

Ear Infection and the Use of Hearing Protection

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Documented instances in which hearing protection devices (HPDs) have been shown to create aural hygiene problems or are the causative agent for infections of the ear canal are rarely described in the literature. Nevertheless, it is not uncommon for hearing conservationists to express concern regarding the potential for HPDs to cause ear infection, particularly in the case of earplugs. This apprehension probably arises as much from misinformation, as from observation of the fact that the ear canal is an ideal culture environment - warm, moist and dark. The purpose of this EARLog¹, is to address such concerns by examining ear canal anatomy, discussing the etiology and prevalence of external ear infection, and providing recommendations to minimize potential problems that can arise within occupational hearing conservation programs (HCPs).

Basic Anatomy

The external ear consists of the auricle (pinna), the external auditory meatus (ear canal), and the tympanic membrane (eardrum) as illustrated in Figure 1. The pinna is a cartilaginous shell-shaped structure attached to the skull by muscles and ligaments which are covered by skin. The ear canal is a generally elliptical S-shaped tube, approximately 25 mm (1 inch) long, with an average diameter of 8 mm at its entrance. It is directed inwards, upwards, and slightly forwards. The eardrum, which terminates the ear canal, forms an airtight and watertight barrier separating the middle ear from the external ear.

The outer half of the ear canal is cartilaginous, with an epithelial layer (skin) possessing numerous hair follicles and associated ceruminous and sebaceous glands. By contrast, the inner or medial half of the canal is osseous (bony), with skin that is only about 1/5 as thick (0.2mm) and nearly devoid of hair follicles and glands.^{2,3} The differences between the outer and inner portions

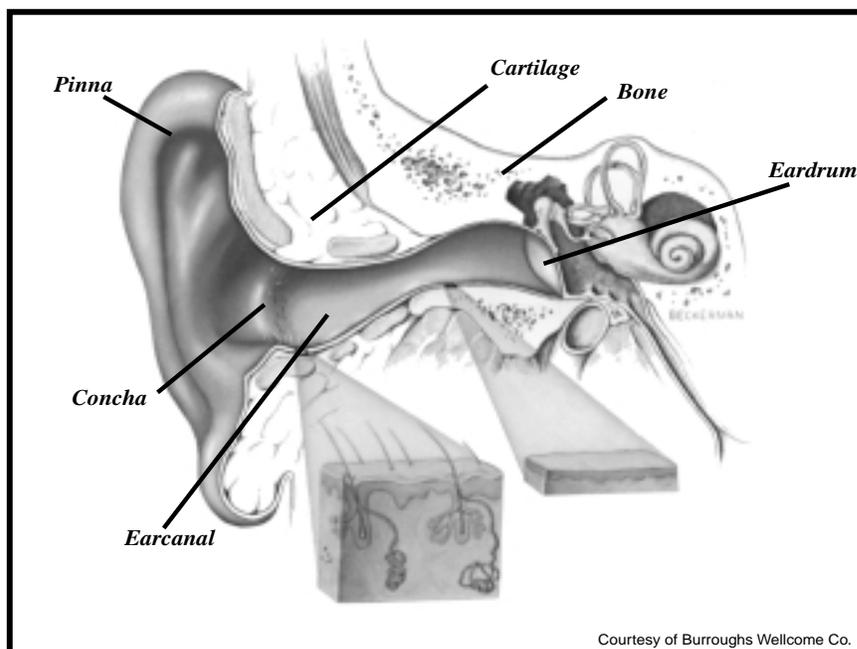


Figure 1. Frontal section of the ear canal with magnification of the skin of the cartilaginous and osseous (bony) portions (from reference 2).

of the ear canal in terms of pore structure and hairiness are similar to those found between the back of the hand and the palm.

