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A study of mercuric oxide and zinc-air battery life in hearing aids

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Abstract

The requirement to phase out mercuric oxide (mercury) batteries on environmental grounds has led to the widespread introduction of zinc-air technology. The possibility arises that high drain hearing aids may not be adequately catered for by zinc-air cells, leading to poor performance. This study investigated the hearing aid user's ability to perceive differences between zinc-air and mercury cells in normal everyday usage. The data was collected for 100 experienced hearing aid users in field trials. Users report 50 per cent greater life for zinc-air cells in high power aids and 28 per cent in low power aids. The average life of the zinc-air cells range from 15 days in high power to 34 days in low power aids. Users are able to perceive a difference in sound quality in favour of zinc-air cells for low and medium power aids. The hearing aid population is not disadvantaged by phasing out mercury cells.

Key words: Hearing aids; Power sources; Environment

Introduction

Prompted in some instances by legislative requirements (EEC Council Directive, 1991), there has been a growing trend for environmental awareness within the consumer battery industry over the last several years which has mainly focussed upon the reduction of the heavy metal content of batteries. The main intention has been to reduce the potential impact of spent batteries finding their way back into the environment via land filling. For the hearing aid industry this has resulted in the gradual replacement of mercuric oxide (HgO or mercury) batteries with the less polluting zinc air system. Replacement of the mercury system has been so extensive that some manufacturers no longer produce mercury cells.

In 1993 the United Kingdom National Health Service Supplies Organisation carried out successful trials of zinc-air batteries (CP44) and in 1993 (Dear Colleague letter) supplies of mercury batteries (CP1) were phased out for all types of hearing aids.

The replacement of mercury batteries led to a concern about the possibility that instruments demanding high currents would not be adequately catered for by zinc-air technology (Glover, 1995).

Most zinc-air systems operate at a lower running voltage than the mercury batteries they replace. The running voltage of a battery often has a controlling influence over the output of hearing aids and indeed there is a great variation between the performance of different manufacturers CP44 cells under different loadings (Figure 1).

Laboratory studies show clearly (Figure 1) that zinc-air batteries are capable of providing twice the life of mercury batteries dependent upon manufacturer and rate of discharge. What is not clear from these discharge tests is whether the initial higher running voltage of the mercury battery results in any perceived improvement in sound quality for the hearing aid user.

The aim of this study therefore, was to test the hypotheses that a) users can perceive a difference between the life of zinc-air and mercury batteries in real life hearing aid usage and b) users cannot detect a difference in sound quality between zinc-air and mercury batteries in real life hearing aid usage.

Method

The majority of information for this paper has been extracted from an analysis of the batteries used by 100 experienced hearing instrument patients at Glan Clwyd hospital in Rhyl, North Wales. Data was collected between between June 1993 and January 1996. Those people who had binaural fittings were asked just to use survey batteries in the instrument in one ear. Patients were provided with commercially available batteries only. For the purposes of this paper battery types have been grouped as either zinc-air or mercuric oxide (mercury). All batteries were identically tabbed, placed in numbered battery packs in a random order known only to the author in multiples of three or six, and were then numbered

