

ORIGINAL ARTICLE

HEARING OUTCOMES AFTER MOBILE EAR SURGERY FOR CHRONIC OTITIS MEDIA IN GREENLAND

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Received 4 March 2008; Accepted 31 July 2008

ABSTRACT

Objectives. Chronic otitis media (COM) with hearing loss (HL) occurs frequently in many populations with limited access to specialized treatment. This article reports on the hearing outcomes following mobile ear surgery in Greenland.

Study design. The study was longitudinal and prospective with pre- and post-operative follow-up data compiled at 1- and 2-year intervals.

Methods. Selection criterion included individuals with COM with or without suppuration (CSOM) and with associated HL. Hearing tests were obtained by using a simple air-conduction (AC) audiometry. The median age of the 274 participants was 27 years (8–60 years), and 45% were males. Sixty-one percent had COM and 34% had CSOM. Myringoplasty or tympanoplasty type I was performed in 88% of the cases.

Results. The median pre-operative AC pure-tone average was 38 dB. The follow-up rate was 75% and 61% at 1- and 2-years. Hearing gain was found in 78% at both follow-ups and was ≥ 10 dB in 62% and 56%, respectively. The median hearing gain was 15 dB and 12 dB, respectively. Independent predictors of hearing gain were pre-operative tympanic membrane atrophy and closure of perforations.

Conclusions. Long-term hearing gain can be achieved with mobile ear surgery and this, in addition to tympanic membrane closure, is important for hearing rehabilitation in populations with poor access to health care.

(Int J Circumpolar Health 2008; 67(4):452-460)

Keywords: tympanoplasty, Inuit, hearing rehabilitation, audiology, Greenland, developing countries

INTRODUCTION

Populations in many regions of the world have sporadic access to specialized treatment because of economic reasons or because they live in remote areas. Ear surgery is highly specialized and despite the high prevalence of chronic otitis media (COM) and associated hearing loss (HL) among Indigenous populations – such as the Inuit in the Arctic, the Aboriginals of Australia and the American Indian and Alaska Native peoples – ear surgery is almost unattainable (1–3). This also is the case for populations in less developed countries (4). In Greenland, almost 4,000 people out of a total population of 55,000 are in need of ear surgery to restore their hearing or to close tympanic membrane perforations to enable the use of hearing aids (5).

Surgery for COM in Inuit populations has shown disappointing outcomes, and a conservative attitude favouring medical treatment has thus been recommended (2,6–8). In a follow-up survey of 102 out of 221 Greenlanders who had had ear surgery at Rigshospitalet in Denmark, 58% had achieved a hearing gain of between 10 and 40 dB (8).

Hearing outcomes after tympanoplasty are frequently reported from tertiary hospitals that offer high-technology medical services while hearing outcomes from alternative operating set-ups such as mobile ear surgery units are rare. In the international literature we found only 3 studies dealing with the outcomes of mobile ear surgery (3,9,10). We have conducted mobile ear surgery since 1998 in Greenland in an effort to lower the costs by bringing the surgery teams to Greenlanders. We recently reported on the technical outcomes of these surgeries (11).

This study presents the hearing outcomes of mobile ear surgeries for COM in Greenland and evaluates potential associations between hearing outcomes and different clinical variables to find better ways of selecting patients and thus enable better prediction of the outcomes.

MATERIAL AND METHODS

The study design was prospective and longitudinal. The travelling teams consisted of an ear surgeon, an ear, nose and throat (ENT) nurse, an anaesthesiologist and an anaesthesiology nurse. The instruments, the portable operation microscope and other medical tools required for ear surgery were checked and supplemented between visits. Instructions for patients and local staff were written in Danish and Greenlandic. Two or 3 operations using general anaesthesia were scheduled each day for a 3- to 4-week period twice a year.