The secretions of the ceruminous and sebaceous glands, together with dead epithelial cells which are regularly cast off and replaced, combine to form cerumen (ear wax), a water-repellent substance that coats and impregnates the skin of the ear canal. This coating is one of the most important protective mechanisms of the ear. It acts as a mechanical barrier which shields the skin from exposure to excessive moisture, and its acidity provides an antibacterial "acid cloak" that inhibits the development of many of the bacteria responsible for ear canal infections.^{2,4,5}

Since the skin that lines the inner portion of the canal is continuous with the external layer of the eardrum, the ear canal can be thought of as a skin-lined

tube. This "lining" migrates outwards from the center of the eardrum towards the entrance of the ear canal at the rate of about 1.5 mm/month. Skin migration, combined with jaw movement, are additional self-protective features of the ear in that they tend to keep the canal clear of excess cerumen and other debris.⁴

What is an External Ear Infection?

The medical term that describes an inflammatory condition of any portion of the skin of the ear canal is otitis externa. This need not necessarily be an infectious process, i.e. one involving an invasion of the body by microorganisms. The inflammation may be caused by mechanical means (scratching) or chemical (caustic or allergenic) substances, or by biologic (bacterial and fungal) agents. Once the skin has been abraded or inflamed it is easier for microorganisms to become implanted in

the follicles and glands of the ear canal and for an infection to develop. Since the air follicles and glands are almost exclusively found in the outer third of the ear canal, infections are also primarily limited to that region.

It is important to distinguish soreness or irritation from the above conditions. For example, irritation may develop when a new user begins wearing HPDs for extended periods of time. (For this reason new users should gradually increase their wearing time over a period of a couple of weeks). This type of irritation is similar to the discomfort many people experience on the bridge of the nose when they initially begin wearing glasses. The irritation will subside without treatment when either the irritant is removed, or the skin has adapted to its presence. In contrast, the resolution of ear canal infections generally requires medical treatment.

Signs and Symptoms of Otitis Externa

Observable signs of otitis externa include swelling and reddening of the ear canal, a greenish-tinted discharge, and sometimes a foul odor to the ear. Symptoms include itching, pain, tenderness upon manipulation of the pinna, a feeling of "fullness to the ear," and hearing loss in those cases in which the swelling and/or discharge is severe enough to have fully obstructed the ear canal.^{2,4,6} However, otitis externa may often be present in the absence of one or more of these signs and symptoms.

The Etiology of Otitis Externa

The incidence of otitis externa in the general population is related to environmental or seasonal conditions, being more prevalent when temperature and humidity are elevated and/or when recreational water sports are common.^{2,6,7} It has been hypothesized that prolonged exposure to water removes the protective ceruminous layer, allowing the skin to soften and absorb moisture. This leads to swelling and obstruction of the sebaceous and ceruminous glands, thus preventing replacement of the cerumen.^{2,4} Itching results, which may give rise to scratching and more itching, and the situation worsens.

Another common cause of otitis externa is excessive cleansing and scratching/digging at the ear canal.^{2,4,5} This not only removes the protective ceruminous layer and creates itching, but may result in trauma or abrasion which further breaches the skin's protective barriers.

In two separate studies of patients with otitis externa it was found that from 63 - 87% reported cleaning their ear canals with cotton swabs, matches, fingernails, or the like.^{8,9}

When the surface barriers to microbial penetration are removed, organisms that are normally found in the ear (such as staphylococcus epidermis) as well as external pathogenic bacteria (such as pseudomonas aeruginosa and staphylococcus aureus) and to a lesser extent fungi, are able to penetrate and thrive in the orifices of the epithelial glands.^{2,4,5} The inflammation then becomes more severe and the infection progresses.

