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Hearing loss associated with weapons noise exposure: when to investigate an asymmetrical loss

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Abstract

The air conduction thresholds in the right and left ears, and the interaural asymmetry of thresholds at 0.5, 1, 2, 3, 4 and 6 kHz were measured in a group of 225 soldiers exposed to a variety of weapon noise who were referred for assessment because of a deterioration in hearing on routine testing. At 0.5 and 1 kHz the threshold levels rarely exceeded 25 dB and the interaural asymmetry was 10 dB or less in 90 per cent of cases. The degree of hearing loss and interaural asymmetry increased as the frequency increased, with the average loss being significantly greater in the left ear at 2, 3, 4 and 6 kHz.

Recommendations are made for the selection of cases of asymmetrical hearing loss exposed to weapon noise which require further investigation to exclude a retrocochlear cause or to define spurious hearing threshold levels.

Key words: Hearing loss, noise induced; Hearing loss, sensorineural; Noise

Introduction

The risk of hearing from weapon noise exposure in the armed forces is great. Peak pressures of between 160 and 180 dB at the user's ear are common (Riihikangas *et al.*, 1980). The beneficial effects of ear defenders are limited for a number of reasons: firstly, they do not protect well against low frequency impulse noise (Ylikoski *et al.*, 1987); secondly, they may not attentuate sound as effectively in field conditions compared with the laboratory (Smoorenburg and Mimpen, 1982; Berger, 1983); and thirdly although issued, they are frequently not used (Riihikangas *et al.*, 1980).

The prevalence of acoustic trauma in servicemen is high. In 1980, 28 per cent of serving infantry personnel in the British Army had significant hearing loss from weapon noise exposure (Coombe, 1980). In 1975 in the US Army, 20–30 per cent of personnel with two or more years service in the combat arms branches had a clinically significant hearing loss. In soldiers with over 15 years service the percentage was over 50 (Walden *et al.*, 1975).

Asymmetry of hearing loss after weapon noise exposure is well recognized. With rifle fire the ear facing the muzzle is exposed to peak pressures 2-4 dB higher than the other ear (Ylikoski *et al.*, 1987). In right-handed persons shooting from the right shoulder the left ear is more severely damaged (McGill and Schuknecht, 1976; Ylikoski, 1989). The degree of hearing loss and asymmetry is, however, poorly documented for the range of weapons in common use.

Unilateral or asymmetrical sensorineural hearing loss is a potentially serious finding in otolaryngology because of the possibility of a retrocochlear cause such as an acoustic neuroma. In such cases further investigation is required unless there is a known reason for the difference between the two ears.

The War Pensions Directorate administers claims for disability relating to service in the armed forces in war or peace. In 1993 they received 180 000 new claims, 80 per cent of which were for hearing loss. Involvement in such cases and the audiometric assessment of servicemen prior to discharge from the Armed Forces has shown a large degree of asymmetry in hearing loss. In most cases there is a gradual loss over a number of years without firmly documented evidence that specific exposure to weapon noise was the cause; therefore, further investigation is required to exclude a retrocochlear pathlogy.

This study was designed to assess the severity of hearing loss and the degree of asymmetry in soldiers referred for audiometric assessment following hearing deterioration as a result of weapon noise exposure.

Patients and methods

Two hundred and thirty soldiers were assessed. All the subjects had a history of past weapon noise

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TABLE I
AVERAGE AIR CONDUCTION THRESHOLD LEVELS AND INTERAURAL DIFFERENCE AT 0.5, 1, 2, 3, 4 AND 6 KHZ

Frequency (kHz)	Right ear (dB)	Left ear (dB)	Difference	p-Value
0.5	10.0	10.1	− 0.1	$p = 0.790$
1	10.8	10.9	− 0.1	$p = 0.810$
2	15.8	19.6	− 3.8	$p = 0.001$
3	32.0	38.3	− 6.3	$p < 0.001$
4	45.3	54.8	− 9.5	$p < 0.001$
6	53.3	62.2	− 8.9	$p < 0.001$

exposure, each having been referred because of a deterioration in hearing detected on routine audiometry as part of a military hearing conservation programme. The average age of the group was 37.4 years with a range of 16 to 55 years.

