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Can permanent sensorineural hearing loss be caused by sleeping with an ear against a train window?

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Abstract

A patient presented to the authors with unilateral sensorineural hearing loss after falling asleep with his ear tightly pressed against a window of a moving train. This study set out to determine whether a train could generate sound levels of sufficient intensity to cause such a hearing loss. A sound level meter was used to measure the sound levels produced at the window of a moving train. Further measurements were made with a rubber attachment on the microphone, that simulated the effect of the ear stuck to the window. The sound levels were found to be amplified by the attachment but not to levels that could cause a hearing loss over a short period. In a second experiment eight healthy volunteers all perceived an increase in sound levels when their ears were pressed against a train window.

It seems unlikely that sleeping with an ear against a train window can cause hearing loss, but it cannot be ruled out.

Key words: Hearing Loss, Noise-Induced; Noise Occupational Exposure; Transportation

Introduction

This study was prompted by a patient, presenting to the authors, who had apparently suffered sudden onset unilateral sensorineural hearing loss after falling asleep with his ear against a train window.

Sudden onset sensorineural hearing loss is a rare condition; 4000 new cases occur annually in the USA and 15,000 world-wide.[1] The causes include; ear surgery, base of skull fracture, noise damage, blast injuries and ototoxic drugs. In most cases no cause is identified and it is thought that viral infections and vascular events may be responsible, although the evidence for this is weak.[2]

A search of world literature found that no case of sudden onset sensorineural hearing loss caused by falling asleep with an ear against a moving train window has been documented. Sensorineural hearing loss has been found to be relatively common in general railway workers[3] however it is likely that most of the workers received most of their noise exposure from maintenance equipment rather than the trains themselves. Studies looking at train crew members showed that they are not subjected to significantly hazardous levels and durations even after many years of exposure.,[4,5] Trains do not appear from previous studies to put their crew and therefore their passengers at risk of hearing loss. We wondered if having an ear pressed firmly against a train window could amplify the noise level sufficiently to cause cochlear damage and therefore decided to see if we could reproduce this effect experimentally.

The aims of this study were to record the sound levels generated at a window of a moving train and to determine if having an ear pressed firmly against the window amplifies the sound level.

Case report

A 36-year-old salesman with no previously noted hearing loss and no family history or past history of ear problems, was travelling on an Intercity train from York to Glasgow. At Newcastle he fell asleep with his left ear against the window. He recalls, that when asleep, his ear had formed a tight seal with the window. When he awoke, at Edinburgh (approximately two hours later), he immediately noticed the hearing in his left ear was diminished and sounds seemed muffled. There was no pain in the ear, nor was there any bruising, bleeding from the canal or other gross signs of trauma. He did not experience any tinnitus or vertigo. He is otherwise very healthy and is not on any medications. He did not have an upper respiratory tract infection at the time of the incident.

His left-sided hearing loss persisted and five months later an ENT consultant assessed him. On examination, both tympanic membranes were normal. Weber's test (512 Hz) was central and both

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Right ear

	250	500	1 KHz	2 KHz	3 KHz	4 KHz	6 KHz	8 KHz
BC	10	20	20	15	10	5	–	–
AC	10	15	20	15	20	15	25	25

Left ear

	250	500	1 KHz	2 KHz	3 KHz	4 KHz	6 KHz	8 KHz
BC	10	20	20	15	–	–	–	–
BCm	–	–	–	–	30	60	–	–
AC	20	20	15	15	30	60	65	60
ACm	–	–	–	–	–	65	65	–

AC = air conduction; BC = bone conduction; ACm = air conduction masked; BCm = bone conduction masked

FIG. 1

Audiometry. Thresholds in dB HL.

Rinne's tests (512 Hz) were positive. Pure tone audiometry, carried out using a Kamplex AD25 audiometer, showed normal hearing in the right ear but a marked sensorineural hearing loss of 60 decibels at high frequencies in his left ear (Figure 1), most severe at 4 kHz, which is typical of noise-induced hearing loss. An magnetic resonance image (MRI) scan, with gadolinium enhancement, of the brain was entirely normal, and specifically showed no vascular lesion, no infarcts and no cerebellopontine angle tumour.

One month later, repeat audiometry was identical to the initial assessment and given that this hearing loss is sensorineural there is little prospect of recovery.

Materials and methods

Two experiments were devised to investigate the noise generated at a window of a moving train. The first used a sound meter to obtain objective readings and the second used volunteers to look for a subjective amplification.

