A CLINICAL CHARACTERIZATION OF SEVERELY AND PROFOUNDLY HEARING IMPAIRED ADULTS ATTENDING AN AUDIOLOGY CLINIC.

by

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July 1990.

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ACKNOWLEDGEMENTS

I would like to acknowledge the advice and encouragement given freely at all stages of the work by Professor G G Browning. Dr G A Day assisted with data gathering and patient management. Dr Stuart Gatehouse provided valuable scientific guidance and Alister Sword and Janet Squair assisted with data organisation and statistical analysis.

I declare that subject to the acknowledgements above:- the development, design, data gathering, statistical analysis and writing of this thesis is entirely my own work.

SUMMARY

Introduction

Although 16% of the adult population have impaired hearing, only about 1% have a severe or profound impairment (pure-tone average over 0.5,1,2 and 4 kHz of 70 dB HL or worse in the better hearing ear). With the advent of cochlear implants attention has been focused on the minority with total impairments. Those with lesser impairments within this group have been studied infrequently, their characteristics seldom reported and their most appropriate management remains undetermined.

The purpose of this thesis is to provide a clinically useful characterization of a hospital population of severely and profoundly impaired patients. Four principal aims were defined. Firstly to determine the aetiology of the impairment. Secondly to describe the major clinical and audiological features of the group. Thirdly to highlight practical testing and management difficulties. Fourthly to estimate aided disability and residual handicap.

Patients

The severely and profoundly impaired were found to represent 12% of those attending the Audiology department of Glasgow Royal Infirmary for the assessment and management of a hearing impairment. To study this group a secondary referral clinic was established. Over an 18 month period 132 patients were studied. To provide controls the records of 213 unselected, mildly and moderately impaired individuals attending the same department were examined.

Method

Two protocols were designed to run consecutively. The first was a combination of research and management. The second was purely for research and included: 1) An aided disability and environmental aids interview, 2) a measurement of hearing-aid gain both at most comfortable loudness and uncomfortable loudness levels for free-field speech, 3) an aided free-field audiovisual speech in noise test (FASIN) and 4) a disability and handicap questionnaire, given to both the study group and an age and sex matched group of mildly and moderately impaired controls.

Findings

Aetiology:

The most important finding was that 64% of the severely and profoundly impaired had a material conductive component, defined as a mean difference between not-masked bone conduction and air conduction in the better hearing ear of greater than 15 dB. This was significantly more common than the control incidence of 29% in the mildly and moderately impaired ($p<0.001$). Otosclerosis (36%) and chronic otitis media (31%) were the most commonly identified aetiologies. The type of impairment was sensorineural in 19% and unknown in 17%.

Audiometry:

Masking for pure-tone audiometry was possible in only 7 patients (5%). Consequently the ear to which bone conduction applied was unknown and thresholds were known to be correct in both ears in only 50 (36%).

Management:

Acoustic feedback was a major problem with 53% of aid fittings requiring one or more mould changes to overcome this problem. The amount of gain employed to reach most comfortable loudness varied by as much as 25 dB for a given pure-tone average. The gain employed was significantly less with a binaural than monaural aid fitting ($p<0.05$). Uncomfortable loudness was a problem in a minority (7%).

Environmental aids:

Although only 18% possessed a special front door alerting device only 29% reported more than mild difficulty with their current door system. A similar pattern was apparent for the telephone alerting system. Special alerting devices appeared to be effective but siting of standard devices was also found to be significantly related to effectiveness ($p<0.05$). About 40% had residual disability with telephone listening and television but numbers were such that no comment can be made on the effectiveness of special telephone listening or television devices.

Disability:

Aided disability measured both by self-report and with a speech-in-noise test (FASIN) was markedly worse for those with pure-tone averages of poorer than 100 dB HL. Aided disability, measured with FASIN, was significantly related to both air-bone gap and pure-tone average. When both pure-tone average and air-bone gap were statistically controlled for, binaural-aid users scored significantly better than monaural users ($p<0.05$). FASIN was able to explain a significant amount of additional variance in reported disability ($p<0.05$) once pure-tone average and air-bone gap were controlled for, indicating that FASIN was usefully measuring additional aspects of disability. The severely and profoundly impaired were significantly more **disabled** in purely auditory listening situations such as telephone listening ($p<0.01$) than mildly and moderately impaired controls. However, reported aided disability in audiovisual listening situations was similar.

Lifestyle and handicap;

There was no quantitative difference in lifestyle between the severely/profoundly and age and sex matched mildly/moderately impaired controls but the severely and profoundly impaired reported greater psychosocial handicap ($p<0.05$).

Discussion

The high prevalence of mixed impairments in the severely and profoundly impaired is not generally appreciated and neither are the difficulties and potential pitfalls of pure-tone audiometry. Both call for skilled otological and audiological assessment. The problems with aid fitting are such that skilled technical support is required.

There would appear to be a role for corrective surgery or bone-anchored hearing aids in many patients but there are unanswered questions in this area requiring further study. Those with large conductive components who are most likely to benefit from surgery are also those who are most likely to benefit from standard hearing aids.

The question of environmental aids requires more study. Little can be said at present concerning the effectiveness of telephone listening and television devices. The requirement for special alerting systems is probably less than is popularly suggested, advice on the repositioning of standard devices may be all that is required in many instances.

To reduce gain requirements and minimise residual disability binaural aids should be fitted whenever possible and those with pure-tone averages of worse than 100 dB HL, who are likely to be particularly disabled even when optimally aided, require special consideration.

Although the severely and profoundly impaired do not quantitatively have a different lifestyle from the mildly and moderately impaired they suffer more psychosocial handicap and may benefit from special counselling in this area.

The level of attention required together with the fact that the severely and profoundly impaired constitute over 10% of a department's caseload, fully justifies running a special clinic for these patients.

CHAPTER 1

INTRODUCTION

A superior ability to communicate through the use of language is what sets man above other animals and hearing is of fundamental importance to this facility. It is unfortunate that the language used to describe auditory dysfunction is often used loosely, leading to confusion and a thesis on hearing disorders must necessarily begin with a linguistic discussion. Two principal areas cause difficulty. The first is describing the degree of auditory dysfunction and the second is distinguishing a hearing disorder from the various effects that a disorder may have on the individual. The patients chosen for study in this thesis have been selected on the basis of an audiometric assessment of the degree of hearing impairment and this subject therefore requires preliminary discussion and clarification.

1.1 Domains of auditory dysfunction

A logical framework which allows separation of the components of auditory dysfunction is required. Davis (1) has outlined a suitable structure linking 4 separate domains based on Wood's adaptation (2) of recommendations from the World Health Organisation (3). A hearing disorder may result in an impairment which may cause disability which may lead to handicap. This sequence corresponds respectively to pathology, abnormal function, reduced ability to perform common tasks and finally to psychosocial limitations. A fuller description of the framework is shown in Table I and this model will be used throughout the thesis.

TABLE I : DOMAINS OF AUDITORY DYSFUNCTION (after Davis (1))

	Definition	Area affected
Disorder	Pathology of the hearing organ	Middle ear Inner ear Hair cells Auditory nerve Brainstem Auditory Cortex
Impairment	Abnormal function of auditory system	Auditory sensitivity Auditory discrimination Auditory localisation Temporal processing Binaural integration
Disability	Reduced abilities of the individual	Speech perception Environmental awareness Orientation
Handicap	Need for extra effort reduced independence	Grade of employment Scope of employment Renumeration Personal relationships Social integration Anxiety, embarrassment

1.2 Grading of auditory dysfunction

Of the four domains of auditory dysfunction, disability is the most recognisable and important as the effects of impaired hearing are most readily apparent when considering the ability to hear speech. It is therefore in terms of disability that auditory dysfunction is most usefully graded. The general public tend to use the terms 'deaf' and 'hard-of-hearing' to indicate an extreme and slight hearing disability respectively and sometimes terms such as 'partially deaf' to indicate intermediate degrees. Considerable confusion can arise however in the used of the term deaf. The Oxford English Dictionary definition (4) is "wholly or partly without hearing" and therefore in the English language deaf is a general term indicating any degree of auditory dysfunction. To restrict it's use to an extreme hearing disability is strictly incorrect. It is of interest to note that this confusion does not arise in the German language where schwerhorigkeit indicates a slight hearing disability and taubheit indicates an extreme disability or total hearing impairment.

In the literature the terms deaf and hard-of-hearing are usually avoided. More precise definitions are required for scientific study, but deaf and hard-of-hearing appear frequently in the publications of charities concerned with the hearing impaired and reading material intended for the general public. These terms cannot simply be ignored. The use of these terms implies that those with an extreme hearing disability are distinct and would seem to warrant separate consideration from those with a lesser disability although exactly how the distinction should be made is not clear.

Other than by self-report, which may be subject to personality factors, the most logical method of measuring disability is to use a speech recognition task, preferably with competing background noise. A near to real-life listening situation can be simulated but there are a number of reasons why this approach has not been generally adopted. Speech tests are difficult to calibrate and administer and no standard speech test has been internationally agreed. For the present at least, other than for research purposes, hearing disability is generally estimated by using thresholds of detection for pure tones. Pure-tone audiometry is relatively simple, international calibration standards have been agreed (5,6) and the results are acceptably repeatable (7,8,9). Using pure-tone thresholds to define disability is rightly open to criticism. This issue has been fully discussed by Noble (10). It is only because the relationship between speech recognition scores or self-report of disability and pure-tone thresholds in the better hearing ear has generally been shown to be sufficiently good that the exercise can be justified (11).

It must always be realised that pure-tone audiometry is a measure of hearing impairment not disability. Furthermore it does not provide information on all aspects of auditory impairment; factors such as frequency and temporal resolution are also important (12,13).

A quantitative assessment of hearing disability is required for a number of different purposes. The one which has received most attention, probably because of financial implications is the assessment of disability for compensation purposes. A large number of often complex formulas using pure-tone thresholds have been described. These have been critically reviewed by Noble (10), Alberti et al (14) and Melnick (15). The original American Academy of Opthalmology and Otolaryngology (AAOO) scheme in the USA (16,17,18) used the frequencies 0.5, 1 and 2 kHz whereas in the UK 1,2 and 3 kHz was preferred. More recently the importance of hearing for higher frequencies has been appreciated and 3 kHz has been incorporated in the American index (19,20) and in the UK the British Association of Otolaryngologists and the British Society of Audiology have recommended using 0.5,1,2 and 4 kHz (21).

A further area where a disability estimate is required is to provide a set of graded categories for clinical purposes. A similar approach to the compensation system has been generally adopted. By quoting an average pure-tone threshold over the frequencies important for speech reception in the better hearing ear, usually 0.5, 1, 2 and 4 kHz, the hearing impaired can be graded into categories based on the degree of disability likely to be suffered. A commonly used scheme is to define four groups; mildly, moderately, severely and profoundly impaired, the lower limit of each group being 25, 50, 70 and 90 dB HL respectively. This is illustrated in Table II (page 23) and is the scheme which will be used throughout this thesis. Different authorities vary slightly in the number of groups defined and in the choice of criterion (22,23,24,25,26,27). There would appear to be no scientific basis for the choice of category boundaries; the groups defined have simply been found by experience to be clinically useful for many purposes including estimation of likely hearing-aid benefit (28) and educational requirements for children.

In a general sense the term deaf would be expected to correspond to those individuals classified as profoundly impaired with average thresholds of worse than 90 dB HL in the better ear (29). As there are very few sounds encountered in normal daily living above this level, these individuals will hear practically nothing without amplification and even then are likely to have difficulty with speech. Hard-of-hearing should correspond to those classified as mildly or moderately impaired with average thresholds of 25 to 70 dB HL. This range encompasses speech levels from a quiet whisper to a loud voice. There is a grey area which is difficult to classify between 70 and 90 dB HL where individuals are best classified as severely hearing impaired and may show features of both the deaf and hard-of-hearing. Individuals in this range will not hear ordinary speech but may be able to hear shouted speech. It is in this group that the term partially deaf has been used.

TABLE II : GRADING OF HEARING IMPAIRMENT

Pure-tone average (dB HL) in the better hearing ear	Degree of impairment
less than 25	not significant
25 - 49	mild
50 - 69	moderate
70 - 89	severe
90 or greater	profound

1.3 Prevalence of severe and profound hearing impairment

Early studies of the adult British population in the 1940's and 50's suggested a prevalence of 'hearing loss' in the region of 6-8% (30,31). Similar estimates were reported from the United States (32,33). The methods of patient identification, data collection and criteria used in these early studies can be criticised and as there is an ever increasing proportion of elderly individuals in the population (34) these studies may not be relevant today. Shepherd (35) critically reviewed the UK prevalence data available in 1978 and highlighted the need for more accurate data. Until 1983, the 1948 questionnaire survey by Wilkins (30) was the most up to date whole population survey of hearing available in the UK. The best and most recently published source of prevalence data for the United Kingdom are preliminary findings from the Medical Research Council (MRC) British National Study of Hearing (NSH) (1,36). This large study is still ongoing but estimates from phase 1 and 2 which studied a stratified sample of 1692 individuals selected from a larger random population sample have been published (36). The results from phase 3 which has increased the number tested to 2662 have not yet been published but results are now available (Gatehouse G, personal communication). Combined results from phases 1,2 and 3 of the NSH (Table III) give the prevalence of auditory impairment in the general population (defined as a pure-tone average of 25 dB HL over 0.5,1,2 and 4 kHz or worse in the better ear) at 16.1% with 95% confidence limits of 15.0 - 17.3%. The estimate given for those with a mild or moderate impairment (between 25 and 69 dB HL) is 15%. An estimate of 0.5% can be calculated for the proportion of the population having a severe impairment (between 70 and 89 dB HL) and 0.3% for for those with a profound impairment (90 dB HL or worse). The prevalence of the severely and profoundly impaired together is thus **0.8%**. The ratio of severe to mild and moderate impairment in the general population is in the order of 30 to 1 and 50 to 1 for profound impairments. Reasonably accurate estimates are available for those with a severe impairment but the numbers with profound impairments are very small and the 95% confidence interval is wide. The actual numbers in phase 1,2 and 3 of the NSH with an impairment of worse than 90 dB HL was only 17 and of them only 6 individuals had an impairment of 100 dB HL or worse.

Disorders of hearing are therefore very common but severe and profound impairments are comparatively rare; the prevalence having been shown to decline exponentially with severity (37) such that it roughly halves for each 10 dB added to the criterion.

The difficulty in estimating the number of profoundly impaired individuals in the population has been emphasised by Thornton (38) and random whole-population studies would have to be very large to identify sufficient numbers of patients. An alternative is to build an inventory or list of individuals with a specified impairment from a particular area. Thornton built a list of severely and profoundly hearing impaired from the Wessex region from information from a variety of sources and by testing a sample from this list was able to provide useful clinical information on the basic characteristics of this group. Combining a verified list with a sample survey has been shown to be an efficient method of evaluating the population with a rare condition. There are however difficulties in verifying the list and eliminating sources of bias to allow a general estimate of prevalence to be calculated (36).

TABLE III : PREVALENCE ESTIMATES OF HEARING IMPAIRMENT IN THE BETTER EAR FROM PHASES 1,2 AND 3 OF THE NSH. n = 2662

Pure-tone average (dB HL) in the better hearing ear	Prevalence (%)	95% confidence interval
25 or worse	16.13	14.99 - 17.27
50 or worse	2.86	2.46 - 3.26
70 or worse	0.81	0.56 - 1.07
90 or worse	0.29	0.09 - 0.49

1.4 Reasons for the present study

There has been a puzzling lack of studies specifically concerned with severely and profoundly hearing impaired adults and it is difficult to understand why this is the case. Numbers are small but not that small. A prevalence of 0.8% is similar to that of many other chronic conditions such as diabetes (39) and rheumatoid arthritis (40) which have been extensively studied. A factor which may have discouraged investigation is that many of the pre-lingually profoundly impaired are established in the deaf community and may not necessarily want to come forward for help. Thornton (38) estimates that less than half of the profoundly impaired population have been seen at any time by an Otolaryngologist. The resistance of the deaf community to medical interest may seem puzzling to those having little experience of this group (41). The deaf community has it's own separate culture, history and language (42,43,44) and crossing these cultural and linguistic barriers can be difficult. In general communication and testing can be difficult with the severely and profoundly impaired but perhaps the real reason why there have been so few studies is that there is still an underlying feeling that conventional audiological management with hearing aids has little to offer the more profoundly impaired patient (29) and it is often accepted that the results of management may be disappointing in those with a severe impairment (45,46).

Recent interest in cochlear implants and the necessary development of selection processes for implant programmes has focused attention on the profoundly hearing impaired adult and has highlighted an embarrassing lack of knowledge on this group (47). Many of the workers on implant programmes admit that they have been brought into contact with patients with whom they have had little previous experience (48). Perhaps the main benefit of implant programmes (although seldom publicised) has been to identify hearing impaired individuals who have not been adequately managed by conventional audiological practices. The numbers of individuals identified in this way and their eventual outcome has not been stated. Why and in what areas conventional audiological management had failed is not clear and requires further study.

Whole volumes have been written on the causes and features of severe and profound hearing impairment in children (49,50,51,52,53) but severely and profoundly impaired adults seem to have received considerably less attention. This is probably because the main concern with children is to ensure that the child receives an adequate education. This is a considerable undertaking, requiring special facilities and the expertise of a number of different professionals who are specially trained and experienced in this highly specialised but narrow field. The audiologist or otologist dealing with adults has a more general role. Severely and profoundly impaired adults must take their place amongst the large number of individuals with lesser impairments attending a standard audiology clinic.

The extensive literature on severely and profoundly impaired children is of little general relevance to adults who are liable to face a very different set of problems. There is little in the literature to indicate what clinical and audiological features are likely to be encountered with the severely or profoundly hearing impaired adult and there is little to indicate the likely aetiology when acquired later in life.

Common audiological test procedures and hearing-aid fitting guidelines are based almost exclusively on studies with mildly and moderately impaired individuals and there is little to indicate how relevant these are for more severely impaired individuals. The need to modify hearing-aid selection methods for the severely impaired has been recognised (54,55) but there is no general agreement on how this should be achieved (56,57,58,59).

Studies on the residual hearing capacity of the severely and profoundly impaired have been few and have for the most part been conducted with children (60,61,62,63). It is noteworthy that Lamore et al (64) have shown that usable residual hearing capacities are often present up to 105 dB HL and therefore those with thresholds of hearing in this area should not be discounted.

1.5 Aims of the study

The purpose of this thesis is to provide a meaningful and clinically useful characterization of a hospital population of severely and profoundly hearing impaired individuals and to highlight ways in which they may differ from the more familiar mildly and moderately impaired. Within this framework four principal aims were defined. Firstly to determine aetiology, which has implications for treatment, prevention and conservation of hearing. Secondly to describe the major clinical and audiological features of the group which are central to management. Thirdly to highlight practical testing and management difficulties, particularly in relation to hearing-aid selection and fitting. Fourthly to estimate residual disability and handicap after conventional management with hearing aids.

1.6 Nature of the study

The study group consisted of 132 adults with a severe or profound hearing impairment identified over an 18 month period at a special secondary referral audiology clinic set up specifically to manage and study these patients. The thesis reports a number of investigations conducted on the group during this time. Results reported include a general and otological examination and pure-tone audiometry which characterize the group. More complex investigations performed included a free-field speech-in-noise performance test, free-field measurements of most comfortable listening levels to speech with hearing aids. An interview was conducted to assess reported aided disability after management and effectiveness of environmental aids. Lifestyle, aided disability and psychosocial function were assessed by a questionnaire and the full management record is presented.

To compare the prevalence of characteristics with the more familiar mildly and moderately impaired, 300 unselected controls were taken from the general audiology clinic in the same department. To provide control data for the questionnaire, mildly and moderately impaired age and sex matched controls were selected from this group.

1.7 Structure of the thesis

Following an outline of the management and research protocols, the thesis divides into three main sections. The first section (chapters 3 and 4) describes the main clinical and audiological features of the group with particular emphasis on the importance of uncertainties with pure-tone audiometry for both diagnosis and management. The second section (chapters 5,6 and 7) deals with management aspects including hearing aids and environmental aids. The final section (chapters 8 and 9) is concerned with the assessment of aided disability and handicap after management. General conclusions are drawn together in the final chapter.

CHAPTER 2

A SPECIAL CLINIC FOR THE SEVERELY AND PROFOUNDLY HEARING IMPAIRED

2.1 History

Interest in the severely and profoundly hearing impaired began at Glasgow Royal Infirmary with a study on the benefits of binaural amplification on 50 severely hearing impaired individuals (65). This study confirmed the advantages of binaural amplification but also highlighted a general lack of knowledge and experience of this group. It became apparent that these patients were not receiving adequate attention when managed alongside the less severely impaired. It was surprising how well many patients performed with correctly fitting and selected hearing aids and it was learned that attention to detail, particularly to ear moulds was essential to a good result, although very time consuming. An unexpected finding was a high prevalence of mixed hearing impairments and it was felt that further work was required to fully characterize and study this group as diverting resource to these patients would have implications for the functioning of the Audiology department. In 1986 it was decided to start a special, separate clinic for the severely and profoundly impaired staffed by a medical practitioner (LMcC) and an audiological scientist (GAD).

2.2 Patients

Over a two year period all patients with a hearing impairment of 70 dB HL or worse in the better hearing ear (averaged over 0.5,1,2 and 4 kHz) attending the Audiology department at Glasgow Royal Infirmary were referred on to the severely hearing impaired (SHI) clinic. This included new referrals from general practitioners and all current attenders and follow up cases from the department. The Audiology department serves a population of approximately 200,000. On average, 2500 patients are seen and 1000 new hearing aids fitted at the Audiology clinics per year.

From May 1986 to July 1988 almost 200 severely and profoundly impaired patients were identified. After an initial setting-up period a clinic programme was finalised in January 1987 and from this date, over an 18 month period, 137 patients were seen.

2.3 Clinic programme

The clinic was initiated with the dual role of both patient management and research. The overall aim was to provide optimum hearing-aid fitting and to characterize and study the group. Two protocols were established to run consecutively, the first for hearing-aid fitting and collection of basic characterization data. The second was purely for research purposes. Four half-day sessions were run per week, 2 for management and 2 for research.

2.3.1 Management protocol

The general management strategy was to fit binaural, high-powered hearing aids as appropriate and to aim for ear moulds which did not allow feedback when the hearing aid selected was set at maximum gain. Patients were followed up until this was achieved. A complete clinical examination was carried out and medical history taken on the first visit. Following this the patient had a second confirmatory pure-tone audiogram. This section provided basic characterization data. Hearing aids were then chosen as appropriate. New impressions for bilateral ear moulds had been taken prior to referral and therefore new moulds were available at the first visit. The patients were followed up thereafter at monthly intervals until a satisfactory fitting was achieved and any otological or rehabilitive problems dealt with. This period provided a management record. After a further period of one month to allow for adjustment to the hearing aids and moulds finally fitted, patients attended for a final management review.

2.3.2 Research protocol

After completing the management protocol, patients were invited back to a separate session for interview and a number of audiological tests designed purely for research purposes. Each patient was allocated one and a half hours. The structured interview consisted of two parts, the first concerned aided disability and the second environmental aids. Special audiological testing consisted of an aided audiovisual speech-in-noise test and measures of most comfortable and uncomfortable listening levels to speech with hearing aids. On completion of the research protocol patients were given a questionnaire to take home and return to the clinic.

2.4 Data collected

A brief description of the data collected from both the management and research protocols is now given. More detailed description will be given later in the relevant chapters.

2.4.1 Clinical examination and history

The age, sex, social class and employment status of patients were recorded. A careful history was taken (LMcC) with the aim of identifying a cause for the hearing impairment. If noise exposure was identified as a likely cause a full occupational history was taken. Any previous ear surgery was recorded and past experience of hearing aids noted. A general medical history was also taken and any other significant disability recorded. Otoscopy was performed after removal of obstructing wax or debris using the operating microscope if necessary. Visual acuity was recorded using Snellen charts with glasses if appropriate.

2.4.2: Management record

After an initial assessment a record was made (LMcC) of all management problems and the action taken at each review until it was felt that problems had been solved or improved as far as was possible. One month after this the patients were reviewed again and a final assessment undertaken. Problems and action taken were considered under three headings; hearing-aid related, ear-mould related or otological.

2.4.3: Interview

A structured interview (LMcC) consisted of two sections. The first gathered information on aided disability and the second on environmental aids. Reported disability in four specified listening conditions; recorded as none, mild, moderate or severe:

a) speech in quiet.

b) speech in noise.

c) television.

d) telephone.