Other predisposing factors for otitis externa include allergy to chemicals or hair dyes and sprays, dermatitis, chronic draining middle ear infections, excessive cerumen (which can trap water in the canal), and systemic conditions which lower the body's resistance, such as anemia, vitamin deficiencies, diabetes, and endocrine disorders.^{4,5} Wearing earplugs has also been suggested as a possible predisposing factor, since their use can increase the temperature and humidity in the canal, create the potential for skin abrasion or local trauma, remove cerumen, and provide a vehicle for the introduction of organisms into the canal.² In one study of 139 patients with otitis externa, 9% were found to have been wearing hearing aids (devices which couple to the ear with an earplug-like device).⁶ However, as discussed below, available epidemiological studies do not generally substantiate concern regarding the potential for earplugs to increase the likelihood of developing an external ear infection.

Prevalence-Anecdotal Evidence

As early as 1956, expert opinion suggested that "cases of external otitis resulting directly from wearing ear protectors are exceedingly rare provided the material in the ear protector is an inert non-toxic substance. Those few cases reported are more often due to failure to keep the ear protectors reasonably clean."¹⁰ The authors cited as evidence reports from the medical directors of three different major aircraft manufacturers. They also pointed out that there were over 1 million hearing-aid wearers who were using their aids for periods of 12 to 16 hours per day, and among that group as well, external otitis was quite rare.

Even today when one reviews the literature or interviews hearing conservation authorities to gather data on the prevalence of otitis externa in occupational HCPs, one is struck with the dearth of factual information. Anecdotal comments abound, but controlled studies are "conspicuous by their absence."¹¹ By implication the problem is neither significant nor widespread; otherwise it would have drawn greater attention and research interest.¹² This qualitative assessment of the situation was recently reinforced by audiologists from the Workers' Compensation Board of British Columbia, where audiometric records for over 60,000 noise-exposed workers in that province have been reviewed annually for the past five years. Although they had considered conducting a study on the incidence of otitis externa, the plans were never implemented due to the lack of feedback from employers and employees alike that any such problems existed.¹³

Prevalence-The Available Data

Table I summarizes the data that provide a numerical estimate of the prevalence of otitis externa. Data on "excessive" cerumen are also listed, when available, although the definition of excessive is often unclear and varies with the investigator.

Hopkinson's¹⁴ study provides the most precise picture of prevalence since all of the otoscopic exams were conducted by one or more physicians using both pneumatic and microscopic otoscopy. The report contains comments, by subject, for all otological abnormalities that were observed. Unfortunately, data on HPD utilization are not provided.

Forshaw and Cruchley¹⁵ reported on a study of sixty long-range patrol-aircraft crew members who were randomly divided into three groups, one wearing premolded earplugs, the second using foam earplugs washed after each use, and the third using foam earplugs washed only once per week. The study lasted eight weeks and included examinations by a medical officer as well as skin scrapings for bacterial culture and fungal examinations. The results indicated no fungal infections or clinically significant bacterial infections, and no differences in positive bacterial cultures across the three groups of users.

Foltner¹⁶ reported data from two investigations. Unfortunately in the larger of the two studies in which otoscopy was conducted by audiometric technicians

Table 1 - Estimates of the prevalence^a of otitis externa and excessive cerumen

Date	Author	Otitis Externa	Excessive Cerumen	Wearing HPDs	Comments
1946	Jamieson	1.5%	—	no	65,000 RAF and army troops; medical diagnosis of in- and out-patients seen by military hospital during 3-year period.
1948	Johnston	2.6%	—	not specified	Survey of factory workers.
1952	Carpendale	0.3%	—	no	1000 "normal young men;" Royal Air Force candidates.
1953	Alkroyd	6.0%	—	no	Incidence data for military personnel in tropical climate.
1957	Senturia	1.1%	—	no	551 newly enlisted Marines in Florida; incidence during 2-1/2 month period.
1965	Cambon et al.	3.0%	—	no	504 Indians on reservation in British Columbia.
1981	Hopkinson	2%	6%	not specified	350 noise-exposed coal miners.
		2%	2%	not specified	150 industrial noise-exposed controls.
1982	Forshaw & Cruchley	0%		yes	Otolaryngic exam w/microscopic otoscopy.
1984	Foltner	— (6%) ^b		yes	60 aircraft crew; 8 weeks usage; exam by physician including skin cultures.
		2%	9%	no	68,647 industrial workers; prevalence of "ear disease, perforation, or occluding wax;" otoscopic exam by CAOHC technicians.
1984	Royster & Royster	2.5%	—	yes	101 industrial workers prior to HCP; otoscopic exam by certified audiologist.
					24,212 noise-exposed workers; yearly prevalence of "otitis externa, fungus, drainage and nonspecific reports of infection;" based on estimates by HPD fitters/issuers at 38 out of 218 sites interviewed.
1985	Berger & Nuss	0%	14%	few	63 industrial workers; TWA ₈ 85 dBA; excessive wax = 75% or more obstruction.
1985	Cooper	0.3%	3.5%	yes	362 industrial workers from 5 plants.
		0.2%	6.0%	no	225 controls from same plants.
					Prevalence of inflammation, drainage, or perforation; otoscopic exam by CAOHC technicians.

