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Risk management of asymmetrical hearing impairment in an armed forces population

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Abstract

The prevalence of asymmetrical hearing impairment in the entire service population (1490 individuals) of a Royal Air Force flying station was estimated from routine audiometric testing recorded in individuals' medical records. Criteria for magnetic resonance imaging (MRI) scanning to exclude the possibility of vestibular schwannoma were determined in accordance with the risk management principle that the cost of the screening should not exceed the value of the likely benefit. MRI scanning should be carried out in the presence of an asymmetrical sensorineural hearing impairment of (a) 15 dB or more at two adjacent frequencies, or (b) 15 dB or more averaged over 0.5, 1, 2, 3, 4, 6 and 8 kHz.

Key words: Hearing loss, sensorineural; Audiometry; Neuroma, acoustic; Mass screening; Magnetic resonance imaging; Risk management

Introduction

From being a response to litigation in the USA over 25 years ago, risk management has now become an integral part of hospitals' programmes to improve the quality of care. Efforts are particularly directed at reducing the chance of adverse incidents occurring as a direct result of treatment, and when these do occur, to reduce their impact. The origin of risk management even earlier in commerce is evident in the definition, 'the identification, analysis and economic control of the risks which can threaten the assets or earning capacity of an enterprise'.[1] The 'assets' may be regarded as good health as well as economic assets and the 'enterprise' may refer to patients as individuals as well as hospitals and other organizations. The corollary to this economic background is that risk management programmes should cost less than the risks that they are attempting to avoid.

The presence of asymmetrical sensorineural hearing impairment is well established as the commonest finding at the presentation of vestibular schwannomata (acoustic neuromata) and other, rarer lateral skull-base tumours. The risk to be managed is that a particular patient who has been found (by whatever means) to have an asymmetrical sensorineural hearing impairment (however defined) turns out to have a tumour. The cost of the risk is the additional cost of late diagnosis of tumours, compared with prompt diagnosis, multiplied by the incidence of the late tumours. The cost of risk management is the cost of each set of investigations multiplied by the number of investigations required.

The incidence of vestibular schwannoma is 0.8:100,000 per annum.[2]

The additional cost of a poor treatment result due to operating on a larger tumour was estimated at £380,000 in 1989,[3] equivalent to £566,000 now, adjusted in line with the retail price index. Prior to the advent of widespread screening, the proportion of large tumours was around 60 per cent.[2,3] Given that the outcome of the 40 per cent of smaller tumours would be unaffected by the risk management programme, the best that could possibly be expected would be the earlier detection of all of the bigger tumours. The maximum possible cost saving would therefore be $0.8 \times 0.6 \times$ £566,000 = £272,000 per 100,000 population per annum.

MRI scanning is recognized as the 'gold standard' in the diagnosis of vestibular schwannoma and is now recommended as the first line investigation.[4] The cost of an MRI scan compares favourably with other methods and if a vestibular schwannoma is not detected by an MRI scan, it is unlikely to be detected in any other way. The aim of this paper was to determine the cost of screening each individual in the RAF with an asymmetrical hearing impairment and to determine at what level of asymmetry investigation would be cost effective.

Method

Data were obtained from the available medical records belonging to all of the military personnel at a single RAF flying station.

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TABLE I
COST OF EACH TEST

Element	Cost (£)
Fresh case out-patient appointment	86
Review out-patient appointment	44
MRI scan (including report)	274
Three days' pay	150
Total	554

Personnel currently have air conducting pure tone audiometry on entering the armed forces and at various intervals, not exceeding five years, thereafter depending upon age and trade. Each medical record therefore contained at least one audiogram. Frequencies tested were 0.5, 1, 2, 3, 4, 6, and in most cases, 8 kHz. Medical histories were examined and patients known to have a conductive hearing loss and/or chronic ear disease were excluded.

For each serviceman the most recent audiogram was recorded. Additional data recorded were age, rank, trade and years of service with the RAF. Data were entered direct into a database written by one of us (CRP) who also wrote the software for the data analysis.

The cost of each screening test was derived from extra-contractual referral rates at the authors' hospital and the daily rate of pay was calculated as the mean basic daily rate of pay of the servicemen[1] involved.