Details were recorded on the possession of and reported effectiveness of front-door and telephone alerting devices, telephone listening and television systems.

2.4.4 Special audiological testing

A free-field audiovisual sentence-in-noise test (see appendix D) was performed in each of 4 modes: Audiovisually, with and without hearing aids, audio alone with hearing aids and finally with vision alone (LMcC, GAD). Free-field hearing-aid gain measurements were made with the patient's personal aid (LMcC, GAD). Most comfortable and uncomfortable listening levels were measured. On a subgroup of 22 binaural aid users, measurements were made both monaurally and binaurally.

2.4.5 Questionnaire

A questionnaire designed to assess lifestyle, aided disability and psychosocial handicap was given to all patients on completion of testing with a stamped addressed envelope to return to the clinic (see appendix E). The questions asked were of a fixed response type.

2.5 Patient numbers

Once a clinic programme were established 137 patients were identified. Of these patients 5 were subsequently found to have non-organic impairments and were referred back to the non-specialist audiology clinic. 132 patients were therefore enrolled in the programme. During subsequent follow-up 3 patients died and 14 defaulted, leaving 115 patients (87%) who completed the management protocol. A further 9 patients failed to attend the research session leaving 106 patients (80%) who were interviewed and had special audiological testing carried out thereby completing the research protocol. A completed questionnaire was returned by 82 of the original 132 (62%).

CHAPTER 3

DIFFICULTIES WITH PURE-TONE AUDIOMETRY.

3.1 Introduction

Pure-tone audiometry is without doubt the most frequently performed audiometric test. Air-conduction thresholds are used to measure the degree of impairment present and together with bone-conduction thresholds the type of hearing impairment can be diagnosed as either sensorineural, conductive or mixed. When performing pure-tone audiometry on patients with a severe or profound hearing impairment several difficulties, not apparent when dealing with the mildly and moderately impaired are encountered and can result in various degrees of uncertainty. Thresholds may not be reached at the maximum output of the audiometer for either air or bone conduction and there may be doubt if the thresholds given are true hearing or vibrotactile. Masking may not be possible due to limitations of the masking output of the audiometer or due to large conductive components. These difficulties may reduce the amount and quality of information available from audiometry and may lead to an uncertain diagnosis for both the degree and type of hearing impairment in one or both ears. This in turn may lead to problems with patient management. The need to consider entire audiograms rather than hearing at individual frequencies further complicates the problem.

A detailed discussion of the limitations of pure-tone audiometry in the severely and profoundly impaired is required and a satisfactory method for dealing with these limitations defined before audiometry can be used to characterize the group. Chapter 4 deals with characterization while this chapter discusses the factors limiting audiometry. In order to highlight and quantify the difficulties likely to be encountered in practice and show how the available information can be used, the discussion is illustrated with the audiometric results of 132 severely and profoundly impaired patients.

3.2 Method

All 132 patients attending the special clinic for the severely and profoundly hearing impaired underwent standard pure-tone audiometry. Before testing otoscopy was performed and any obstructing wax or debris was removed. Pure-tone audiometry was performed in a sound-deadened booth on a recently calibrated Kamplex AC4 audiometer using THD 39 earphones with MX41/AR cushions and a Radioear B71 bone vibrator. The maximum outputs available with this set-up (Table IV) conform to standards for a type 1 diagnostic audiometer defined in BS 5966 (66) and IEC 645 (67). Pure-tone audiometry was performed using recommended procedures from the British Society of Audiology (BSA) and British Association of Otolaryngologists (BAOL) (68),(69),(70). Air and bone conduction conduction was tested from 0.5 kHz in octave bands to 4 kHz. Hearing was not tested at 0.125, 0.250 and 8 kHz as the maximum output of the audiometer at these frequencies was considered to be too low to supply useful information.

TABLE IV : MAXIMUM OUTPUT OF THE KAMPLEX AC4 AUDIOMETER

Frequency (Hz)	Air conduction (dB HL)	Bone conduction (dB HL)	Narrow band masking (dB equivalent)
125	90	-	70
250	110	40	90
500	120	60	100
1000	120	70	100
2000	120	70	100
4000	120	70	100
8000	100	40	80

3.3 Better and poorer hearing ears

Many patients may have symmetrical hearing impairments and therefore it is strictly incorrect to speak of a better and poorer hearing ear without defining the difference that constitutes material asymmetry. For most purposes it is the degree of overall impairment which is of interest not the side to which it applies and for this purpose it is justifiable to speak of a better hearing ear even if the difference in thresholds is very small. This has been the approach in the National Study of Hearing (36). If a difference between the ears is of interest then a definition of material asymmetry is required. A difference of 10 dB is usually taken to indicate material asymmetry (71).

3.4 Off-scale thresholds

The inclusion criterion for this study was an air-conduction pure-tone average over 0.5,1,2 and 4 kHz of 70 dB HL or worse in the better hearing ear. The initial decision to include patients in the study as well the need to further classify the group on the basis of a speech-frequency average demands that a rule be devised for dealing with off-scale air-conduction thresholds. In order to provide an audiometric diagnosis of type of hearing impairment a rule for dealing with off-scale bone conduction is also required.

Table V shows the number of ears in which thresholds were off-scale for each frequency for air conduction and bone conduction. Off-scale bone conduction was encountered more frequently than off-scale air conduction. A measurable threshold for either air or bone conduction was most likely to be present at 1 kHz, being present in 92% of the ears tested for air conduction and 83% of patients for bone conduction. Air-conduction thresholds were measurable over roughly equal proportions of ears over 0.5, 1 and 2 kHz and only started to fall off at 4 kHz. Bone-conduction thresholds were less frequently measurable at 0.5 and 2 kHz than 1 kHz and present in less than 50% of patients at 4 kHz. Off-scale thresholds were encountered relatively infrequently in the better hearing ear. Table VI shows that at least one off-scale point was encountered for air conduction over 0.5,1,2 and 4 kHz in the poorer hearing ear in 40 patients (30%) but in only 16 patients (12%) in the better hearing ear.

TABLE V : DISTRIBUTION OF OFF-SCALE THRESHOLDS FOR AIR AND BONE CONDUCTION. n = 264 EARS IN 132 INDIVIDUALS

Frequency (Hz)	No. of off-scale thresholds	
	Air conduction	Bone conduction
500	22	48
1000	20	22
2000	27	45
4000	46	79
Total	115	194

TABLE VI : NUMBER OF OFF-SCALE AIR-CONDUCTION THRESHOLDS OVER 0.5,1,2 AND 4 kHz n = 132 INDIVIDUALS

No. of thresholds off-scale	No. of patients (%)	
	Better ear	Poorer ear
none	116 (88)	92 (70)
one	9 (7)	16 (12)
two	6 (4)	12 (9)
three	0 (0)	2 (2)
four	1 (1)	10 (7)

3.5 Speech frequency average

To obtain an air-conduction speech-frequency average the basic problem is to gain the maximum information with the minimum of data substitution for off-scale thresholds. It would have been possible to consider only 0.5,1 and 2 kHz or only the best 2 speech frequency thresholds (72) but information on high frequency hearing which has been shown to be important (73,74) would have been lost. The number of off-scale thresholds encountered at 4 kHz was considered to be sufficiently small to justify inclusion in the speech frequency average. It was decided that if a threshold was not measurable at 0.5,1,2 or 4 kHz by air conduction then the audiometer maximum + 5 dB (125 dB HL) was substituted. Using this rule the 4 frequency average may be underestimated but the average produced will allow patients to be ranked by severity of hearing impairment.

3.6 Vibrotactile thresholds

Vibortactile air-conduction thresholds may lead to the assumption that there is residual hearing when none exists and vibrotactile bone-conduction thresholds may result in the faulty diagnosis of a conductive component. There have been a number of studies which have attempted to measure vibrotactile thresholds since the early reports of Wegel in 1932 (75). According to these reported studies (76,77,78,79,80), vibrotactile thresholds are only likely to be encountered at at 0.5 and 1 kHz with the AC4 audiometer over 0.5,1,2 and 4 kHz. The minimum vibrotactile threshold for bone conduction is generally given as 50 dB HL at 0.5 kHz and 70 dB HL at 1 kHz. For air conduction the minimum vibrotactile thresholds is given as 100 dB HL at 0.5 kHz and 120 dB HL at 1 kHz.

In the study group air-conduction thresholds were recorded at 100 dB HL or worse at 0.5 kHz in 54 ears and at 120 dB HL at 1 kHz in 4 ears. Bone-conduction thresholds were recorded at 50 dB HL or worse at 0.5 kHz in 14 patients and at 70 dB HL at 1 kHz in 6 patients. Careful enquiry was made in the patients giving potentially vibrotactile thresholds and all reported hearing rather than feeling the test sound.

3.6.1 Definition of a total hearing impairment

For the purposes of this study, using an AC4 audiometer, a modification of the definition of a total hearing impairment recommended by Martin (81) would seem appropriate. Air-conduction thresholds were rejected and the patient deemed to have a total hearing impairment when only two points of air conduction were present over 0.5,1,2 and 4 kHz at the audiometer maximum at 2 and 4 kHz or 100 dB HL at 0.5 kHz or 120 dB HL at 1 kHz. Using this definition 1 patient were deemed to be bilaterally totally impaired and 12 unilaterally.

3.6.2 Off-scale bone conduction

It is not feasible to substitute the audiometer maximum for off-scale bone conduction in the same way as air-conduction because the output for bone conduction is so much less than for air conduction. Substituting the bone-conduction maximum + 5 dB would tend to overestimate any differences between air and bone conduction and lead to a faulty diagnosis of a conductive defect. For this reason it was decided not to use a bone-conduction average but to consider air-bone gaps to define the type of impairment (see later, section 3.8).

It would seem reasonable to reject all bone conduction and consider it off-scale unless at least two thresholds are present as recommended by Berger (82) and that neither of these can be potentially vibotactile ie. 50 dB HL or worse at 0.5 kHz or 70 dB HL at 1 kHz. Using this definition bone-conduction was considered to be off-scale in 34 patients (26%)

3.7 Masking difficulties

Masking is essential to isolate the test ear for bone-conduction audiometry. Without masking the ear with the better cochlear function only can be tested. Masking of the non-test ear is also required for air-conduction audiometry when there is a difference or potential difference of more than 40 dB between the air conduction threshold of the test ear and the bone-conduction threshold of the non-test ear.

Masking using the recommended plateau method ideally requires a minimum of 40 dB of masking noise above the threshold of masking (M) in the non-test ear (70). With the AC4 audiometer the maximum output for narrow-band masking noise is 100 dB of equivalent masking across the speech frequencies. This restricted output therefore only allows the plateau method of masking to be used as recommended when air-conduction thresholds are 60 dB HL or better in the non-test ear. In practice, a full 40 dB of masking noise above M may not be required in every case but it is generally very difficult to interpret a masking function with less than 30 dB of masking noise available above M. This effectively rules out masking for the the severely and profoundly impaired who by definition have average thresholds poorer than 70 dB HL. Of the 1056 air-conduction thresholds over 0.5,1,2 and 4 kHz in both ears measured in the 132 patients in this study, only 53 thresholds (5%) were measured at less than 70 dB HL and therefore an ear in which the masking output of the audiometer is adequate is encountered infrequently.

The possibilities of masking are further reduced by conductive components. Early in the study it became apparent that conductive components were common. Any conductive component in the non-test ear will reduce the effective masking by an amount equal to the size of the conductive component and the increased level of masking required will increase the possibility of cross masking.

For the theoretical reasons mentioned above masking is seldom possible in the severely and profoundly impaired. In practice when considering complete audiograms rather than thresholds at individual frequencies it may be possible to make a decision when only one or two individual frequencies are maskable. Out of the 132 patients tested, masking was considered to add useful information in only 7 patients (5%). All that is usually available from pure-tone audiometry in the severely and profoundly impaired is not-masked air and bone-conduction thresholds and it these that will form the basis of further discussion.

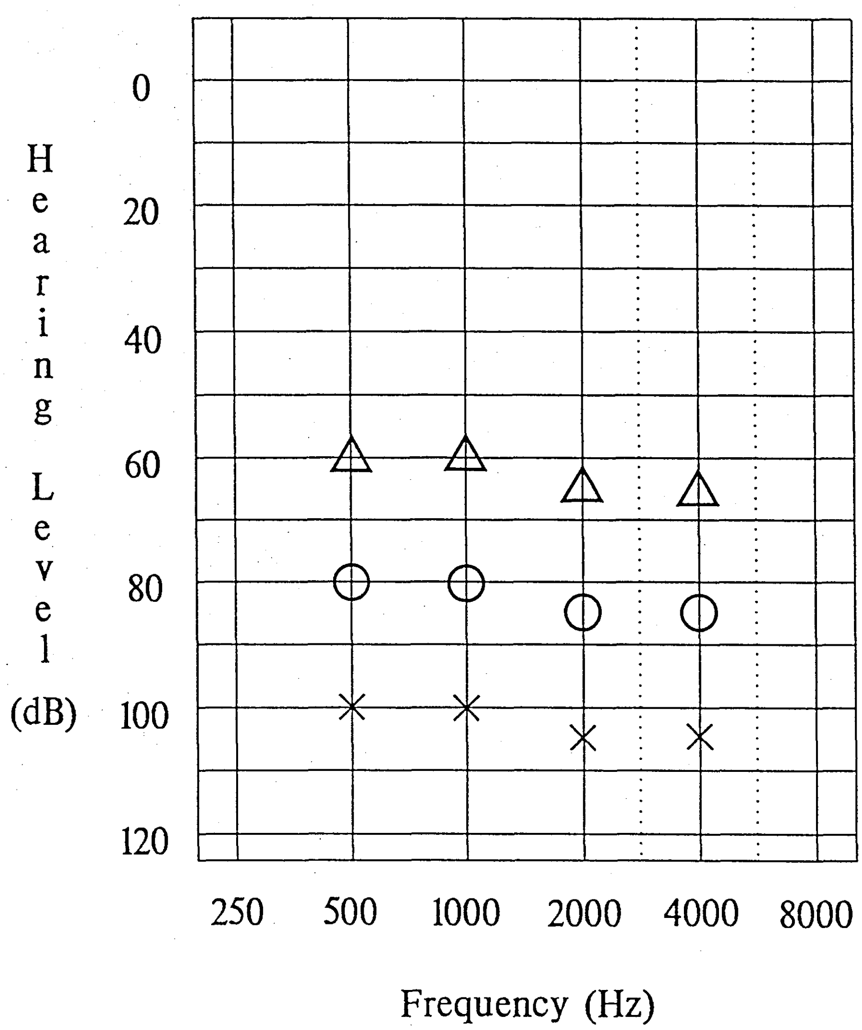
3.8 Air-bone gaps

There is a problem in providing an overall estimate of the size of an air-bone gap. A gap measured at only one frequency may be unrepresentative and therefore misleading while gaps averaged over all 4 speech frequencies may also be misleading as off-scale points may be encountered. A compromise is to consider only gaps at frequencies in which bone-conduction thresholds are actually recordable. An average can then be computed which uses the maximum information available and will be an average of 2,3 or 4 gaps depending on the number of points of bone conduction measurable. It must always be borne in mind that an air-bone gap may exist when bone conduction is off-scale and may be as large as 49 dB (audiometer AC maximum (120 dB HL) - audiometer BC maximum (70 dB HL) = 50 dB).

Without masking it is impossible to decide which ear or ears bone conduction thresholds apply to. It is possible only to speak of potential air-bone gaps in one or both ears. It is usual to classify both the degree and type of hearing impairment present in terms of the hearing in the better ear but without masking of bone conduction the type of hearing impairment can only be defined in the better ear if no potential air-bone gap exists in that ear (a pure sensorineural impairment). In all other cases the type of hearing impairment present can only be defined in terms of the difference between not-masked bone conduction and air-conduction threshold in the better hearing ear.

Consider the audiogram illustrated in Figure 1, there is a potential air-bone gap of 20 dB in the right ear and 40 dB in the left ear. The not-masked bone conduction may apply to either or both ears. The patient has either a bilateral mixed impairment or an asymmetric sensorineural impairment with a conductive component which may apply to either ear. Clinical experience would indicate that the bone conduction is most likely to apply to the better or both ears, but there is no theoretical reason why it could not apply to the poorer ear only. The minimum size of air-bone gap possible in this individual will be 20 dB and the maximum size will be 40 dB. Considered as hearing unit the patient has a definite conductive component with reference to the better hearing ear no matter which ear the bone conduction actually applies to.

FIGURE 1 : EXAMPLE AUDIOGRAM



Explanation re nature of symbols can be achieved by referring to Appendix B, P 161.

3.9 Information available based on the potential existence of air-bone gaps

An audiometric diagnosis of the degree and type of impairment in the severely and profoundly impaired almost invariably depends on a consideration of not-masked air-conduction and not-masked bone-conduction thresholds. The following is a suggested method of using this information based on a consideration of the potential existence of air-bone gaps in either or both ears and the degree of air-conduction symmetry.

Firstly, the size of air-bone gap necessary to decide that a conductive component exists must be decided. Secondly, the difference between not-masked bone and air conduction that would allow or potentially allow cross hearing must be set. Thirdly the maximum possible air-bone gap that could be present must be considered. It is conventional to define an air-bone gap as a difference between air and bone conduction of greater than 15 dB (83). The potential for cross hearing and the maximum size of air-bone gap possible depend on the limits of transcranial attenuation of sound delivered by headphones. There have been several important studies in this area (84,85,86,87) but Snyder (88) has reported the largest series and gives the possible range for pure-tones by air conduction over the speech frequencies as 40 to 80 dB. Snyder's figures are given in Table VII.

TABLE VII : TRANSCRANIAL ATTENUATION RANGE FOR AIR CONDUCTION

(after Snyder (88))

Frequency (Hz)	Attenuation (dB)	
	min	max
500	45	75
1000	40	75
2000	40	80
4000	40	85
mean	41	79

As transcranial attenuation can be as low as 40 dB, if there is a difference or a potential difference of more than 40 dB between not-masked bone conduction and air conduction then cross hearing is possible. A difference of greater than 80 dB is likely to indicate a non-organic hearing impairment. The degree of asymmetry becomes important when potential air-bone gaps of greater than 40 dB exist in both ears. In this situation it may not be possible to decide which side the air-conduction thresholds are being measured from as either may be the result of cross hearing. In practice it is only when thresholds are symmetrical that material doubt will exist about both ears. If a better and poorer ear can be clearly identified then the air-conduction thresholds in the better ear can be assumed to be correct.

There are 3 possible situations for each ear: 1) No potential air-bone gap, 2) potential air-bone gap less than 40 dB and 3) potential air-bone gap of greater than 40 dB. It follows that there are 6 possible combinations for each patient. These combinations are now described and example audiograms are given in appendix B.

3.10 Definable categories

The following is a description of the 6 audiometric combinations possible when only air conduction and not-masked bone conduction are known. The number of patients from the study group falling into each category is given with the percentage in brackets. One patient defined as having a total hearing impairment in both ears makes a possible 7th category.

1. No potential air-bone gap in either ear:

   These patients have a bilateral sensorineural hearing impairment and the levels are correct.

   Number = 7 (5%)

2. No potential air-bone gap in the better ear with a potential air-bone gap of less than 40 dB in the other:

   These patients have a sensorineural impairment in the better ear. The hearing level in the other ear is known but it's type is not.

   Number = 14 (11%)

3. No potential air-bone gap in the better ear with a potential air-bone gap of greater than 40 dB in the other:

   These patients have a sensorineural impairment in the better ear. The hearing level in the other ear is not known and neither is its type.

   Number = 4 (3%)

4. Potential air-bone gap in both ears but less than 40 dB in both ears:

   The air conduction thresholds are correct in both ears. If bone conduction is present the patient has a conductive component. If not then the hearing type is unknown.

   Number = 29 (22%)

5. Potential air-bone gap in both ears but greater than 40 dB in one ear:

   The hearing level in the poorer ear is not known. If bone conduction is present the patient has a conductive component. If not then the hearing type is unknown.

   Number = 30 (23%)

6. Potential air-bone gap of greater than 40 dB in both ears:

   The hearing level by air conduction in both ears may be suspect. If there is significant asymmetry then the hearing by air conduction in the better ear is likely to be correct but no such assumptions can be made if the impairment is symmetrical. If bone conduction is present the patient has a conductive component. If not then the hearing type is unknown.

   Number = 47 (36%)   Symmetrical = 21   Asymmetrical = 26

It follows that are four levels of certainty for hearing by air conduction and four for type of hearing impairment. The hearing by air conduction may be known to be correct in 1) both ears, 2) in one ear only (always the better hearing ear), 3) in one ear but not which side and 4) in neither ear (presumed totally hearing impaired). The type of hearing impairment may be known in 1) both ears, 2) in one ear only and the ear can be identified, 3) in one or both ears but which ears cannot be identified, 4) in neither ear.

From a consideration of the above it was deduced that the hearing level by air conduction was known with certainty in both ears in 50 patients (38%). The hearing in the better ear only was known with certainty in a further 60 (46%), there may be doubt about the hearing in both ears in 21 (16%) and in 1 patient the hearing level in both ears was unknown. A pure sensorineural hearing impairment was present in the better or both ears in 25 (19%). A conductive component was present in one or both ears in 85 (64%) and the type of hearing impairment was unknown in 22 (17%).

3.11 Discussion

No previous author has tried to systematically categorise audiograms from the severely and profoundly impaired. If the information available is to be used to usefully characterize a population then a method of dealing with the uncertainty and avoiding errors of interpretation must be defined. The method described is not perfect and may seem unnecessarily complicated but this has been unavoidable.

A masking output of 100 dB of equivalent masking is inadequate for this group of patients. There is no technical reason why masking should not be available to 110 dB of equivalent masking as in the now obsolete Peters AP6 audiometer. As a large proportion of patients have a conductive component to their hearing impairment this further limits the scope for masking as cross masking may occur almost immediately making interpretation of the masking function impossible. Higher levels of masking should be possible with an insert receiver with less likelihood of cross masking but there are problems with the accurate placement of the receiver and calibration is difficult. In this group masking should be regarded as an added bonus on the rare occasions when it is possible.

An interesting although infrequently used alternative to the plateau method of masking is the sensorineural acuity level method (SAL) which uses bone-conducted masking noise. This technique enjoyed some popularity in the 1960's (89,90,91) but has been used infrequently since. This method may potentially have a place when bone conduction thresholds are good. It would of course be useless when bone conduction was off-scale.

The results obtained by audiometry will depend to a large extent on the maximum output of the audiometer used. For diagnostic purposes a major problem is the limited output of the bone-conduction vibrator. The B71 vibrator can be driven up to about 85 dB HL but distortion at this level together with the possibility of vibrotactile sensation and air radiated sound make this impractical (92). The limits of bone-conduction audiometry with a standard bone vibrator are in the region of 65 - 70 dB HL (93).

The limits of masking, and to a lesser extent off-scale points and potential vibrotactile thresholds can greatly reduce the information available from audiometry. As the air-conduction thresholds in the better hearing ear are generally taken to indicate the overall degree of impairment, once a satisfactory method for dealing with off-scale points has been devised and a definition of a total impairment agreed the degree of impairment in all patients can be usefully measured.

As only not-masked bone conduction is available the side to which the bone conduction applies is unknown in every case. Only differences between not-masked bone conduction and air conduction in the better hearing ear can be usefully employed to classify the type of hearing impairment.

CHAPTER 4

AETIOLOGY AND CLINICAL FEATURES.

4.1 Introduction

Recent interest in cochlear implant has focused attention on a minority of the profoundly hearing impaired with total or near-total impairments. The aetiology and clinical features of this group have been well described in contrast to the severely and profoundly impaired with lesser impairments. In cochlear implant patients meningitis, trauma and ototoxocity are the most common aetiologies (48,94,95,96,97). Implant patients form a highly selected group and the clinical features of this group such as age, social class, and the presence of other disabilities are greatly influenced by the selection criteria of the implant programme. The aetiology and clinical features of those rejected from implant programmes would be of interest but this has seldom been reported. Fujikawa (98) has reported a group of 20 patients with impairments in the region of 90 to 100 dB HL, all were presumed to be sensorineural and ototoxicity was the commonest aetiology.

Difficulties are encountered when searching the literature for information on the aetiology and clinical features of severe and profound hearing impairments. Studies are often concerned with a particular pathology and seldom give an indication of how severe an impairment is likely to arise from that pathology. The mildly and moderately impaired are often singled out for hearing-aid or related research and epidemiological or sociological studies are often concerned with a particular age group or employment category.

Information on aetiology must therefore be gleaned from a variety of sources and useful information on the clinical features likely to be encountered would seem to be almost impossible to obtain.

