preoperatively	
		Yes	30 (63/210)
		No	70 (147/210)

Data collection

An electronic database was utilized to capture pre- and postoperative patient data. As part of the standard pre- and postoperative protocol, adult CI recipients completed the Abbreviated Profile of Hearing Aid Benefit (APHAB) as an outcome measure for hearing-related QoL and the Tinnitus Reaction Questionnaire (TRQ) as a measure of tinnitus distress. TRQ, APHAB and CNC data were captured for adult CI recipients preoperatively and at fixed postoperative intervals, including 3-, 6-, 12-, 24-, 36- and >36 months postoperative intervals. These postoperative data points were combined and reduced to only include 6-, 12- and >24-months postoperative intervals.

Description of variables

Outcome variable

In order to measure hearing-related QoL outcomes over time, retrospective APHAB data were utilized. The APHAB is a clinical instrument and generic self-report measure that quantifies the disability associated with a hearing loss, as well as the relief achieved with amplification (Cox & Alexander, 1995). Although the APHAB, in its original format, was designed as a questionnaire for hearing aid users, it has also been utilized in CI related studies to document subjective patient reports regarding hearing and benefits with CIs (Kloostra et al., 2015; Skarzynski et al, 2006). The APHAB was also utilized in a number of other CI related studies to measure outcomes in terms of QoL (Dillon et al., 2018), health-related QoL (Ramos-Marcias et al., 2016) and hearing-related QoL (Sladen et al, 2017).

The APHAB consists of 24 questions, divided into four sub-domains, namely ease of communication (assessing communication effort under fairly easy listening conditions), background noise (assessing speech understanding in competing noise), reverberation (assessing speech understanding in reverberant rooms) and aversiveness (assessing the

negative reaction to environmental sounds) (Cox & Alexander, 1995). Answers to the 24 statements of the APHAB were converted to an overall as well as four sub-domain scores as per questionnaire design (Cox & Alexander, 1995). The questionnaire mostly consists of negative descriptors and reversed scoring was applied for questions that were positive descriptors. Therefore, a higher percentage score is representative of greater perceived difficulties due to HL and consequently a lower hearing-related QoL.

Explanatory variables

Data regarding demographical and clinical characteristics (Table 1) of the study sample were collected retrospectively. From the retrospective data set, thirteen potential predictor variables were identified, namely gender, chronological age at interval, onset of hearing loss (pre- or post-lingual), course of hearing loss (sudden or progressive), balance concerns, duration of hearing loss before implant, age at implant, first ear implanted, bilateral implantation, duration of CI use at interval, TRQ score and consonant-vowel nucleus-consonant (CNC) word and phoneme scores. CNC scores were determined in quiet at 65dB SPL.

The *Tinnitus Reaction Questionnaire* (TRQ) is a validated and reliable, 26-item questionnaire that was developed to measure the general psychological distress associated with tinnitus (Wilson et al, 1991). This study utilized the TRQ as a subjective, self-report measure to assess and quantify the level of perceived disstress experienced by adult CI recipients with tinnitus. As per TRQ protocol questions were totalled to represent a score out of 104 (Wilson et al, 1991). Due to all statements being negative descriptors, a higher total score is associated with a higher level of tinnitus related psychological distress. Previous studies have

successfully utilised the TRQ to report on subjective tinnitus-related distress as experienced by CI recipients (Távora-Vieira et al, 2013, 2015).

Statistical analysis

Statistical software packages (SAS version 9.4 and IBM SPSS version 25) were used for the analysis. Descriptive statistics were used to describe the study population in terms of demographical and clinical characteristics (Table 1). Data on tinnitus distress (Table 3) and speech perception scores (supplementary Table 1) were also explored by means of descriptive statistics. Scores for each of the four APHAB sub-domains, as well as the overall APHAB score (indicating overall hearing-related QoL), were considered as continuous outcome variables.

