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Hyperacusis and stapes surgery: An observation in fifty patients after stapedotomy

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Objective: To assess hyperacusis after stapedotomy and its possible influencing factors.
Study design: Prospective, interventional, and longitudinal study.
Setting: A tertiary referral center.
Patients: Fifty consecutive patients (35 females, mean age = 46.8 years).
Intervention: All patients underwent stapedotomy. The validated Portuguese version of the "Hyperacusis Questionnaire" (HQ) was administered before and two weeks and one month after surgery.
Results: No hyperacusis was reported by any patient before surgery. At two weeks after surgery, all patients experienced hyperacusis, with a mean HQ at 16.88 ± 6.54 (range 4–25). One month after surgery, hyperacusis had already resolved in most patients. Gender, preoperative presentation or surgeon had no influence on HQ scores ($p > 0.05$). Patients with previous contralateral stapedotomy showed lower HQ scores ($p = 0.001$). Audiological parameters improvement measured at one month after surgery (PTA, SRT and contralateral SRT) were associated with HQ higher scores.
Conclusion: This study confirms that hyperacusis is a common complaint after stapedotomy that usually resolves in one month after surgery. The HQ highest scores were registered among patients with the highest audiological gain after surgery. This suggests that hyperacusis may be a positive prognostic factor for audiological success after stapedotomy.

1. Introduction

Hyperacusis is defined as intolerance to ordinary sounds or increased sensitivity to environmental sounds that would not be expected to be bothersome or uncomfortable (Baguely, 2003; Hallberg et al., 2005; Schwartz et al., 2011). It can have a negative impact on the quality of life, as it often compromises concentration, sleep, and emotional status, turning professional, familial and social lives difficult (Moller et al., 2014; Fackrell et al., 2015).

The mechanism of hyperacusis is not completely understood (Silverstein et al., 2015). Among the possible aetiologies, impairment of the peripheral auditory system, diseases and syndromes of the central nervous system, hormonal and infectious diseases have been reported. However, in most cases, hypersensitivity to sound is idiopathic (Katzenell, Segal, 2001).

Hyperacusis and loudness intolerance is not an infrequent complaint in patients who have undergone stapedotomy for otosclerosis (Ramsay et al., 1997). However, little is known about the pathophysiology and prognosis of this postoperative complaint. In this study, we aimed to assess hyperacusis after stapedotomy and determine possible predictive factors for its severity.

2. Materials and methods

This prospective, interventional, and longitudinal study included consecutive patients undergoing primary stapedotomy, from 2017 to 2019, in a tertiary center. Exclusion criteria included pediatric patients and revision stapedotomy.

The validated Portuguese version of the "Hyperacusis Questionnaire" (HQ) (Bastos, Sanchez, 2017) was used. Patients answered the questionnaire before the surgery, and two weeks (one week after removing the dressing at the first postoperative visit) and one month (at the time of the first postoperative

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audiological exams) after surgery.

Data regarding gender, age, presentations before surgery, surgery side and surgeon were collected as well.

Preoperative and postoperative audiometric data were recorded according to the American Academy of Otolaryngology – Head and Neck Surgery standards for reporting. Air and bone-conduction thresholds at 0.5, 1, 2 and 3 kHz were recorded and used to calculate the pure-tone average (PTA). If thresholds at 3 kHz could not be obtained, the average of thresholds at 2 and 4 kHz would be used in its place. Pure-tone and speech audiometry (including PTA and Speech Recognition Threshold, SRT) were performed before and 1 month after surgery, for comparison purposes. Masking was used (especially preoperatively) as appropriate.

2.1. Stapedotomy - surgical techniques

Transcanal approach was always used.

Surgical steps: Following skin infiltration of the external ear canal (EEC) anteriorly and posteriorly with local anaesthetic (lidocaine 1% and adrenaline diluted to 1:200 000), an incision was made in the posterior EEC and the tympanomeatal flap was elevated towards the posterior tympanic spine, in order to elevate the annulus from the sulcus. A small curette was used to remove the posterior tympanic spine while avoiding damage to the underlying chorda tympani. The bony rim obscuring the inferior portion of the incudomallear joint was removed with a curette. Mobility of the malleus, incus and stapes was checked and stapedotomy was only performed if the malleus and incus were mobile and the stapes was fixed. With a perforator, a hole was created in the posterior two thirds of the stapes footplate, and the incudostapedial joint was separated with a knife, and the stapes tendon cut with fine Bellucci scissors. After cutting posterior crus of the stapes with crurotomy scissors, the anterior crus was fractured at the level of the footplate with a 45° hook, rotating towards the promontory. After measurement, a Teflon prosthesis (4 mm in diameter) was placed onto the footplate with the loop over the incus. Spongostan® was placed around the piston and served as a seal to prevent perilymph leakage. The tympanomeatal flap was repositioned and one otowick was placed in the EEC (to be removed one week after surgery).