By definition a severe or profound impairment cannot be purely conductive and must therefore be sensorineural or mixed. Browning and Gatehouse (99) state that a sensorineural component is no more common in otosclerosis than in the general population and therefore imply that a severe or profound from this cause must be fairly uncommon. If an air-bone gap of 35 dB is considered typical of otosclerosis then it would require an additional sensorineural component of 35 dB to result in a severe impairment. Data from the NSH (36) gives a prevalence of about 8% for impairments of worse than 35 dB in the better ear. In contrast Cawthorne (100) described just under half of a series of 866 patients with otosclerosis as having a "severe" impairment although exactly how "severe" was defined was not reported. Of 510 patients with presumed otosclerosis, Morrison (101) reported that 6% had a sub-total impairment although again how this was estimated is not clear. In a further small personal series Morrison (102) estimated that otosclerosis was the commonest cause of severe adult hearing impairment, defined as thresholds poorer than 75 dB HL for the speech frequencies. Browning and Gatehouse (103) state that as in otosclerosis a sensorineural component is no more common in chronic otitis media than in the general population and therefore imply that a severe or profound from this cause must be fairly uncommon. This is supported by Paparella et al (104) who have shown that a sensorineural component is frequently present in chronic otitis media but that this is usually small. However Gristwood and Beaumont (105) state that a sensorineural impairment in conjunction with chronic otitis may be slight, moderate, profound or total.

Noise would seem to rarely cause a severe or profound hearing impairment (106).

Otological surgery is also a potential cause of severe and profound hearing impairment. This fact is understandably seldom publicised by otologists. A figure of up to 5% is generally quoted for the incidence of "dead ears" after stapedectomy (107) but the real figure may be higher. Inner ear damage from tympano-mastoid surgery is a recognised complication. Smyth (108) quotes a figure of from 1 to 3% for tympanoplasties but a figure for mastoid surgery does not seem to have been reported.

Childhood hearing impairment is a special area but as hearing impaired children will grow up into hearing impaired adults a knowledge of the aetiology and degree of hearing impairment in this group is important. In a study reporting on 3,462 children born in one year in a multi-centre EEC study (109), having a pure-tone average of poorer than 50 dB HL in the better ear, 33% had a speech-frequency average of poorer than 100 dB HL. Rubella was the commonest reported cause but in over 40% the cause was unknown. Newton (110) reported on 111 children with a bilateral sensorineural hearing impairment of poorer than 25 dB HL. Roughly half had an impairment of poorer than 80 dB HL. Post-natal acquired causes accounted for less than 5% of her group (almost all meningitis). It would seem from these studies that about 1/2000 children will grow up with a severe or profound hearing impairment and that with a hospital catchment population of 200,000 we would expect to have around 100 severely and profoundly impaired adults from congenital causes alone.

This chapter reports the clinical characteristics and aetiology of 132 patients with severe and profound hearing impairments attending the severe hearing impairment (SHI) clinic. Where possible a comparison is made between the severely and profoundly impaired and a control group of unselected mildly and moderately impaired individuals attending the same audiology department.

4.2 Method

On the patients' first visit to the SHI clinic a full otological history was taken. Details of previous hearing-aid experience and otological surgery were noted and a full occupational history was taken if previous noise exposure was reported. An assessment of any disabilities other than hearing was made with particular attention to general health, mobility or visual problems. Otoscopy was performed after removal of any obstructing wax or debris with suction and an operating microscope if necessary. Visual acuity was assessed at 2 meters with a Snellen chart with glasses if appropriate.

Pure-tone audiometry was performed according to recommended methods with a Kamlex AC4 audiometer as described in chapter 3.

4.3 The general audiology clinic population

In order to provide an overall assessment of the population attending hospital for assessment and management of a hearing impairment irrespective of the degree of hearing impairment, the case records and audiograms of 300 unselected patients attending the general audiology clinic over a 2 month period were reviewed. This is the population from which the severely and profoundly impaired were drawn. The 300 were consecutive attenders. If a patient had attended more than once during the 2 month period they were counted only once. This sample comprised both new referrals and referrals from general practitioners and follow up cases. The sample was checked for completeness by referring to both the doctors' letter and the clinic register.

The age, sex, social class, pure-tone average and type of hearing impairment with respect to the better hearing ear and previous hearing aid use were recorded. A profile of the general audiology clinic population grouped by degree of impairment is shown in Table VIII. The severely and profoundly impaired together were found to represent 12% of clinic attenders. The characteristics of 213 mildly and moderately impaired identified in this survey were used to provide a comparison with the severely and profoundly impaired in the study where possible.

TABLE VIII : GENERAL CLINIC POPULATION PROFILE n = 300

Pure-tone average (dB HL) in the better hearing ear	Category	No.	%
0 - 24	normal	67	19
25 - 49	mild	126	42
50 - 69	moderate	87	29
70 - 89	severe	27	9
90 -	profound	9	3
total		300	100

4.4 Findings

On entry to the study five patients were identified with non-organic hearing impairments and were referred back to the general audiology clinic leaving 132. They have not been included in the analysis. These patients had originally produced audiograms which were classified as severe but on repeat testing their thresholds were found to be exaggerated. Two of these patient were subsequently found to have a mild impairment with pure-tone averages of less than 50 dB HL and three had moderate impairments in the range of 50 - 69 dB HL. Of the remaining 132 patients 47 had a profound impairment with average thresholds over 0.5,1,2 and 4 kHz of 90 dB HL or poorer and 85 had a severe impairment with averages of between 70 and 89 dB HL.

4.4.1 Age, sex and social class

Figure 2 shows the age distribution of the severely and profoundly impaired attending the SHI clinic. The median age was 70 years with a range of 16 to 95 years. The majority were elderly with 39% being 70 years or older. The median age of the severely impaired was 69 years with a range of 16 to 94 years. The median age of the profoundly impaired was 72 years with a range of 33 to 95 years. Figure 3 shows the age distribution of the mild and moderately impaired attending the same department. The median age of the mild and moderately impaired was 71 years with a range of 26 to 99 years. There was no significant difference in age distribution between the severely/profoundly impaired and the mildly/moderately impaired (Mann-Whitney U test).

The majority (67%) of patients attending the SHI clinic were female. There was no sex difference between the severely and profoundly impaired. There were significantly more females in the severely and profoundly impaired group than in the mildly and moderately impaired sample (55%) (Chi-square = 4.12, Df = 1, $p<0.05$)

Figure 4 shows the social class distribution, by socio-economic group, of the severely and profoundly impaired. The majority (76%) belong to manual social class groups. This is in keeping with the general social class structure of the locality (111). There were no significant differences in social class between the severely and profoundly impaired or between the severely/profoundly and mildly/moderately impaired.

FIGURE 2 : AGE DISTRIBUTION OF THE SEVERELY AND PROFOUNDLY IMPAIRED

n = 132

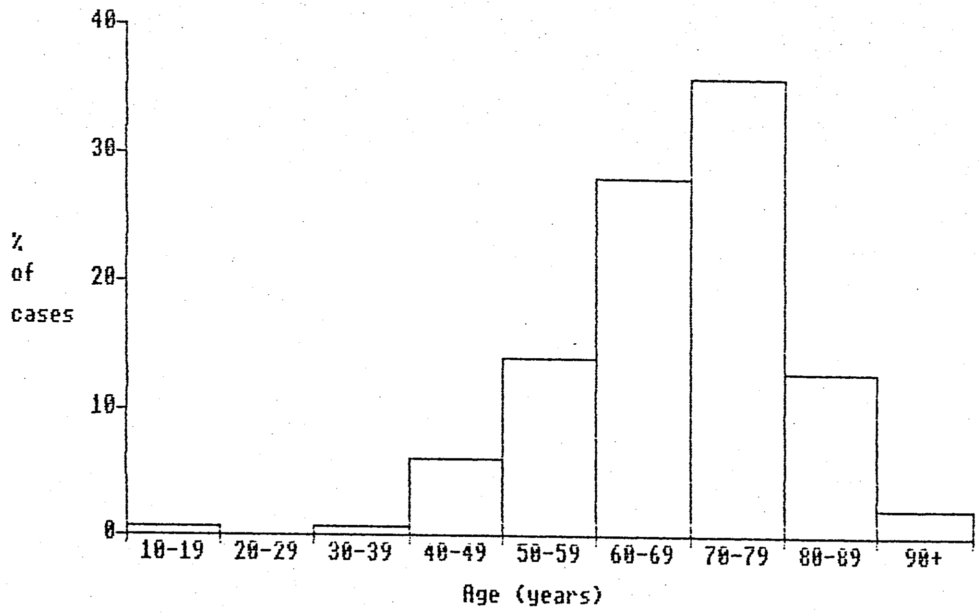


FIGURE 3 : AGE DISTRIBUTION OF THE MILDLY AND MODERATELY IMPAIRED

SAMPLE n = 213

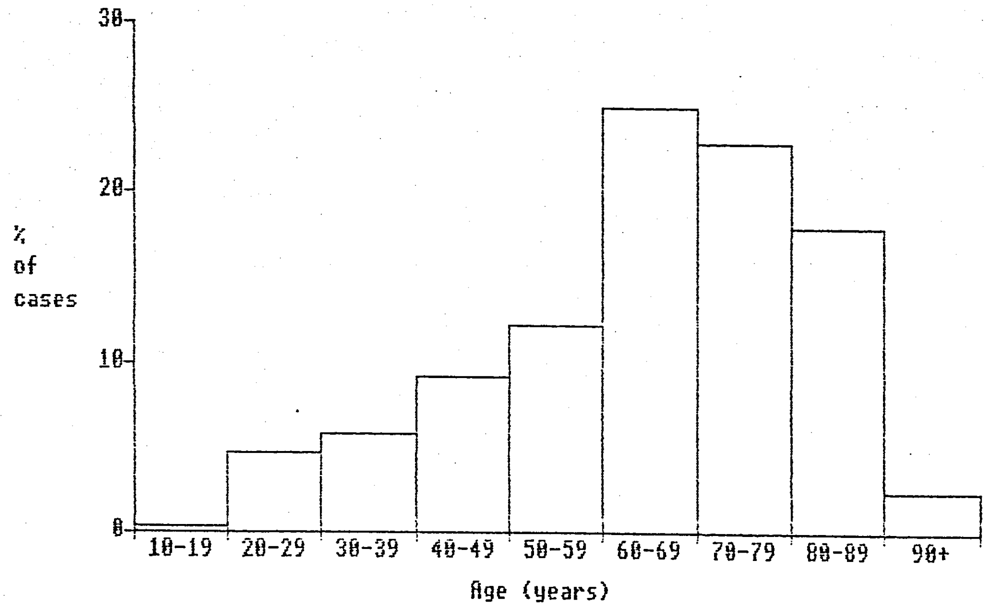
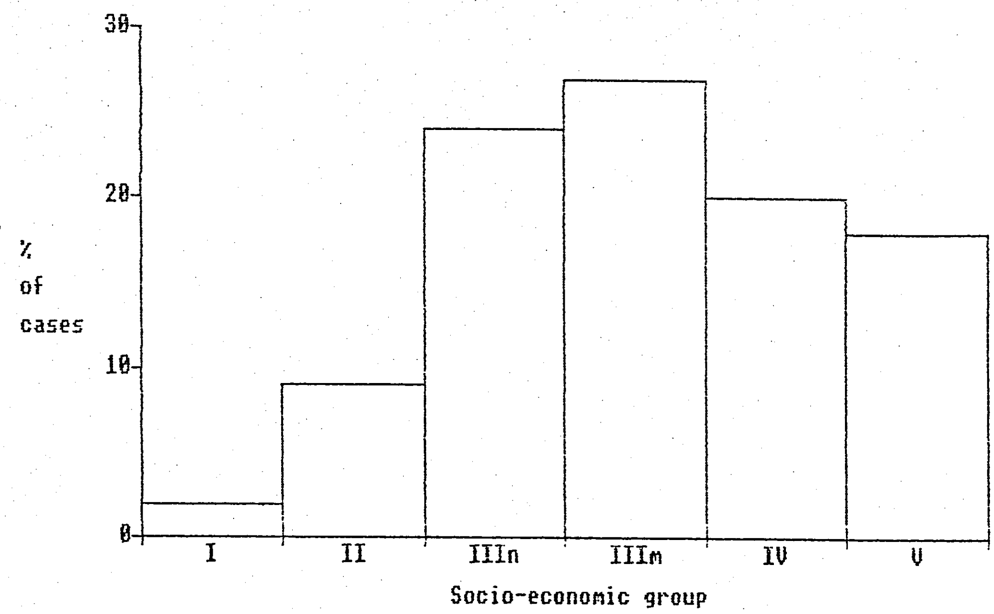


FIGURE 4 : SOCIAL CLASS DISTRIBUTION OF THE SEVERELY AND PROFOUNDLY IMPAIRED n = 132



4.4.2 Audiometry

The previous chapter considered the difficulties in performing and interpreting pure-tone audiometry in this group and a method of using the available information was described. Using this method only one patient was considered to be totally hearing impaired bilaterally and 12 unilaterally. However because of masking difficulties air-conduction thresholds were known to be correct in both ears in only 50 (38%) and therefore the number with a total impairment in the poorer hearing ear may have been greater. The distribution of air-conduction thresholds in the better and poorer hearing ear, measured without masking, averaged over 0.5,1,2 and 4 kHz are shown in Figures 5 and 6. Excluding the ears with a total impairment the mean threshold in the better hearing ear was 85.8 dB HL (SD=12.5) and 94.3 (SD=14.5) in the poorer hearing ear. Figure 7 shows the degree of asymmetry between the ears.

Not masked bone-conduction thresholds were measurable and not considered to be vibrotactile in 99 (75%) patients. A significant conductive component, defined as a difference of 15 dB or more between not-masked bone conduction and air conduction in the better ear at two or more frequencies, was present in 85 (64%) of patients. This compares to 28% when the same criteria were applied to the mildly and moderately impaired sample. The distribution of air-bone gaps with reference to the better ear is shown in Figure 8.

FIGURE 5 : PURE TONE AVERAGE IN THE BETTER HEARING EAR n = 132

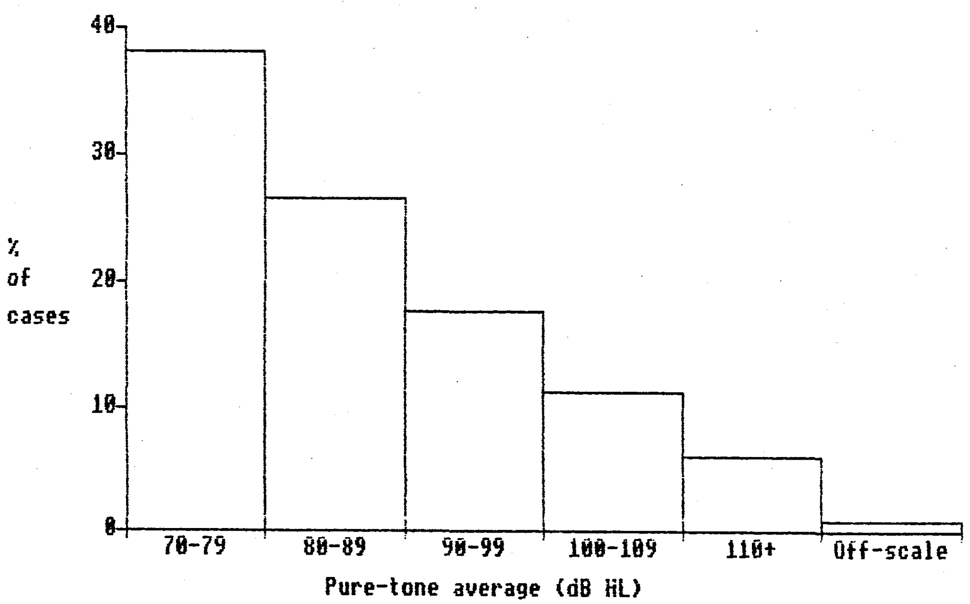


FIGURE 6 : PURE-TONE AVERAGE IN THE POORER HEARING EAR n = 132

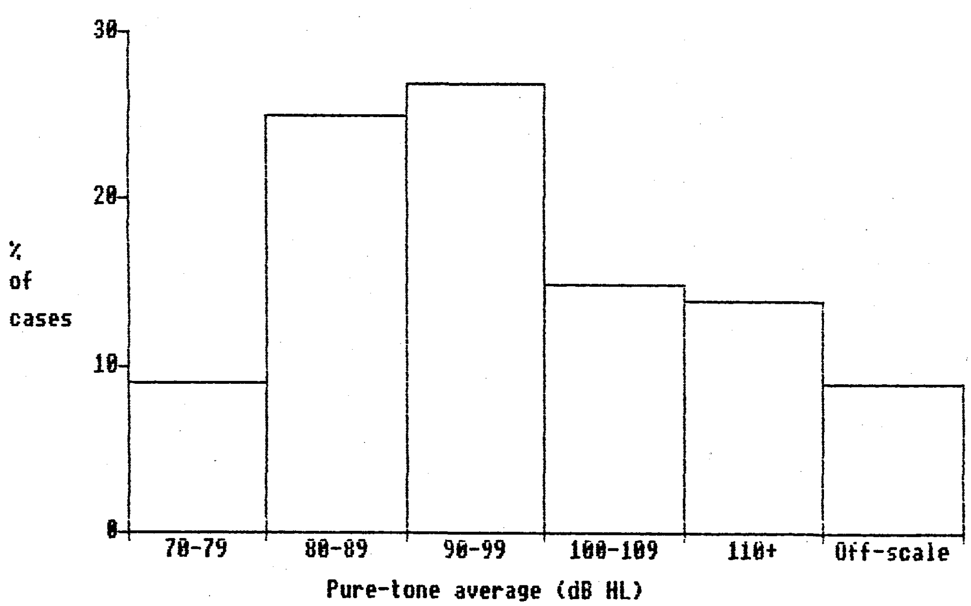


FIGURE 7 : PLOT OF RIGHT AGAINST LEFT EAR n = 132

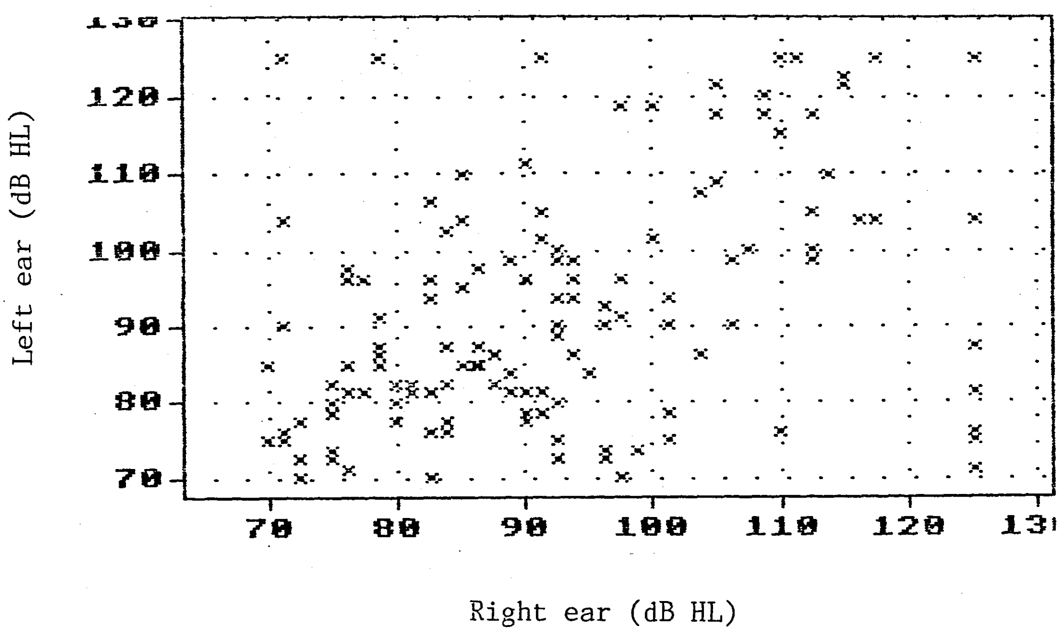
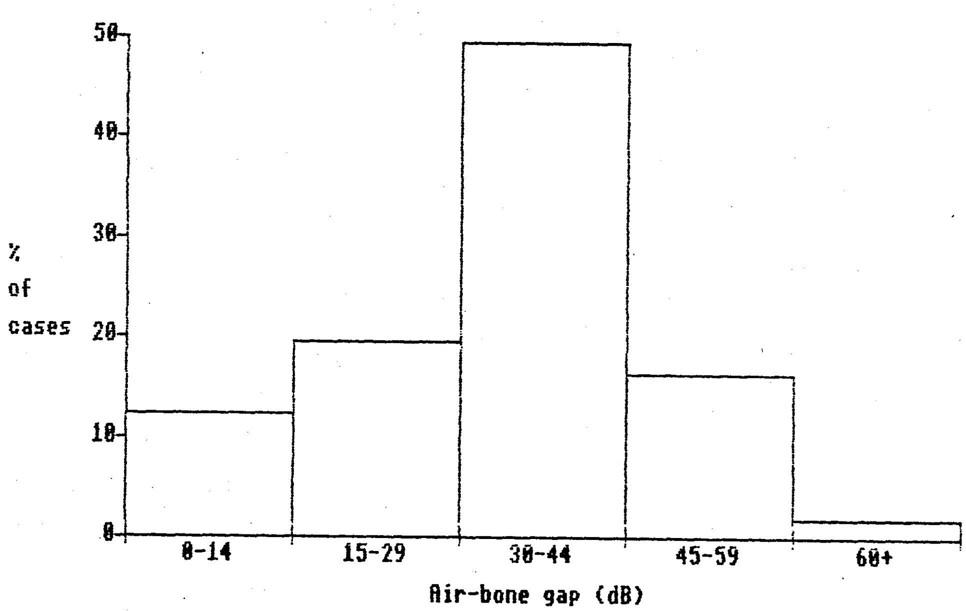


FIGURE 8 : DISTRIBUTION OF AIR-BONE GAPS n = 99



If surgery to improve hearing is to be considered then the true air-conduction thresholds of the ears with a conductive component are particularly important. Of the 85 patients with a conductive component of greater than 15 dB with reference to the better hearing ear there were potential air-bone gaps of less than 40 dB in both ears in 20 (24%). In this group the air-conduction thresholds are known to be correct in both ears without the need for masking. In a further 49 (58%) there was either a potential air-bone gap of greater than 40 dB in the poorer ear only or in both ears in combination with a clearly identifiable poorer hearing ear. In this group the true air-conduction thresholds in the poorer hearing ear is unknown without masking but is known with certainty in the better ear. In a further 16 (19%) there were bilateral potential air-bone gaps of greater than 40 dB and symmetrical air-conduction thresholds. In this group, as a poorer hearing ear cannot be confidently identified, there may be doubt about the true air-conduction thresholds in one or other ears (one is correct).

A pure sensorineural impairment, defined as an air-bone gap of less than 15 dB or an air-conduction average of less than 85 dB with off-scale bone conduction, was present in 25 (19%) of patients. These patients by definition cannot be profoundly impaired. In 22 (17%) it was not possible to diagnose the type of hearing impairment by pure-tone audiometry. All but one of these patients had a profound impairment.

The configuration of the audiogram is worthy of comment. It has received great interest in relation to hearing-aid fitting (112,113,114,115,116,117,118) and may give an indication of the type of impairment present in the absence of measurable bone conduction. A steeply sloping configuration is more likely to be associated with a purely sensorineural than a mixed impairment. Table IX shows the differences between mean thresholds over 0.5,1,2 and 4 kHz for the better hearing ear. It can be seen that the number with a steeply sloping audiogram configuration is small.

TABLE IX : AUDIOGRAM CONFIGURATION FOR BETTER HEARING EAR n = 132

		% with difference greater than		
Frequency interval (kHz)	mean difference (dB)	0 dB	20 dB	40 dB
0.5 - 1	2.1	67	9	1
2	4.4	68	12	5
4	12.5	80	37	7
1 - 2	2.3	67	8	1
4	10.4	80	29	5
2 - 4	8.1	87	20	1

4.4.3 Otoscopy

Out of 264 ears, 191 were normal on otoscopy and 73 were abnormal. Minor degrees of tympanosclerosis were considered normal. The 73 abnormal ears were distributed between 54 patients, 19 having bilateral abnormalities (Table X). Apart from otits externa in 3 ears in two patients all abnormalities were variants of chronic otitis media (CSOM). Inactive mucosal type chronic otitis media was the most common, being present in 29 ears in 20 patients. An aural discharge was present in 14 ears in 11 patients being due to otitis externa in 2 patients and chronic otitis media in 9. One patient had a cholesteatoma but was considered unfit for surgical management, another patient had active chronic otitis media which may have been associated with cholesteatoma but it was impossible to reach a diagnosis as the patient was intolerant of examination and suction of the ear and was considered unfit for anaesthesia.