An otological history was taken, with special attention given to the type and amount of previous weapon noise exposure. A full ENT examination was then performed. Pure tone audiometry was carried out by trained personnel in a soundproof chamber using a manually operated diagnostic audiometer. Air conduction thresholds for the frequencies 0.5, 1, 2, 3, 4 and 6 kHz were measured. The left ear was tested first. Retests were done at 1 kHz and the definitive thresholds taken as the best of the test and re-test thresholds. Bone conduction thresholds were measured on each side at 1, 2 and 3 kHz, and soldiers with conductive losses were further investigated by tympanometry and stapedial reflex testing.

Five soldiers were excluded from the study: two with suspected spurious hearing threshold levels (later confirmed by evoked response audiometry), two with a unilateral conductive hearing loss (one having a tympanic membrane perforation and the other otosclerosis), and one soldier with hearing loss following a severe head injury.

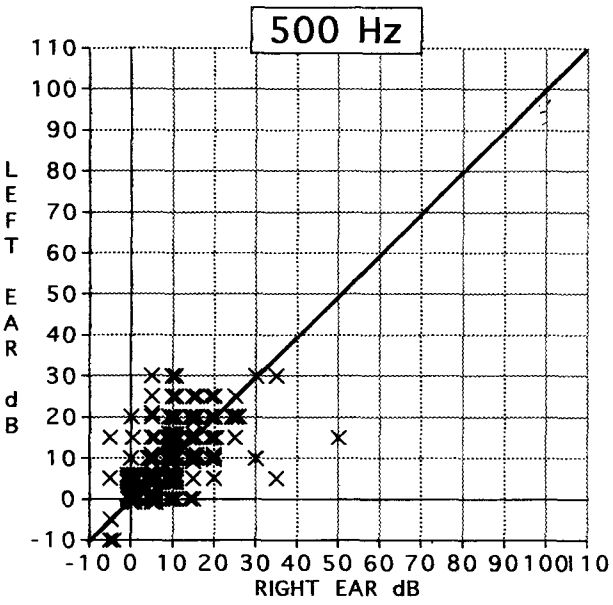

FIG. 1
Scatterplot comparing air conduction thresholds in the right and left ears at 0.5 kHz.

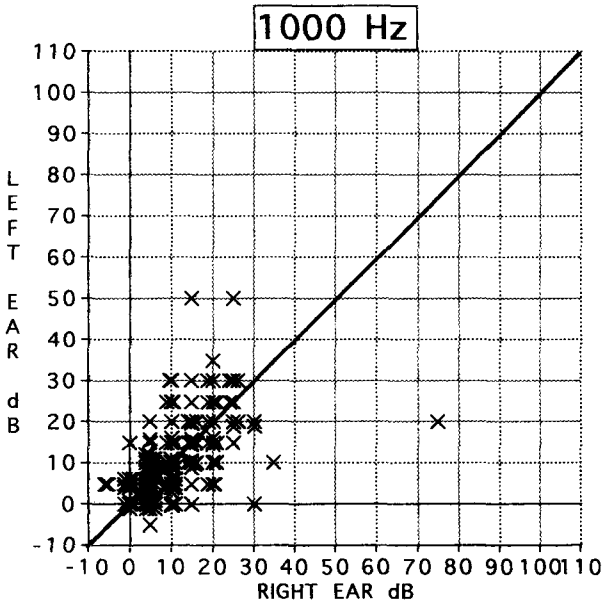

FIG. 2
Scatterplot comparing air conduction thresholds in the right and left ears at 1 kHz.