2.2. Statistical analysis

The SPSS® version 24 software was used and *p* values below 0.05 were considered statistically significant. Descriptive analyses were performed considering absolute and relative frequencies (for categorical variables) as well as mean and standard deviation (SD) (for continuous variables). Normal distribution was checked using skewness and kurtosis. Differences among paired groups were evaluated with paired-sample *t*-test, for normal distributed data, and Wilcoxon if normal distribution was not present.

Multiple linear regression was used to identify variables correlated to HQ scores after stapedotomy.

3. Results

The study population included a total of 50 Caucasian patients (15 males; 35 females). The mean age at surgery was 46.8 years (range 26–72 years) and the main symptom before surgery was hearing loss.

Twenty-one patients underwent surgery on the right ear and twenty-nine on the left. Fourteen patients had history of contralateral stapedotomy and eight patients planned to receive future contralateral stapes surgery.

3.1. Hyperacusis after stapedotomy

Before surgery, no hyperacusis was noticed by any patient. However, two weeks after surgery, it was experienced by all (Fig. 1). The highest mean HQ score was registered two weeks after surgery at 16.88 ± 6.54 (range 4–25) (Table 1). In thirty patients (60%) the HQ score was higher than 16 and, among them, twenty one (42%) had an HQ score higher than 21 (Fig. 1).

The highly scored questions were: “Do you find it harder to ignore sounds around you in everyday situations?“; “Has anyone you know ever told you that you tolerate noise or certain kinds of sound badly?“; “Are you particularly sensitive to or bothered by street noise?“; “Do you find the noise unpleasant in certain social situations (e.g. night clubs, pubs or bars, concerts, firework displays, cocktail receptions)?“; and “When someone suggests doing something (going out, to the cinema, to a concert, etc.), do you immediately think about the noise you are going to have to put up with?“.

One month after surgery, hyperacusis had resolved and no more a symptom mentioned by most patients.

3.2. Factors potentially influencing hyperacusis after stapedotomy

Analyses showed that gender, presentations before surgery and surgeon had no influence on HQ scores at two weeks after surgery ($p > 0.05$) (Table 2), but patients with previous contralateral stapedotomy showed lower HQ scores than patients without history of stapes surgery ($p = 0.001$).

Audiological results at one month after surgery showed that a lower PTA, SRT and contralateral SRT were associated with higher HQ scores, registered two weeks after stapedotomy (Table 3). Thus, a higher HQ score at two weeks after surgery was correlated with a larger pre- and post-operative PTA ($p = 0.012$; $rs = 0.353$) and SRT ($p = 0.003$; $rs = 0.417$) differences (Table 3).

Lower postoperative PTA and SRT, and greater pre- and post-operative PTA and SRT differences, contributed to 67% of higher HQ scores registered two weeks after surgery ($r^2 = 0.668$; $p < 0.005$).

4. Discussion

Hyperacusis affects 2–15% of the population and both central and peripheral etiologies have been reported (Katzenell, Segal, 2001; Sammeth et al., 2000). Common underlying causes of hyperacusis include head injury, cochlear trauma, adverse medication reactions, hearing loss, surgery, aging, chronic ear infections, superior semicircular canal dehiscence and autoimmune disorders (Knipper et al., 2013).

Grading hyperacusis is a challenging task. The Hyperacusis Questionnaire (HQ) was developed to characterize and measure hypersensitivity to sound, and it is the most commonly used measurement (Khalfa et al., 2002). An HQ score ≥16 is considered abnormal (Khalfa et al., 2002).