TABLE X : OTOSCOPIC ABNORMALITIES

Otoscopic finding	ears	patients
Otitis externa	3	2
Active mucosal CSOM	6	4
Inactive mucosal CSOM	29	20
Cholesteatoma	1	1
Active CSOM (uncertain type)	1	1
Open mastoid (inactive)	12	9
Open mastoid (active)	3	3
Healed CSOM	18	14
Totals	73	54

4.4.4 Previous Surgery

Of the 40 (30%) patients having had previous major ear surgery, 6 had had bilateral operations. Open mastoid surgery and stapedectomy were the most common operations having been performed in 12 and 14 patients respectively. A tympanoplasy had been performed in 7 and in a further 5 various tympanomastoid procedures had been performed. In 2 the type of procedure carried out was not known but in both cases there was a post-auricular scar associated with a normal tympanic membrane and the procedure was probably a cortical mastoidectomy. Surgery was not considered to be the principal cause of the impairment in the better hearing ear in any patient but of 12 shown to have a total hearing impairment in one ear, 7 were in an operated ear. Of these 7 ears, 5 had a stapedectomy, 1 an open mastoid and in the other the type of previous surgery was unknown.

4.4.5 Aetiology

Table XI shows the aetiology of all patients derived from consideration of the history, examination and audiometry. No patient with a conductive component and a normal tympanic membrane gave a history of trauma or a congenital impairment so all were considered to have otosclerosis. There were 9 patients in whom an audiometric diagnosis of the type of impairment was not possible but an aetiology could be assigned on the basis of the history or otoscopy: 3 had a clear history of meningitis, 2 had congenital impairments and 4 had either a tympanic membrane perforation or a mastoid cavity indicating chronic otitis media. In only 2 patients who had been shipyard workers for over 20 years was the hearing impairment considered to be potentially due to noise exposure. In 27 (20%) patients the aetiology was unknown this being made up of 9 with sensorineural impairments and 18 with an unknown impairment type.

TABLE XI : AETIOLOGY n = 132

Condition	Male (%)	Female (%)	Total (%)
Otosclerosis	12 (25%)	36 (75%)	48 (36%)
Chronic otitis media	16 (39%)	25 (61%)	41 (28%)
Congenital	4 (50%)	4 (50%)	8 (6%)
Meningitis	1 (17%)	5 (83%)	6 (5%)
Noise exposure	2 (100%)	0 (0%)	2 (2%)
Unknown (sensorineural)	4 (44%)	5 (56%)	9 (7%)
(type unknown)	5 (27%)	13 (73%)	18 (14%)
Total	44 (33%)	88 (67%)	132 (100%)

4.4.6 Previous hearing aid experience

Only 3 patients had never used a hearing aid before coming to the clinic. One profoundly but not totally impaired individual had been told that an aid would be of no benefit and the other 2 who were severely impaired, had never sought help before. The median number of years of hearing aid use was 22 with a range of 0 to 48. Only 5 (4%) patients had used binaural aids previously.

Of the 213 mildly and moderately impaired clinic attenders sampled 132 (62%) had never used a hearing aid before.

4.4.7 Employment

Only 28 of the group were younger than 60 years and the majority of these (70%) were female. 19 (14%) were in full time employment, made up of 14 severely and 5 profoundly impaired individuals. Only 3 were in non-manual occupations. 9 were registered as unemployed and 4 women considered themselves working as housewives.

4.4.8 Other disabilities

A significant visual impairment, defined as a corrected visual acuity of poorer than 9/6, was present in 20 (15%). A significant mobility problem, defined as using a wheelchair or other mobility aid, was present in 10 (8%). A significant other health problem was present in 16 (12%). This included chronic obstructive airways disease, congestive cardiac failure, intermittent claudication and cancer. Overall 29 (22%) were considered to have another significant disability in addition to a hearing impairment.

4.5 Discussion

The majority attending the SHI clinic had a significant conductive component to their hearing impairment with reference to their better hearing ear. This is perhaps surprising but confirms early reports by Morrison (102) that otosclerosis and chronic otitis media are the most common causes of severe and profound impairments in an adult hospital population. This group is quite different from that selected for cochlear implants. It is also important to note that 28% of the mildly and moderately impaired identified in the department sample also have a significant conductive component in their better hearing ear. This figure should be compared to the 19% of the hearing impaired identified in the NSH (1) who were found to have a conductive or mixed impairment in their better hearing ear. It is probable, because of the association of otalgia, otorrhoea and asymmetric hearing with middle ear disease and the greater unaided disability of a conductive impairment compared to a sensorineural (83,119) that a hospital population will have a higher prevalence of conductive and mixed impairments than the general population. Severely and profoundly hearing impaired patients attending a hospital audiology clinic may not be representative of the general population and this has been highlighted by Thornton (38). Many of the more extremely affected may feel that the hospital has nothing to offer them and many of those established in the deaf community may feel likewise. A hospital group is however the population that an audiological service is called called upon to deal with, and as such, a knowledge of the characteristics of this group is particularly important, both for patient management and planning of clinical services.

The finding of such a high prevalence of mixed impairments in the severely and profoundly impaired raises important management issues. There is the possibility of surgery to correct hearing but here masking difficulties assume great importance. Without masking air-conduction thresholds were known to be correct in both ears in only 24% of those with a conductive component Great care would need to be exercised in the selection of suitable patients in order to avoid operating on a "dead" or only hearing ear. An aggressive otologist may believe that by closing an air-bone gap in a mixed impairment the patient may be able to use a less powerful aid and therefore derive more benefit (120,121). This remains an unproven but widely held view and of course the number of suitable patients who would accept surgery on this basis is unknown. There is also the possibility of using bone-conduction hearing aids in many patients. Conventional bone-conduction aids with a vibrator held by a headband are uncomfortable and therefore unpopular but the recent introduction of bone-anchored aids may be suitable for a number of these patients (122,123,124). The finding of a large number of profound otosclerotics should be borne in mind by those fitting cochlear implants. A profound otosclerotic may have bone-conduction thresholds in the region of 70-80 dB HL which would be off-scale with standard audiometry in conjunction with air-conduction thresholds of greater than 120 dB HL. Such a patient would be classified as having a total hearing impairment but may still have usable residual hearing and benefit more from a stapedectomy and a hearing aid than a cochlear implant.

Since it is known that the severity of a hearing impairment generally increases with age (125) it is surprising that no significant difference in age distribution could be shown between the severely and profoundly impaired and perhaps even more surprising that no age difference could be found between the severely/profoundly and the mildly/moderately impaired identified in the general clinic sample. It is probable that the conductive component or event resulting in an extreme impairment is relatively age independent and that it is this which in most cases results in the patient crossing the 70 dB HL threshold. There is no reason to believe that the gradual deterioration of hearing usually associated with ageing is not operating in these individuals and a follow up study after a reasonable passage of time would answer important questions on progression. The female preponderance in the severely and profoundly impaired is probably due to the high incidence of otosclerosis which is known to be more common in females (126). This study has shown that 75% of those considered to have otosclerosis were female. Little can be said about the influence of social class as the clinic population is heavily weighted towards the lower classes.

The 22% having significant other disabilities is no more than would be expected in an elderly population (127,128) but these other disabilities will have to be taken into account when considering rehabilitation programmes.

The 68% of those less than 60 years old working full time is perhaps a higher proportion than would have been expected in a disabled group in an area of relative social deprivation and high unemployment, but previous studies have shown that the severely hearing impaired are no less likely to be employed than the general population although they may be underemployed, being forced to accept employment of a lower status than they would otherwise have expected (129,130).

CHAPTER 5

MANAGEMENT PROBLEMS

5.1 Introduction

The selection and fitting of hearing-aids for the severely and profoundly impaired has received little study. Byrne et al (131) have recently drawn attention to this fact. Byrne's paper concentrates on the selection of the most appropriate aid characteristics but makes little mention of the practical difficulties in actually fitting high-powered aids to these individuals. This chapter attempts to describe and quantify the practical problems encountered in managing the severely and profoundly impaired with hearing aids.

Acoustic feedback with high-powered ear-level aids is a well recognised problem (132,133). There is certainly no possibility of using vented ear moulds, Gatehouse (134) and MacKenzie et al (135) having shown that venting can markedly reduce the available gain. The gain limits with ear-level aids have been measured by Grover and Martin (136) and various techniques for producing moulds with a better acoustic seal have been described (137,138) but how much of a problem this is in a clinical setting and how it can be overcome has never been investigated. Powerful body-worn aids are often recommended for the more extremely impaired (139,140,141) but the number who require or will accept these aids is unknown.

Due to the high incidence of chronic otitis media and the requirement to wear tight fitting ear-moulds otological problems may also be anticipated in the group.

Over 60% of the study group have a conductive component to their impairment but this chapter does not consider a surgical option to improve hearing or the use of implantable bone-conduction aids. This is the subject of a further study on this group of patients (Giles ML et al, in preparation). Initial results would suggest that the place of surgery is perhaps less than would have been expected simply from a consideration of the incidence of conductive impairments. Currently it is felt that all patients should be optimally fitted with conventional hearing aids before a surgical option is considered. Even after successful surgery the majority will still require a hearing aid and therefore if a surgical option is chosen at a later date time and effort will not have been wasted fitting hearing aids.

5.2 Method

The basic aim of management was to provide binaural aids where appropriate which did not allow acoustic feedback when set at maximum gain. Hearing aids were selected from the National Health Service high-powered range (see appendix E) by considering the audiogram, wishes of the patient and result of trial periods. The gain required was estimated using Lybarger's 'half-gain rule' (142,143) which has been verified for the mildly and moderately hearing impaired by a number of studies (144,145). The aid(s) selected from the available range was the one with the smallest maximum gain which provided the required gain + 10 dB.

After an initial decision as to which aids(s) were likely to be suitable and a simple trial of moulds and aids in the clinic, patients were reviewed at monthly intervals until a satisfactory fitting was achieved. Any otological problems encountered were dealt with over the same period.

At each monthly review, problem areas were noted and recorded for each ear, grouped as hearing-aid related problems, ear-mould problems or otological problems. Hearing-aid related problems were recorded as loudness discomfort, not loud enough or lack of clarity. Ear-mould problems were recorded as acoustic feedback, mould discomfort or manipulative. Otological problems were recorded as otitis externa, active chronic otitis media or other. Solutions to these problems were likewise recorded as hearing-aid related, ear-mould related or otological. Hearing-aid solutions were divided into aid modifications (peak clipping or tone control adjustments) or change of aid type. Ear-mould solutions were divided into mould modifications or taking of impressions for new moulds. Otological treatments were noted.

Once a satisfactory fitting had been achieved patients were reviewed after a further period of one month and a final problem assessment undertaken.

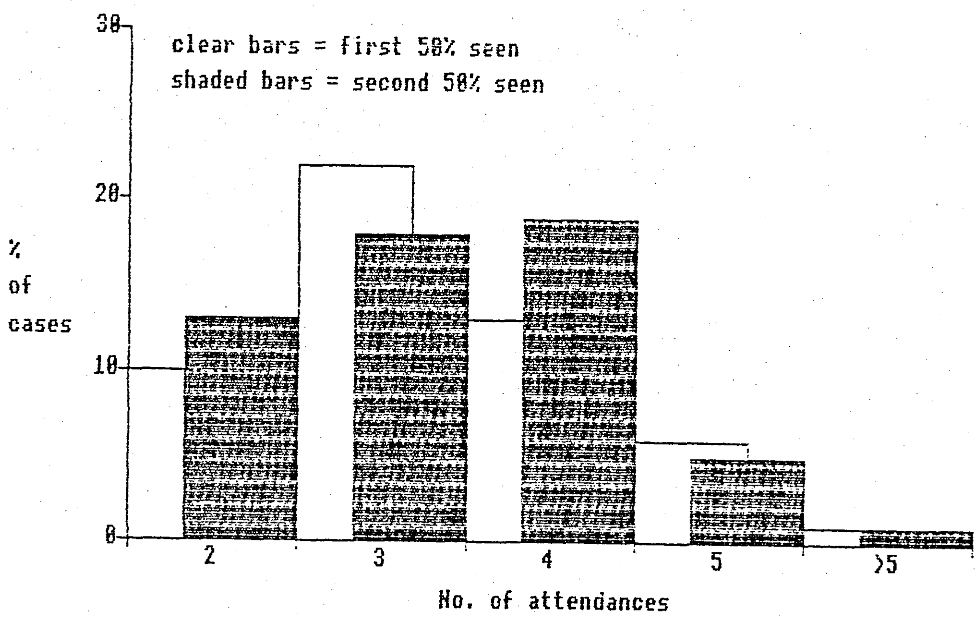
5.3 Findings

Although 132 patients were enrolled in the clinic only 115 completed the management protocol. An attempt was made to trace the defaulters. Three patients had died and 5 reported that they were unfit to attend due to illness. 4 patients did not want to come back. Of these 4, 3 had transport problems and 1 did not consider further visits worthwhile. The remaining 5 patients could not be contacted which may have been due to a change of address.

The number and distribution of clinic attendances required for management is shown in Figure 7. The number of attendances required for the first 50% seen are shown separately from the second 50%.

The number of attendances required by the first 50% seen was not significantly different from the second 50% (Mann-Whitney U test). The mean number of attendances required was 3.3 with a range of 2 to 7. A satisfactory fitting was achieved in 3 visits (an initial attendance and a 2 reviews) in 63% of patients.

FIGURE 9 : NUMBER OF CLINIC ATTENDANCES n = 115



5.3.1 Hearing aids

Of 115 individuals completing the management protocol, binaural fittings were recommended for 98 (85%) but 17 declined to wear a second aid. A binaural fitting was not recommended for the 12 patients with no recordable hearing in one ear or where there was asymmetry of more than 30 dB. Thus a total of 196 hearing aids were fitted to 115 individuals being made up of 34 (30%) monaural and 81 (70%) binaural fittings. The type of aid(s) finally issued are shown in Table XII. The mean number of hours use per day was 15.8 (SD=2.5). 5 individuals wore at least one aid for 24 hours a day.

The most common problem was that the aid(s) were reported as not loud enough. This was noted in 43 fittings (22%). In general the solution offered for this problem was to change from an ear-level to a more powerful body-worn aid but this was accepted by very few such that on final review, 29 fittings (15%) were still considered by the patient not to be loud enough. In total, body-worn aids were recommended for 33 individuals in the group (29%) but accepted by only 12 (10%).

Only 8 fittings (4%) were reported as not clear enough. Tone control modifications did not solve the situation. The same 8 fittings were still reported as not clear at final review.

The aid was reported as too loud in 20 fittings (10%) and by either changing to a less powerful aid or introducing peak clipping, at final review 14 fittings (7%) were still reported as too loud.

TABLE XII : TYPE OF HEARING AID FINALLY FITTED n = 115

Aid type	No. of patients		
	Binaural	Monaural	Total
BE30 series	16	9	25
BE50 series	63	15	78
BW61	0	3	3
BW81	2	7	9
Total	81	34	115

5.3.2 Ear moulds

Impressions for new moulds were taken on referral to the clinic and new moulds were therefore available on the first visit. Repeat impressions or mould alterations were required in 104 (53%) of the 196 aid fittings to overcome acoustic feedback. 35 (18%) required 3 or more impressions or mould alterations. On final review 10 fittings (5%) were still giving problems with acoustic feedback. A further 21 ear moulds were modified to overcome mould discomfort but on final review 18 (9%) were still reported as causing discomfort. Thus a total of 28 (14%) of the 196 aid fittings were not ideal despite the attention given to them.

5.3.3 Otological problems

Otological problems were infrequently encountered, the most common being otorrhoea which was present at some stage in 9 individuals (8%) due to otitis externa in 3 and active chronic otitis media in 6. This was treated by steroid/antibiotic ear drops and on final review only 3 individuals (3%) still had otorrhoea.

5.4 Discussion

Despite our best efforts an unfortunately large number of patients still had problems with their aid fitting. On review, one month after management, 33% of fittings were still causing difficulty which was apparent to us or reported by the patient. In 3 (3%) more than one problem was present. The aid was reported as not loud enough in 15%, causing discomfort in 9%, too loud in 7% and acoustic feedback was still a problem in 5%. The latter problem accounted for the largest amount of the time spent with these patients. The smallest imperfection in ear-mould fit can result in troublesome feedback with ear-level aids. It was generally possible to overcome this problem but feedback remained an insurmountable problem in 5%. It may be that these individuals have a particular configuration of the pinna and external ear canal such that sound is radiated through the tissues to the aid microphone (mechanical feedback) rather than round the mould (acoustic feedback) although this was not obvious clinically. The same impression material (Steramould) was used for all patients so no comment can be made in this area. No particular mould type seemed to be superior. Hard acrylic with soft silicone tips were the most popular with the patients but seemed to offer no specific advantages. Careful checking of impressions against moulds often revealed inaccuracies and inconsistency in mould manufacture was probably an important factor. Impressions were sent to an outside laboratory for mould manufacture and therefore little comment can be made in this area. Sometimes an unsatisfactory mould could be modified but usually a new mould was necessary.

Errors in both impression taking and mould manufacture will be cumulative and small variations will occur randomly explaining why often simply taking new impressions and requesting new moulds resulted in moulds which did not allow feedback. Further research in both impression taking methods and mould manufacture is required to establish the optimum techniques.

We have drawn attention to the frequency with which discomfort can occur with tightly fitting moulds. In two patients this resulted in frank ulceration of the pinna which was difficult to heal. These patients were so dependant on their hearing aids that they continued to wear painful moulds to the point where ulceration occurred.

The reluctance to change to a body-worn aid for those who were using an ear-level aid at maximum or near maximum gain or complained that the aid was not loud enough is surprising. Many of these individuals had had previous experience with early body-worn aids and associated them with poor quality sound and other problems.

Aid controls were generally left at standard settings to allow the maximum available gain of the aid to be utilised. Tone controls were adjusted only if the patient complained of lack of clarity but in the few who complained of this, tone control adjustments made no noticeable difference.

Few patients complained of loudness discomfort. Peak clipping which was the only form of output limiting available was introduced in those who complained that an aid supplying the required gain was too loud. It was found to be successful in relatively few, most patients preferring occasional loudness discomfort to the distortion inherent in peak clipping. Many patients reported that they turned the gain of their aids down when they encountered noisy surroundings such as traffic. The requirement for output limiting in these patients would appear to small. Perhaps an automatic gain control (AGC) system would have been more successful than peak clipping but there are still technical problems in fitting an effective AGC system to ear-level aids with high gains as this inevitably reduces the available gain. Good AGC systems are available on many commercially available, high-powered body-worn aids but as previously stated there was a marked reluctance to use body-worn aids.

Specific otological problems were encountered surprisingly infrequently. The requirement for an otologist to be in attendance at a special clinic for the severely and profoundly impaired would not appear to be justified for management directed primarily at conventional hearing-aid provision but as the incidence of conductive impairments is high a good otological assessment is essential. If surgery to improve hearing or implantable bone-conduction aids are shown to be a viable proposition for this group then the role of the otologist would be considerably expanded.

CHAPTER 6

SUPRATHRESHOLD LOUDNESS JUDGMENTS

6.1 Introduction

The basic requirement of a hearing aid is that it should provide sufficient gain without distortion for the individual to receive amplified speech at their optimum or most comfortable listening level (MCL). Subject to the maximum gain possible with the hearing aid selected, the individual is free to alter the gain control to cope with the differing speech levels encountered in day to day living. A further consideration is that the maximum power output (MPO) of the aid should be such that the individual is able to fully utilise their available dynamic range with the provision that they are not frequently troubled by reaching an uncomfortable loudness level (UCL) (146,147,148,149).

It has been shown in the previous chapter that acoustic feedback with high-powered ear-level aids was difficult to eliminate and the expenditure of considerable time and effort was required to provide ear moulds which did not allow feedback with the aid set at maximum gain. It is probable that few patients would select maximum gain in normal daily use. Indeed, due to the high levels of distortion inherent in using aids at maximum gain (150,151) it is desirable that the selected aid is not used at this setting. It would seem to be unnecessary to spend time and effort providing patients with high gain which will not be used. A knowledge of the gain likely to be selected to achieve MCL in daily living would allow effort to be concentrated on providing high gain without feedback to those who would actually use it

The time honoured 'half-gain rule' was originally derived by Lybarger (142,143) to provide an estimate from the pure-tone average of the gain likely to be used to reach MCL in everyday situations. This relationship has been verified by a number of subsequent studies in the mildly and moderately impaired (144,145) and had been used as the basis for many prescriptive hearing aid fitting procedures (152,153,154). However, although the 'half-gain rule' provide a useful estimate for groups of patients, the gain used to achieve an MCL varies considerably between individuals for a given pure-tone average, typically over a range of about 20 - 30 dB (144,145,155). Only one study by Byrne et al (131) has looked specifically at the gain at MCL in the severely and profoundly impaired. As Byrne's study was primarily concerned with selecting the most appropriate hearing-aid frequency response, the range of gains used for a given pure-tone average was not reported but an inspection of the raw data given in the paper confirms that typically there was a range of about 20 dB. It would seem that a consideration of the pure-tone average is likely to give no more than a rough guide to the gain which will be selected by an individual patient.

Both the type of hearing impairment and aid fitting have been shown to influence the gain selected in the mildly and moderately impaired. Berger (156) has shown that those with a conductive component tend to select more gain for a given pure-tone average and it has been shown that binaural aiding compared to monaural aiding reduces the gain selected by about 3 to 5 dB (157,158). It would be useful to know if a binaural fitting compared to a monaural fitting reduced the gain selected in the severely and profoundly impaired and if those with a conductive component were likely to select more gain than those with a sensorineural impairment for a given pure-tone average. If this was the case, and the amount of gain involved was material then it would indicate that more time an effort should be spent on providing feedback-free gain for monaural aid users and those with conductive components.

Uncomfortable loudness levels are of interest for two reasons. Firstly, from a theoretically point of view, in combination with threshold and MCL measurements they can give an indication of the patient's available dynamic range. Those with the largest dynamic ranges generally being considered to gain the most benefit from hearing aids and those with the smallest are often prescribed aids with output limiting systems (159). Secondly, from a clinical point of view it may be important to know how likely it is that uncomfortable loudness will be experienced with a particular aid in normal day to living. It is probable that those with sensorineural impairments would be more likely to experience loudness discomfort than those with a mixed impairment but again this has not been previously investigated in the severely and profoundly impaired.

There have been two major criticism of the use of MCL and UCL measurements. Firstly there is the test-retest variability of these measurements (160,161,162,163,164,165,166). This is a criticism of hearing aid fitting procedures using these measurements. Secondly there is the question of their external validity. This has been seldom reported but Walden et al (167) have shown that the gain selected at MCL measured under laboratory conditions with a speech input of 70 dB SPL does correspond to the gain selected in day to day living by mildly and moderately impaired subjects. It is probable however that individuals will tend to speak louder to a severely or profoundly impaired patient.

After fitting patients with what was considered to be the best and most acceptable fitting from the range of high-powered National Health Service aids available (see chapter 5) a study was undertaken to determine the gain used to MCL and UCL under laboratory conditions using a speech input of 75 dB SPL. Two principal aims are defined. Firstly to determine the reliability of MCL and UCL measurements in the severely and profoundly impaired. Secondly to examine the relationship of gain used at MCL and UCL with degree and type of hearing impairment. A second study was undertaken on a subgroup of patients to determine the gain used monaurally versus binaurally.

6.2 Patients

106 patients were available for testing. Of these 106, 8 were excluded. In 5 it was impossible to adequately perform the test due to acoustic feedback (see below) and there were 3 very elderly patients who were not capable of performing the tasks required. This leaves 98 patients who completed the study. The group comprised 64 severely impaired and 34 profoundly impaired individuals. The mean pure-tone average was 85.0 dB HL (SD=11.6). The median age was 69 years with a range of 18 to 89 years. There were 68 binaural aid users and 30 monaural aid users. All but 10 individuals were fitted with NHS BE (behind the ear) ear-level aids. BE 30 series aids were fitted to 20 and BE 50 series were fitted to 66. The body worn aids used were a BW 61 in 2 and a BW 81 in 8. The electroacoustic characteristics of these aids are given in appendix C.

From this group a subgroup of 22 binaural aid users were selected who had symmetrical hearing with a pure-tone average difference between the ears of less than 10 dB.