For each serviceman the audiometric data were compared between the two sides and the prevalence of asymmetry using a number of different criteria was derived. The criteria used were 10, 15, or 20 dB hearing threshold difference at a single frequency or any two frequencies; 10, 15, or 20 dB at two adjacent frequencies; or 5, 10, 15, or 20 dB averaged across all frequencies.

The raw data in our study reveal the prevalence of asymmetric hearing impairment in the study population. In the absence of a longitudinal study, we have made the assumption that the prevalence of asymmetry in recruits is very low and that the annual incidence remains uniform (rather than increasing, say, with age) in the given population over an extended period. Thus we have estimated the incidence of new cases of asymmetry per year as the prevalence divided by the average number of years served.

Results

One thousand four hundred and ninety medical records were examined. Eighteen were excluded for a past history of ear disease and data from 1472 records were therefore used in the risk management analysis. One thousand three hundred and fifty personnel were male and 122 female. Distribution of length of service is shown in Figure 1. The flying station concerned serves as a training base and this accounts for the high number of personnel in their first year of service. The mean length of service (completed years) was 10.7 years and the average age (at the last audiogram) was 30.2 years.

[1]In this paper 'serviceman' refers to personnel of both sexes.

TABLE II
PREVALENCE OF ASYMMETRICAL HEARING IMPAIRMENT USING VARIOUS CRITERIA

Criterion	Personnel (*n*)	Prevalence (per 100,000)
10 dB difference at one frequency	1 137	77 242
15 dB difference at one frequency	642	43 614
20 dB difference at one frequency	331	22 486
10 dB difference at any two frequencies	678	46 060
15 dB difference at any two frequencies	244	16 576
20 dB difference at any two frequencies	100	6 793
10 dB difference at two adjacent frequencies	172	11 685
15 dB difference at two adjacent frequencies	55	3 736
20 dB difference at two adjacent frequencies	21	1 427
5 dB average difference	283	19 226
10 dB average difference	75	5 095
15 dB average difference	25	1 698
20 dB average difference	8	543

The elements of the cost of each test to exclude vestibular schwannoma are shown in Table I.

The prevalence of asymmetrical hearing impairment at each of the 13 criteria is shown in Table II. The left ear was the worse ear in two out of three cases (data not shown) a fairly constant proportion whichever criterion was used. The approximate incidence (derived from the prevalence, as described above) and the annual cost of screening (per 100,000 servicemen) is shown in Table III.

It is seen from Table III that the criteria which lead to the cost of screening being less than the value of the maximum benefit (£272,000) are 15 dB or more difference at two adjacent frequencies, or 10 dB or more average difference. When these two criteria were combined, 92 individuals were found to have an asymmetrical hearing impairment, and the

TABLE III
INCIDENCE OF ASYMMETRICAL HEARING IMPAIRMENT AND COST OF SCREENING PER 100,000

Criterion	Incidence (new cases/ year)	Cost of screening (£)
10 dB difference at one frequency	7 215	3 997 000
15 dB difference at one frequency	4 074	2 257 000
20 dB difference at one frequency	2 101	1 164 000
10 dB difference at any two frequencies	4 303	2 384 000
15 dB difference at any two frequencies	1 548	858 000
20 dB difference at any two frequencies	635	352 000
10 dB difference at two adjacent frequencies	1 092	605 000
15 dB difference at two adjacent frequencies	349	193 000
20 dB difference at two adjacent frequencies	133	74 000
5 dB average difference	1 796	995 000
10 dB average difference	476	264 000
15 dB average difference	159	88 000
20 dB average difference	51	28 000