The study started in 1998 and, up until 2002, 10 visits in 7 different districts were carried out. Ten senior ear surgeons, but without prior mobile ear surgery experience, performed the operations. The patients who came from towns and remote settlements were selected from an existing waiting list according to the following criteria, which included the severity of HL: (1) bilateral or unilateral suppurative COM (CSOM), (2) bilateral COM and (3) unilateral COM. Children younger than 8 years of age were not included. The ear surgeons performed the pre-operative examinations and information was given through an interpreter. Database sheets were obtained with relevant pre-, per- and post-operative variables. All patients gave informed consent to the operations. The

patients were discharged the day after their surgeries with instructions for post-operative care. Follow-up was performed by the travelling ENT specialists without interference from the ear surgeons. High standard audiometry as recommended by the American Academy of Otolaryngology-Head and Neck Surgery is not possible to perform in Greenland and audiometry could only be performed in quiet rooms and without reliable bone conduction (12). The audiometers were Madsen TBN 85, ISO 389: 1991 (E). Audiometry results, which from now on are denoted as hearing and hearing gain, are therefore only given as air-conduction (AC) pure-tone average (PTA) measures of 500, 1000 and 2000 Hz. Local audiometry assistants obtained the audiograms. In total, 88% of the patients had a myringoplasty or a tympanoplasty type I performed. The detailed pre- and post-operative regimen and operative procedures are published elsewhere (11).

Statistics

Data were processed by SPSS 13 for Windows. Differences between rates in 2 or more groups were tested by Fisher's exact

test, the chi-square test with Yates' correction or $N \times 2$ tables.

The Mann-Whitney U-test was used for testing difference between independent variables within 2 groups, and the Kruskal-Wallis test was used for testing difference between independent variables within multiple groups. Multiple regression analysis with backward stepwise exclusion was used for testing for potential predictor variables of the continuous outcome in hearing gain. All test results are given as two-sided values. Level of significance was a p -value ≤ 0.05 .

RESULTS

The median age of the 274 patients in the study was 27 years (range: 8–60 years) and 123 (45%) were males. There was no difference in age, sex or diagnoses between those followed up on and those lost to follow-up. The follow-up rates, the number of hearing tests obtained and the mean and median hearing levels and gains at 3 weeks, 1 year and 2 years are shown in Table I.

Table I. Participation rate, number of hearing tests and descriptive statistics of obtained air-conduction pure-tone average (AC PTA) (average of 500, 1,000 and 2,000 Hz), including hearing gain before and 1 and 2 years after mobile ear surgery for chronic otitis media in 274 patients attending a mobile ear surgery project in Greenland, with follow-up at 3 weeks, 1 year and 2 years.

Status	Pre-operative	3 weeks n (%)	1 year n (%)	2 years n (%)
Clinical examination	274	265 (97) ^a	204 (75) ^a	168 (61) ^a
Hearing test	241 (88)	130 (47) ^b	177 (65) ^b	167 (61) ^b
AC PTA (dB)				
mean	39.85	27.14	26.88	29.70
median	38.00	22.00	22.00	25.00
AC PTA gain (dB)		n=111	n=158	n=148
mean		13.14	13.25	10.59
median		15.00	15.00	12.00

^a136, 30 and 26 patients, respectively, turned up for clinical examinations only.

^b1, 5 and 28 patients, respectively, turned up for hearing tests only.

Of those who had hearing tests after surgery 124/158 (78%) after the first year and 115/148 (78%) after the second year achieved some sort of PTA hearing gain and 98 (62%) and 83 (56%) achieved hearing gain ≥ 10 dB, respectively. In total, 29/158 (18%) and 28/148 (19%) reported a deterioration in PTA hearing, respectively, and 14 (9%) and 12 (8%) reported a deterioration of ≥ 10 dB in PTA, respectively.

Table II gives an overview of the number of patients in the different categories of hearing impairment before surgery and after 1- and 2-year follow-ups. From Tables I and II, it is clearly seen that surgery had improved hearing and that 38% had normal hearing after 2 years compared with only 7% who had normal hearing pre-operatively. The best results were obtained in the groups with pre-operative hearing levels of ≤ 60 dB while the frequency of patients with hearing levels of > 60 dB was stationary.