6.3 Method

Patients were seated in a sound-deadened room 2 meters in front of a loudspeaker at zero azimuth playing a passage of speech without background noise at 75 dB SPL measured at the centre of the head. The speech consisted of a male speaker reading a passage from a Sunday magazine.

In order to simulate real life listening conditions and allow a comparison with reported levels of loudness, tests were performed with the patient's fitted hearing aid(s). If the patient was a binaural aid user then the test was performed binaurally and if the patient was a monaural aid user then the test was performed monaurally. As a preliminary the aid(s) were turned up to maximum gain to check for acoustic feedback. Any slight feedback present was overcome by applying petroleum jelly round the mould. If this did not overcome the feedback the patient was excluded from the test.

With the speech tape running the patient was asked to adjust the gain control of their aid(s) to their most comfortable listening level. The instructions given were "please adjust the setting of your aid(s) to the level which is both comfortable and allows you to hear most clearly." Patients were given adequate time and told to indicate when they had set their aids satisfactorily. The aid or aids were then removed without touching the gain controls and the gain used measured on a 2cc coupler in a Bruel and Kjaer model 4222 acoustic test chamber with a type 2118 acoustic test station. This allows measurement of hearing-aid outputs up to 150 dB SPL. The input on the test station was set to 75 dB SPL to correspond to the test level. The hearing-aid gain recorded was averaged over 0.5, 1 and 2 kHz. The aid(s) were returned to the patient and the patient asked to turn up the gain control of the aid(s) until uncomfortable loudness or the maximum gain of the aid was reached. The BSA has published a recommended procedure for determining uncomfortable loudness levels (168) but the instructions recommended were not considered suitable when the patient was being asked to alter the gain setting themselves. The instructions given were "please turn up the volume control of your aid until it is so loud that you would not be comfortable listening at that level for more than a short time." These instructions probably result in a measure of initial loudness discomfort as described by Hawkins (169) rather than extreme discomfort. To assess the test-retest variability of both MCL and UCL measurements the tests were repeated 3 times on 12 patients within the same test session.

The possibility of cross hearing is a particular problem in this group of patients because of the impossibility of masking (see chapter 2). There is frequently doubt about the hearing in the poorer hearing ear and this may confuse results. As with threshold measurements it cannot be assumed that the MCL or indeed UCL measurement is actually referred to the ear under test. All 30 patients who were using monaural aids were using the aid in the better hearing ear and the measurements can be assumed to relate to the ear under test. The interpretation of the results in binaural users require more care as an aid fitted in the poorer hearing side could conceivably be heard in the better side. For the vast majority of patients a binaural fitting was a new system and although almost all were very experienced hearing aid users, there may have been difficulty in adjusting the second aid. For these reasons measurements were analysed for the better hearing ear only.

For the binaural versus monaural study the same basic procedure was performed as detailed above but MCL and UCL measurements were taken firstly with both aids being used together and then with each individually. Although this group were selected to have near symmetrical hearing to ensure that a binaural effect would occur, the gain required to MCL and UCL was analysed for the better hearing ear only.

6.4 Findings

6.4.1 Test-retest variability

36 test-retest comparisons were available by considering differences between test 1 and test 2, test 2 and test 3 and test 1 and test 3. The MCL test-retest difference varied over a range of 13.0 dB. The largest single difference was 7.0 dB. Of the 36 test-retest comparisons 50% were within a range of less than 3.3 dB (25th to 75th percentile) and 80% within 7.1 dB (10th to 90th percentile). Of the 12 patients tested only 7 reached a true UCL (the other 5 being able to tolerate their aid at maximum gain without loudness discomfort) therefore only 21 test-retest comparisons were available. The UCL test-retest difference varied over a range of 14.3 dB. The largest single difference was 8.2 dB. Of the 21 UCL test-retest comparisons 50% were within a range of less than 3.5 dB (25th to 75th percentile) and 80% within 8.2 dB (10th to 90th percentile).

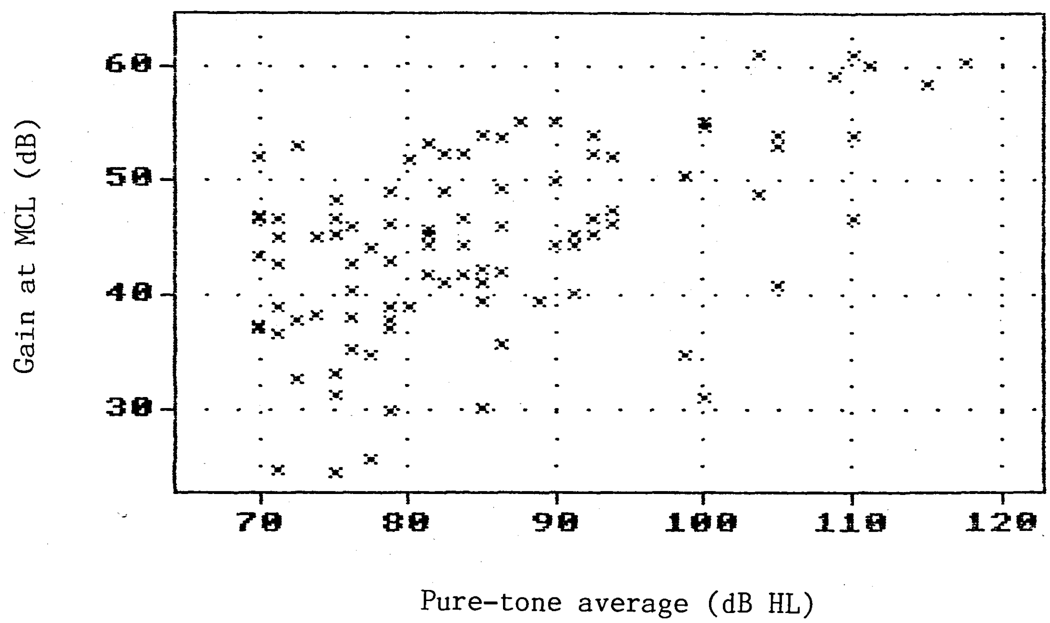
6.4.2 Gain at MCL

Table XIII shows that the gain to MCL typically varied over a range of 20-25 dB for a given 5 dB pure-tone average band. The correlation between gain and pure-tone average although significant, is fairly modest (Spearman's correlation coefficient = 0.53, $p < 0.001$). Figure 8 shows that the 'half-gain rule' underestimated the gain at MCL for 62 patients (63%) and the addition of a further 10 dB still underestimated the gain for 13 (13%).

TABLE XIII : GAIN AT MCL BY PURE-TONE AVERAGE n = 98

Pure-tone average (dB HL)	No.	Mean gain (dB)	Range(dB) lower	upper	width	Interpercentile range(dB) 25th-75th	10th-90th
70 - 74	17	41.5	24.7	53.0	28.3	9.4	15.0
75 - 79	22	40.0	24.3	49.0	24.7	10.6	15.0
80 - 84	16	45.8	39.0	53.3	14.3	7.3	12.3
85 - 89	12	44.2	30.0	55.0	25.0	8.3	18.0
90 - 99	16	46.2	31.0	55.0	24.0	6.0	12.3
100 +	15	54.8	40.7	61.0	20.3	7.0	11.3

FIGURE 10 : GAIN AT MCL IN RELATION TO PURE-TONE AVERAGE n = 98



In this group of patients air-bone gap correlates with the pure-tone average (Spearman's correlation coefficient = 0.51, $p < 0.001$) and therefore pure-tone average must be controlled for when considering air-bone gap. As the criteria for the presence of a material air-bone gap has been set at greater than 15 dB and the maximum output for bone conduction from the audiometer is 70 dB HL across the speech frequencies, those with pure-tone averages of less than 85 dB HL (audiometer maximum of 70 + 15 dB) can be split into two groups with similar pure-tone averages: those with a conductive component and those with a pure sensorineural impairment. 61 of the 98 patients tested had a pure-tone average of less than 85 dB HL, 20 having a sensorineural and 41 a mixed hearing impairment. The mean pure-tone averages for both groups were similar: those classified as sensorineural had a mean pure-tone average of 77.8 dB HL (SD = 5.0) and those classified as conductive or mixed had a mean pure-tone average of 77.0 dB HL (SD = 4.8).

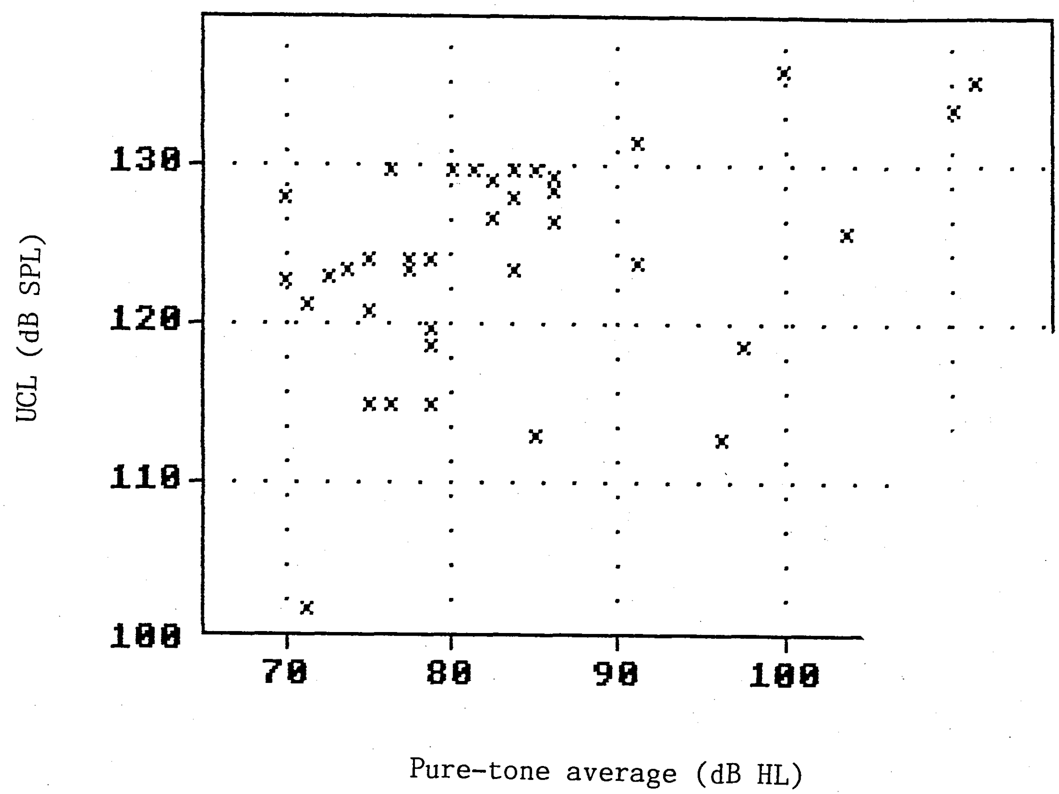
The mean gain to MCL used by those with a sensorineural impairment was 40.8 dB (SD = 7.3) which is not significantly different from the 42.2 dB (SD = 6.8) of those with a conductive or mixed impairment (Mann-Whitney U test).

6.4.3 Uncomfortable loudness levels

All patients had a 'top limit' with their fitted hearing aid whether imposed by the aid itself or by uncomfortable loudness. Only 37 patients (38%) were limited by uncomfortable loudness, the remaining 61 (62%) being able to turn their hearing aids up to maximum gain without experiencing loudness discomfort in the test situation. Figure 11 shows a plot of the 37 patients reaching UCL against pure-tone average. There is a wide scatter, however there would appear to be a tendency for UCL to increase with pure-tone average (Spearman's correlation coefficient = 0.44, $p < 0.005$). Only one patient experienced a UCL at less than 110 dB SPL and only 9 at less than 120 dB SPL.

FIGURE 11 : UNCOMFORTABLE LOUDNESS IN RELATION TO PURE-TONE AVERAGE

n = 37



In order to investigate the relationship between type of hearing impairment and 'top limit' while controlling for pure-tone average the 61 patients having a pure-tone average of less than 85 dB HL were again examined separately. Those with a sensorineural impairment were more likely to be limited by uncomfortable loudness than those with a mixed impairment (Table XIV).

TABLE XIV : 'TOP LIMIT' IN RELATION TO HEARING TYPE n = 61

Hearing type	Limited by UCL (% of total)	Limited by aid (% of total)	Total
Mixed	12 (29)	29 (71)	41
Sensorineural	14 (70)	6 (30)	20
Total	26	35	61

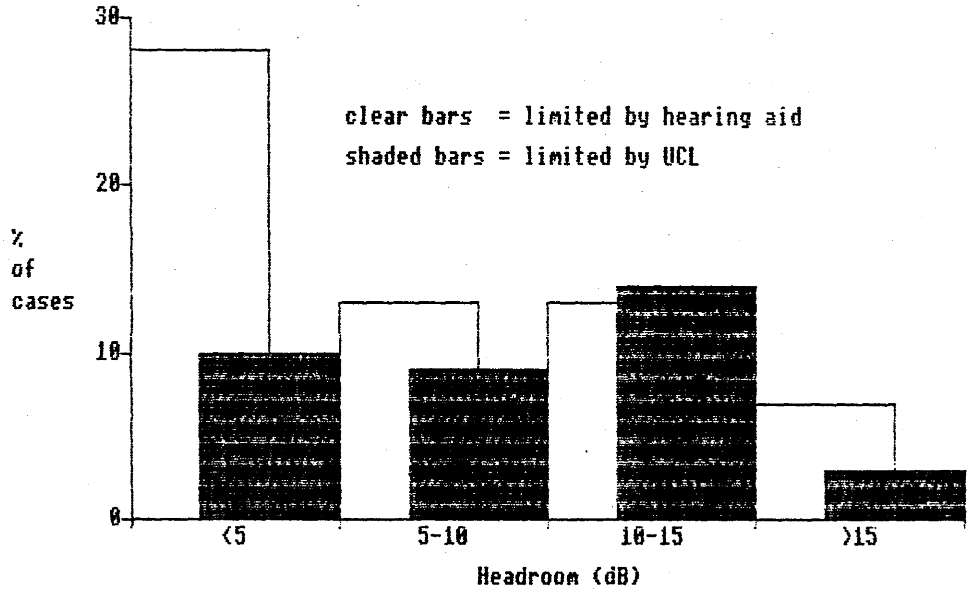
Chi-square = 7.53, Df = 1, $p<0.005$

6.4.4. Gain available above MCL

A measure of true dynamic range was not possible with the test set-up. The hearing aids still gave an appreciable amount of gain when set at minimum and therefore threshold measures were not obtainable with the speech level set at 75 dB SPL. It would have been possible to reduce the speech input but this would have required calibration corrections and would have introduced a further source of variability. The amount of gain available above MCL is an important component of the dynamic range and it is useful to coin the term 'headroom' for this portion.

Figure 12 shows the headroom for all patients. 38(39%) had less than 5 dB of headroom and of these 38 patients 28 (74%) were limited by their aid rather than uncomfortable loudness.

FIGURE 12 : HEADROOM DISTRIBUTION n = 98



6.4.5. Monaural versus binaural aids

In the binaural versus monaural substudy the gain used at MCL in the better hearing ear when using a binaural fitting was subtracted from the gain used with a monaural fitting. The range of differences was from -11.0 to +5.3 dB. The mean gain difference was -2.0 dB. Although the difference is small a Wilcoxon signed-rank test shows that significantly less gain was used at MCL in the binaural situation ($p<0.01$).

6.5 Discussion

The variability of MCL measurements is small in comparison to the great variation in gain selected for a given pure-tone average. The observed variation in gain is therefore likely to be real rather than the result of variability in the measurement. As would be expected those with poorer pure-tone averages did tend to select more gain but the relationship can provide no more than a rough guide to the gain selected. In general the 'half gain rule' tended to underestimate the gain selected and indeed half the pure-tone average + 10 dB underestimated the gain selected for a sizable minority.

Those with conductive components did not seem to use more gain than those with sensorineural impairments for a given pure-tone average. This is at variance with the findings of Berger (156) and Brooks (144) although the actual increased gain selected by those with conductive components in these studies was modest. Berger reports a gain increase of about 1/5 of the air-bone gap. Byrne (131) was unable to show any increased gain requirement for the severely and profoundly with conductive components.

Interpretation of the UCL findings is complicated by the fact that only 1/3 reached uncomfortable loudness with their personal aids. As would be expected it has been possible to show that over a given range or pure-tone averages, those with a sensorineural impairment were more likely to experience uncomfortable loudness than those with a mixed impairment. Further work on uncomfortable loudness has been conducted using a similar method on the same group of patients in conjunction with Dr M Giles. An inductively coupled BW 81 hearing aid with a type 6023 receiver was used for all patients and an input level of 75 dB SPL was again selected. The inductive coupling eliminated acoustic feedback and allow testing for a UCL up to 139 dB SPL (see appendix C). 105 patients were tested and even with this increased output 46 (44%) still did not reach uncomfortable loudness. It is of interest that 25 of the 46 were severely rather than profoundly impaired. The true UCL for a large number of the severely and profoundly remains unknown. Hearing aids which can provide a distortion-free output much in excess of 140 dB SPL are simply not available and so perhaps for the time being the question remains largely academic.

Some would argue that patients should never experience loudness discomfort with their aid and conclude that the 1/3 who experienced a UCL were inappropriately fitted. This is a debatable point. In the previous chapter it was shown only 7% complained that their aids were too loud. Individuals with normal hearing may start to complain of uncomfortable loudness at sound levels of not much greater than 75 dB SPL. Why should the hearing impaired be protected from this unless it will damage their residual hearing? This is also debatable (170,171,172). It is often argued that experiencing uncomfortable loudness will cause the patient to reject their hearing aid but this is not the case in the severely and profoundly impaired. The minimum reported daily use of an aid was 8 hours and the mean was 15.8 hours.

Of more concern is the number who may have been given an aid which did not allow them to fully utilise their full dynamic range. This is more likely as it was shown in the previous chapter that 15% reported that their aid was not loud enough and few would accept more powerful body-worn aids. Our policy now is try commercial ear-level aids with higher gains and outputs in such cases but the problems of fitting these aids without feedback is a formidable challenge. Also of concern are those who were limited by uncomfortable loudness and had little 'headroom'. Although clincically only 7% of patients complained, 10 patients (10%) were limited by uncomfortable loudness and having less than 5 dB of headroom in the test situation. These patients were very much a minority but with hindsight may have benefitted from an automatic gain control system (AGC). Our policy is now to fit a commercial aid with an AGC to such patients although their effectiveness remains to be evaluated.

The sub-study on binaural gain showed that less gain was used at MCL with a binaural fitting but that the amount involved appeared to be relatively small but may be clinically useful in cases where feedback free gain is a problem. The degree of uncertainty concerning the hearing in the poorer hearing ear and the extensive previous experience of many patients with a monaural fitting make interpretation of this sub-study difficult and further work would be required with a more highly selected group to provide a precise measure of the binaural advantage in this group.

The gain likely to be used can only be roughly predicted from the audiogram and therefore those who will use the highest gains and hence require most attention to ear moulds cannot be reliably identified by pure-tone audiometry. If a method for measuring gain to MCL is available then this should be employed to identify the high gain users. The method would appear to be reliable but it's external validity has not been tested. How gain to MCL measured under laboratory conditions relates to gain used in every day living is unknown. This requires further study. Measuring MCL in conjunction with UCL will help to identify the minority who may require an AGC system. If facilities are not available for measuring MCL and UCL then there would seem to be no alternative but to ensure that everyone has a hearing aid complex which does not feedback within the broad range of gains possible for a given pure-tone average.

CHAPTER 7

ENVIRONMENTAL AIDS (ASSITIVE LISTENING DEVICES)

7.1 Introduction

For many individuals with a mild or moderate hearing impairment a hearing aid may be all that is required to overcome their disability but the severely and profoundly impaired may suffer considerable residual disability in spite of optimum hearing-aid fitting. It is for this reason that environmental aids (assistive listening devices), have until now been considered to be of particular value to the severely and profoundly impaired and are generally promoted with this target population in mind. As well as specially designed devices, simple modifications to existing home systems such as resiting of bells may be beneficial. There are now many different aids to daily living available (173) but these can be conveniently classified into three categories;

a) Alerting aids: Examples are front door alerting systems, alarm clocks and various sound activated indicators such as baby-crying alerting devices. These can give either a visual warning or a loud auditory signal. Similar systems are available to alert the individual to an incoming telephone call.

b) Telephone listening aids: These can be amplifiers fitted to the telephone, loop systems or devices incorporating a keyboard and visual display unit (174).

c) Television listening aids: These include additional amplifiers, induction loops and teletext systems.

In the UK, finance for these devices has usually been under the control of the Department of Social Security through the social work service or by the patient purchasing them for themselves. The Department of Health which is responsible for hearing-aid provision has had a minimal role in the provision of accessory aids. The Royal National Institute for the Deaf (RNID) has contributed by publishing a series of booklets on the various devices available and demonstrates such equipment at their centres throughout the country but does not provided finance directly.

Few hospital audiology departments in the UK have even the most basic environmental aids on display and there would appear to be minimal communication between the hospital based audiology services, social work services, and the various charities involved. This has resulted in haphazard and piecemeal provision of these devices and has made any serious attempt to assess their role or value difficult.

In addition to specially designed devices there are many modifications to the home listening environment which may be made. This includes repostitioning of bells and telephones. All that may be required to encourage this is appropriate practical advice.

Previous surveys have shown that few hearing-impaired individuals in the UK make use of any special environmental aids (175) although they may be used more frequently in other countries. Lundborg (176) reported that a large proportion of hearing impaired subjects in Sweden used at least one other amplifying or communicative device in addition to a hearing aid.

Harris (177) has reported on the infrequent possession and use of environmental aids by a group of severely impaired individuals. He lists a number of reasons why more aids were not used by them including lack of knowledge of the equipment available, lack of opportunity to 'try out' equipment and difficulty in obtaining or installing aids. He blames this mostly on poor provision of services but adds that there may also be psychological reasons why these devices are not used such as fear of stigmatization or undue dependence on others.

It is surprising, considering the time and resource spent on promoting environmental aids by institutions such as the RNID, that there has been so little clinical research on this subject. Neither the effectivnes or the need for special systems has ever been evaluated.

This chapter examines the reported effectiveness of existing front door, telephone and television systems used by severely and profoundly hearing impaired adults attending an audiology clinic. The relationship of reported difficulty in these areas to degree of impairment, age, social class and living alone is examined. Factors relating to knowledge of and possession of special systems are also reported.

7.2 Method

On completion of hearing-aid fitting 106 patients attending the special clinic for the severely and profoundly hearing impaired were interviewed regarding special environmental aids and any modifications to existing standard systems which had been made. Up to this point in the protocol patients had not received any specific advice or help from the clinic on environmental aids. This was given subsequently.

Of the 106 patients, 68 had a pure-tone average of between 70 and 90 dB HL (averaged over 0.5,1,2 and 4 kHz in the better hearing ear) and 38 had a pure-tone average of poorer than 90 dB HL. There were 33 males and 73 females. The median age of the patients was 70 with a range of 28-95 years. 52 (49%) lived alone. All were experienced hearing aid users and wore their aid(s) the majority of the day (mean hours of use = 15.8 (SD=2.5)).

Patients underwent a structured interview designed to assess difficulty experienced with the front door, television and telephone and possession and effectiveness of devices used. The type of door alerting system was noted with particular enquiry as to its position in the house. Patients were asked how often the system was successful in alerting them to a visitor at the door. This was recorded as seldom, sometimes, mostly or always. If the reply was seldom or sometimes then the system was considered to be ineffective. Similar enquiry was made about the telephone system type and position within the house. How often the individual was successfully alerted to an incoming call was again recorded as seldom, sometimes, mostly or always. Difficulty with hearing on the telephone was recorded as none, mild, moderate or severe. If moderate or severe difficulty was reported the system was considered to be ineffective. Patients were asked what television system was used and to grade the difficulty experienced in using television. Additional enquiry was made about nuisance caused to other members of the household or neighbours by excessive television volume.

Patients were asked if they had sought advice about environmental aids and if so from where. Finally to provide a measure of ability to pay for the purchase and fitting of a typical simple device they were asked if they could afford to pay thirty pounds. This sum was chosen as it represents the current cost of having a special telephone fitted by British Telecom. The other aids cost approximately the same to purchase and install.

7.3 Findings

7.3.1 Door alerting system

The majority (71%) of patients reported that they were regularly successfully alerted by their current doorbell system, responding to it mostly or always.

