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Noise exposure of care providers during otosurgical procedures

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Abstract. *Noise exposure of care providers during otosurgical procedures. Objective*: To monitor the noise exposure of care providers during otological surgery due to drilling and suction in the operating room.
Methods: A clinical study monitoring different standard otosurgical procedures was conducted; cochlear implantation (CI), mastotympanoplasty, and mastoidectomy alone. Noise exposure to the surgeon and assistant were monitored with wireless personal noise dosimetry and stationary sound monitoring. Both maximum peak level in dBC (Lpeak) and time-average sound pressure level in dBA (equivalent level or Leq) were measured during drilling episodes. Frequency analysis in one third octaves covering the frequency bands 6.3 Hz to 20 k Hz was performed using a sound analyzing program.
Results: When averaged over the entire procedure, the sound pressure level was highest for the surgeon and the assistant with values of 76.0 dBA and 72.5 dBA, respectively, during CI. Lpeak was 135.9 dBC. Leq for the stationary sound measurement was 74.2 dBA. During cortical bone work using a cutting burr, 84.6 dBA was measured. Mean values of $L_{95\%}$ (estimation of the background noise) were between 55.8 dBA and 61.2 dBA. Frequency analysis showed the highest sound pressure level for all procedures was between 2.5 kHz and 3.15 kHz.
Conclusion: This is the first study to use personal sound dosimetry to monitor noise exposure during otosurgical drilling. In accordance with other studies, the results presented show sound levels below international occupational noise level regulations. However, the measured noise exposure during drilling could have negative effects on care providers based on unfavorable acoustical comfort.

Introduction

Because the middle and inner ear structures are embedded in the temporal bone, otosurgical procedures like mastotympanoplasty (TM) and cochlear implantation (CI) are associated with drilling out petrosal and mastoid bone. During otosurgery, drilling and suction cause noise exposure not only to the patient, but also, to some extent, the care providers. Chronic noise exposure, mainly in the high frequencies, is associated with sensorineural hearing loss. The risk of hearing impairment (average hearing loss >35 dBA at 1, 2, and 3 kHz) at age 60 due to 40 years of exposure to noise levels of 100 dBA has been estimated at 55%.[1] This noise-induced hearing loss (NIHL) is associated with a loss of quality of life.[2] NIHL has been documented in certain healthcare occupations such as orthopedic staff and dental staff nurses.[3,4] The risk of noise exposure to the patient is well described in the literature where it has been assessed in cadaver specimens and patients.[5-7] Somewhat mixed findings, mainly regarding the opposite ”not-operated” ear, have been described.[8-9] Hilmi *et al*.[10] recently investigated the effect of high speed (>8000 Hz) otological drilling on the patient’s hearing. Finally, with the introduction of ‘soft surgery’ in cochlear implant (CI) candidates with residual hearing, the effect of noise exposure when touching the endosteal membrane has been investigated.[11] In contrast, little is known about the level of noise exposure to the otosurgical care providers. The aim of this clinical study was to measure the extent and frequency of noise exposure to care providers during some standard otosurgical procedures associated with drilling and suction/irrigation.

Materials and methods

Surgery and care providers

Three types of otosurgical procedures were monitored for noise exposure. The types of surgery were chosen based on frequent otological drilling procedures at a tertiary referral center. The following procedures were included: (1) CI with a cortical mastoidectomy, posterior tympanotomy, and implant bed in an infant; (2) cortical mastoidectomy with posterior tympanotomy for cholesteatoma surgery in an adult (mastotympanoplasty, MT); and (3) cortical mastoidectomy (M) alone in an adult. Care providers in this setting consisted of the surgeon, the surgeon's assistant for instrumentation (nurse), and the surrounding personal such as the anesthesiologist. All surgery was performed in the same operating room, providing similar reverberation characteristics. Detailed reverberation parameters of this room were not collected. Noise exposure for the patients themselves was not investigated in the current study.