a) Rates in this table are prevalence, except as noted under comments.

b) Doesn't fit in either column; see comments.

$$\text{For a given period of time, prevalence} = \frac{\# \text{ existing cases (old \& new)}}{\text{population at risk}} \text{ and incidence} = \frac{\# \text{ newly diagnosed cases}}{\text{population at risk}}$$

(68,647 subjects), "ear disease, perforation, and occlusive wax," were grouped together. Since the other data in Table I indicate a higher prevalence of excessive wax than of ear disease, it is likely that her 6% figure which is cited in the Table is dominated by that factor. This is substantiated by her other study (101 subjects) in which one audiologist conducted all of the otoscopic examinations and individually reported the data - 2% otitis externa and 9% excessive ("occlusive") cerumen.

Royster and Royster¹⁷ conducted a unique study in which they interviewed HPD fitters and issuers, or in some cases HCP administrators, at 218 sites across the continental U.S. Interviewees were asked to "describe any type of problems you have observed with the wearing of hearing protection by your employees." They were then asked for estimates of the frequency of occurrence of the problems they specified and whether they attributed them to the use of HPDs. No effort was made to specifically elicit comments regarding canal irritation or otitis externa, and likewise due to the nature of the study it was not possible to verify the accuracy of the assertions or perceptions of those who were interviewed.

At 51 of the 218 sites surveyed by the Roysters, external otitis was mentioned as a problem for the wearers of insert

HPDs, but at only 38 of those sites was the interviewee able to provide an estimate of the number of occurrences. It was from those 38 estimates based on experience with over 24,000 employees that they computed an annual prevalence rate of 2.5%. It is also important to note that of the 51 interviewees mentioning otitis externa as a problem, 28 (55%) did not attribute its incidence to the use of HPDs.

The most recently reported data are from Cooper,¹⁸ who studied 587 employees at five midwestern industrial facilities. Otoscopy was conducted by audiometric technicians. Information on HPD usage and medical histories were recorded. Subjects reporting infrequent HPD use and those who wore hearing aids were excluded. The subjects were divided into premolded earplug users, foam earplug users, and those who didn't wear HPDs. The prevalence of otitis externa was less than 0.5% across all groups, with no statistically significant differences among the groups.

Cooper also reported data on the presence of cerumen. She defined a partial blockage as a 50% or greater obstruction, and a total blockage as 100%. The prevalence of partial blockage did not vary significantly across groups. It averaged about 5%. The only statistic that varied significantly across groups was

that of total cerumen blockage, which was reported as 7.4%, 2.0%, and 6.0% for the premolded users, foam users, and nonusers respectively. The author suggested that foam earplugs, due to their surface texture and the fact that they are inserted into the ear canal in a compressed state, can actually penetrate and adhere to excessive wax to facilitate its partial removal.