Results

The average air conduction threshold levels for right and left ears at 0.5, 1, 2, 3, 4 and 6 kHz are listed in Table I. The average air conduction threshold level increases as the frequency increases on both sides. The difference between the two ears is calculated by subtracting the average left ear threshold from the average right ear threshold, a negative figure indicating the hearing to be worse on the left side. At all frequencies the average air conduction threshold level was greater on the left. At 0.5 and 1 kHz the difference is not significant, but the significance increases with the frequency, being maximal at 4 kHz ($p < 0.001$).

The results for the six frequencies tested are demonstrated in three forms:

(i) Scatterplots - comparing the air conduction thresholds in the right and left ears, with a diagonal line of equivalence (Figures 1-6).

(ii) Histogram - showing the difference in air conduction thresholds between the two sides (a negative figure indicating the hearing is worse on the left) (Figure 7).

(iii) Graph of the cumulative total percentage - the percentage of soldiers in which the difference in air conduction thresholds between the two ears is within a given level in dB (Figure 8).

Discussion

The audiometric results from this group of servicemen show both the severity and asymmetry of hearing loss which may result from exposure to noise from weapons. Close attention to the noise exposure history usually reveals that a mixture of weapons has been used over a number of years. In some cases most of the noise exposure has been from rifle fire, and in these more hearing loss has occurred

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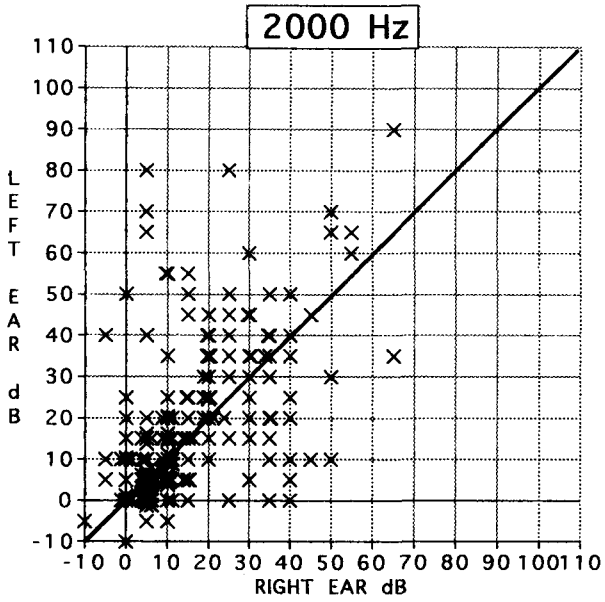

FIG. 3

Scatterplot comparing air conduction thresholds in the right and left ears at 2 kHz.

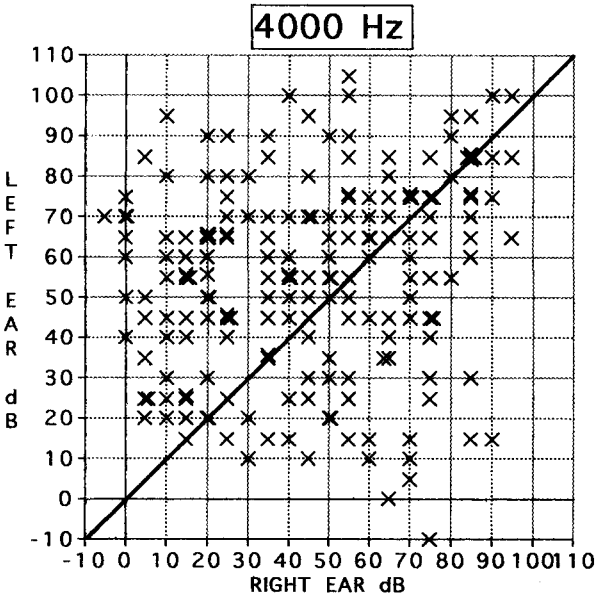

FIG. 5

Scatterplot comparing air conduction thresholds in the right and left ears at 4 kHz.

in the forward facing ear (usually the left); however, in the majority of cases there has been exposure to rifle, mortar, anti-tank and artillery fire in variable proportions, plus explosions, engine and radio noise, with or without ear defenders.