Experiment 1

A Castle GA206 sound level meter was used to record the sound levels in dB(A) generated by a Turbostar class 170 intercity train, travelling at high speed between Glasgow and Edinburgh. To recreate the plunger-like effect of the ear against the window, a rubber attachment was fitted to the microphone of the sound meter (Figure 2). The distance from the aperture of the attachment to the microphone was 23.5 mm, the average length of an adult ear canal.[6] Unfortunately due to the width of the microphone the internal diameter of the attachment (14 mm) was bigger than the average diameter of an adult ear canal (9 mm). The sound level was measured with the microphone coupled to the window with the rubber attachment and the microphone against the window without the attachment. The rubber attachment was pressed against the window by hand in order to recreate the effect of the ear being pressed against the window by the weight of the head while sleeping (we believe that this would cause a slight positive pressure inside the ear/rubber attachment). Separate readings were taken with the train passing through open environment and with enclosed surroundings, such as embankments, trees and tunnels. Readings were taken over 30 second periods. Ten readings were taken for each of the four categories (attachment on, open and enclosed environment; attachment off, open and enclosed environment) and the range recorded. Sharp spikes on the meter were not recorded.

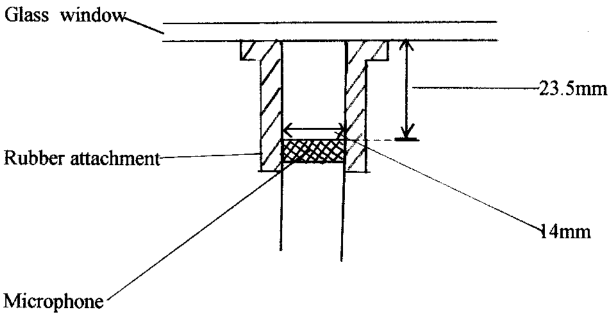

FIG. 2

Microphone attachment (cross section).

Experiment 2

Eight volunteers were recruited to subjectively measure the difference in sound levels on a moving train. The subjects were aged 25–31 and the mean age was 28. All of the subjects were in good health and none had a previously noted hearing problem. The subjects were asked to note the sound level with the head in the normal position for a traveller sitting in the seat next to the window. The subjects then positioned their ear close to, but not touching, the window (pinna about 1 cm from the window pane) and then pressed their ear firmly against the window. The subjects then recorded if they felt the noise perceived in the two positions was the same as, slightly louder, or significantly louder than the noise they noted with their head in the normal position. The subjects made their observations while travelling on a turbostar class 170 train travelling from Glasgow to Edinburgh. The subjects each made their observations independently and were unaware of the other subjects' findings.

Results

Experiment 1

The sound levels recorded with, and without, the attachment are given in Table I, they are divided into two different categories depending on the acoustics of the surrounding environment.

The highest sound level recorded was 110 db (A), which lasted for 10 seconds as the train passed through a tunnel at speed, however this was

TABLE I

SOUND LEVEL RECORDINGS

	Open surroundings	Enclosed surroundings
With rubber attachment	92–97 dB(A)	98–105 dB(A)
Without rubber attachment	70–75 dB(A)	82–88 dB(A)

excluded from the study because its duration was too short. The noise levels in this experiment varied from 70–105 dB(A).

The environment through which the train travels has an influence on the noise level recorded at the window. If the train is travelling with embankments or trees at the side of the track, or through bridges or tunnels, the noise generated by the train is reflected back to the train and therefore the sound levels recorded at the window are increased. There does not appear to a significant difference between the levels of amplification caused by the different types of enclosed surroundings. If the train is travelling through an open area the sound disperses easily and the levels recorded at the window are lower.

The addition of the rubber attachment increases the noise levels recorded by the meter. If the amplification was caused by sound waves travelling through the solid rubber to the microphone then a similar amplification would occur when the microphone is held tightly against the window; no such amplification was found to occur when this was done. Furthermore if the sound wave was travelling by bone conduction then bilateral hearing loss should occur. The amplification is therefore caused by the sound waves travelling better through the column of compressed air created by the plunger effect of the rubber attachment.

Experiment 2

With the ears close to the window, three subjects perceived the noise to be slightly louder than that with their heads in the normal position, five thought that the noise was of the same intensity and none thought that it was significantly louder. With the ears pressed firmly against the window, all eight felt that the sound level was significantly higher than that noted with their head in the normal position.

Discussion

The history of this patient's hearing loss strongly suggests that noise exposure on the train caused the hearing loss and indeed no other cause was identified by examination or investigations. The sensorineural hearing loss of this patient is maximal at 4 kHz, characteristic of noise exposure, and it is unilateral. If the sound wave was transmitted by bone conduction bilateral hearing loss would occur, the fact that the hearing loss is unilateral suggests that the noise generated at the train window travels to the cochlea via the ear canal. Furthermore there is a good temporal correlation between the exposure and the onset. It is possible that the train journey brought to light a pre-existing hearing loss, since his pre-injury hearing level is not known, but the pattern of the hearing loss (unilateral high tone), and its severity in a man of this age, strongly suggest a causal link.