The paired sample t-test compared overall and domain APHAB scores, as well as TRQ scores between time intervals to determine if statistical significant differences existed between the respective intervals. Spearman correlation coefficients were used to assess associations between tinnitus distress (TRQ scores) and hearing-related QoL (APHAB overall and sub-domain scores) over time. This test was chosen because it is a non-parametric test with free test distribution and is therefore suitable for analysis of data that is not normally distributed.

Multiple linear regression was performed to examine the simultaneous effect of multiple predictors, listed under explanatory variables, on the outcome variables over time. The final models in Table 4 included only the explanatory variables found to be significant.

It was decided to make use of a more conservative p-value of 0.01 to indicate statistical significance. This reduced the chance of a false positives/ type I error of incorrectly rejecting

the null hypothesis, while simultaneously increasing the accuracy of any significant results obtained.

Table 2. Hearing-related quality of life scores depicted from APHAB results

Symbol	*Time interval*		*Overall APHAB*	*Ease of communication sub-domain*	*Background noise sub-domain*	*Reverberation sub-domain*	*Aversiveness sub-domain*
A	*Preoperatively*	Mean (SD)	61 (16.5) $^{(A,B)(A,C)(A,D)}$	59.3 (25.5) $^{(A,B)(A,C)(A,D)}$	76.9 (16.7) $^{(A,B)(A,C)(A,D)}$	75.7 (20.7) $^{(A,B)(A,C)(A,D)}$	32.1 (26.7) $^{(A,B)(A,C)(A,D)}$
		n	*n*=210	*n*=210	*n*=210	*n*=210	*n*=210
		Range	9.0 - 98.4	1.0 – 99.0	20.6 – 99.0	8.3 – 99.0	1.0 – 99.0
B	*6-months postoperatively*	Mean (SD)	39.8 (15.7)$^{(B,C)}$	28.1 (17.9)	53.1 (20.8)$^{(B,C)}$	53.2 (22.34)	25.9 (21.1)
		n	*n*=160	*n*=161	*n*=161	*n*=161	*n*=161
		Range	10.9 - 87.4	2.8 - 87.0	6.8 - 99	8.7 - 99.0	1.0 - 97.0
C	*12-months postoperatively*	Mean (SD)	36.4 (15.2)	24.9 (18.1)	48.5 (19.8)$^{(C,D)}$	47.7 (20.5)	24.9 (19.61)
		n	*n*=126	*n*=127	*n*=127	*n*=127	*n*=127
		Range	8.5 - 72.3	1.0 - 78.7	2.8 - 99.0	6.5 - 99.0	1.0 - 97,0
D	*>24-month postoperatively*	Mean (SD)	40.2 (17.3)	29.5 (21.9)	53.7 (20.86)	54.9 (25.2)	24.7 (19.5)
		n	*n*=104	*n*=104	*n*=104	*n*=104	*n*=104
		Range	8.6 - 80.9	1.0 - 99.0	10.2 - 99.0	10.5 - 99.0	1.0 - 75.0

Symbol superscripts represents time intervals which present with statistically significant difference between them (p <0.01) on paired sample t-test

Results

Hearing-related quality of life outcome profile

Overall APHAB scores, as well as scores for all four APHAB sub-domains showed an improvement in hearing-related QoL outcomes from the preoperative time-interval to each of the three postoperative time-intervals (Table 2). Mean overall APHAB scores decreased from the preoperative time interval to the 6 months, 12 months and >24 months postoperative intervals. The background noise and reverberation APHAB sub-domains had statistically significant ($p<0.01$) higher mean scores compared to the other sub-domains at the preoperative interval as well as all postoperative intervals. Aversiveness APHAB sub-domain mean scores were statistically significantly ($p<0.01$) lower than all other sub-domains preoperatively and statistically significantly ($p<0.01$) lower than the reverberation and

background noise sub-domains at the 6 months, 12 months and >24 months postoperative intervals.