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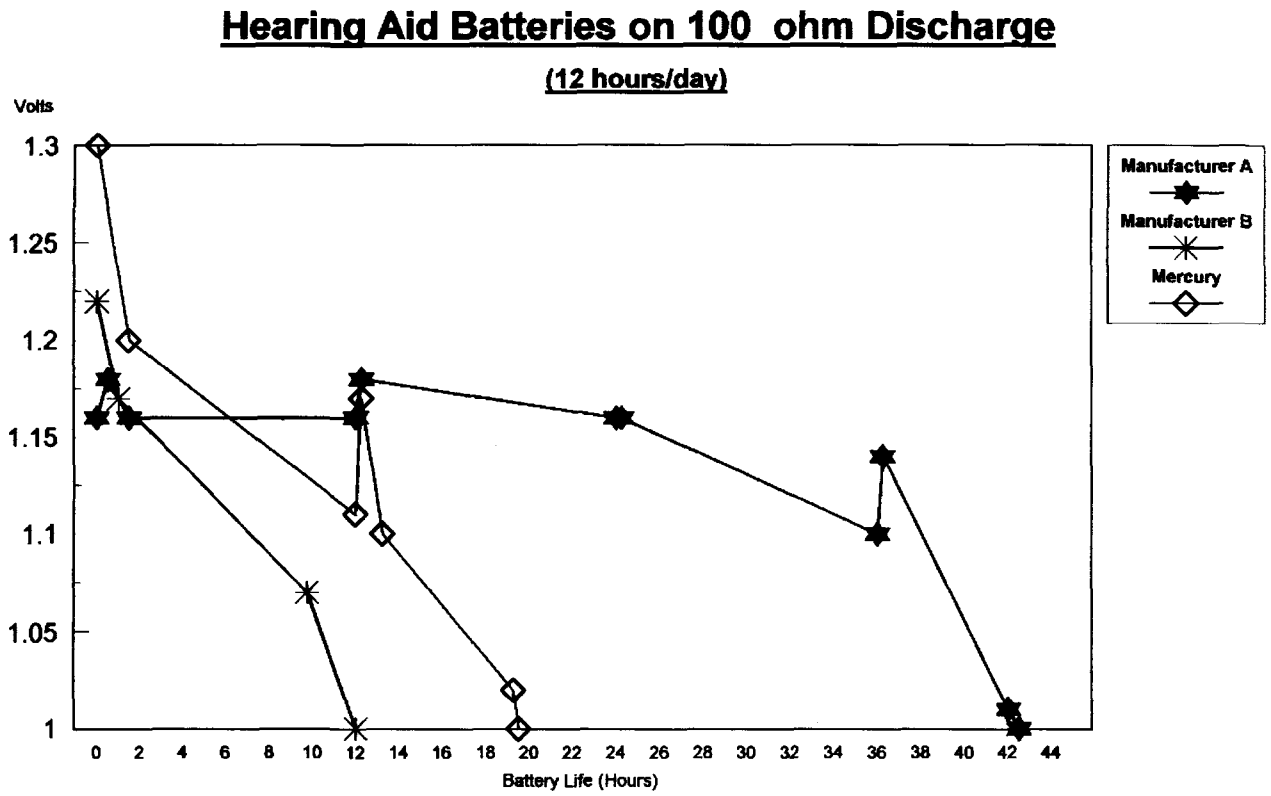