The principal type of front-door alerting system varied considerably and this is illustrated alongside the number reporting difficulty with each system in Table **XV**. A system other than a bell or knocker sounding in the hall, which is the standard position in most houses, was used by 41 (39%). A dog was reported as the main front-door alerting system by 6 patients. A visual alerting system was used by 19 (18%).

All except one of the 19 using a visual alerting system were successfully alerted to the front door, reporting success mostly or always. The one exception had the light system only in the hall. All 6 patients with dogs were successfully alerted. Of 81 patients using an auditory front-door system 48 (59%) reported that they were successfully alerted. The most common position of the device was the hall. This was the case in 65 (80% of those using an auditory system). When in this position the system was successful in 34 (52%) of houses. Only 15 (19% of those using an auditory system) had the device situated in the living room and 12 (80%) of this group were successfully alerted. The position of the alerting device would therefore seem to be important but the numbers locating the device other than in the hall were too small for statistical testing.

Difficulty with the door bell system was not significantly correlated with degree of hearing impairment or age, either for those with or without special systems or the group as a whole. Success or failure could not be shown to be significantly related to living alone or social class.

TABLE XV : PRINCIPAL FRONT DOOR ALERTING SYSTEM n = 106

Device	Position	Total number (%)	Number ineffective (% of total)
Electric bell	hall	42 (40)	21 (50)
	living room	14 (13)	3 (21)
	kitchen	1 (1)	0 (0)
Chime	hall	4 (4)	2 (50)
	living room	1 (1)	0 (0)
Simple knocker	hall	11 (10)	4 (36)
Letter box	hall	8 (7)	4 (50)
Light system	hall only	1 (1)	1 (100)
	living room only	12 (11)	0 (0)
	entire house	6 (6)	0 (0)
Dog	variable	6 (6)	0 (0)
Total		106 (100)	31 (39)

7.3.2 Telephone alerting system

Out of 77 patients possessing a telephone 54 (70%) reported that they were regularly successfully alerted by their current system. Only two had a special loud telephone bell and one an alerting light. None of these patients had difficulty in being alerted. In the remaining 74 patients the main difference between systems was the number and position of telephones within the house (Table XVI). 58 (75%) had a single telephone and remainder had various multiple systems. 41 (53%) had a telephone in the living room and these patients were more likely to be successfully alerted to the telephone if it was situated there than elsewhere in the house (Chi-square = 8.1, Df = 1, $p < 0.005$).

Difficulty with the telephone alerting system was not significantly correlated with pure-tone average or age. Success or failure could not be shown to be significantly related to living alone or social class.

TABLE XVI : TELEPHONE POSITION n = 77

Place	Total number (%)	Number ineffective (% of total)
Hall	30 (39)	17 (57)
Living room	26 (34)	5 (19)
Kitchen	2 (3)	1 (50)
Living room + hall	10 (13)	1 (10)
Living room + bedroom	5 (6)	1 (20)
Hall + kitchen or bedroom	4 (5)	2 (50)
Total	77 (100)	50 (65)

7.3.3 Telephone listening system

Overall 38% (29 of 77) reported residual disability when listening on the telephone (Table XVII). Special telephones had been obtained by nearly half (49%) of the patients, the majority being amplified handsets rather than induction loop systems, even though all patients had a 'T' position available on their aid(s). Although there is a trend suggesting special listening devices are more effective than standard systems there is no statistically significant difference (Chi-square = 0.63, Df = 1, NS). All of the patients with a conventional handset used it in conjunction with their aid. On the other hand, the majority (86%) of those using an amplified handset removed their aid to use it. All binaural aid users either switched one of their aids off or took it out when using the telephone.

Reported difficulty was significantly correlated with pure-tone average (Spearman's correlation coefficient = 0.40, $p < 0.001$).

Possession of a special telephone was not related to degree of impairment, age, social class or living alone but was, as might be expected, related to ability to pay 30 pounds (Chi-square = 4.2, Df = 1, $p < 0.05$)

TABLE XVII : TELEPHONE LISTENING SYSTEM. n = 77

Type	Total number (%)	Number ineffective (% of total)
Conventional	39 (51)	19 (49)
Amplified handset	28 (36)	7 (25)
Loop system	10 (13)	3 (30)
Total	77 (100)	29 (38)

7.3.4. Television system

All patients had a television set but only 4 individuals had a special device for it. This was an amplified headset in one and a teletext system in three patients. The numbers of individuals possessing these devices were insufficient to adequately assess effectiveness but all 4 possessing a special aid reported no or mild difficulty only. All of the other 102 patients who did not have a special device used their hearing aid(s) when listening to television. Moderate or severe difficulty with television was reported by 37 of 106 (35%). This was significantly correlated with pure-tone average (Spearman's correlation coefficient = 0.35, $p < 0.001$). 24 patients (23%) were aware that the excessive volume required for them to watch television disturbed their relatives or neighbours. The percentage that disturbed others is likely to be higher. However, patients will not seek and act on advice unless they consider this to be a problem. Hence, a further 10 patients (those that recognised they disturbed others but had no residual disability) has to be added to the 37 patients who reported a residual disability, making a total of 47 patients (44%) who would merit being given help or advice.

7.3.5 Previous advice on environmental aids

Advice had been sought on environmental aids by 57 patients patients (54%). The aid most commonly used was a special telephone listening system and all of the 38 patients with one had received advice on this from British Telecom. Although advice was also sought from them by 23 of the 38 patients regarding telephone alerting systems only 3 were subsequently fitted.

21 patients had consulted the social work services and 19 door light systems were fitted by them. Only 9 patients had approached the RNID. No patient reported having received any advice on environmental aids from previous visits to hospital audiology departments or from their general practitioner.

7.4 Discussion

The most important finding of this study has been that only half of those who did not use any special systems at all reported more than mild difficulty in the home situations investigated. There is therefore not a general requirement for all severely and profoundly impaired individuals to have their homes modified. Having previously received help on an ad-hoc basis a large proportion do in fact own special environmental aids or have had some simple environmental modifications carried out. This is in contrast to the findings of Harris (177). More than mild difficulty was reported by roughly 1/3 of the group overall and a closer consideration of this group is required.

It was not possible to predict which patients were most likely to have difficulty with alerting systems as no significant relation could be found with pure-tone average, age, social class or living alone. This was the case when considering the group as a whole or those who did or did not possess special systems separately.
It is perhaps surprising that no significant relation could be found between difficulty with alerting systems and pure-tone average but it must be borne in mind that these individuals wear hearing aids almost all the time and this will tend to minimise the effect of degree of impairment. Simply being aware of an environmental sound does not require high quality hearing and even the most profoundly impaired

will potentially be able to be successfully alerted by a sufficiently loud auditory input.

The more severely impaired were more likely to have difficulty with listening on the telephone and with television and could be singled out for special attention in these areas. Possession of a special telephone listening system was related only to ability to pay. This is not surprising as there is no provision for special telephones by the current welfare system. Because of the small numbers of television aids little can be said about these devices.

We have been able to show that light systems, dogs and properly situated alerting bells are effective. This is not surprising but it does mean that there is a basis for giving relevant advice. It would seem sensible to recommend changing the position of alerting bells as a first option for those reporting difficulty and if this was not successful then perhaps a light system could be tried. It must be stated that a few patients who had light systems reported that they were often embarrassed by having every light in the house flash when there was a visitor at the door and they were also inconvenient at night. It is difficult to define a role for an audiology department in this area. It is impractical and beyond the scope of a service based in a hospital clinic to have direct responsibility for changing a patient's home environment. This is rightly a matter for the individual or the social work department although domiciliary visits by audiologically trained personnel have been recommended (178). Enquiry should be made so that those having difficulty are identified and good and relevant advice should of course be available to them. Better communication with the social work service would undoubtedly help those identified as having difficulties in the home who were unable to help themselves.

We have not been able to show that special telephone listening systems are generally effective and the numbers using special television systems were too small for any conclusion on likely effectiveness to be reached. Advice on the usefulness of special telephone and television systems for the severely and profoundly hearing impaired must for the present be guarded. We know that the severely and profoundly hearing impaired perform poorly on purely auditory tasks, depending on speechreading in most situations and it is perhaps too much to expect for them to manage well on a telephone (179) although they may potentially do better with television when they can see a speaker. There is no reason why these special aids should not be subject to a thorough scientific evaluation as has been the case with hearing aids. For the present it is important that individuals are at least given the opportunity to try out these devices before they consider purchase. As British Telecom was the most frequently consulted institution it is important that they are aware of and sympathetic to the difficulties likely to be experienced by the severely and profoundly impaired.

CHAPTER 8

FACTORS RELATING TO AIDED DISABILITY

8.1 Introduction

A study which attempts to characterise the severely and profoundly hearing impaired would be incomplete without an assessment of the disability likely to be suffered by these individuals. Without hearing aids most of the severely and profoundly impaired would hear virtually nothing in normal day to day living and would have to rely totally on speech reading. Almost without exception these individuals wear hearing aids for all their waking hours (see chapter 5). Unaided disability may be of interest in the mildly and moderately impaired who frequently use hearing aids only when required (180,181) but aided disability is the measure of interest in the severely and profoundly impaired. This distinction necessitates a different approach to the assessment of disability in the severely and profoundly impaired.

Pure-tone thresholds cannot be used to estimate aided disability although there will be obviously be a relationship to pure-tone average as those with the worst pure-tone averages will be the most difficult to aid successfully. The alternative methods available are self-report or an aided performance test.

Self-report can be assessed either by interview or a questionnaire and has some advantages, the most important of which is validity. The information is generally easy to obtain but can be influenced by mood, exaggeration and personality and is only strictly relevant to the actual questions asked. These problems may not adversely affect validity but they make a between subject comparison difficult.

There have been various approaches to objective performance testing, usually involving word or sentence recognition tasks. To simulate real life listening conditions tests can be performed with or without competing noise, with audition alone or audio-visually. Strictly speaking the scores obtained apply only to the test situation but some degree of external validity is usually assumed. One of the main advantages of a performance test is that it's repeatability can be assessed and there should be less influence from extraneous factors.

This chapter evaluates aided disability in the severely and profoundly impaired measured both by self-report and an audiovisual speech test. Two main questions of clinical relevance are posed. Firstly, what is the relationship between aided disability and pure-tone thresholds, type of hearing impairment, age, sex and type of hearing-aid fitting? Secondly, does an aided performance test usefully provide more information on aided disability than can be predicted from the pure-tone average, air-bone gap and other patient factors?

8.2 Patients

One month after completion of the management protocol and fitting of appropriate hearing aids (see chapter 2), 106 patients returned to the research testing session. All 106 patients underwent a disability interview but 11 patients did not undergo the audiovisual speech test. Three very elderly patients were unable to perform the tests and one patient considered to have a total hearing impairment was not tested. Two patients who were totally blind were not tested and a further 4 were not tested either because they could not spare the time for the test. There were therefore 95 patients who had both an audiovisual speech test and a disability interview. This group consisted of 37 profoundly impaired and 76 severely impaired individuals. The mean pure-tone average in the better hearing ear over 0.5,1,2 and 4 kHz was 86 dB HL (SD=11.5). The median age was 70 years with a range of 18 to 94 years. There were 39 males and 66 females.

8.3 Method

8.3.1 Aided disability interview

Structured interviews were conducted by a medical practitioner (LMcC). Disability was enquired about in four specific situations using hearing aids as appropriate. Patients were asked to rate their difficulty in understanding speech in a quiet situation with a single clear speaker and again in noisy conditions such as in a pub or club with many people speaking together. Ratings were recorded on a four point scale as no difficulty, mild difficulty, moderate or severe. Patients were similarly asked about difficulty with television, watching a programme with a clear view of a speaker such as the News and asked about difficulty understanding speech on the telephone again recorded on a four point scale.

8.3.2 FASIN a Free field Audiovisual Speech in Noise test.

A full description of FASIN (182) is given in appendix D. It is a free-field audiovisual speech-in-noise test which has been shown to be suitable for the severely hearing impaired. The basic unit of the test is the BKB sentence list (183). Four speakers are used for each list which consists of 16 sentences with either 3 or 4 key words. Each list is scored out of 50.

Patients were seated 2 meters in front of a 26 inch black and white video monitor wearing their usual hearing aids and glasses if required. Two loudspeakers were arranged on either side of the video monitor at 45 degrees to the frontal azimuth. The audiovisual sentence lists were played from one channel of a Sony-U-Matic video system and speech-shaped noise from the other channel. Both channels were fed through an audio mixer such that the speech to noise ratio was +5 dB. This signal to noise ratio had previously been shown to be appropriate for severely hearing impaired subjects (65). The output was then fed through an audio amplifier to the loudspeakers. Speech was adjusted to arrive at 75 dB SPL at the centre of the patients head.

Patients were given one practice list and time to adjust their hearing aid(s) to what they felt was the optimum level before beginning the test. The test was performed with one list in four different modes. Audiovisual performance was assessed firstly with hearing aids and then without aids. Secondly a list was performed with aided audition alone (video monitor turned off) and thirdly a list was performed with vision alone (audio amplifier turned off). Out of 10 sentence lists, 6 which had been shown to be of equal difficulty both audiovisually and by vision alone were chosen and these were used in a random order. Responses were recorded by a tester sitting beside the patient and patients were encouraged to guess. The FASIN test has been shown to be reproducible both within and between test sessions and after allowing one practice list does not suffer from practice effects.

8.4 Findings

8.4.1 Raw data

Table XVIII shows the number of patients reporting no or mild disability in relation to pure-tone average in all four listening situations. Not surprisingly the vast majority (81%) of patients reported moderate or severe disability with speech in noise but relatively few reported moderate or severe difficulty with speech in quiet (25%) or television (37%). The pattern of reported disability for speech in quiet in noise and television was fairly constant for those with a pure-tone average of up to about 100 dB HL above this level disability increased dramatically. For telephone listening the fall off was more gradual.

Figure 13 shows the distributions of aided audiovisual FASIN scores. There is a good spread of scores without gross floor or ceiling effects but vision alone, audio alone and un-aided audiovisual scores all suffered from floor effects. The median aided audiovisual FASIN score was 26 with a range of 0 to 47. Figure 14 shows the aided audiovisual FASIN score in relation to pure-tone average. As with self-report those with pure-tone averages of poorer than 100 dB HL scored very poorly. There was no significant difference in score between 10 dB pure-tone bands up to 100 dB HL but above this level the score was significantly worse (Mann-Whitney U test, $p<0.05$)

TABLE XVIII : REPORTED DISABILITY IN RELATION TO PURE-TONE AVERAGE

n = 106.

Pure-tone Average (dB HL)	No.	No. reporting no or mild disability (% of total)			
		SIQ	SIN	TV	TEL
70 - 79	38	33 (87)	7 (18)	28 (74)	31 (82)
80 - 89	32	27 (84)	8 (25)	21 (66)	22 (69)
90 - 99	20	16 (80)	4 (20)	14 (70)	8 (40)
100 -	16	4 (25)	1 (6)	4 (25)	2 (12)
Total	106	80 (75)	20 (19)	67 (63)	63 (59)

SIQ = Speech in quiet SIN = Speech in noise TEL = Telephone

FIGURE 13 : FASIN SCORE DISTRIBUTION n = 95

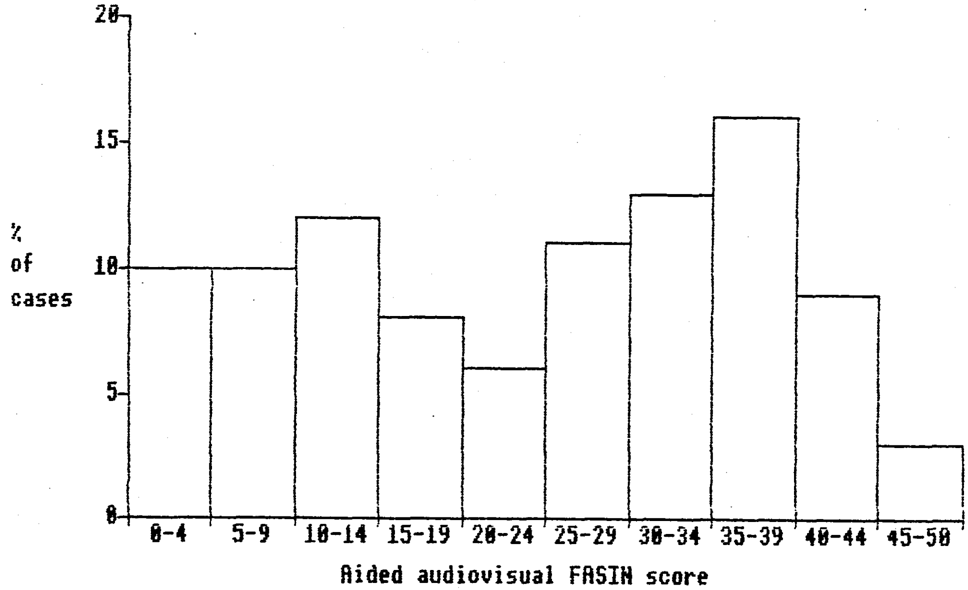
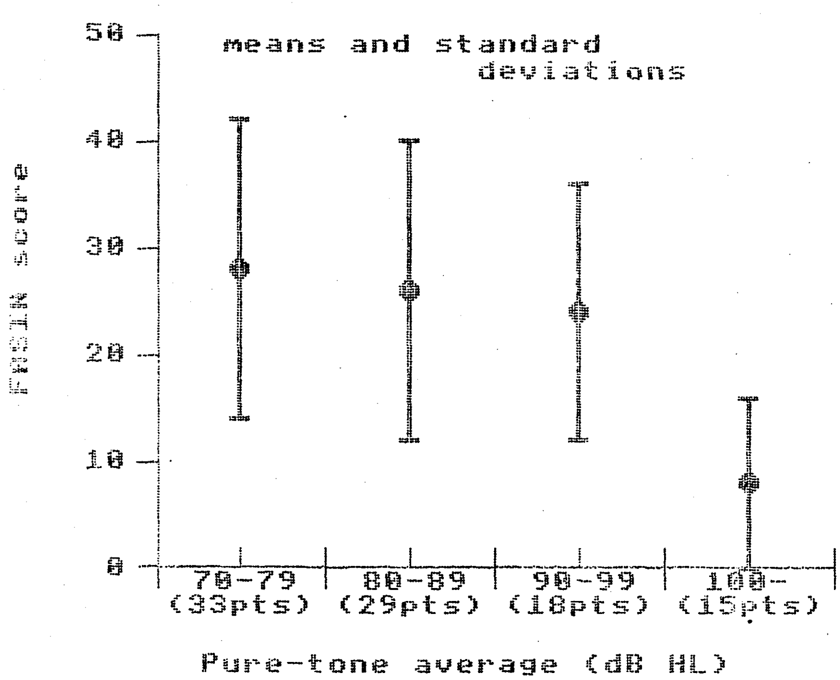


FIGURE 14 : AUDIOVISUAL FASIN SCORE IN RELATION TO PURE-TONE AVERAGE

n = 95



8.4.2 Data transformations

An analysis of the various factors contributing to aided disability requires a multivariate analysis. There are however a number of problems with the data which must be addressed prior to analysis. Audiovisual FASIN scores were not normally distributed (Figure 13) which is a requirement for a parametric multivariate analysis. To overcome this difficulty raw FASIN scores were ranked and transformed using the BLOM transformation on the SSPS PC program. This results in a normal distribution and ensures that the assumptions underlying conventional multivariate analysis are achieved.

The reported disability variables speech in quiet, speech in noise, TV difficulty and telephone difficulty were dichotomised and coded as either 1 or 2. Pure-tone average in the better hearing ear was split into three: 70-79, 80-89 and 90+ dB HL and coded as 1,2 or 3. Mean air-bone gap was dichotomised at 30 dB. Age was dichotomised at 70 years and aid fitting was either binaural or monaural.

8.4.3 Analysis

Preliminary one-way analyses of variance of audiovisual FASIN against the patient variables showed a significant effect of pure-tone average ($p<0.001$) but no main effects of air-bone gap, age, sex or type of aid fitting. Prior to multivariate analysis an analysis of covariance was performed and no major interactions demonstrated.

Table XIX shows the results of a stepwise multiple regression with normalised audiovisual FASIN as the dependent variable. 27.5% of the variance is accounted for by pure-tone average, air-bone gap and type of aid fitting. The addition of age and sex had no significant effect on the analysis. This analysis shows that once pure-tone average is controlled for, air-bone gap has a significant effect and once both pure-tone average and air-bone gap are controlled for, those using binaural aids are significantly less disabled. It is of interest to note that the direction of the effect of pure-tone average and air-bone gap are in opposite directions and will therefore tend to cancel each other out. This explains why a simple one-way analysis of variance was unable to show the effect of air-bone gap and aid-fit and it is only once pure-tone average is controlled for statistically by the stepwise multiple regression that the effects become apparent.

TABLE XIX : SUMMARY OF MULTIPLE REGRESSION ON AUDIOVISUAL FASIN.

Independent variable	Variance explained (%)	B	SEB	Significance
Pure-tone average	16.0	-1.2	0.24	$p < 0.0001$
Air-bone gap	7.4	0.7	0.23	$p < 0.005$
Aid-fit	4.1	0.4	0.21	$p < 0.05$

B = Regression coefficient and SEB = the standard error of this coefficient.

To assess the effect of factors on reported disability a different approach is necessary. A parametric multiple regression cannot be used. A logistic method is required. Such a procedure is available on the SPSS PC program. A series of stepwise logistic multivariate analyses were performed with speech in quiet, speech in noise, television and telephone as dependant variables. As in the parametric analysis pure-tone average and air-bone gap accounted for the largest part of the explained variance. Once these were controlled for, FASIN score was able to account for a significant amount of additional variance ($p<0.05$). This was the case for all measures of reported disability except speech in quiet. This indicates that FASIN was measuring additional aspects of disability.

8.5 Discussion

The major determinant of aided audiovisual FASIN score was pure-tone averages but when this was controlled for, those with large conductive components scored better. This is in keeping with the findings of Carlin and Browning (119) who demonstrated this in the mildly and moderately impaired. Those using binaural aids scored significantly better than monaural aid users and this confirms the findings of Day et al (65). Aided audiovisual FASIN is a useful objective test of aided disability.

There are many advantages in using a performance test such as FASIN to measure disability rather then relying on self report but unfortunately previous work has shown that the results are probably insufficiently stable for use on individual patients when looking for small differences in performance such as might be of interest if two different hearing aids were being compared on an individual basis (182). In a clinical situation FASIN will provide a reasonable objective measure of aided disability which may be particularly useful for looking at differences between subjects where self-report may be problematic. This study has shown that FASIN is able to measure aspects of aided disability in addition to what can be deduced from a consideration of the pure-tone audiogram.

Those with a pure-tone average of worse than 100 dB HL would seem to particularly disabled even when optimally aided. This is broadly in agreement with the findings of others (61,62,64) and would indicate that in general aidable residual hearing is present up to about this level. As cochlear implants are steadily improved the indications for their use will almost certainly creep down into the region of residual hearing above 100 dB HL and as hearing aids are improved, hopefully many of those with impairments of worse than 100 dB HL will gain more benefit (184,185). Both will come into direct competition in this region and clinical trials comparing benefits will certainly be required.

CHAPTER 9

A COMPARISON OF AIDED DISABILITY, LIFESTYLE AND PSYCHOSOCIAL HANDICAP WITH THE MILDLY AND MODERATELY IMPAIRED

9.1 Introduction

It is likely that a severe or profound hearing impairment will result in a considerable disability even with optimum aiding and consequently in a significant handicap. The amount of disability will depend on the particular listening situation under consideration. The nature of handicap will vary with the individual's lifestyle and may in turn dictate the type of lifestyle which can be adopted. A hearing impairment may interfere with certain areas of a patient's life but not at all in others. To choose a famous example: Beethoven wrote much of his best music when he was deaf. He was considerably disabled being unable to hear his music and was therefore unable to perform as a virtuoso or conductor and had to earn a living solely as a composer (186). There is no doubt that he was socially handicapped and this almost led him to suicide. Beethoven's handicap was primarily psychosocial and certainly did not interfere with his work as a composer or his capacity to earn a living.