Tinnitus distress profile

TRQ scores are summarized in Table 3 and represent general tinnitus distress with no ear specific results, as the TRQ mainly measures psychological and emotional components of tinnitus related handicap (Fackrell & Hoare, 2014). With TRQ score >0, almost half (49.52%) of the adult CI recipients in this study sample reported tinnitus distress preoperatively, while 39.36% still experienced tinnitus distress >24 months postoperatively. The paired sample t-test showed that there was a consistent and significant ($p<0.01$) reduction in tinnitus distress at every postoperative time interval compared to the preoperative baseline.

Table 3. Tinnitus Reaction Questionnaire scores

					p-value			
Time interval	*n*	*Mean (SD)*	*Range*	*Median*	*1*	*2*	*3*	*4*
1.Preoperatively	210	13.2 (21.5)	0 - 101	1		0.000*	0.000*	0.002*
2. 6-months postoperatively	150	5.9 (12.8)	0 - 67	0	0.000*		0.074	0.908
3. 12-montsh postoperatively	113	5.4 (12.2)	0 - 65	0	0.000*	0.074		0.496
4. >24-montsh postoperatively	89	6.3 (14.8)	0 - 99	0	0.002*	0.908	0.496	

** Significant: p <0.01 on paired sample t-test*

Associations between hearing-related quality of life outcomes and tinnitus distress

Twelve months postoperatively, higher tinnitus distress was associated with poorer hearing-related QoL outcomes ($r = 0.28$, $p < 0.01$). Higher tinnitus distress was also associated with poorer hearing-related QoL outcomes within the APHAB *aversiveness* sub-domain

preoperatively (r = 0.30, p < 0.01) as well as 12 months (r = 0.34, p < 0.01) and >24 months (r = 0.30, p < 0.01) postoperatively (Figure 1).