A number of important considerations arise when a unilateral or asymmetrical sensorineural hearing loss is detected.

(1) Is it a true asymmetry or is there a spurious hearing threshold level (non-organic hearing loss)?

The prevalence of non-organic hearing loss is very variable, depending on the population studied. In the Army the prevalence is highest in recruits when there is an increased degree of emotional disturbance and possibly emotional immaturity (Gold *et al.*, 1991), and in those who are leaving or have left the Army, when there is a potential for financial gain (Johnson *et al.*, 1956). Apart from these two groups the prevalence is low, with well motivated servicemen having little to gain and much to lose by producing spurious hearing threshold levels.

Hearing loss from noise exposure rarely affects the frequencies of 0.5 or 1 kHz to a significant degree. Of the 225 soldiers only eight exceeded a level of 25 dB in either ear at 0.5 kHz and only 16 at 1 kHz. In only two was the threshold worse than 25 dB in both ears.

In the assessment of claimants for noise-induced hearing loss, Coles and Mason (1984) have stated

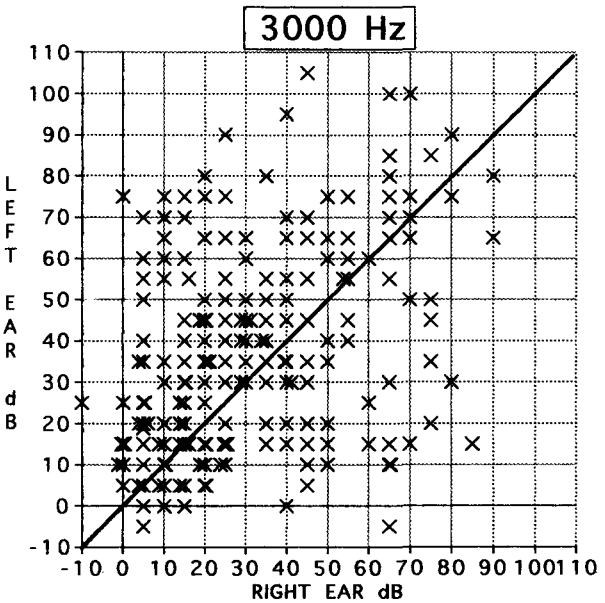

FIG. 4

Scatterplot comparing air conduction thresholds in the right and left ears at 3 kHz.

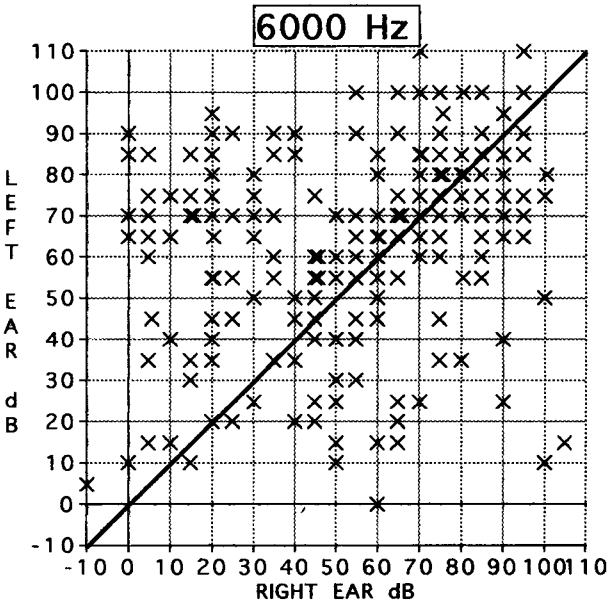

FIG. 6

Scatterplot comparing air conduction thresholds in the right and left ears at 6 kHz.