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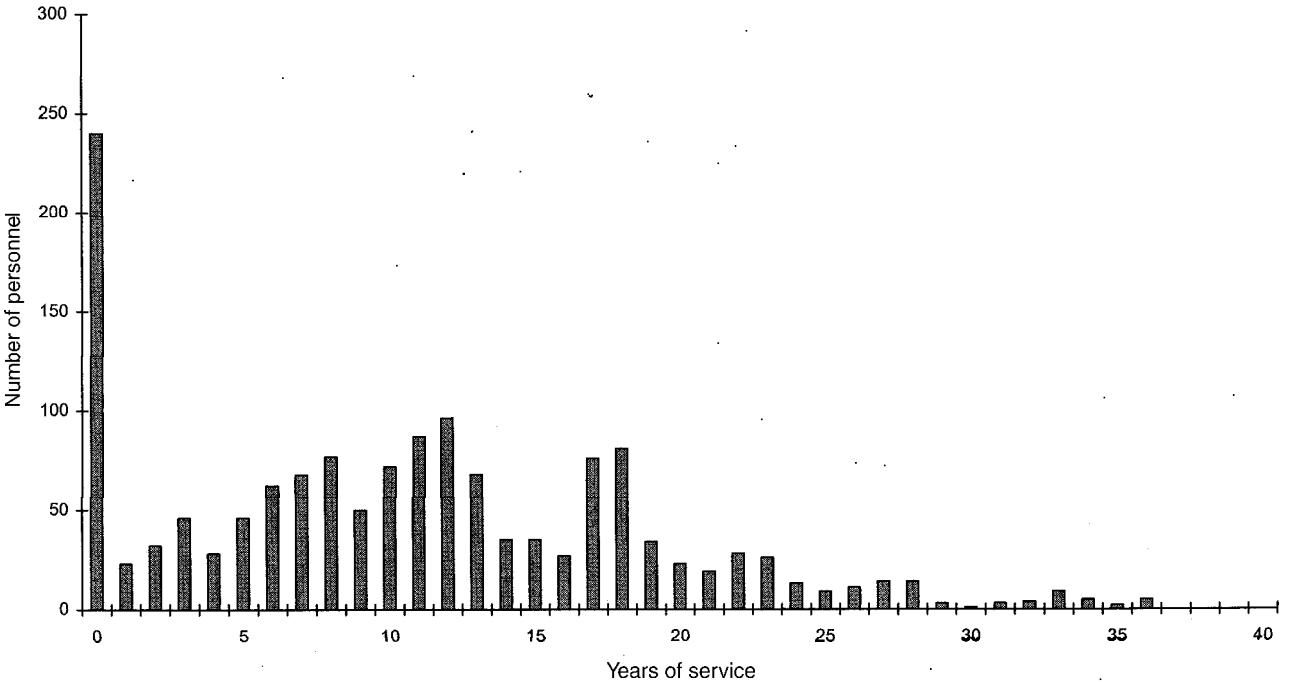

FIG. 1
Distribution of years of completed service.

cost of MRI screening was £323,000. When 15 dB or more difference at two adjacent frequencies, or 15 dB or more average difference were combined, 61 individuals were found to have an asymmetrical hearing impairment, and the cost was £214,000.

Using this criterion, the prevalence of asymmetry (grouped in three-year bands to produce a clearer pattern) is shown in Figure 2. The straight line represents the line of best fit using the least squares method with a coefficient of determination, R^2 = 0.91. This histogram confirms that our assumptions that the prevalence of asymmetry in recruits is very low and that the annual incidence is uniform are both true.