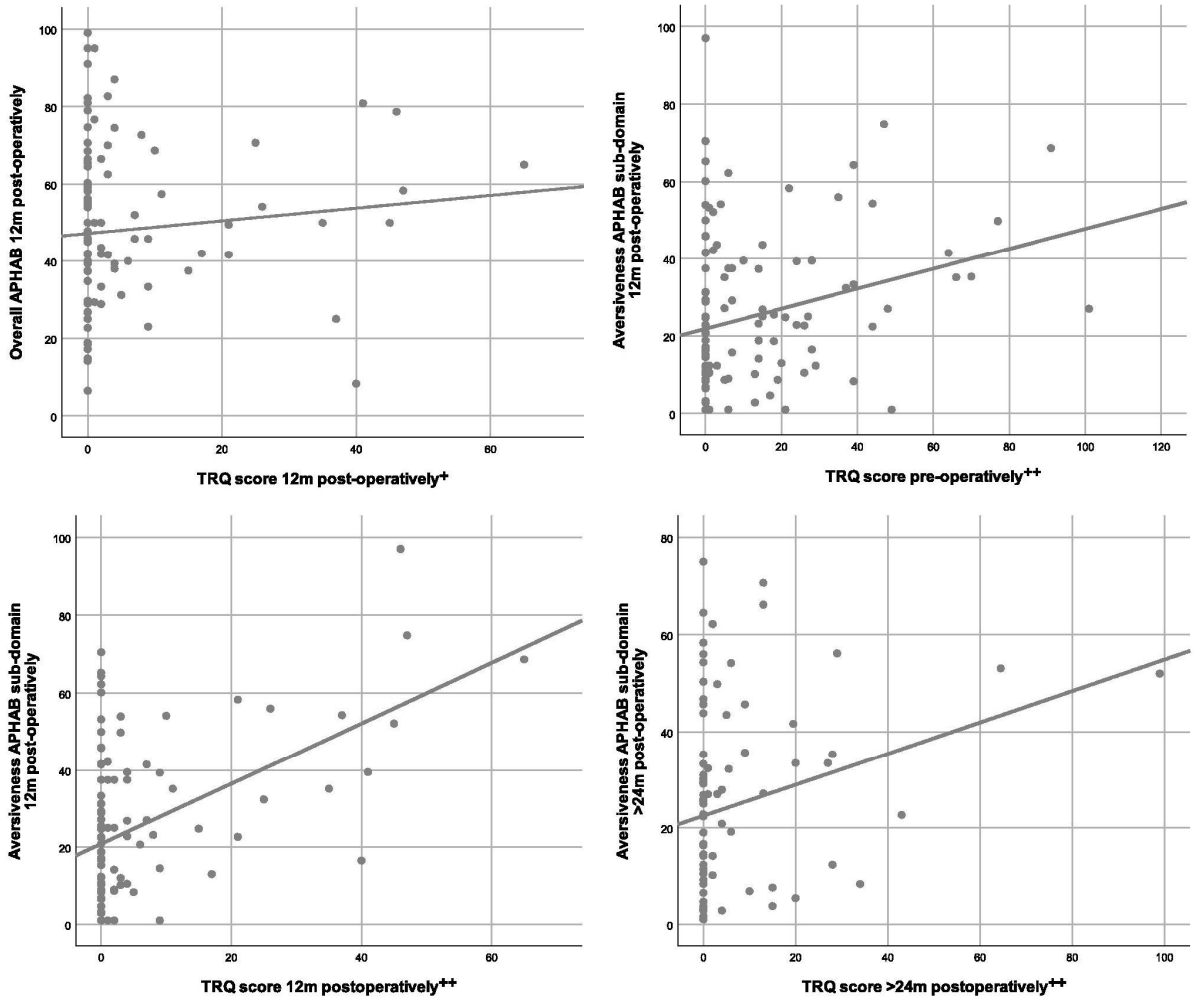

Figure 1. Scatter plot representing the significant associations between hearing-related quality of life (APHAB scores) and tinnitus distress (TRQ scores) across time intervals.
Presented is 12 months postoperative overall APHAB versus 12 months postoperative TRQ score, 12 months postoperative aversiveness sub-domain versus preoperative TRQ score, 12 months postoperative aversiveness sub-domain versus 12 months postoperative TRQ score and lastly >24 months postoperative aversiveness sub-domain versus >24 months postoperative TRQ score

**Significant: p <0.01*
+ r=0.10-0.29; small correlation
++ r=0.30-0.49; medium correlation
+++ r=0.50-1.00; large correlation

Multiple regression analysis

Twenty multiple linear regression models were run of which only four were significant. Furthermore, only two out of the 13 predictor variables were found to be significant predictors for hearing-related QoL, namely tinnitus distress and age at implant (Table 4). Preoperatively, better (lower) APHAB *ease of communication* sub-domain scores were

predicted by lower tinnitus distress and better (lower) APHAB *reverberation* sub-domain scores were predicted by lower TRQ scores and younger age at implantation. At 12-months postoperatively, better (lower) APHAB overall scores were predicted by a younger age at implantation and lower TRQ scores, and a better (lower) APHAB aversiveness sub-domain score was predicted by lower TRQ scores. Determination coefficients (R^2) showed that 26% or less of the variations in outcomes can be explained by the models.

Table 4. Multiple linear regression analysis results

Outcome variable	*Predictors (individual variables of significance)*	*Parameter estimates*	*p-value*	*Pr > F (model p-value)*	R^2	*df*	*Sum of squares*
Overall APHAB 12-months postoperative (n=103)	Age at implant	0.27	0.0087*	0.0017*	0.21	7	4876.352
	TRQ score 12 months postoperative	0.39	0.0005*				
Ease of communication APHAB sub-domain Preoperative (n=135)	Age at implant	0.54	<0.0001*	0.0019*	0.21	11	18313.968
	TRQ score preoperative	0.26	0.0008*				
Reverberation APHAB sub-domain Preoperative (n=135)	Age at implant	0.42	<0.0001*	0.0017*	0.21	11	1141.630
Aversiveness APHAB sub-domain 12-months post-operative (n=103)	TRQ score 12-months postoperative	0.78	0.0019*	0.0001*	0.26	7	5081.749