Recommendations

Prior to issuing HPDs the fitter should visually examine the external ear to identify any medical or anatomical conditions which might interfere with or be aggravated by the use of the protector in question. If such conditions are present, HPDs should not be worn until medical consultation and/or corrective treatment can be obtained, or the suspected condition has been shown not to constitute a problem. Areas of concern include extreme tenderness, redness or inflammation (either in or around the ears), sores, discharge, congenital or surgical ear malformations, and additionally in the case of earplugs, canal obstructions and/or impacted or excessive cerumen. The latter condition, however, is difficult to judge since few data are available on the effects of earplugs on the formation buildup, and possible impaction of wax.

As with all clothing and equipment that comes in repeated and intimate con-

tact with the body and the work environment, the cleanliness of HPDs must be considered. HPDs should be cleaned regularly in accordance with manufacturers' instructions, and extra care is warranted in environments in which employees handle potentially irritating substances. Normally, warm water and soap are recommended as cleansing agents. Solvents and disinfectants should generally be avoided.

Earplugs should be washed in their entirety and allowed to dry thoroughly before reuse or storage in their carrying containers. Earmuff cushions should be periodically wiped or washed clean. Their foam liners can also be removed for washing but must be replaced since they do affect attenuation. Earplugs and earmuff cushions should be discarded when they cannot be adequately cleaned or no longer retain their original appearance or resiliency.

Stressing hygiene beyond practical limits, however, can compromise the credibility of the HPD issuer/fitter. It is often difficult enough to get employees to replace or repair worn out HPDs, let alone clean them routinely. And in spite of this, the epidemiological data previously discussed give no indication that the use of HPDs significantly increases the prevalence of external ear disease.

If an ear irritation or infection is reported the exact extent and etiology of the problem should be investigated first-hand by medically trained personnel to determine whether the causative agent is an HPD or one of the other predisposing factors cited above. When HPDs are implicated, a common cause has been found to be earplugs or even earmuffs that are contaminated with caustic or irritating substances, or sharp or abrasive matter. If such contamination is likely or unavoidable, and repeated insertion and removal are required during a workshift, formable earplugs that are manipulated by the user prior to insertion may not be the best choice.

In one reported case of earplug contamination,¹⁹ more careful hygiene practices, combined with the use of corded plugs to allow removal without touching the protector, eliminated the problem. In another situation,¹⁹ in which underground miners in a warm and humid environment were experiencing

otitis externa, switching from a pre-molded vinyl plug to a foam plug decreased the incidence. Canal irritations can also arise due to the use of missized or inappropriate HPDs, omission of a "break-in period" for new users, or the use of worn out HPDs whose once resilient parts are no longer soft and flexible. For example, one reported cause of ear irritation has been the continued wearing of V-51R (pre-molded PVC) earplugs beyond their useful life, i.e. after they have hardened from exposure to cerumen and sweat.¹⁷ In rare instances individuals may develop circumaural or canal inflammation as a result of allergic reactions to the materials from which earmuff cushions or earplugs are composed. Rectification of the above problems involves resizing or issuing alternative HPDs, retraining of users, and periodic replacement of worn out devices.

If incidences of external ear problems are detected, it is important to determine if they are limited to a particular department or operation, to one or more brands or types of HPDs, to a change in the HPDs being utilized, to a particular time of year, or if they are perhaps due to some other policies or procedures that may have been modified within the work environment. This will allow a reasoned approach and help to avoid an overreaction which could compromise the HCP, without necessarily resolving the problem at hand.

Closing Remarks

Examination of the physiology of the typical healthy ear canal suggests that its natural defense mechanisms render it exceedingly resistant to infection. This observation is substantiated by the available anecdotal and epidemiological data on the prevalence of otitis externa among both users and non-users of HPDs. For both groups prevalence was found to be approximately 2%. Although hearing protection devices should not be worn in the presence of some preexisting ear canal pathologies, and care must be exercised regarding selection and use under certain environmental conditions, regular wearing of HPDs does not normally increase the likelihood of contracting otitis externa.

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