As with disability a quantitative measure of handicap would be clinically useful and there are a number of possible approaches to this problem. Much of the published work on hearing handicap is however concerned with medico-legal compensation and is discussed in this context by Noble (10). There has been relatively little work relevant to patient rehabilitation and even less on those with severe and profound impairments (187,188). Unlike disability there are no tests available for hearing handicap and assessments must rely on self report. Stephens (189) has reviewed a number of different approaches to measurement of hearing handicap including handicap scales and personality measures and stresses the importance of using different approaches together rather than individually to provide an overall picture. Early scales such as the Hearing Handicap Scale (190) and the Social Hearing Handicap Index (191) are concerned mostly with speech recognition and are more concerned with disability than handicap. Further confusion has been added to the separation of disability from handicap by disagreement between the American and World Health organisations on their definitions. More recently introduced scales such as the Hearing Measurement Scale (192), the Hearing Performance Inventory (193) and the Hearing Handicap Inventory for the Elderly (194) are an improvement on older systems as they include questions on both disability and handicap and allow a distinction to be made between them. Using a different approach, Thomas (181) has successfully highlighted the difficulties experienced at work by patients with severe acquired hearing loss using an employment questionnaire.

The group under consideration in this study have certain common features which in themselves restrict the patients expectations and lifestyle. The majority are elderly females, more than half of whom are living alone and mostly of social class III,IV and V. As so few of the group are in gainful employment or of employable age (see chapter 4), measures related to socio-economic performance are not generally relevant and the effect of a hearing disability will most likely be felt in the areas of social function, recreation and psychological response.

The psychological affects of hearing impairment have been reviewed by Cooper (195) and more recently by Jones and White (196). There would seem to be no evidence that hearing impairments are associated with frank psychotic illness although there is some evidence that neurotic disorders may be more common (197,198,199,200,201).

From a purely clinical point of view, where the aim must be to provide optimum rehabilitation, it would be useful to know in what ways residual disability, lifestyle and handicap differ in the severely and profoundly impaired compared to the mildly and moderately impaired who constitute the greater part of the caseload of an audiology department.

This chapter compares aided disability, lifestyle and handicap in terms of psychosocial function assessed by a questionnaire between the severely and profoundly impaired and a group of age and sex matched controls with mild and moderate impairments attending the same department.

9.2 Method

A questionnaire with a reply paid envelope was given to 106 patients who had completed the management and testing protocol, to fill out at home and post back. The questionnaire borrows questions from many sources as no existing questionnaire seemed to be fully appropriate for this group of patients. The main problem with most existing material is that disability questions are asked without the help of hearing aids.

As the severely and profoundly impaired wear hearing aids almost all the time the questions used in this study are asked with the help of hearing aids. Some questions have been taken from the questionnaire used in phase 3 of the MRC British National Study of Hearing and some from the Hearing Measurement Scale (192), a revised form of which has been shown to have some validity with this population (202). Most of the questions were however designed specifically for this survey. Section B of the questionnaire concerns lifestyle and section C is concerned with disability and handicap. The questionnaire is printed in full in appendix E.

The questionnaire was returned by 82 (77%) patients. Their median age was 68 and there were 24 males and 58 females. The mean hearing impairment in the better hearing ear was 82 dB HL. 65% were of social class III,IV and V and 43 (52%) lived alone.

To provide control data the same questionnaire was sent to 150 patients with a mild or moderate impairment (25 to 69 dB HL averaged over 0.5,1,2 and 4 kHz in the better hearing ear) who had been managed and fitted with hearing aids in the ordinary audiology clinic in the same department. Replies were received from 109 (73%). From the returned questionnaires 82 controls were individually matched by sex and 5 year age band to the study group. The mean hearing thresholds in the better hearing ear of the control group was 47 dB HL.

From the lifestyle section the number of social outings per month was estimated by adding the number of times the patients attended meetings, talks or church (Question 3a) and the number of times the patient went to the cinema, bingo or other entertainment (Question 3b). The amount of television watched per week was directly recorded from Question 2a.

From knowledge of the characteristics and lifestyle of the group, 6 questions were selected which related to psychosocial function and therefore related to handicap rather than disability.

Questions 11 concerned embarrassment about hearing difficulties. Questions 10,14 and 15 enquired about social isolation and being left out of conversations. Questions 9 and 16 relate to restricted enjoyment from social activities. A single measure of psychosocial handicap is desirable and this was estimated by combining the reports on questions 9,10,11,14,15 and 16. All questions were on a four point scale but Questions 10 and 16 were inverted so that all questions were scaled the same way. This gave a variable with a range of 0 to 18.

9.3 Findings

9.3.1 Aided Disability

Aided Disability within the severely and profoundly impaired group has been considered in detail in the preceding chapter where it was found that both measured and reported disability were significantly worse in those with pure-tone averages of worse than 100 dB HL and in those with a sensorineural impairment.

This section compares reported disability between severely/profoundly impaired individuals and mildly/moderately impaired individuals in 5 listening situations; speech in quiet, speech in noise, radio, television and telephone.
Speech in quiet and speech in noise were graded on a three point scale (no difficulty, some difficulty and great difficulty) and radio, television and telephone listening were graded on a four point scale (easily, with some difficulty, with great difficulty and not at all).

The distributions of the difficulty reported by the two groups in the five listening situations are shown in figures 15 to 19. Mann-Whitney U tests failed to show any significant differences in difficulty with speech in either quiet or noise between the groups and no difference could be shown between difficulty with television. Significant differences were shown between distributions with the severely and profoundly impaired reporting more difficulty with the radio ($p < 0.05$) and telephone ($p < 0.005$).

FIGURE 15: SPEECH IN QUIET DISABILITY: COMPARISON WITH MILD/MODERATES

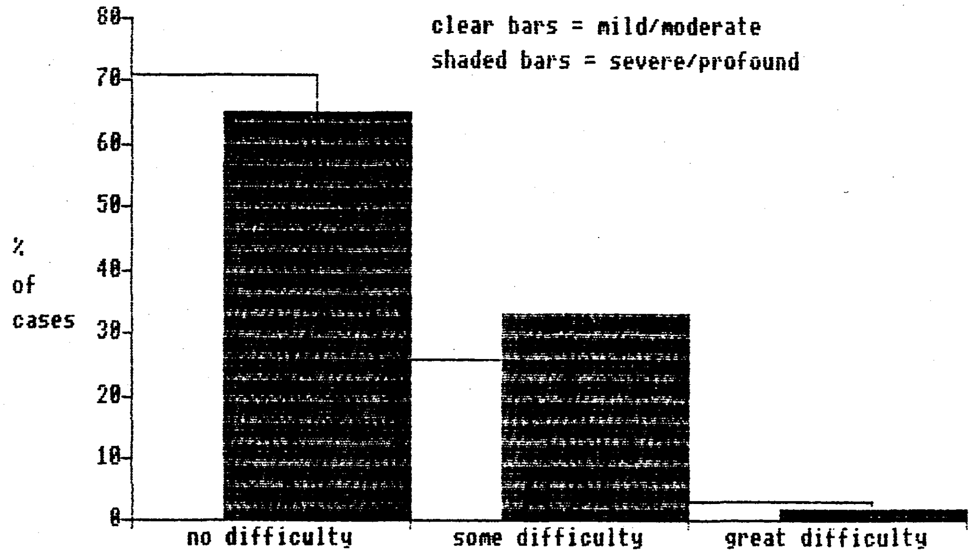


FIGURE 16: SPEECH IN NOISE DISABILITY: COMPARISON WITH MILD/MODERATES

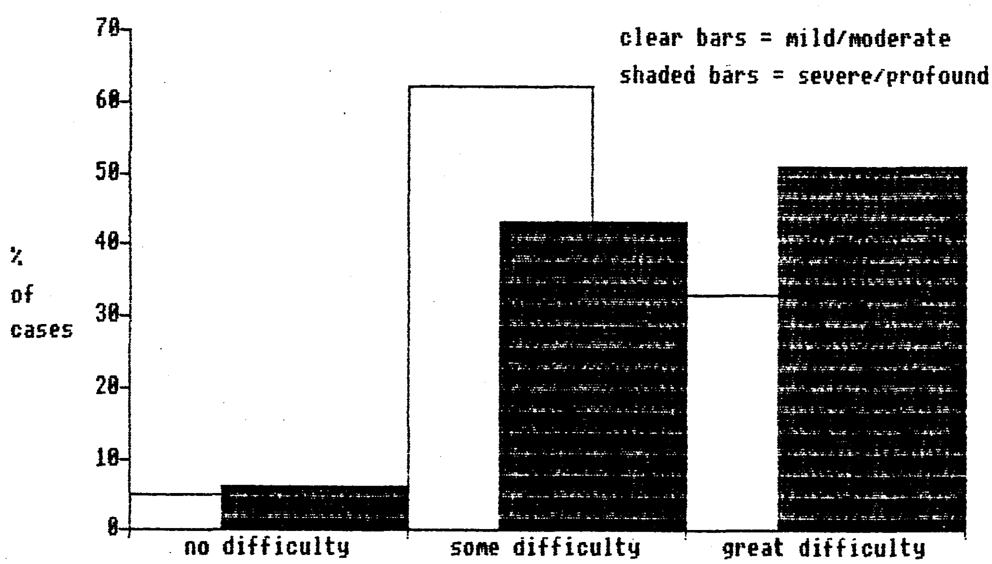


FIGURE 17: TELEVISION DISABILITY: COMPARISON WITH MILD/MODERATES

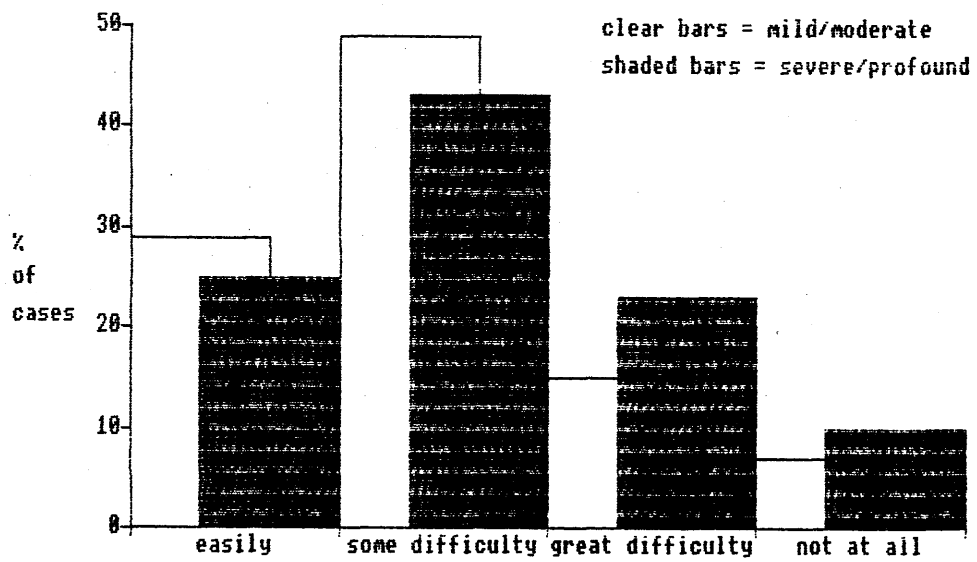


FIGURE 18: TELEPHONE DISABILITY: COMPARISON WITH MILD/MODERATES

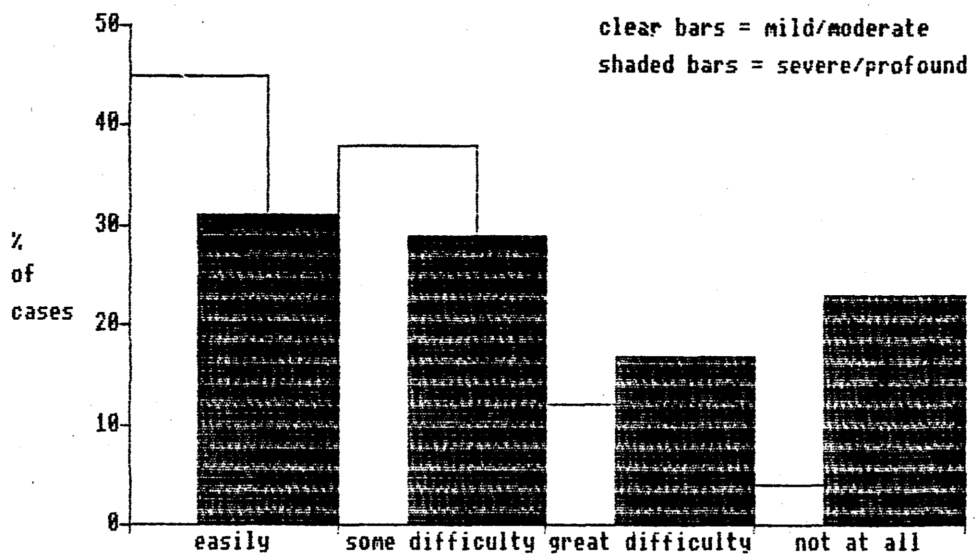
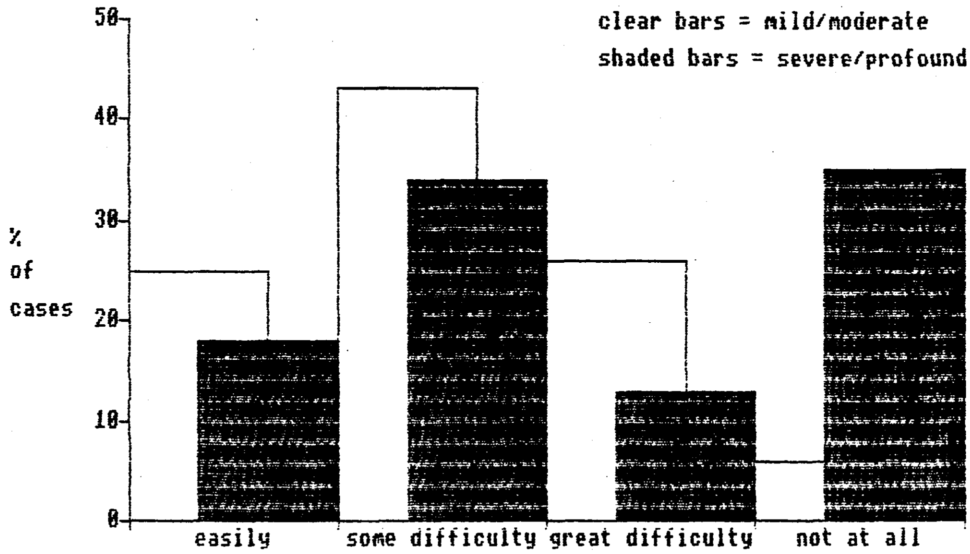


FIGURE 19: RADIO DISABILITY: COMPARISON WITH MILD/MODERATES



9.3.2 Lifestyle

The mean number of outings per month for the severely and profoundly impaired was 4.4 (SD = 6.1) which is similar to the 4.5 (SD = 5.9) for the mildly and moderately impaired group (Figure 20). Only a small portion of either impairment group seemed to be socially active. The mean number of hours of television watched per week was 24.0 (SD = 17.4) for the severely and profoundly impaired group which is not significantly different from the 26.6 (SD = 15.9) for the mildly and moderately impaired (Figure 21). A few individuals watched in excess of 60 hours per week (8.5 hrs per day). For both groups the amount of television watched was inversely correlated with the number of social outings (Spearmans's correlation coefficient = -0.29, and -0.34, $p < 0.005$)

FIGURE 20: SOCIAL OUTINGS PER MONTH

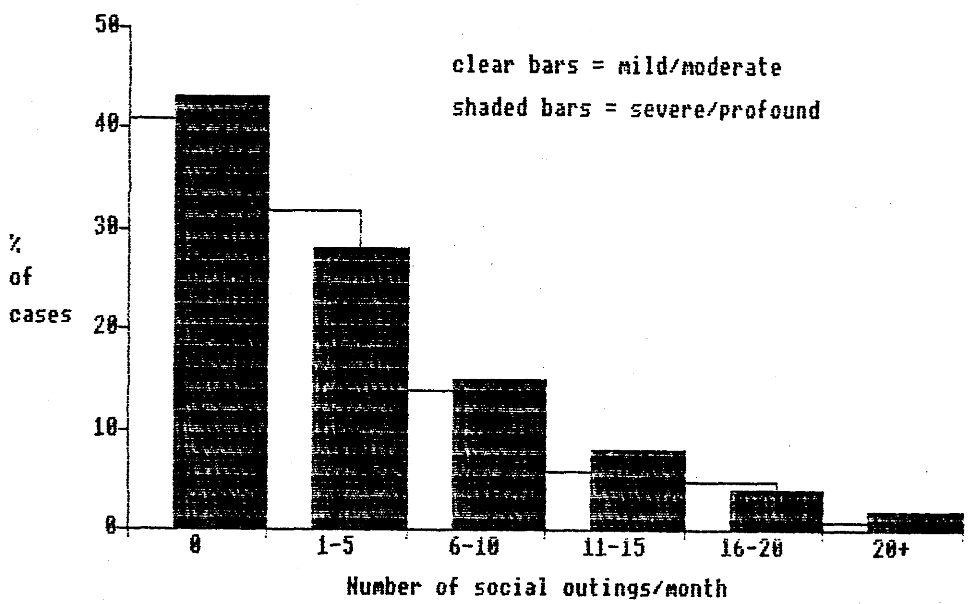
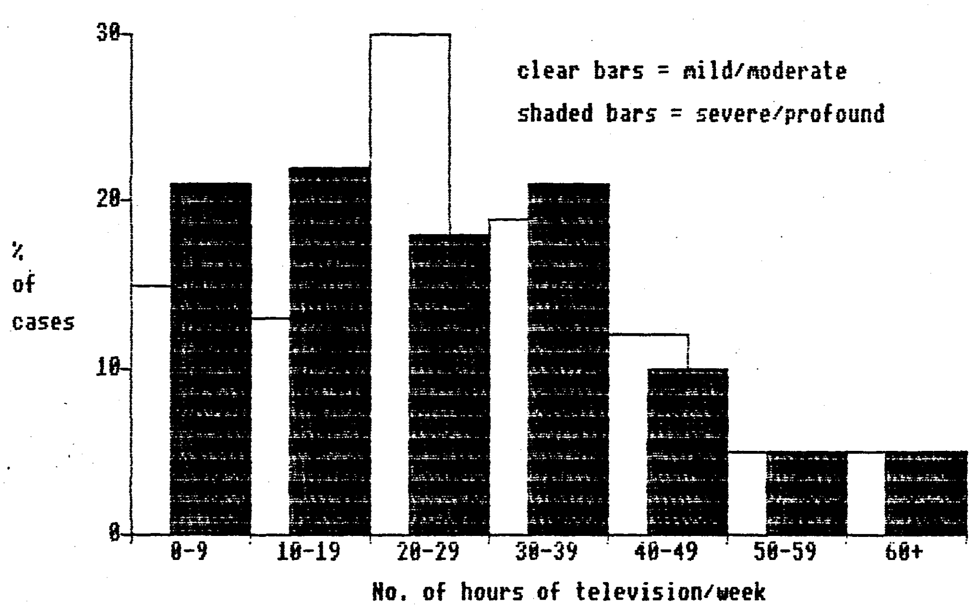


FIGURE 21: AMOUNT OF TELEVISION WATCHED PER MONTH



9.3.3 Psychosocial handicap

The mean psychosocial handicap score for the severely and profoundly impaired was 12.2 (SD = 3.8) which is significantly greater than the 10.3 (SD = 4.1) for the mildly or moderately impaired (Mann-Whitney U test, $p < 0.01$). Differences were tested for in each of the component questions and for all except Question 15 scores were significantly worse in the severely and profoundly impaired.

Question 12 which enquired about embarrassment with wearing hearing aids was analysed separately (Figure 23). The degree of embarrassment was low in both groups and there was no statistical difference.

FIGURE 22: HANDICAP SCORE DISTRIBUTION

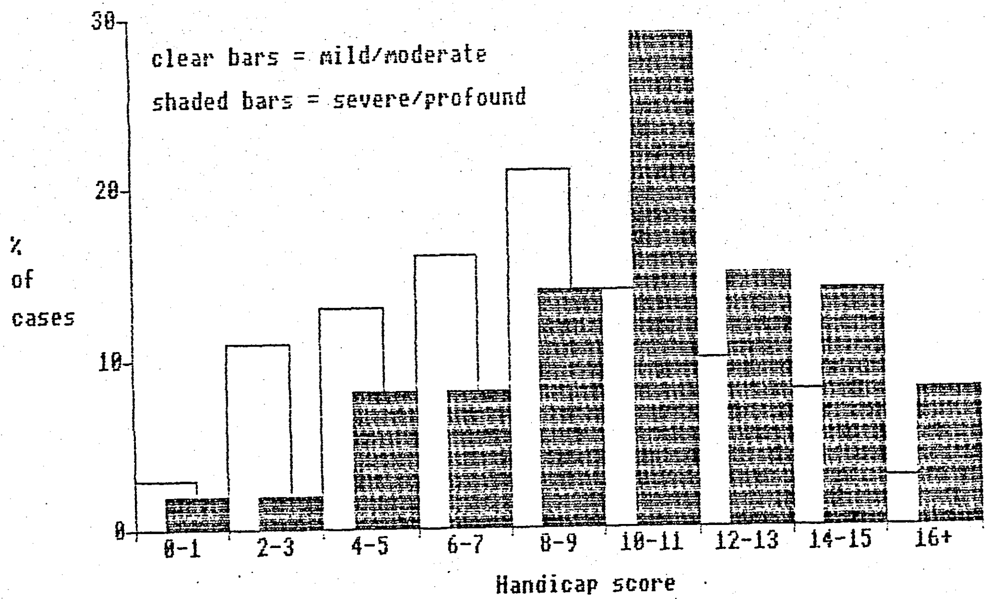
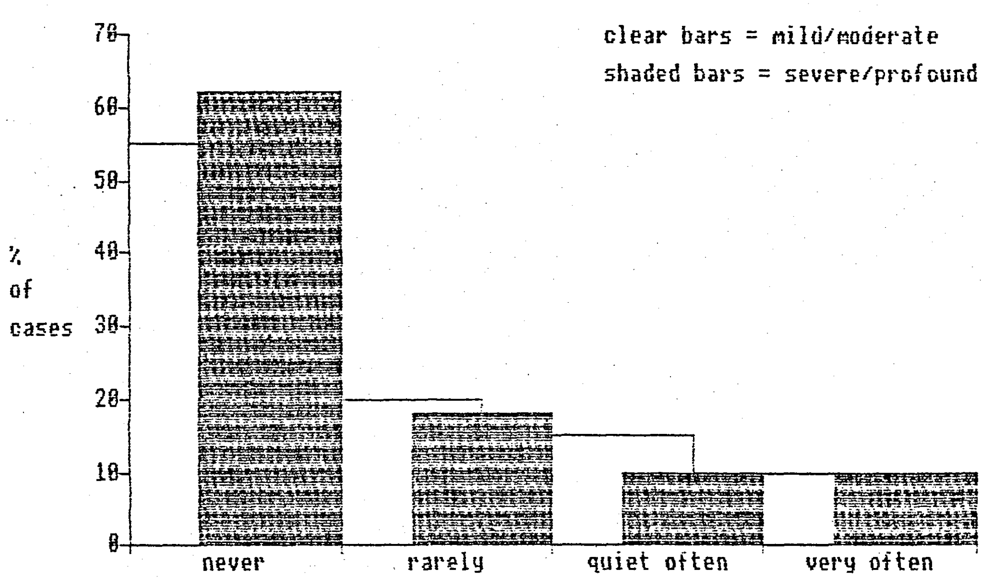


FIGURE 23: EMBARRASSMENT SCORE DISTRIBUTION



9.4 Discussion

It is perhaps surprising that there appeared to be no difference in the reported disability for both speech in quiet and speech in noise between the severely and profoundly impaired and the mildly and moderately impaired controls. With speech in quiet, Question 8 specifically stated that there was only one speaker and for television, Question 1 specifically stated that the programme was the News. The severely and profoundly impaired would probably receive a sufficiently good auditory input to supplement speech reading in these situations and may be minimally disabled. How disabled they would be in a quiet room with many speakers or watching television programmes other than the News is not known. Both groups reported considerable difficulty with speech in noise and as the mildly and moderately reported near maximal disability in this situation it is not surprising that the severely and profoundly impaired were not shown to be more disabled. Another possibility is that the severely and profoundly impaired, due to their greater experience may in fact be better able to use speechreading in a noisy situation. For radio and telephone listening there is no possibility of using speechreading and disability will depend on the quality of auditory input. It is therefore expected that the severely and profoundly impaired will be considerably more disabled in these situations than the mildly and moderately impaired.

Information on the lifestyle is important for planning rehabilitation. It is perhaps surprising that no differences could be found in the amount of social activity between the severely/profoundly and the mildly/moderately impaired. Neither group seemed to be socially active. The scope of the comparison was certainly very simple but this has been the finding of others

(203,204). Quantitatively social activity has not been found to be greatly influenced by degree of hearing impairment. This is perhaps because control groups of normally hearing individuals have not been included (205). This is a criticism which can be levelled at the comparison in the present study. Gilhome Herbst (206) has shown that when a normal control group is employed differences may become apparent.