Sound level measurement

A wireless personal noise dosemeter, CR 110A doseBadge® (Cirrus Research plc), was attached to the shoulder of the surgeon and the surgeon's assistant (Figure 1). The shoulder turned toward the sound source was chosen, based on the site of the operation. Before and after each measurement, each doseBadge® noise dosemeter was calibrated acoustically, using a calibrator (RC: 110A Reader Unit) with a sound pressure level of 114.0 dB at 1000 Hz. The dosimeter measures, stores, and calculates the parameters essential for compliance with the noise regulations at work, including Leq (equivalent level) and Lpeak (maximum peak level in dBC). Leq is the time-averaged sound pressure level in dBA, meaning that if someone worked 8 hours with that type of burr at a Leq of 80 dBA, he or she would be exposed to a noise level of 80 dBA.

Along with these overall values, the dose badge records a time history, or noise profile, throughout the measurement. In addition to sound dosimetry, a stationary sound level measurement was performed using the NOR140 Sound analyzer. Again, this device was acoustically calibrated before and after each measurement using the Norsonic Sound Calibrator type 1251 with a sound pressure level of 114.0 dB at 1000 Hz.

A frequency analysis using a post-processing PC sound-analyzing program was performed on the stationary measurement. To characterize the continuous level of background noise, $L_{95\%}$ (dBA) was measured; this is the noise level that is exceeded during 95% of the measurement period. If relevant, the Lpeak (dBC) was also measured. Sound level meter functionality and performance is standardized in the current international standard, IEC 61672:2003. IEC 61252:1993 gives specifications for personal noise dosemeters.

During surgery, the drilling times were noted to allow correct comparison for measurement analysis. Also, different stages of the surgery were followed (cortical bone vs more deeply situated bone).

Figure 1
Wireless noise dosemeter, type doseBadge®

Results

Sound level measurements with the dosimeters are detailed in Table 1. This table provides an overview of the procedure times and the noise exposures of both the surgeon and his/her assistant. During procedure 1 (CI), the surgeon and assistant were exposed to a Lpeak of 124.8 dBC and 130.4 dBC, respectively. During procedure 2 (TM), Lpeak was 135.9 dBC; and during procedure 3 (mastoidectomy alone) it was 119.0 dBC and 123.7 dBC for the surgeon and assistant, respectively. For the measurement of Leq, the entire procedure time was used during procedures 1 and 3. During procedure 2, the phase of middle ear reconstruction was not included in noise level averaging. Therefore, Leq values were 76 dBA and 72.5 dBA for the surgeon and assistant, respectively, during procedure 1. Figure 2 illustrates the detailed analysis of the

Table 1

Wireless personal dosimetry: Leq and Lpeak during 3 otosurgical procedures

Care provider	Procedure	Leq dBA	Lpeak dBC	Measurement time
Surgeon	CI	76.0	124.8	2 h 49 min
Nurse	CI	72.5	130.4	2 h 49 min
Surgeon	MT	68.5	/	1 h 54 min
Nurse	MT	72.0	135.9	1 h 54 min
Surgeon	M	72.7	119.0	1 h 47 min
Nurse	M	69.4	123.7	1 h 47 min

Note: The measurement time for procedure 2 does not include middle ear reconstruction. CI; cochlear implantation; MT: mastotympanoplasty; M: mastoidectomy. Mean drilling time was 60.6 minutes (range 48-76 min).

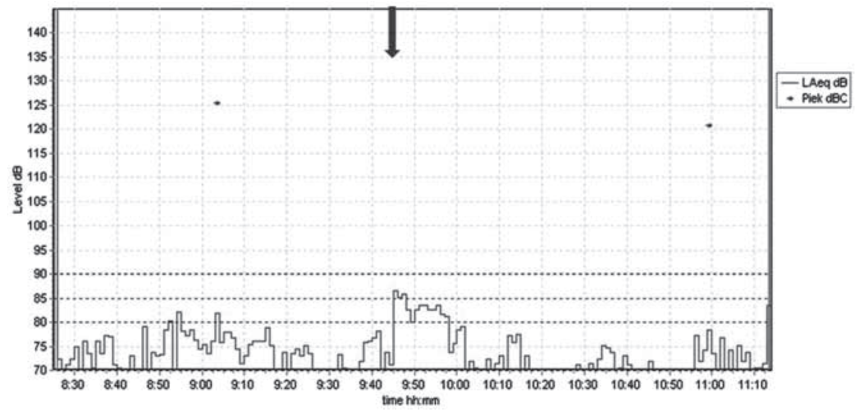

Figure 2

Detailed measurement of the surgeon's noise exposure during procedure 1 (CI). Arrow indicates the beginning of the posterior tympanotomy.

entire procedure, as measured from the surgeon's shoulder. As depicted, the highest measured Leq was 84.6 dBA for the surgeon during cortical bone work with a cutting burr.