** Significant: p <0.01 on multiple linear regression analysis*
df: degrees of freedom
Pr>F: p-value of the F-test (with F-test testing the significance of the model)
R^2: determination coefficient

Discussion

This study yielded findings of the negative impact of tinnitus on hearing-related QoL that are consistent with those of previous studies, but also produced some unique findings. When controlling for many factors known to be predictive of QoL outcomes, tinnitus distress and age at implantation were found to have a significant effect on the hearing-related QoL

outcomes of adult CI recipients. An association was found between tinnitus distress and aversiveness of sound, suggesting that CI recipients who experience tinnitus are more likely to find certain sounds disruptive.

Hearing-related quality of life (APHAB)

With respect to the preoperative time interval, a statistically significant decrease was seen for overall APHAB scores up to one year post-implantation, with no significant change thereafter. This finding suggests that cochlear implantation significantly improves the hearing-related QoL of the CI recipient up to 12 months post-implantation, where after this improved hearing-related QoL reaches a plateau. In terms of average APHAB scores, the most significant improvement in hearing-related QoL outcomes in the present study was seen at the 6 months postoperative interval for both the overall APHAB and all four sub-domains. The findings of this study is consistent with previous findings of a significant improvement in health-related QoL scores between pre- and post-implantation, with this significant improvement continuing up to one year post-implantation (Knopke et al, 2017; Lenarz et al, 2017; Contrera et al, 2016). Both Lenarz et al (2017) and Knopke et al (2017) found that the most significant improvement in QoL outcomes was seen at the 6 months postoperative interval.

Study results identified *background noise* and *reverberation* as the APHAB sub-domains with which adult CI recipients experience the greatest problems. These observations of greater difficulty with speech perception in noise may be explained by the general difficulty of following speech in noise with CIs (Arnold & Baumgärtel, 2018; Badajoz-Davila et al, 2018). Contrary to this, *aversiveness* was identified as the sub-domain in which the least problems were experienced. The phenomenon of not avoiding sounds may be explained by

the suggestion that the presence of external noise/ sound may have a suppressing effect on the perception of tinnitus (Zenner et al, 2017; Harris et al, 2011).

Tinnitus distress (TRQ)

The number of participants in this study reporting preoperative tinnitus distress is in line with reports in recent years of the prevalence of preoperative tinnitus (Kloostra et al, 2015; Mikkelsen et al, 2017; Ramakers et al, 2018). Overall, the tinnitus profile of the adult CI recipients in this study showed a significant decrease in average tinnitus distress scores at all three postoperative time intervals compared to the preoperative level. However, there was no significant improvement after 6 months post implantation. It shows the positive effect that cochlear implantation has on reducing tinnitus distress together with the increase in hearing-related QoL outcomes as previously shown by others. Likewise, this decrease of tinnitus post-implantation was found by Ramos-Marcias et al (2018) at one year after CI activation, by Kim et al (2016) who showed a tinnitus reduction in 40% of adult CI recipients 6 months post-implantation and by Knopke et al (2017), who found significant decreases in tinnitus distress between consecutive time-intervals up to two years post-implantation. Tinnitus reduction has often been identified by CI recipients with single-sided deafness as the primary benefit of their CI (Mertens et al, 2016; Ramos-Marcías et al, 2018; Galvin et al, 2018). This evidence has contributed to the consideration of a CI as an appropriate, cost effective and worthwhile treatment option for patients who experience tinnitus (Ramos-Marcías et al, 2018; Elgandy et al, 2018).