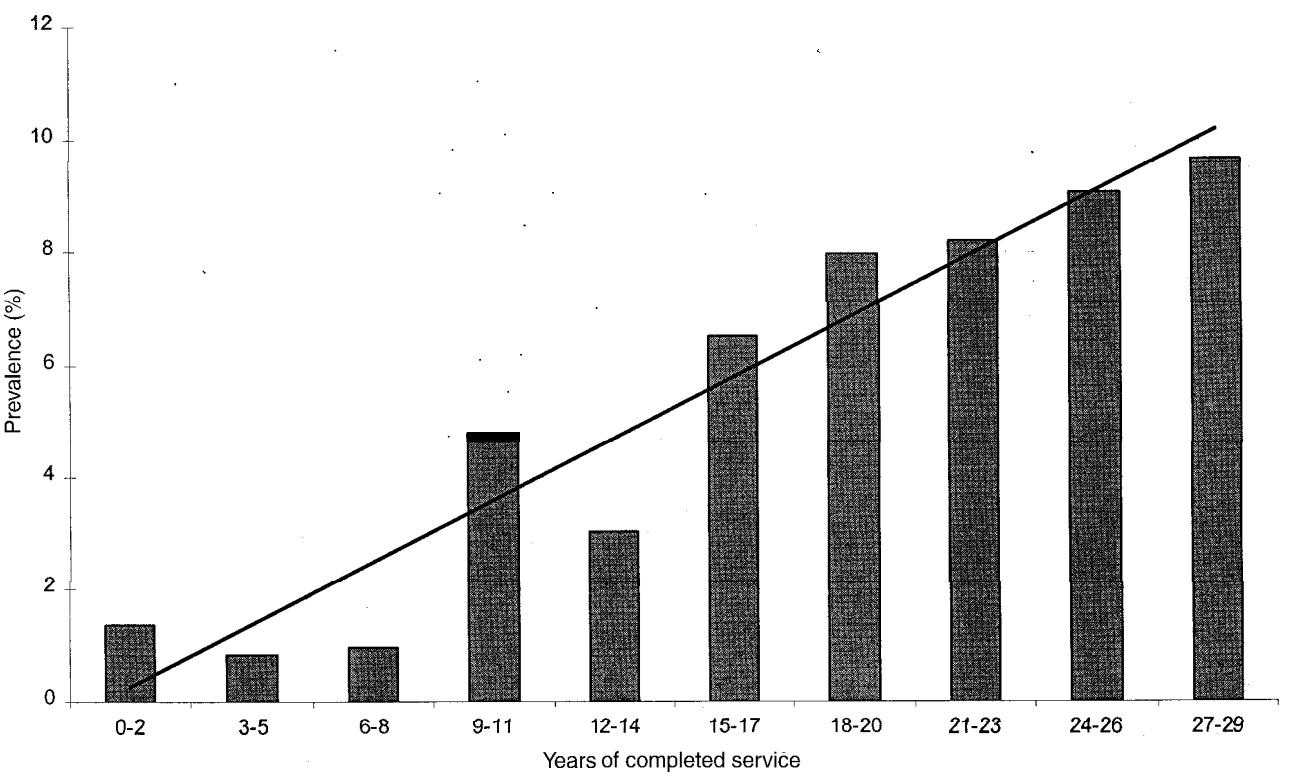

FIG. 2
Prevalence of asymmetry by years of service.

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Discussion

There is little debate that in general otological practice investigation of asymmetrical sensorineural hearing impairment to exclude vestibular schwannoma is a highly cost effective screening procedure. What is open to debate is the precise criterion used to define 'asymmetrical'.[5] In the UK the Northern regional guidelines propose an asymmetrical sensorineural hearing impairment of 20 dB or greater at two adjacent frequencies, even if there is another accountable cause.[4] Perhaps driven by rumours (which we have been unable to substantiate in communications with the UK's two principal indemnity organizations, the Clinical Negligence Scheme for Trusts, and the NHS Litigation Authority) that delayed diagnosis of vestibular schwannoma is the commonest cause of litigation in otology, the indications from informal conversations at medical meetings, etc are that some otologists may be using a difference of 20 dB or even less at a single frequency as their criterion for screening investigation.

It is something of a truism that patients in general otological clinics have otological symptoms. Service patients are distinctive in that many are asymptomatic – referral commonly arises as the result of a hearing loss (in one or both ears) discovered in the hearing conservation programme. The armed forces are one of the UK's biggest employers and noise exposure, albeit with appropriate ear defenders, is common and arises from the use of weapons, machines, and proximity to vehicles and aircraft. The particular problem faced by the armed forces was to balance the requirements of best practice with the need to avoid unnecessary expense and the risk of overwhelming the MRI scanners. The only rational solution was to establish criteria for screening investigations, *a priori*, using risk management principles.

Routine audiometry for service personnel includes air conducting thresholds only. At the time of audiometry the health of the middle ear is checked and tuning fork tests are used to differentiate between sensorineural and conductive components of hearing impairment. Any individuals known to have middle-ear disease were excluded from the analysis. We have assumed that the remainder did not have a significant conductive component. If a significant proportion did, the effect would be to lower the incidence of asymmetrical sensorineural hearing impairment that in turn would lower the cost of screening. Our criteria for screening may therefore overestimate the degree of asymmetry at which screening becomes cost effective.

With a training role, the flying station under study had an unusually high proportion of personnel in their first year of service. We considered excluding these personnel from the analysis on the assumption that they would have normal hearing on entry and have had insufficient time for that to change, but separate analysis (not shown) revealed that our conclusions were the same either way. The average age of the study population was low compared with the general population, and given that the incidence of vestibular schwannomata increases with age, we would expect a lower incidence of vestibular schwannoma than assumed above. If that were the case, the yield of positive MRI results would be lower than we have calculated, and in our population the criteria might not be cost effective, albeit by a small margin. Conversely, in an older population, the criteria would be more cost effective, although there would then be the risk (again small) that cases of vestibular schwannoma might be missed because the threshold was set too high. Because we have no data as to the incidence of vestibular schwannoma in the service population, we have made no assumptions in this respect.