Based on our clinical experience, hypersensitivity to sound is a commonly recognized complaint after stapes surgery, particularly during the first two weeks after surgery. However, few data have been published about post-stapedotomy hyperacusis. The first report goes back to 1974 when McCandless et al. demonstrated that 89.5% of a sample of 19 stapedectomy patients complained of hyperacusis, and among the factors studied (age, postoperative time of follow-up, type of prosthesis, amount of sensorineural or conductive involvement, or side of the ear), no consistent patterns were proved to be associated with hyperacusis (McCandless, Goering, 1974). After this, several reports on post-stapedotomy hyperacusis emerged. However, no robust evidence on this

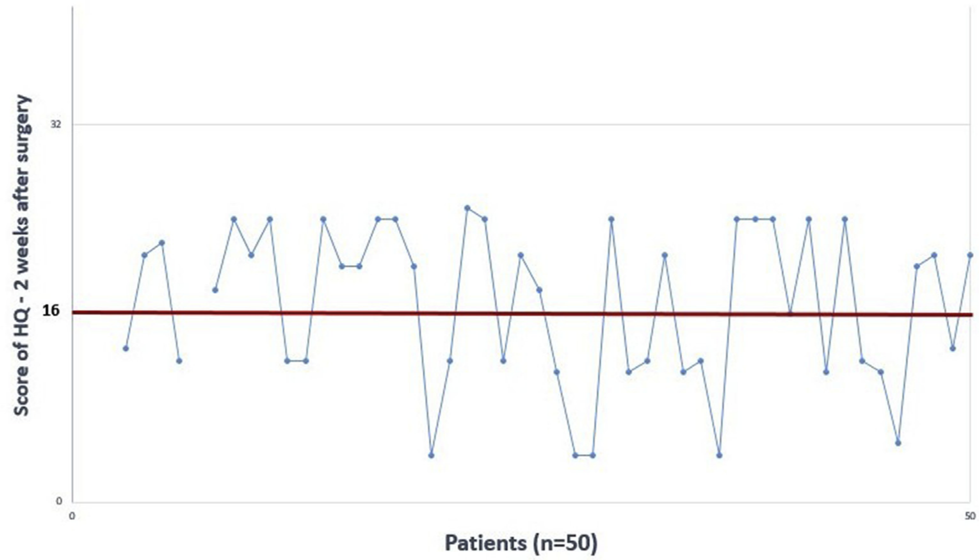

Fig. 1. Hyperacusis Questionnaire score two weeks after surgery.

Table 1
Hyperacusis questionnaire (HQ) scores.

TIME	Mean	Standard Deviation
Preoperative	0	0
2 Weeks after stapedotomy	16.88	6.54
1 Month after stapedotomy	0.28	0.64

matter has been published yet.

The first aim of this study was to assess hyperacusis after stapedotomy. It was concluded that nearly 100% of patients experienced hyperacusis and 60% scored >16 in HQ two weeks after stapedotomy (Fig. 1), with almost complete resolution of the symptom one month after surgery. These findings bring scientific evidence to corroborate our clinical experience.

Table 2
Factors potentially influencing hyperacusis after stapedotomy.

Factor		HQ Score (mean ± SD)	Sig. 2-tailed
Gender	Female (n = 35)	16.91 ± 1.15	p = 0.95
	Male (n = 15)	16.80 ± 1.58	
Major symptoms before surgery	Hearing loss (n = 40)	16.32 ± 1.01	p = 0.35
	Hypoacusis and Tinnitus (n = 10)	19.1 ± 2.18	
Contralateral Stapedotomy	Yes (n = 14)	11.14 ± 0.97	p = 0.001
	No (n = 36)	19.11 ± 1.01	
Surgeon	Surgeon 1 (n = 5)	17.2 ± 0.73	p > 0.05
	Surgeon 2 (n = 12)	17.60 ± 1.15	
	Surgeon 3 (n = 22)	16.04 ± 1.23	
	Surgeon 4 (n = 2)	17.75 ± 0.98	
	Surgeon 5 (n = 9)	16.95 ± 0.98	

Table 3
Analyses of audiological thresholds (dB) and Hyperacusis Questionnaire score two weeks after surgery.