An increase in perceived tinnitus distress was correlated with a decrease in hearing-related QoL outcomes based on APHAB scores. This finding is in line with those of others who

explored QoL (Brüggemann et al, 2017; Brüggemann et al, 2016) and health-related QoL outcomes (Knopke et al, 2017; Olze et al, 2012).

In addition, tinnitus distress was identified as a significant predictor of poorer hearing-related QoL outcomes not only preoperatively, but also 12 months postoperatively. Preoperatively, better scores for *ease of communication* and *reverberation* APHAB sub-domains were predicted by lower tinnitus distress. At 12-months postoperatively, better APHAB overall scores and better APHAB *aversiveness* sub-domain scores were predicted by lower tinnitus distress. Previously both le Roux et al (2017) and Lenarz et al (2017) identified preoperative tinnitus as a significant prognostic indicator for reduced QoL outcomes in adult CI recipients. However, this present study adds to existing literature by suggesting that both preoperative tinnitus and residual tinnitus post CI were predictive of poorer hearing-related QoL. Contrary to expectations, speech perception testing outcomes were not identified as a predictor for hearing-related QoL outcomes in this dataset. Even though this is not the first time this finding has been reported (Capretta & Moberly, 2016), it is possible that the speech perception test utilized in this study was not sensitive enough to detect speech perception changes after implantation in correlation with hearing-related QoL.

An additional finding from this study was that *aversiveness* was identified as being associated with tinnitus distress, as higher tinnitus distress correlated with poorer hearing-related QoL outcomes for this specific sub-domain preoperatively as well as 12 and >24 months postoperatively. This association was consistent with the identification of tinnitus distress as a significant predictive factor for poorer hearing-related QoL outcomes within the *aversiveness* APHAB sub-domain specifically. Suggested by this result is the negative emotional reaction to both tinnitus and surprising sounds. This association was likely found

due to the TRQ mainly measuring psychological and emotional components of tinnitus related handicap (Fackrell & Hoare, 2014). To corroborate this statement, Olze et al. (2011) utilized the brief *COPE* to measure the coping behavior of 43 adult CI recipients in unpleasant situations and found a linear correlation between evasive coping (denial, self-blame, venting) and tinnitus. A further explanation for this phenomenon may be the well-known co-occurrence of tinnitus and hyperacusis (Pienkowski, 2019). Four out of 10 (40%) individuals who experience tinnitus also experience some form of hyperacusis (Baguley, 2018).

The emotional and cognitive burden brought on by tinnitus, can add to a higher psychological burden that adults with a hearing loss face, resulting in poorer QoL outcomes (Brüggemann et al, 2017). Previous reports have stressed the fact that perceived tinnitus distress should be taken into account when evaluating prospective CI candidates and choosing the side for implantation (Bovo et al, 2011; Ramos-Macías et al, 2015). An evidence-based prediction model of CI outcomes will allow clinicians to counsel CI recipients preoperatively on realistic expectations regarding tinnitus recovery and adjust treatment and lifestyle strategies to foster an increased chance of tinnitus recovery postoperatively (Ramakers et al, 2018). The feasibility of including tinnitus screening as part of the standard assessment protocol for CI candidacy should be considered, in order to identify those at risk for tinnitus distress, facilitate more accurate prediction of outcomes and to earmark patients for whom tinnitus suppression might be the primary motivation for actively using their cochlear implant (Ramos-Marcías et al, 2015). Postoperative counselling and rehabilitation services should be tailored according to the unique needs of each individual and their families and therefore additional support services, in terms of tinnitus specialities, should be available to CI recipients as required, either through the core team or through additional access (Müller &

Raine, 2013). Close collaboration between CI and tinnitus specialities will offer a more integrated treatment and rehabilitation approach to CI recipients and address the need for comprehensive care of psychosomatic disorders throughout the entire CI process (Brüggemann et al, 2017; Harris et al, 2011).