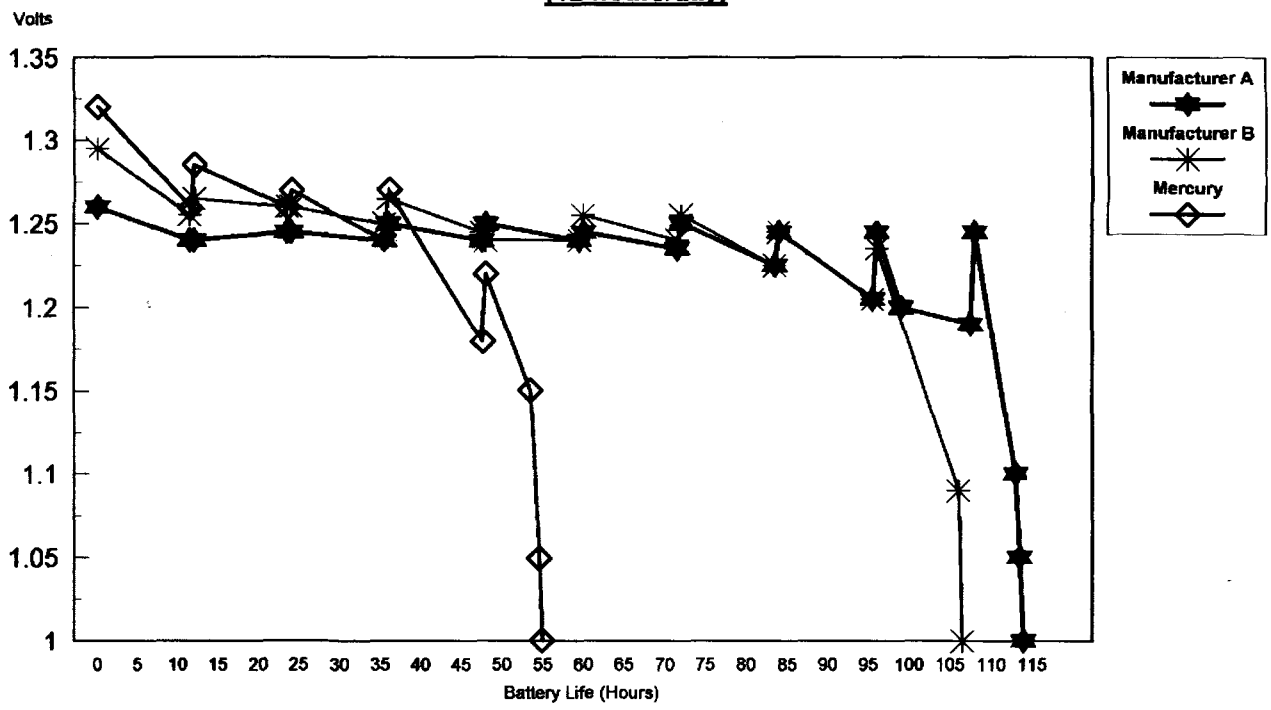

FIG. 1

Battery voltage against time for two simulations of hearing aid type. 100 ohm/12 hours per day, for high drain instruments and 330 ohm/12 hours per day, for medium drain instruments (Products were of 1993 manufacture).

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for identification i.e. patients were only aware of the battery pack number and the battery number and not what type of battery they were using. The fact that there is more zinc-air data than mercury is because several zinc-air manufacturers were studied. This does not affect the analysis unduly since the mercury sample size is sufficient to represent the full population.

The patients were then asked to provide certain basic information about the life of each battery; battery life in days, battery life rating and sound quality ratings are reported. The battery life and sound quality ratings were obtained by selection of a performance category which was then assigned a numerical value once the questionnaires were returned.

Performance categories and score allocations were as follows:

Excellent	−5
Good	−4
Acceptable	−3
Poor	−2
Dreadful	−1

This work has been restricted to results from NHS 675 (CP44) size hearing instruments and all the statistically reported data is taken from users who have experienced testing both zinc-air and mercury batteries although it will be unknown to the patients concerned. National Health issued hearing aids conform to three basic classifications namely low power BE10 series, medium power BE30 series and high power BE50 series. The statistically analysed findings have been grouped by these hearing aid series. This study has been aimed at understanding typical lifetimes and user perceptions of hearing aid batteries, therefore, no attempt has been made at this point to discriminate between one type of aid within a given series and another even though the difference in current drain between a BE51 aid and BE53 may be quite marked. Hearing aid settings and typical daily usage (in hours) also affect battery lifetimes (in days) but again have not been used for sorting data on this occasion.

The statistical findings from a total of 657 batteries are reported. Some data has been excluded from the database, this was only done under the following circumstances:– Incorrectly filled in questionnaires; questionnaires in a sequence containing confused or overlapping insertion/removal dates; reported faulty instruments; reported ear infections or other ailments impeding sound perception; batteries being replaced as a precaution prior to an important event; Users reporting instruments left switched on overnight.

Additionally because all batteries were returned after completion of testing it was possible to discharge all cells for which the tabs had been replaced. It was therefore possible to exclude some zero life results on the grounds that the battery was functioning perfectly well when returned.