It has been previously thought that trains generate noise intensity levels of between 70–85 dB(A), which are not sufficient to cause sensorineural hearing loss[4,5] and our readings without the rubber attachment agree with this.

Our findings show that a rubber attachment, which creates a tight seal with the window, amplifies the noise levels generated by a train. The method of this amplification is not certain, however we postulate that the rubber attachment has a 'plunger' type effect thus creating a slight positive pressure inside the attachments cavity. The force used to press the attachment therefore creates a column of compressed air, which facilitates the sound transmission to the microphone. The plunger effect augments the train noise sufficiently at achieve sound levels, which are greater than the action levels set out by the UK Health and Safety Executive.[7]

Further amplification is obtained from the environment through which the train passes. Enclosed surroundings around the railway track reflect the sound back to the carriages. The results of the augmentation of the noise levels produce sustained noise intensity levels up to 105 dB(A); these levels are enough to cause sensorineural hearing loss,[7,8] although not in such a short time period as in this case. If other factors, which amplify train noise such as the type of locomotive and the type of track,[9] that it is travelling over are present it would be possible to generate even higher sound levels.

It is difficult to develop an experimental model that mimics the human ear in this situation. The transfer of sound from the window to the ear/microphone inside this closed system depends on many factors such as the air pressure, the volume, and the physical properties of the canal/attachment. A study on the transfer of sound from personal cassette players' headphones on the ear[10] found that simple measurements with a coupler overestimated the sound level compared to a model of a human ear with a microphone (KEMAR mannequin with an artificial ear simulator). Ideally we would have used a similar experimental set up, but unfortunately this was not possible with the resources for this project. Recognizing that the rubber attachment may not be the ideal model for the pinna to window interface, we devised the second experiment to look for further evidence to support our objective findings.

The second experiment provides subjective evidence of an amplification of noise when an ear is pressed against a train window. The subjects all felt that the noise was significantly louder when they pressed their ears against the window. An increase of around 10 decibels is required in order to perceive a significant increase and this therefore corresponds closely to our sound meter readings. The subjects did not perceive a significant increase in noise levels with their ears close to, but not up against, the window, this suggests that it is not merely the proximity to noise source that causes the amplification but rather the acoustic effect of the pinna pressed onto the flat surface of the window. The experiment is admittedly rather crude and one cannot draw too strong a conclusion from it, but the results are consistent and easily reproduced (the reader can try this for himself the next time he travels on a train).

We did not find sound levels high enough to cause sensorineural hearing loss, over a short period, in this study. The sound levels recorded with the attachment could cause a sensorineural hearing loss, but the length of exposure would be in the region of a few years rather than few hours. We did find that sound levels are amplified when a rubber attachment is used to create a seal against the window, this amplification was also found to occur when the subjects in the second experiment held their ears against the window.

It seems unlikely that the passenger in question received sufficient noise exposure to cause his hearing loss, however, some individuals are more sensitive than others to cochlear damage, and some trains and environments are noisier than others. We, therefore, cannot rule out sleeping with an ear against a train window as a cause of sensorineural hearing loss.

References

1 Hughes GB, Freedman MA, Haberkamp TJ, Guay ME. Sudden sensorineural hearing loss (review). *Otolaryngol Clin North Am* 1996;**29**:393–405

2 Pitkaranta A, Jukunen I. Sudden deafness: lack of evidence for systemic viral infection. *Otolaryngol Head Neck Surg* 1998;**118**:397–9

3 Henderson D, Saunders SS. Acquisition of noise-induced hearing loss by railway workers. *Ear Hear* 1998;**19**:120–30

4 Clark WW, Popelka GR. Hearing levels of railroad trainmen. *Laryngoscope* 1990;**100**:1134–8

5 Malleson SM. Confirmation noise exposure levels by analysis of the audiometric data in long service underground train drivers. *J Occup Med* 1989;**39**:107–10

6 Salvinelli F, Maurizi M, Calamita S, D'Alatri L, Capelli A, Carbone A. The external ear and tympanic membrane. A three dimensional study. *Scand Audiol* 1991;**20**:253–6

7 Medical Research Council. *Damage Arising from Leisure Noise,* (a review of literature). London: Health and Safety Executive Books, 1985

8 Malchaire J. Strategy for prevention and control of the risks due to noise. *Occup Environ Med* 2000;**57**:361–9

9 Bhattacharya SK, Bandyopadhyay P, Kahyap SK. Calcutta metro: is it safe from noise pollution hazards? *Ind Health* 1996;**34**:45–50

10 Rice CG, Breslin M, Roper G. Sound levels from personal cassette players. *Br J Audiol* 1987;**21**:273–8

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