Success was defined as an intact tympanic membrane at both 1- and 2-year follow-ups and was strongly associated with hearing gain (Mann-Whitney U-test: 1-year follow-ups: 128 successes with median gain = 17 dB and 41

failures with 5 dB median gain; $p=0.009$ and 2-year follow-ups: 94 successes with median gain = 15 dB and 29 failures with 3 dB median gain $p=0.008$).

The univariate associations between selected clinical variables and the hearing pre-operatively and hearing gain at the 1- and 2-year follow-ups were tested. Sex, middle ear status, myringosclerosis, Valsalva test, graft type, ossiculoplasty, state of middle ear mucosa and ossicles were not significantly associated with hearing gain. However, if the group denoted as moist middle ear mucosa was excluded from the calculations, patients with pre-operative suppuration had a higher hearing gain after surgery at both 1- and 2-year follow-ups ($p=0.03$ and $p=0.02$, respectively).

Age: The oldest age group (41–60 year-olds) had significantly higher pre-operative hearing loss compared with that of the younger age groups ($p=0.001$) and at 2-year follow-ups the 2 youngest age groups (median hearing gain: 16 dB and 23 dB, respectively) had achieved the best hearing gain compared with the two older age groups (median hearing gain: 8 dB and 8 dB, respectively) ($p=0.02$). Higher hearing gain

Table II. Pre-operative and 1- and 2-year post-operative hearing loss in air-conduction pure-tone average (AC PTA) (average of 500, 1000 and 2000 Hz) of 241 patients scheduled for ear surgery for chronic otitis media in Greenland, according to hearing loss categories.

Hearing Loss AC PTA-range (dB)	Pre-operative n=241 (%)	1 year n=177 (%)	2 years n=167 (%)
Normal: 0–20	16 (7)	81 (46)	64 (38)
Mild: >20–40	122 (51)	60 (34)	61 (37)
Moderate: >40–60	82 (34)	25 (14)	34 (20)
Moderate-severe: >60–75	13 (5)	9 (5)	5 (3)
Severe: >75–90	7 (3)	2 (1)	2 (1)
Profound: >90	1 (0.4)	0 (0)	1 (0.6)

was also found among the youngest age groups at 1-year follow-ups but without statistical significance (median hearing gain: 18 dB, 17 dB, 12 dB, and 14 dB, respectively) (ns).

Diagnosis, perforation type and retraction: Patients with CSOM ($p < 0.001$), total tensa perforations ($p = 0.03$) and retractions ($p = 0.03$) all had statistically significantly worse hearing pre-operatively than their counterparts, but there were no significant differences in hearing gain between those with pre-operative CSOM and COM after 1- and 2-year follow-ups.

Atrophy, indication for operation and satisfaction: Atrophy of the tympanic membrane was significantly associated with higher pre-operative hearing loss ($p = 0.02$), and those with atrophy also had lower hearing gain at both 1- and 2-year follow-ups (median hearing gain: 5 dB and 0.5 dB, respectively) compared with those without atrophy (median hearing gain: 15 dB and 20 dB, respectively) ($p = 0.02$ and $p = 0.002$, respectively). The indication for operation was also associated with a significantly worse hearing gain at both 1- and 2-year follow-ups when the indication was “drying out” compared with “hearing improvement”

or a “combined indication” (median hearing gain at 2 years: 1,0 dB, 10,0 dB and 15,5 dB, respectively) ($p = 0.001$ and $p < 0.001$, respectively). Finally, satisfaction was associated with hearing outcomes. Those being dissatisfied at 2-year follow-ups had significantly lower hearing gain compared with those being satisfied (median hearing gain: 2.5 dB and 15 dB, respectively) ($p = 0.003$). This was also the tendency at 1-year follow-ups but without being significant (median hearing gain: 5 dB and 17 dB, respectively) (ns). However, satisfaction or dissatisfaction after 2 years was not associated with differences in pre-operative hearing levels (ns).