The process of removing questionable data from the database will not have been complete partly because some users will not have reported problems with either their health or their hearing aids. The fact that batteries are issued for free may also create minor problems with the data since when problems arise, replacing a battery is simple and does not involve the user in any inconvenience or cost. Such factors as build up of ear wax or moisture in connecting tubes, etc., will have had some effect on results, and it is virtually impossible to be certain if a patient has inserted the wrong battery in the hearing aid; there are for example some instances where it appears that zinc-air batteries were assigned a mercuric oxide battery number by the patient, however, suspicion was not used as grounds for exclusion.

An analysis of user comments has also been carried out. Each battery questionnaire sheet had a space for user comments which was primarily intended for information such as changes in patterns of usage. However, the comments section was used by patients for providing unsolicited remarks concerning battery performance. The user comments have been extracted, not only from the Glan Clwyd Hospital Survey, but also from a smaller study carried out in conjunction with the National Deaf Children's Society. The study group was extended in particular to obtain more information regarding a range of high power commercial aids. Comments have been classed as being either favourable or adverse.

Results

Battery life

The life of the battery was measured in terms of length of service as recorded by the user and users subjective rating. Figure 2 shows the life in days for BE50 hearing aids versus the battery life rating. The

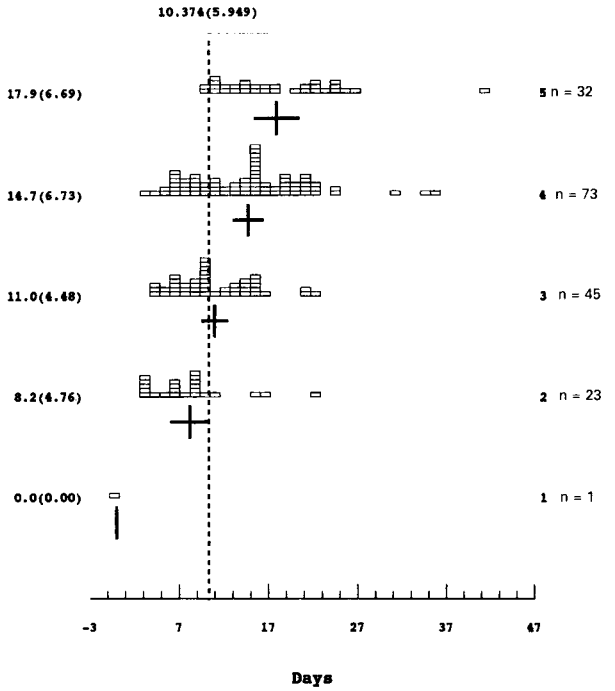

FIG. 2

User panel survey, NHS BE50 Series aids: Life in days versus battery life rating.

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TABLE I
USER PANEL DATA FOR NHS HEARING AIDS. LIFE IN DAYS OF INDIVIDUAL BATTERIES

		Zinc-air		Mercury			
AID	Number of users	n	Median	n	Median	*p* value	Better for:
BE 50	9	123	15	25	10	0.00004	Zn/air*
BE 30	18	296	15	58	10	<0.0001	Zn/air*
BE 10	9	66	32	16	19	0.003	Zn/air*
E39PL	9	207	8	27	6	0.014	Zn/air*

* Denotes a difference of $p<0.05$ Mann-Whitney test.

TABLE II
USER PANEL DATA FOR NHS HEARING AIDS. LIFE RATING (ON A FIVE POINT SCALE) OF INDIVIDUAL BATTERIES

		Zinc-air		Mercury			
AID	Number of users	n	Median	n	Median	*p* value	Better for:
BE 50	9	121	4	24	3	0.00101	Zn/air*
BE 30	18	295	4	56	2	<0.0001	Zn/air*
BE 10	9	65	4	15	3	0.00032	Zn/air*
E39PL	9	191	4	27	3	0.0258	Zn/air*

* Denotes a difference of $p<0.05$ Mann-Whitney test.