Age at implant

In addition to tinnitus distress, younger age at implantation was also indicated in this study as a significant predictor for better hearing-related QoL outcomes. While Farinetti et al. (2014) supports this finding, a number of studies found no association between age at implantation and QoL outcomes (Sladen et al, 2017; Lenarz et al, 2017; Copeland & Pillsbury, 2004; le Roux et al, 2017; Garcia et al, 2018; Capretta & Moberly, 2016). Cochleovestibular complications, including tinnitus and vertigo, were suggested to be more common in recipients implanted at an older age (Farinetti et al, 2014), and could possibly be an explanation for the significant association between hearing-related QoL outcomes and age at implantation in this study as well.

General discussion and study limitations

The sense of hearing is one of the vital senses utilized to communicate with and function within the environment (Redfors et al., 2014). It has been suggested that an impairment of hearing has implications for general QoL (Chia et al., 2007; Dalton et al., 2003; Fisher et al., 2009). For CI recipients, health-related QoL can be defined as a multi-dimensional concept used to symbolize the comprehensive effect that cochlear implantation has on the self-esteem, social life and everyday activities of the CI recipient (Loeffler et al., 2010). Disease specific QoL outcomes, however, represents a patient's perception on a specific health problem (Fitzpatrick et al, 1998). Since disease specific QoL outcome measures are strictly relevant to

a particular disease (Loeffler et al, 2010), hearing-related QoL outcome measures, for example, specifically report on the effect of a hearing impairment on the daily activities and lifestyle of the patient. Our study's results add to an increased understanding of the factors that influence hearing-related QoL outcomes in adult CI recipients. Prognostication should be prioritized by CI programs in order to improve predictions of CI outcomes (Black et al, 2011). The importance of standardized, routine documentation of outcome data is advised as such continuous, uniform collection of QoL outcome data may also contribute to determining the impact of postoperative rehabilitative strategies on a CI recipient's perceived benefit from the device.

Even though this study was able to address the effect that tinnitus distress has on the hearing-related QoL of CI recipients, there were limitations based on the study design. Firstly, utilizing a retrospective data set, even though providing a larger number of participants, comes with the inevitable incidence of missing data. A Wilcoxon signed rank test was used to compare APHAB and TRQ scores at each time point. There was not a statistically significant difference ($p<0.05$) at 3 and 6 months, and for those at 24, 36 and >36 months. To minimize the amount of missing data, the values at 3 and 6 months, and at 24, 36 and >36 months were combined by using either the only available score, or using the mean of the values that were available; the 12 month score remained unchanged for all other variables. This resulted in the 6, 12 and >24 month scores. As a result, it was not possible to track specific, individual CI recipients over time and determine the exact number of participants for whom tinnitus decreased, worsened, or initiated following implantation. Secondly, the APHAB was not designed as a measure of QoL specifically. However, in a recent systematic review and meta-analysis that examined the impact that hearing-assistive devices has on the health-related QoL of adults with single-sided deafness (Kitterick et al, 2015), the APHAB was specifically

referred to as a disease-specific measure of health-related QoL. In studies related to adult cochlear implantation specifically, the APHAB is referred to as a measure of QoL (Dillon et al., 2018), a measure of health-related QoL (Ramos-Macías et al., 2016) and a measure of self-perceived hearing-related QoL (Sladen et al., 2017). In spite of the fact that the APHAB is frequently linked to health-related QoL, the APHAB was referred to as a measure of hearing-related QoL for the purpose of this study.

Conclusion

In adult CI recipients, less tinnitus distress and a younger age at cochlear implantation were significantly predictive of better hearing-related QoL outcomes. Moreover, study results provided evidence of a lowering in tinnitus distress as a result of cochlear implantation and also indicated a correlation between decreased tinnitus distress and improved hearing-related QoL. Suitable preoperative counselling and postoperative rehabilitation should be prioritized for CI recipients who experience tinnitus.

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Declaration of interest

The authors of this paper declare no conflict of interest or competing financial interests.

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