In a multiple regression model using backward stepwise exclusion, pre-operative atrophy of the tympanic membrane was the only independent predictor of outcomes in hearing gain at both 1- and 2-year follow-ups while success, defined as an intact tympanic membrane, was only a significant independent predictor at 1-year follow-ups (see Table III). In the 1-year analysis, 130 patients with complete datasets could be included and hearing gain was the dependent variable. The variables included

Table III. Prediction of gain in air-conduction pure-tone average (AC PTA) (average of 500, 1,000 and 2,000 Hz) at 1- and 2-year follow-ups in patients having undergone ear surgery for chronic otitis media in Greenland. Multiple linear regression using backward stepwise exclusion with removal $p \geq 0.1$ for 7 independent variables at 1-year follow-ups ($n = 130$) and for 4 independent variables at 2-year follow-ups ($n = 107$).

	Final model variables	β	SE	t	p
1-year follow-ups	constant	6.434	8.019	0.802	0.424
	atrophy	8.095	3.864	2.095	0.038
	success/failure	-7.120	3.098	-2.299	0.023
2-year follow-ups	constant	-1.866	9.317	-0.200	0.842
	atrophy	10.012	4.148	2.414	0.018
	success/failure	-6.193	3.618	-1.712	0.090

β = regression coefficient, SE=standard error, t = t-test result

in the model were age, sex, perforation type, middle ear status, retraction, atrophy and success/failure of tympanic membrane healing, which all, except for sex, were associated with hearing gain in the univariate analyses and therefore considered to be potential predictors. In the 2-year analysis, 107 patients were available with intact datasets. Included were age and sex and the 2 independent predictors from the 1-year regression analysis. Scatter plots of residuals and fitted predictors did not show any discernible patterns at either the 1- or 2-year tests, and the validity of the analyses was thus accepted.

DISCUSSION

COM and associated HL are very frequent in Greenland (13). Conservative medical treatment, ear surgery or hearing aids are the 3 treatment modalities. Disappointing hearing gains from ear surgery have been reported from trials in the Inuit population in Canada. Even ear surgery performed at high-tech hospitals far from the patients' homes have shown disappointing outcomes (2,6–8). The present study examines the results of a new strategy for COM ear surgery on populations living in remote areas. The particular problems of mobile ear surgery are the lack of pre-operative specialized care and the near impossibility of thorough follow-ups by specialists. Also, hearing tests can usually only be obtained in suboptimal settings, and reliable bone conduction hearing tests cannot be made. Therefore, it is not possible to present air-bone gap results, which is the internationally recommended standard for reporting hearing outcomes after ear surgery (12). However, in this study, hearing

results were obtained in pre- and post-operative equal settings and with equal audiometers. The results presented here should therefore be considered with these circumstances in mind.

The participation rate was acceptable at 1-year follow-ups but was low at 2-year follow-ups. This may introduce bias, but we found no significant differences in pre-operative variables between those followed-up on and those lost to follow-up.

In the present study more than three-quarters achieved hearing gain and almost two-thirds continued to experience hearing improvements 2 years after their surgeries. This is considerably more than the 25% with hearing improvements in a study with a 65% follow-up rate of Canadian Inuit who had had ear surgery at a central hospital in Churchill, Manitoba, but only a little more than the 58% reported in a former follow-up study of Greenlanders operated on in Copenhagen with a follow-up rate of 46% (2,8). Three internationally published studies from Australia, Mexico and Namibia have reported on mobile ear surgery. Mak and co-authors studied retrospectively the outcomes of ear surgeries performed on 273 Aboriginals from Western Australia between 4 and 67 years of age with a follow-up of 102 patients. A mean hearing improvement of 13 dB in air-bone gap between 500 and 4,000 Hz was reported, and hearing improvement of ≥ 10 dB was achieved by 46% (3). In another study, Mak and his group reported on the outcome of ear surgeries performed on Aboriginal children (14). Barrs and co-authors studied the outcome of ear surgeries on 123 patients from Tepic in West Central Mexico. Only limited air-conduction audiological evaluation was possible as post-operative hearing

tests were available for only 38 patients with an average AC PTA hearing gain of 13 dB (9). An “ear camp” study from Namibia of 61 children with a median age of 12 years and an 82% follow-up rate also found an average AC PTA hearing gain (250–4,000 Hz) of 13 dB (10).