During procedure 2, Leq of 68.5 dBA and 72 dBA was measured for the surgeon and assistant, respectively, whereas Leq was 72.7 dBA and 69.4 dBA, respectively, during procedure 3. When analyzing only the main drilling part of procedures 2 and 3, the surgeon's Leq was 64.7 dBA and 74.9 dBA, respectively. For the assisting nurse, Leq was 71.3 dBA and 70.3 dBA during the main drilling part of procedures 2 and 3, respectively. As shown in Figure 2, higher sound pressure levels were measured during short periods of drilling.

The results of the stationary sound measurement are depicted in Table 2, showing mean values of Leq, $L_{95\%}$, and Lpeak for each procedure. The highest Leq occurred during CI, at 74.2 dBA. The value of $L_{95\%}$ lies between 55.8 and 61.2 dBA.

Frequency analysis in dB is shown in Figure 3, giving an idea of which frequencies are most often represented during noise exposure due to drilling and suction/irrigation. The highest sound pressure level during CI was noted at 6.3 Hz and 2.5 kHz. During TM, the highest sound pressure level was noted at 6.3 Hz. Procedure 3 had the highest exposure levels of 6.3 Hz and at 3.15 kHz. Mean drilling exposure time for all 3 procedures was 60.6 minutes (range 48-76 min).

Discussion

Occupational noise exposure is well outlined according to European (and consequently Belgian) regulations in the directive of 2003.[12] These regulations are based on mean daily (8 hours) or weekly noise level exposure. In Belgium, occupational noise exposure should not exceed 87 dBA and a peak level of 140 dBC. At levels above 85 dBA, hearing protection is recommended, and above 80 dBA, hearing preservation measures should be provided. Overall, the results of this study show that the lower limit of 80 dBA is respected during

Table 2
Stationary measurements: mean values for each of the 3 otosurgical procedures

Procedure	Leq dBA	$L_{95\%}$ dBA	Lpeak dBC
CI	74.2	61.2	108.9
TM	67.2	56.1	101.4
M	71.0	55.8	121.9

CI: cochlear implantation; MT: mastotympanoplasty; M: mastoidectomy.

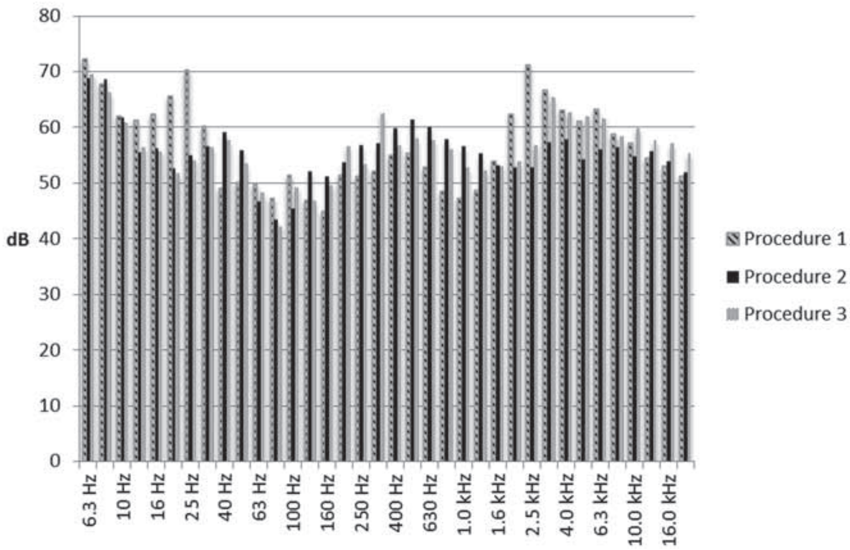

Figure 3
Frequency analysis of the stationary measurements during all 3 procedures

the monitored procedures; therefore, according to the current European regulations, no hearing protection measures for care providers are necessary. The data presented here show more moderate noise levels than that of Parkin *et al.*[6] who measured average noise levels during drilling ranging from 65 dBA to 96 dBA, depending on the drill and burr used. Simultaneous drilling and suction generated noise levels ranging from 91 dBA to 108 dBA.[6] Also, in a cadaver study, Yin *et al*. measured sound intensity at the level of the patient's cochlea in dB SPL.[7] These levels ranged from 120 dB to 122 dB SPL during drilling in cortical bone, and from 117 dB to 121 dB SPL during drilling in the mastoid cavity. In this study, there were no statistically significant differences between cutting and diamond burrs ($p>0.05$).