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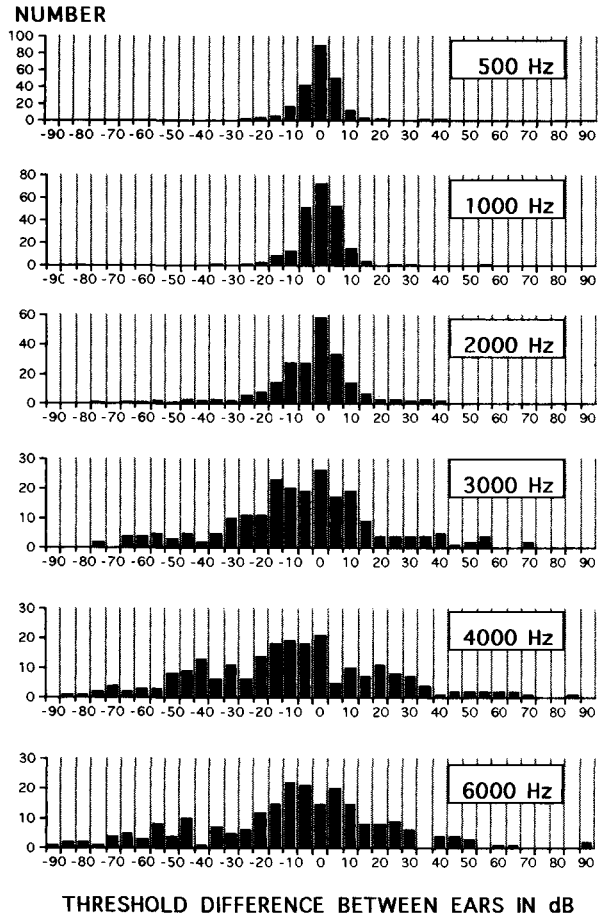

FIG. 7

Histogram showing the air conduction threshold level difference between right and left ears in 5 dB units.

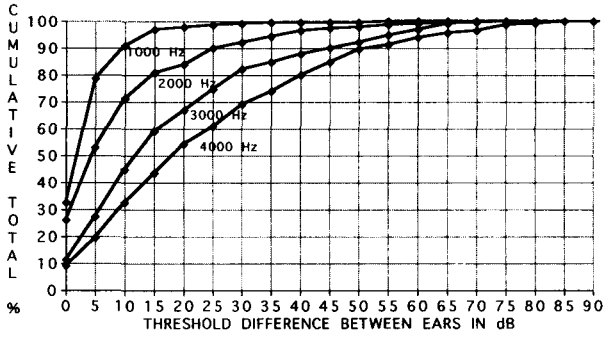

FIG. 8

Graph showing the air conduction threshold level difference between the two ears and the cumulative total percentage at 1, 2, 3 and 4 kHz.

that flattening of the audiogram is suggestive of spurious hearing threshold levels and recommend that such cases are further investigated by cortical evoked response audiometry. This recommendation is certainly validated by these results.

(2) Is the degree of asymmetry 'significant'?

In large scale hearing surveys the left ear appears to be slightly poorer than the right at high frequencies, especially at 4 kHz. At lower frequencies the right appears to be marginally poorer than the left (Ward, 1957; Kannan and Lipscomb, 1974; Axelsson *et al.*, 1981; Rudin *et al.*, 1988; Pirila *et al.*, 1991).

In most cases of industrial noise exposure it is expected that the hearing loss in the two ears will be symmetrical. Exceptions will occur if there is close proximity to the noise source of one side or the other, especially with hand-held tools. In a large study of cases sent for compensation assessment for presumed industrial hearing loss, Alberti *et al.* (1979) found that more than five per cent has a significant asymmetry in hearing thresholds (an average difference of 15 dB or more at 0.5, 1, 2 and 4 kHz) which was wholly attributable to workplace noise. In a smaller group, Robinson (1985) showed an average difference of 15 dB or more (at the frequencies of 0.5, 1, 2, 3, 4 and 6 kHz) in over 10 per cent of cases.