In the absence of a longitudinal study, which would require considerable resources, the annual incidence of asymmetrical hearing impairment may be derived from the prevalence divided by the number of years over which the impairment has arisen, provided that the prevalence at year 0 is very low and that the annual incidence is uniform. The impressively linear increase in prevalence with the number of years served (Figure 2) allows us to make that assumption safely. Our study has defined the appropriate threshold for investigation that is appropriate when a new case of asymmetrical hearing impairment is discovered. Since the incidence of impairment was uniform in our population, we may also deduce that there is no need to establish different criteria for length of service, or by implication, the closely related factor of age.

An age-related prevalence of asymmetrical hearing impairment has been shown elsewhere.[6] Quite obviously the number of years served is highly correlated with age (correlation coefficient = 0.934). It is not quite unity because the age of recruits varies from 17 years to the mid-twenties. What we cannot deduce is whether the steady increase in asymmetry is due to age alone, or some other factor associated with service in RAF, possibly noise exposure. This is the subject of a further study.

Although screening becomes cost effective if the difference is 15 dB or more at two adjacent frequencies, or 10 dB average when the two subsets are taken individually, combination of the criteria shows that the two subsets only overlap partially, and the combined criterion ceases to be cost effective. The combined criterion of 15 dB or more at two adjacent frequencies, or 15 dB average is however cost effective. It is worth noting that this threshold is no higher than the majority of published recommendations.

One of the principal difficulties of risk management is knowing which costs to include. The cost of the MRI scan is unavoidable. Although under current guidelines, referral for a newly diagnosed significant hearing loss is mandatory, the out-patient costs and much of the wasted days' pay could be avoided if GPs requested the MRI scans direct. No study that we have seen has included the element of pay for a day spent away from work. For many servicemen a visit to the hospital requires a day away from work due to the distance travelled. Since the

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patients' employer and the medical services are part of the same organization, the cost should be included. In civilian practice less time might be spent away from work, and the hospital does not in any case have to bear the cost. To ignore this cost however would be to take a very narrow view of risk management. Perhaps surprisingly, even if the cost of the screening investigation was reduced to the cost of the MRI alone, the criteria that are cost effective (Table III) would be almost the same.

The benefits of early diagnosis are even more dependent upon a complex set of assumptions concerning the cost of treatment, rehabilitation, and disability and other benefits. Early pensions depend upon a variety of factors (even within a single organization) and are not easy to calculate. The lost value of training and experience is even harder to quantify. Although the value of early treatment could be limited to that incurred by the armed forces, once again this takes a narrow view of risk management and we have therefore chosen to accept the previous estimate of the value of early treatment adjusted for inflation.[3]

It has been suggested that the principal alternative cause for a progressive sensorineural hearing loss in service personnel is noise exposure: although weapons might account for a large number of cases of left-sided hearing loss[7] we found that the worse ear was the right ear in one third of cases. If this is a chance occurrence, a similar number of left-sided losses should also have occurred by chance and we feel that it is unsafe to assume that the cause is noise exposure just because the left is the worse side.

If noise is indeed the principal cause, the use of established guidelines might have resulted in an excessive number of patients presenting for screening investigations, but we have found that the appropriate threshold for cost-effective screening is, if anything, lower than published guidelines. The chance of an asymmetrical hearing impairment of only 12 dB averaged over 0.5, 1, 2, 3, 4, and 6 kHz being due to noise is only five per cent.[8] Since our guidelines require a greater degree of asymmetry, noise exposure (in any industry) is not therefore a reason for deferring investigation.

Conclusion

Application of the principle that any risk management programme should identify the maximum number of personnel at risk whilst ensuring that the cost of the programme does not exceed the value of the benefits leads us to recommend referral for an otological opinion for anybody found to have a symmetrical hearing impairment of:
(a) 15 dB or more at two adjacent frequencies, or
(b) 15 dB or more averaged over 0.5, 1, 2, 3, 4, 6, and 8 kHz.

If air and bone conducting audiometry confirms that the impairment is sensorineural, an MRI scan should be performed.

Individuals who present with other otological symptoms should be investigated in accordance with established criteria such as the Northern regional guidelines already mentioned.

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