In this study, the AC PTA hearing improved both numerically and in hearing-level categories (see Tables I and II). Long-term normal hearing was achieved in 31% as a minimum (see Table II). The groups with pre-operative HL > 60 dB did not improve, probably because of a significant contribution from a sensorineural component in the HL. Sensorineural HL is common and starts at an early age in Greenland because of noise traumas from rifle shooting, motorboat engines and snowmobiles (15,16).

The hearing gain between pre-operative results and post-operative results showed relatively consistent median hearing gains of 15 dB and 12 dB at both 1- and 2-year follow-ups (see Table I). Surprisingly, the median hearing gain was the same after 3 weeks, but the number of hearing tests at 3 weeks was only 111. Overall, there were large variations in hearing gain and 14 (9%) patients at 1-year and 12 (8%) patients at 2-year follow-ups even experienced a deterioration of ≥ 10 dB in their hearing. All of these had either ear discharge at the follow-ups or had middle ear tympanosclerosis, granulation or secretion at surgery.

As expected, we found a highly significant univariate association between closure of the tympanic membrane perforations and hearing gain. Recently, we reported that the only factor associated with the closure of the tympanic membrane in mobile ear

surgery was the skill of the surgeon (11). Highly specialized skills are also important for improving hearing gain, but additional variables also influence the magnitude of that gain. Thus, patients with pre-operative variables such as older age, CSOM, total tensa perforations or retractions all had pre-operative hearing that was worse than their counterparts. Older age also continued to be associated with lower hearing gain at 2-year follow-ups. This is probably due to the presence of sensorineural HL in the older age groups. In contrast, the highly significant difference in hearing between CSOM and COM patients pre-operatively disappeared after surgery. The reason for this may be that patients with CSOM who had their tympanic membranes closed also achieved a higher hearing gain as compared with COM patients, and this equalizes the difference although a higher number of those with CSOM pre-operatively still had CSOM post-operatively. The same argument accounts for patients with total tensa perforations and retractions pre-operatively.

The presence of an atrophic tympanic membrane pre-operatively was associated with poorer outcomes in hearing gain at both 1- and 2-year follow-ups. Atrophy represents a condition with weak sound amplification, but in ear surgery the diseased tympanic membrane is exchanged by a graft. Therefore, it is somewhat surprising that atrophy instead of other variables is highly associated with poor hearing gain. The group in whom the indication for operation was a combination of hearing improvement and drying out had the highest hearing gain when compared with the groups who only had surgery for hearing improvement or drying out. Satis-

faction was strongly associated with hearing gain at 2-year follow-ups. This was not because of differences in the pre-operative hearing between the different groups experiencing satisfaction, thus the difference after 2 years is a real hearing gain effect.

In a study like this, several variables may interact with the outcomes. Therefore, we examined for true independent predictors of outcomes in hearing gain by performing a multiple regression analysis. Due to partially incomplete datasets, a number was not available for this analysis. We found the model reasonable because of equally good residual fits of the predicting variables throughout the range of hearing gain. The only variable being predictive for outcome of hearing gain at both follow-ups was pre-operative presence of tympanic membrane atrophy, while surprisingly an intact tympanic membrane after surgery was a predictor only at the 1-year follow-up. This may be explained by the smaller number in the analysis at 2 years. In a comparable study of 68 Aborigines in Australia, increasing age was the only predictive variable of a successful outcome whereas age in the present study was not an independent predictor (3).