A greater degree of asymmetry of hearing loss is to be expected in weapon noise exposure. With rifle fire, the handedness of the subject will often be of relevance; however, careful questioning is required as some left-handed subjects have always fired right-handed or have changed from left to right during their careers. The new rifle in use is now right-hand fire only. For most other weapons the firing position is fixed and therefore the amount of noise exposure to the two ears is determined by the head position relative to the weapon. Other factors include the use of ear defenders on either side, and in radio operators the possible noise hazard from radio offsetting the protective effect of the headset.

The results from this study clearly show that the average loss in the middle and high frequencies is significantly greater in the left ear. At 0.5 and 1 kHz the average threshold is nearly identical on the two sides and the degree of asymmetry is small, with 90 per cent of cases showing agreement to within 10 dB. At higher frequencies the average hearing loss increases as the frequency increases, as does the degree of asymmetry, such that at 4 kHz only 33 per cent of cases agree to within 10 dB.

(3) Is there an 'acceptable' reason for the asymmetry?

The age range at detection of acoustic neuromas is wide, with up to 70 per cent diagnosed within the age range of this population (Johnson, 1977). The main presenting symptom in two-thirds is a progressive unilateral hearing loss and in over half the audiogram configuration is of a high frequency loss (Johnson, 1977; Moffat *et al.*, 1989). We are therefore obliged to exclude the possibility that an acoustic neuroma is the cause of an asymmetrical hearing loss in a fairly large proportion of individuals exposed to weapon noise.

The soldier may describe a particular episode of weapon noise exposure which was followed by severe hearing loss and tinnitus which only partially recovered. Sometimes the post-noise exposure audiogram can be compared with an earlier audiogram taken as part of a military hearing conservation programme. In these situations no further investigation is required; the soldier is protected from further hazardous noise and the audiogram is repeated six months to one year later. The loss may occur early in

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a soldier's career, perhaps in basic training, with no significant deterioration developing over a prolonged period. In the remainder, however, a deterioration in hearing may have occurred in one or both ears over a number of years in a serviceman exposed to a range of weapons. In such cases it is difficult to reliably attribute the hearing loss to the weapon noise exposure.

The configuration of the pure tone audiogram is often unhelpful in that not all cases of high frequency dips are caused by noise exposure, and not all cases of noise exposure show a high frequency dip. The 'textbook' description of noise-induced hearing loss is of a symmetrical high frequency sensorineural loss with a dip maximal at 3, 4 or 6 kHz, but in weapon noise exposure the greatest loss may be at 8 kHz or above in 30 per cent of cases and will not be seen as a notch or dip as the frequencies above 8 kHz are rarely tested (Ylikoski, 1989).

Conclusions

- Asymmetrical hearing loss is common after weapon noise exposure. This is significant at 2, 3, 4 and 6 kHz. The hearing loss is greater on the left.
- In some cases, asymmetry is the result of a unilateral conductive hearing loss, a well documented head injury or exposure to bomb blast and need not be investigated further.
- Investigation to exclude a retrocochlear pathology or spurious hearing threshold level is necessary when: (a) the air conduction threshold in either ear exceeds 25 dB at 0.5 or 1 kHz; or (b) when the difference in air conduction thresholds between the two sides exceeds 10 dB at the same frequencies.
- In the absence of other clinical indications, immediate investigations are not required in soldiers giving a history of considerable exposure to weapon noise despite an average difference in air conduction thresholds of greater than 10 dB over the frequencies 0.5, 1, 2, 3, 4 and 6 kHz. The soldier should be protected from further noise hazard and pure tone audiometry repeated at six months to one year later. In the presence of further deterioration despite protection from hazardous noise, further investigation should be instituted.

The finding of an average difference of greater than 10 dB over this frequency range in the absence of a substantial history of weapon noise exposure requires further investigation.

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