In the current study, the different steps in standard otosurgical procedures were correlated with different noise exposure rates for the care providers. The first step of the mastoidectomy begins with drilling away the cortical bone with a cutting burr, which is the hardest and, therefore, probably the loudest part. This generated a Leq of 78.6 dBA for the surgeon. In the Parkin *et al*. study, cutting burrs were found to be up to 9 dBA more intense than diamond burrs.[6] In contrast, based on the fact that cortical bone in infants is softer, procedure 1 initially caused less noise exposure than at the stage of the posterior tympanotomy (arrow in Figure 2).

Because pediatric CI plays a significant role in current practice, it was important to include this measurement in an infant. In a recent laboratory experiment, Dalchow *et al*. showed that noise levels did not exceed 76 dBA outside a radius 4 cm around the drill location.[9] Lee *et al*.[4] investigated different drilling instruments, including high speed drilling, and found a noise exposure rate for the operator comparable to the results of the current study. Although sound levels varied from 69 dBA to 83 dBA, situated below Korean (and European) occupational noise-level regulations, ear protection was recommended owing to individual susceptibility to noise and the fact that the otologic surgeon is repeatedly exposed to prolonged drilling noise. Based on similar findings in the current study, the authors of this article agree with the results of Lee *et al*.[4] considering protective measurements for care providers in ear surgery.

This clinical study is the first to investigate both the level and frequency of the noise exposure during otosurgical drilling for care providers measured by dosemeters at the ear level. Figure 3 shows the frequency analysis during the procedures. The analysis is important for hearing protection, as ear plugs could be designed for high frequency noise exposure. In accordance with the study of Hilmi *et al*.,[10] the highest noise level generated was between 2 kHz and 6 kHz. In their study, the average results showed that the sound transmission trailed off at the higher frequencies, dropping to 84 dBA at 8 kHz and 40 dBA at 16 kHz. Our current results agreed with those of Hilmi, showing that the contribution to the overall dBA level, generated by drilling, is negligible for frequencies above 6.3 kHz. All procedures showed a high sound pressure level at 6.3 Hz (not kHz). Because an A-filter will be applied, this low-frequency peak should not be considered clinically relevant. Finally, regarding the surrounding care providers such as the anesthesiologist, the stationary measurement shows a maximum Leq of 74.2 dBA or less; again, no additional hearing protection is strictly required.

In addition to the physiological effect of noise exposure on tinnitus and high frequency hearing loss, attention must be drawn to the acoustical comfort of the care providers in the operating room.[13] Noise can have a detrimental effect on work productivity. Sandrock *et al*.[14] showed that for mental tasks, noise-sensitive persons are more distracted by noise than noise-insensitive persons. Furthermore, they suggested that noise-sensitive subjects not only consider a noisy situation to be more annoying, but experience higher levels of strain than noise-insensitive persons.

In the Netherlands, a 2007 ergonomics guideline suggested a sound level of 45 dBA for concentrated surgical work.[15] At first impression, the measured Leq values seem well above the suggested guidelines; however, a more correct interpretation is achieved using the $L_{95\%}$ measurement. $L_{95\%}$ filters the verbal communication and short increased noise levels, providing an estimation of the background noise. Stationary measurements showed a mean $L_{95\%}$ value between 55.8 dBA and 61.2 dBA (Table 2). Although experienced otosurgeons are accustomed to this level of noise exposure during drilling, long drilling procedures could induce negative effects, like increased strain and fatigue, for both the surgeon and the entire operating room team.

Conclusion

In accordance with other studies, the results of this clinical study show that levels of noise exposure for care providers during otosurgical drilling lie below international occupational noise level regulations. However, the measured noise exposure during drilling could have negative effects on care providers based on unfavorable acoustical comfort.

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