Audiological Thresholds (mean ± SD)		Sig. 2-tailed
PTA – Preoperative	57.16 ± 1.54	p = 0.602
PTA – Posoperative	28.23 ± 1.58	p = 0.016 rs = – 0.340
PTA Difference[a]	28.93 ± 1,43	p = 0.012 rs = 0.353
SRT - Preoperative	56.00 ± 1.29	p = 0.309
SRT – Posoperative	25.50 ± 1.14	p = 0.006 rs = –0.383
SRT Difference[a]	30.50 ± 1.55	p = 0.003 rs = 0.417
Contralateral SRT	26.60 ± 1.99	p = 0.006 rs = - 0.383

rs: Spearman's Rank Correlation Coefficient.
[a] Difference between preoperative and postoperative audiological threshold.

The second purpose of this study was to determine possible predictive factors for hyperacusis after stapedotomy. No consistent association was found between post-stapedotomy hyperacusis and gender, presentations before surgery or surgeon who performed the stapedotomy. However, we found that lower postoperative PTA and SRT, as well as greater pre- and postoperative PTA and SRT differences, contributed to higher HQ scores. Based on these findings, in the future, hyperacusis after stapedotomy may be considered as a positive prognostic indicator for hearing improvement.

Mechanical causes have been related to hyperacusis after stapedotomy. Removing part of the footplate and substituting the stapes with a prosthesis can alter sound pressure transmission, by influencing the impedance matching system at the mechanical (ossicular) and hydraulic level. The amplification force at the base of the prosthesis is higher than at normal intact mobile footplate, due to the reduced diameter of the prosthesis. Another explanation could be the lack of the inhibiting effect by an intact stapedius muscle, which produces distortion at high-intensity levels. These hypothetic mechanical changes in the middle ear are the basis of the recent minimally invasive surgery for the treatment of hyperacusis, proposed by Silverstein et al. (Silverstein et al., 2016). These authors proposed a round and/or oval windows reinforcement with temporalis fascia or tragal perichondrium to treat hyperacusis.

Besides peripheral mechanic reasons for hyperacusis, the acoustic overexposure related to these mechanical alterations in stapes surgery has been demonstrated to result in increased gain within central auditory pathways (Hébert et al., 2013).

Actually, in sound deprivation (as occurs in otosclerosis), it is believed that the auditory system adapts to changes in the input it receives, and loudness perception is modulated as a consequence (Formby et al., 2003; Munro, Blount, 2009).

Additionally, hyperacusis could be influenced by a psychoacoustic mechanism. In this study, patients with previous contralateral stapedectomy had HQ lower scores than patients that underwent stapedectomy for the first time, probably due to emotional and psychological phenomena.

Based on the mentioned above hypotheses, hyperacusis after stapedotomy may be a sum of peripheral mechanic dynamics, central auditory pathway modulation and psychological influences.

According to our sample, hyperacusis is an expectable phenomenon that should be clearly explained pre-operatively to patients before stapedotomy. This can minimize the emotional reaction to sounds after surgery and eventually decrease postoperative HQ scores. Despite the small sample in this study, it can be concluded that lower postoperative PTA and SRT and greater pre- and postoperative PTA and SRT differences contribute to higher HQ scores.

This study has some limitations. Firstly, we only reported PTA and SRT values. Further studies should include air-bone gap, bone conduction threshold and speech discrimination in order to complement our findings. Additionally, addressing differences between patients with unilateral versus bilateral hearing loss would also be interesting. Secondly, in the future, it would be interesting to evaluate both HQ and loudness discomfort levels. Evaluating postoperative hyperacusis in patients that underwent stapedotomy by different techniques, such as LASER, would also be of great importance. Nevertheless, as far as we know, this is the first prospective study that assesses hyperacusis after stapedotomy, at different post-operative time points and analyses not only clinical but also audiological influencing factors. Evaluating hyperacusis after stapedotomy will be carried on by increasing the sample size and the follow-up time. Other post-operative complaints such as vertigo or tinnitus will be analysed and compared with patients that undergo other middle ear surgeries, in order to further the relevance of the findings reported in this study.

5. Conclusions

This prospective study proves that hyperacusis is a common complaint after stapedotomy that is commonly resolved during the first month after surgery. The highest Hyperacusis Questionnaire scores were registered in patients with the highest audiological gain after surgery. This suggests that hyperacusis might be a positive prognostic factor for audiological success after stapedotomy.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent

Informed consent was obtained from all individual participants included in the study.

Financial disclosure

The authors have no financial disclosure to declare.

Declaration of competing interest

The authors declare that there is no conflict of interest.

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