TABLE III
USER PANEL DATA FOR NHS HEARING AIDS. SOUND QUALITY RATING (ON A FIVE POINT SCALE) OF INDIVIDUAL BATTERIES

		Zinc-air		Mercury			
AID	Number of users	n	Median	n	Median	*p* value	Better for:
BE 50	9	122	4	25	3	0.0753	Zn-air
BE 30	18	258	4	50	3	0.00022	Zn-air*
BE 10	9	66	4	16	3	0.265	Zn-air
E39PL	9	191	4	27	3	0.0956	Zn-air

* Denotes a difference of $p<0.05$ Mann-Whitney test.

distribution by rating closely correlates with the recorded battery life. The dotted line represents the mean life of all batteries including mercury. The vertical and horizontal lines represent the mean and 95 per cent confidence interval within each rating. The mean life and standard deviation are quoted on the left of the left axis for each rating. Data in Tables I, II and III are grouped by NHS hearing aid series. Within each series hearing aids are manufactured to the same tender specification, 50 series being high powered and 30 and 10, medium and low power respectively.

The user recorded battery life for high and medium power hearing aids, as shown in Table I, is significantly longer for zinc-air cells. In low power hearing aids the difference is still in favour of zinc-air. Users report 50 per cent greater life zinc-air cells in high power aids and 59 per cent and 28 per cent respectively for medium and low power. The life of zinc-air cells range, on average, from 15 days in BE50s to 34 days in BE10s.

The battery life rating for all hearing aid types (Table II) is significantly higher for zinc-air cells. Users are generally more than satisfied with the life of zinc-air batteries with a median of "Good" but the life time of mercury batteries is often regarded as unacceptable or "Poor".

Sound quality

The users rating of sound quality (Table III) was always superior for zinc-air cells, however it was not significant for the BE50 and 10 series ($p>0.05$). The sound quality of zinc-air batteries was rated as "Good" and mercury as "Acceptable". These results are further supported by the comments made by users (Figure 3) where mercury batteries generally receive a greater percentage of adverse and a lower percentage of favourable comments than zinc-air batteries irrespective of aid type.

Discussion

Before the trial commenced there was a degree of scepticism regarding the reliability of responses that would be received particularly in relation to battery life and sound quality ratings. Whereas it is unrealistic to correlate the recorded life versus battery life rating, on the grouped data for BE50 hearing aids (Figure 1) it is shown that users are surprisingly accurate in correctly rating the life, especially in view of the fact that there were three different types of instruments at a variety of different gain settings. The pattern was similar for BE30 and 10 series aids.

The Mann-Whitney non-parametric ranking test was used to analyse the data. This is because as there

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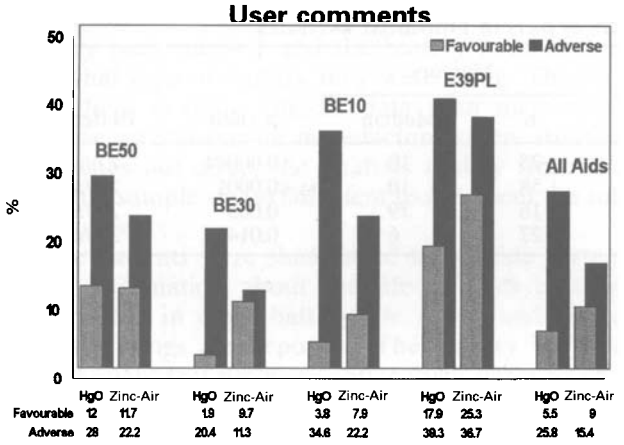

FIG. 3

Analysis of user comments by type of aid. A total of 163 mercury and 1766 zinc-air batteries were tested. The percentage of adverse and favourable comments are reported.

are outliers caused by different usage patterns i.e. difference between two hours per day and 16 hours per day, some of the data may not have been normally distributed. This would have been compounded by the fact that there are several different models of aids within each group, and in the case of high power aids some batteries apparently did not work properly (some zinc-air battery manufacturers covered in the survey produce cells which are not suitable for high power aids on high settings).