Conclusions

Mobile ear surgery is economically attractive and in Greenland has shown acceptable outcomes with more than 75% of patients achieving hearing gain. Furthermore, closure of tympanic membrane perforations in those who do not obtain hearing gain is important for rehabilitation through hearing aids. In this study, only 2 variables – atrophy and post-operative intact tympanic membrane – were found to be explanatory for predicting

hearing gain after ear surgery. Thus, only the pre-operative presence of atrophy in the tympanic membrane predicted the outcome in hearing gain. This indicates that even in populations with high numbers of CSOM cases and rather poorly conditioned chronic ears there are no obvious contraindications for ear surgery. Furthermore, the likelihood of a positive outcome of ear surgery in these populations with high incidence of COM is acceptable. We therefore recommend that the mobile ear surgery strategy be implemented in other remote populations and in less-developed countries without access to specialized care in order to improve the ear health and hearing status in these populations.

Acknowledgements

We are indebted to our colleagues who participated in the study as ear surgeons and ENT consultants. Thanks are also due to the local audiometry assistants and staff in the districts in Greenland that took part in this study.

REFERENCES

1. Pedersen CB, Zachau-Christiansen B. Chronic otitis media and sequelae in the population of Greenland. *Scand J Soc Med* 1988;16:15–19.
2. Duval L, MacDonald S, Lugtig L, et al. Otitis media in the Keewatin: 20 years of experience 1970–1991. *Arct Med Res* 1994;53(Suppl 2):676–679.
3. Mak D, MacKendrick, Weeks S, Plant AJ. Middle-ear disease in remote Aboriginal Australia: a field assessment of surgical outcomes. *J Laryngol Otol* 2000;114:26–32.
4. Minja BM, Moshi NH, Ingvarsson L, Bastos I, Grenner J. Chronic suppurative otitis media in Tanzanian school children and its effects on hearing. *East Afr Med J* 2006;83:322–325.
5. Homøe P, Christensen RB, Bretlau P. Prevalence of otitis media in a survey of 591 unselected Greenlandic children. *Int J Pediatr Otorhinolaryngol* 1996;36:215–230.

6. Baxter JD. Chronic otitis media and hearing loss in the Eskimo population of Canada. *Laryngoscope* 1977;87: 1528–1542.
7. Baxter JD, Katsarkas A, Ling D, Carson R. The conservative treatment of chronic otitis media in Inuit elementary school children. *J Otolaryngol* 1979;8: 201–209.
8. Bretlau P, Kirkegaard J, Thomsen KA, et al. Kronisk otitis media i nutidens Grønland. In: Kern P, Cordtz T, editors. *Nuna Med 91 – en grønlandsk medicinsk konference*. Nuuk, Offset, Greenland, 1991;136–138. [in Danish]
9. Barrs DM, Muller SP, Worrndell DB, Weidmann EW. Results of a humanitarian otologic and audiologic project performed outside the United States: Lessons learned from the “Oye, Amigos!” project. *Otolaryngol Head Neck Surg* 2000;123:722–727.
10. Lehnerdt G, van Delden A, Lautermann J. “Ear Camp” for children in Namibia. A field report. *HNO* 2006;54:46–51.
11. Homøe P, Siim C, Bretlau P. Outcome of mobile ear surgery for chronic otitis media in remote areas. Accepted for publication in *Otolaryngol Head Neck Surg* 2008;189(1):56–61.
12. Committee on Hearing and Equilibrium guidelines for the evaluation of results of treatment of conductive hearing loss. *Otolaryngol Head Neck Surg* 1995;113:186–187.
13. Homøe P. Otitis media in Greenland. Studies on historical, epidemiological, microbiological, and immunological aspects. *Int J Circumpolar Health* 2001; 60(S2):1–54.
14. Mak D, MacKendrick A, Bulsara M, Coates H, Lannigan F, Lehmann D. Outcomes of myringoplasty in Australian Aboriginal children and factors associated with success: a prospective case series. *Clin Otolaryngol Allied Sci* 2004;29:606–611.
15. Baxter JD, Røjskjær C. A Greenland-Baffin zone project. *J Otolaryngol* 1979;8:312–325.
16. Counter SA, Klareskov B. Hypoacusis among the Polar Eskimos of Northwest Greenland. *Scand J Audiol* 1990;19:149–160.

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