A group analysis has been performed between zinc-air and mercury battery types. A within user analysis would have been possible from the design and would have been more sensitive. However since differences reported are significant, the weaker analytical approach does not invalidate the result.

The life of zinc-air cells in the laboratory has been shown to be twice that of mercury (Cretzmeyer *et al.*, 1977) and more recently by the author Lacey in a range of commercially available instruments. In this study, user reports show there to be 50 per cent greater life for BE50 series aids and 59 per cent and 28 per cent for BE30s and BE10s. The fact that zinc-air life is not double that of mercury may indicate that many users are replacing their batteries before they are exhausted. Factors such as moisture in the tubing, poorly fitting moulds, accumulations of wax, etc. could be partially responsible for this effect. Since mercury batteries have a higher running voltage than zinc-air, at least initially, they would be expected to be less susceptible to some of these effects. The higher initial running voltage of the mercury batteries may also lead some users to set their hearing aids on a lower gain setting than for zinc-air, if this were not readjusted during the life of the battery it is possible that zinc-air cells are being required to deliver larger currents than mercury cells for a significant percentage of their life; this may also contribute to the fact that mercury users rate sound quality lower than zinc-air. The difference between laboratory data and this study is that in the laboratory there is no subjective judgement of the performance of the hearing aid, users on the other hand may be replacing batteries early in an attempt to overcome frustrations of perceived instrument performance limitations, which is more likely to be caused by unrealistic expectations. A further consideration may be that if, as seems likely from the data, users are less satisfied with the sound quality of mercury batteries. They may use their hearing aids less frequently thus artificially extending the life of the battery. Other contributory factors may be that users have a large range of settings over which they are satisfied with the performance of the aid, and there is also a possibility that some of the outlying mercury results are in fact wrongly attributed zinc-air batteries.

It can be seen from the analysis of user comments that those users wearing high powered hearing aids were more prone to comment upon their level of satisfaction giving a higher proportion of both favourable and adverse comments than users of lower powered instruments. Reponses for the Oticon E39PL aid, taken from a total of 28 mercury and 229 zinc-air batteries, show little difference between the comments for mercury and zinc-air batteries. The same is true of the 25 mercury and 230 zinc-air batteries tested in BE50 aids. Included in the analysis of users comments were all the batteries which had given zero life. This amounted to 1/163 (0.6 per cent) mercury batteries and 29/1766 (1.6 per cent) zinc-air batteries. The zinc-air figure can be fairly reduced to 7/1744 (0.2 per cent) if the batteries giving zero life which were incapable of meeting the NHS specification (DoH procurement specification for zinc-air primary battery type CP44), or which have been superseded by versions better capable of powering high drain aids are removed. As mercury batteries are capable of powering all aids, this would seem to indicate that problems with high powered aids are related more to the nature of the user's hearing loss, instrument and/or fitting or other physiological difficulties rather than the battery's ability to power the device.

The usage of BE10 series aids is a lot more erratic than higher power aids which is representative of the group of patients to which low power aids are issued in that they are usually mild hearing losses and can be more selective about when they wear the instrument.

There is less data for BE10s than 30s and 50s because the test duration is longer. This increases the chances of both mistakes being made and users becoming disinterested in the trial and giving up. Lower numbers of BE50s are reported because most of the high power survey aids were private rather than NHS issue.

Conclusions

The data collected from the Glan Clwyd user survey show that users are more satisfied with zinc-air batteries in terms of both battery lifetime and sound quality. The phasing out of mercury cells does not disadvantage the NHS hearing aid population and there is no evidence in this study of patients with

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commercial aids being adversely affected either. The data also provides a useful indicator for battery purchasing and hearing aid dispensing departments in terms of the average battery lifetimes for a range of instrument types.

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