Although differences in lifestyle between the severely/ profoundly impaired and the mildly/moderately impaired controls were not apparent, levels of psychosocial handicap were higher in the severely and profoundly impaired. This is an expected finding being the area where a hearing impairment is most likely to have an impact (207,208) although Thomas et al (209) found no difference in emotional status or social integration between normal and hearing impaired elderly individuals. Handicap was certainly reported as high in the severely and profoundly impaired. Simply adding the replies of questions together tends to hide the fact that almost 50% had stopped all or most group activities and 80% reported restricted enjoyment of social and personal life.

Once optimal aiding has been accomplished how should a rehabilitation programme for the severely and profoundly impaired differ from one for the mildly and moderately impaired? The areas which should seem to require specific attention in the severely and profoundly impaired are purely auditory listening and handicap. Skilled counselling may modify the patients attitude to their hearing impairment and help to relieve anxiety but although laudable, the effectiveness of counselling is unproven. Stephens (210) simply suggests "A variety of counselling techniques have been developed and are widely taught, and the novice therapists/clinicians should seek training in a system appropriate to their own philosophy." Psychological intervention has been used with tinnitus sufferers where other forms of intervention have failed to fully relieve the problem. This has included relaxation therapy (211) and cognitive therapy (212,213). Perhaps this kind of approach would be beneficial to some of the severely and profoundly impaired.

It is difficult to see how the severely and profoundly impaired can be helped further with purely auditory listening situations. Advice on hearing tactics may be helpful to some but the experienced severely or profoundly impaired patient may know far more about this already than a normal-hearing advisor. The effectiveness of many environmental aids, which have the potential for overcoming some of the purely auditory situations, remains unproven (chapter 7). Until such times as research is available on the effectiveness of intervention, the clinician can only be aware of the difficulties likely to be encountered and must base rehabilitation on his or her own best judgement.

CHAPTER 10

GENERAL CONCLUSIONS

10.1 Overview

The stated aim of this thesis has been to fully characterize a population of adult severely and profoundly impaired patients attending a hospital audiology department. The role of this final chapter is to discuss how the findings obtained have contributed to this aim both in terms of a contribution to knowledge and patient management and to outline areas requiring further study.

The findings cannot be generalised to the whole adult population of severely and profoundly impaired individuals and no attempt has been made to do this, but it is probable that the group identified would be typical of that found in any UK centre. Unpublished results from the MRC National Study of Hearing show no difference in the the distribution of degree and type of hearing impairment between data collected in Glasgow, Cardiff, Nottingham or Southampton (Browning GG, personal communication).

The results are discussed under 4 headings: aetiology and clinical features, disability, lifestyle and psychosocial handicap and finally management. Following on from this, areas for future research are described.

10.2 Discussion of principal findings

10.2.1 Aetiology and clinical features

The most important finding in this area and possibly of the whole study has been the high prevalence of mixed impairments due to otosclerosis and chronic otitis media. This confirms early reports by Morrison (102) but is not generally appreciated. There are many who consider a severe or profound impairment synonymous with a sensorineural pathology. Conductive or mixed impairments are in general more common in hospital populations than the general population but there were more than twice the number of mixed impairments in the severely and profoundly impaired than in the mildly and moderately impaired attending the same department. Indeed the proportion of mixed impairments may have been even higher as many of those with off-scale bone conduction may also have had mixed impairments. If all those with unknown types of impairment had a conductive component then the figure would have increased from 64% to 81%.

What is surprising is that the severely and profoundly impaired were not generally older than the mildly and moderately impaired. There was a greater range of age in the severely and profoundly impaired but this does not account for the similarity. Presumably only a minority of mild and moderate impairments will progress to a severe or profound impairment. As only a small proportion of hearing impairments are of sudden onset most of the severely and profoundly impaired will have gone through a stage of mild and moderate impairment but this may have happened at any stage in their lives and progressed either quickly or slowly. Further work on the progression of hearing impairments would be required to answer this problem.

Such a study has been carried out and initial results would suggest that the rate of deterioration in the severely and profoundly impaired is similar to that reported in mild and moderates being roughly 5 to 10 dB per decade (Giles M and Browning GG, personal communication). It is probable that in many cases it is the addition of the conductive component which causes the impairment to be severe or profound and this event is likely to be relatively age independent.

10.2.2 Aided disability

Aided disability as assessed by both self report and FASIN is perhaps less than would have been expected in this group. The level of reported aided disability remained relatively constant up to about 100 dB HL. The comparison with the mildly and moderately impaired showed that although aided disability may be no worse in audiovisual situations, in purely auditory situations such as telephone listening, the severely and profoundly impaired are considerably more disabled. A comparison using an audiovisual speech test such as FASIN with the mildly and moderately impaired would have been of interest but the fixed signal-to-noise ratio although broadly suitable for the severely and profoundly impaired would almost certainly have caused ceiling effects if used on the mildly and moderately impaired. The alternative would be to administer the test adaptively such that the signal to noise ratio was varied to achieve a constant performance score (214). A system for delivering FASIN in this way is being developed.

Within the severely and profoundly impaired it has been possible to show that FASIN performs well as an objective test of aided disability and that using this test those with a large conductive component were shown to perform better for a given pure-tone average than those without. This is the first time that this has been demonstrated in the severely and profoundly impaired. We have confirmed the findings of previous work which has shown less disability in severely and profoundly impaired binaural aid users (65).

10.2.3 Lifestyle and psychosocial handicap

Although no difference could be found quantitatively in the amount of social activity between the severely/profoundly impaired and the mildly/moderately impaired there was a difference in the amount of psychosocial handicap reported. This is broadly in line with the finding of others (203,204). Hearing impairment is without doubt a disabling condition but it does not seem to alter lifestyle greatly although without doubt it reduces the quality of life experiences. The scope of lifestyle within the age and social class group of both the severely/profoundly and mildly/moderately impaired is probably limited and therefore it is perhaps not surprising that no difference was found. A comparison with the normal hearing individuals of similar age and social class would be required to address this difficulty.

10.2.4 Patient management

The major management issue raised by the finding of high levels of conductive pathology is the possibility of surgery and implantable bone-conduction hearing aids. There are a great deal of unanswered problems here. Firstly how successful is surgery likely to be? The reported results from stapedectomy are generally good (107). The results of tympanoplasty although good for closure of tympanic membrane defects are less certain for ossiculoplasty (108,215,216). Surgery would almost always be performed on the poorer hearing ear. It has been shown that without the possibility of masking there is frequently doubt about the true hearing thresholds in the poorer ear. Operating on an ear with no or little hearing would be a waste of time and put the patient to unnecessary risk, particularly if a general anaesthetic and hypotension was employed. A surgeon operating on a 'dead' ear would be unaware that this was the case and would probably simply conclude that surgery had not been successful as there would be no difference between pre and post-op audiometry.

Implantable bone conduction aids are a real possibility for many patients. The side of fitting is largely irrelevant and risks of damage are much less than for middle ear surgery.

When fitting high-powered aids acoustic feedback is a formidable problem but with perseverance can be overcome perhaps at the expense of causing unnecessary mould discomfort in some. It is not possible other than very generally to predict which patients will require the largest gains. Surprisingly those with conductive pathology did not require more gain but previous authors who have shown an increased requirement for conducive pathology have reported only a modest increase (82,144) and it is possible that selection of increased gain was discouraged by increasing distortion as aids approached maximum gain (150,151).

Binaural aiding was shown to reduce gain requirements and should be recommended whenever possible both to reduce gain requirements and reduce disability.

General levels of disability in the home environment were surprisingly low without any advice having been given on environmental aids. Possession of special dedicated devices was low but so also was reported disability. Special alerting systems seemed to be effective but simply repositioning standard systems was also effective. The effectiveness of telephone listening systems and television devices remains unknown. For the present it would seem reasonable to give simple advice about positioning of standard alerting systems reserving special alerting systems if this was not successful. Special telephone and television aids should be given an adequate trial period.

The question of special counselling arises. As the severely and profoundly impaired suffer more psychosocial handicap than the mildly and moderately impaired a case could be made for concentrating more effort on this aspect. The effectiveness of counselling has never been adequately assessed although common sense tells us that it would seem like a good idea.

Overall, considering the potential for surgery, the difficulty in management and the higher levels of residual disability and handicap a good case can be made for running a special clinic for the severely and profoundly impaired. Furthermore numbers are such that any sizable audiology department could justify such a clinic. The clinic should provided the following facilities.

1. A skilled otological assessment to select those who may be suitable for surgery or implantable BC aids, not a junior member of staff who may be insufficiently experienced.

2. A high quality audiometry service provided by an audiological scientist or senior technician who will fully understand the limits of audiometry in this group.

3. A high quality hearing-aid fitting service that can provide moulds which do not allow feedback. A facility for estimating gain requirements would help, and follow up to ensure that optimum fitting

had been achieved is essential.

The following further services may be required.

4. Advice and demonstration of environmental aids
5. A special counselling service, perhaps offering relaxation or cognitive therapy for the most severely handicapped.

10.3 Areas for further study

As the problems of masking in this group greatly limit the usefulness of pure-tone audiometry ways of overcoming this problem are desirable. Cochleography is unique among tests of hearing in that it does not require masking and has been shown to be useful in situations where masking is not possible (217). It is of course an invasive test but by using a high-output system possibly with ear inserts high levels of stimulation could be achieved and a study on those with potential 'dead' ears would show how often this was the case (218). Bone-conducted cochleography has not been widely reported but it is feasible (219) although there are stimuli problems (220). Bone-conducted cochleography could be potentially useful when bone conduction thresholds are present but masking is impossible. Many patients have been identified who fall into this category and a clinical study on the usefulness and practicality of this would be worthwhile.

The question of surgery requires further study. As almost all the impairments are mixed rather than purely conductive very few patients would be able to dispense with hearing aids altogether after successful closure of air-bone gaps although they may manage with less powerful hearing aids. However in the absence of an alternative to pure-tone audiometry there is almost always doubt about which ear or ears the conductive component applies to. Two important issues are raised by this. Firstly, how many patients would accept surgery on this basis and secondly would surgery materially benefit these patients. Further clinical studies are required in both these areas. A similar problem is raised regarding the new surgically implantable bone conduction aids. Studies in these areas are now underway. Preliminary results are available and they would suggest that surgery to improve hearing does have a useful role, being appropriate for about 25% of those with conductive components, a further 25% being most suitably managed with implantable bone-conduction aids. The vast majority of suitable cases will accept surgery (Giles M and Browning GG, personal communication).

The environmental aids survey has perhaps posed more questions than it has answered. There is no reason why the effectiveness of environmental aids should not be assessed in the same way as hearing aids. Possible lines of future research with environmental aids in the severely and profoundly impaired would be to perform a speech test over the telephone with hearing aids and a conventional telephone, an amplified handset and hearing aid plus an inductive coupler. Similarly an audiovisual performance test such as FASIN could be performed with television and hearing aids compared to television plus hearing aids with an inductive coupler. Such studies would put the whole question of environmental aids on a more scientific footing.

APPENDIX A

GLOSSARY OF TERMS, DEFINITIONS AND ABBREVIATIONS

1. Abbreviations

AC	Air conduction.
AGC	Automatic gain control
ANSI	American National Standards Institute.
BC	Bone conduction.
BSA	British Society of Audiology.
BAOL	British Association of Otolaryngologists.
BS	British Standard.
CSOM	Chronic suppurative otitis media.
dB	Ten times the logarithm of the square of the amplitude ratio between a particular quantity and a specified or assumed reference.
dB HL	Hearing level in decibels. The intensity of a pure-tone with reference to a zero at the specified frequency which is published as an international standard.
dB SPL	The sound pressure level expressed in decibels.
EEC	European Economic Community.
Df	Degrees of freedom (Chi-square tests)
FASIN	A Free Field Audiovisual Speech in Noise Test.
Hz	Unit of frequency, equal to one cycle per second.
IEC	International Electrotechnical Commission
ISO	International Standards Organisation.
MCL	Most comfortable listening level.

MRC	Medical Research Council.
MPO	Maximum power output of a hearing aid.
NS	Not statistically significant
NHS	National Health Service.
UCL	Uncomfortable loudness level.
PTA	Pure-tone average over 0.5,1,2 and 4 kHz.
RNID	Royal National Institute for the Deaf.
SD	Standard deviation.
WHO	World Health Organisation

2. Terms and definitions

Air-bone gap	The difference between air conduction and bone conduction frequencies. In this study defined as a difference of greater than 15 dB.
Air conduction threshold	Thresholds of hearing for a sound presented to the ear with an earphone or similar device
Audiogram	A graph which shows hearing thresholds as a function of frequency
Audiology	The science of hearing
Binaural	A term meaning using both ears at once
Bone conduction threshold	Thresholds of hearing for a sound presented by a bone vibrator usually applied to the mastoid process.

Bone vibrator	A transducer which produces a vibration which excites the skull directly
Cholesteatoma	A particular type of chronic otitis media associated with a keratin producing sac which gradually expands and damages structures within the ear.
Chronic otitis media	A chronic infection of the middle ear space. There are 2 types; cholesteatoma and mucosal type. It is often associated with an unpleasant discharge from the ear.
Cochlear implant	A electrical stimulator which is placed within the inner ear and produces a sensation of sound.
Compression	A term applied to hearing aids which produce a narrower dynamic range at the output than at the input.
Conductive hearing impairment	A hearing impairment due to interference with the sound transmission to the sense organ, usually in the outer or middle ear.

Coupler (2cc)	A cylindrical metal capsule one end of which is formed by a standard microphone. It is used for measuring the output of hearing aids.
Disability	The inability arising from an impairment to perform basic and general social, cognitive or bodily skills.
Dynamic range	The useful intensity range of a sensory system or instrument.
Cochleography	Measurement of acoustically evoked electrical signals from the cochlea, usually by means of an electrode placed on the promontory.
Handicap	The sum of social, personal, cultural or economic disadvantages suffered because of disabilities.
Impairment	Deficient or abnormal functioning of any physiological or psychological system of the body.

Masking	A general term for the ability of one sound to prevent another sound from being heard.
Mastoid	The part of the skull immediately behind the ear.
Mixed hearing impairment	A combination of conductive with sensorineural impairments.
Monaural	A term meaning using only one ear.
Octave	A doubling of frequency on a frequency scale.
Otitis externa	Inflammation of the outer ear.
Otology	The science of ear diseases.
Otosclerosis	A disease of the middle ear causing fixation of the stapes bone and resulting in a conductive or mixed hearing impairment.
Otoscopy	The visual inspection of the external ear and tympanic membrane.
Psychosocial	Relating both to social and psychological areas.

Recruitment	An abnormality of intensity perception whereby the growth of loudness of a sound occurs at a greater rate than its intensity compared to normal ears.
Sensorineural hearing impairment	An impairment due to an abnormality of the sense organ, the auditory nerve or both.
Snellen chart	A chart with letters of the alphabet of different sizes used for testing visual acuity.
Speechreading	A recently introduced term having the same meaning as lipreading.
Stapedectomy	An operation to restore hearing caused by otosclerosis.
Tympanic membrane	Ear drum
Tympanoplasty	An operation which reconstructs middle ear structures which have usually been damaged by chronic otitis media.

Uncomfortable loudness level	This is an intensity level representing the minimum intensity felt to be uncomfortable.
Vibrotactile	Sound perceived by sensation rather than hearing.

APPENDIX B

EXAMPLE AUDIOGRAMS

This appendix shows examples of the 6 categories of audiogram possible when only air conduction and not-masked bone conduction are available. These are fully described in chapter 3.

Symbols:

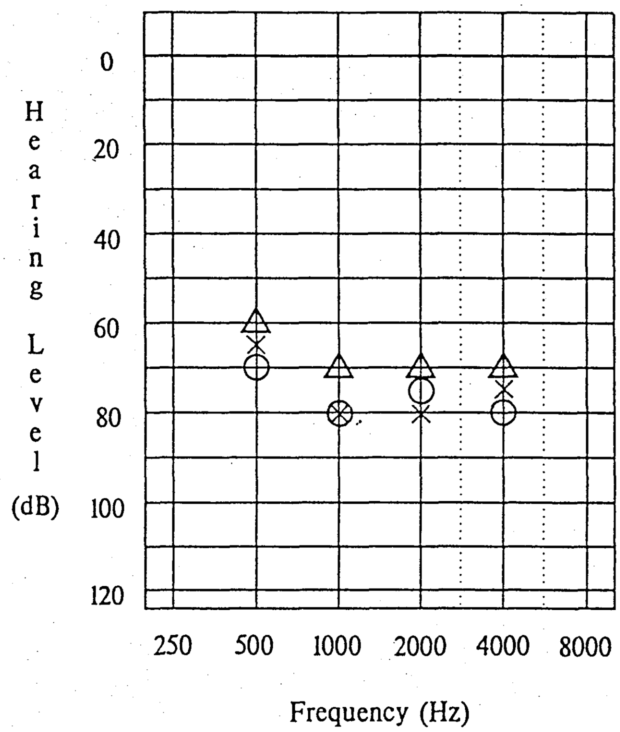
Air conduction threshold in right ear ○

Air conduction threshold in left ear ×

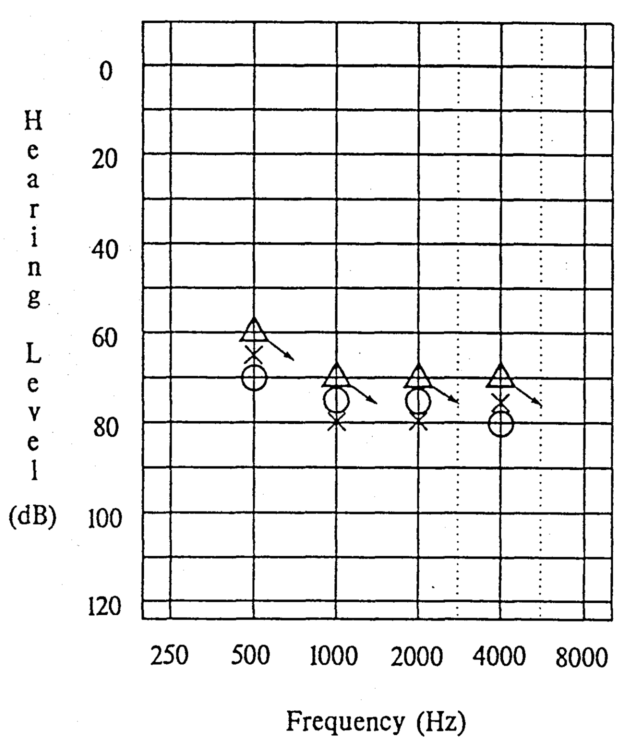
Not-masked bone conduction threshold △

Threshold off-scale 

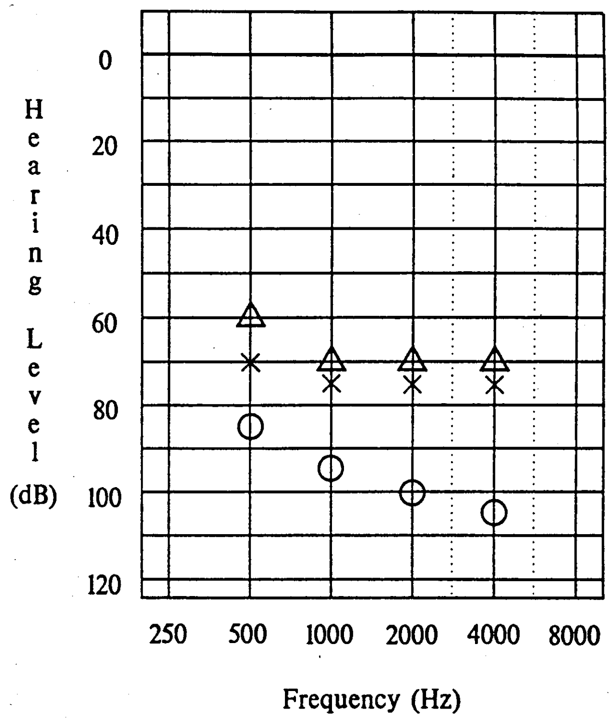
Audio 1A (air-bone gaps < 15 dB, BC present)



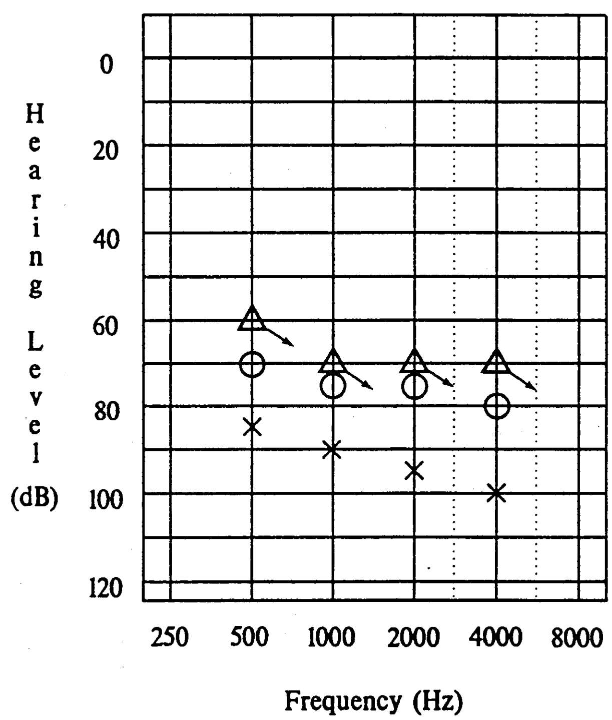
Audio 1B (air-bone gaps < 15 dB, BC absent)



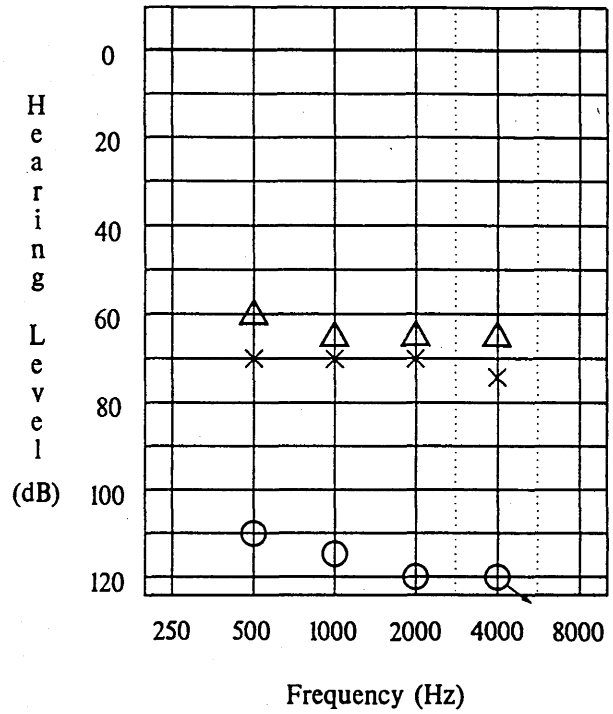
Audio 2A (gap < 15 dB one side, 15–40 dB other side, BC present)



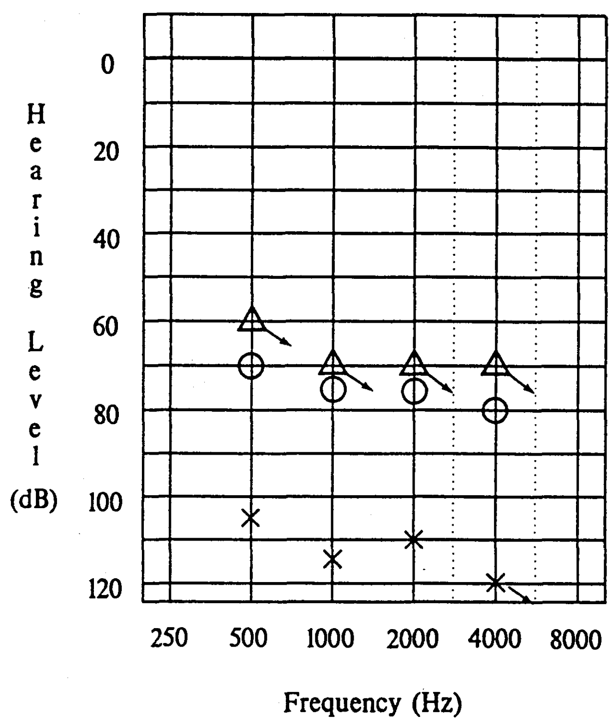
Audio 2B (gap < 15 dB one side, 15–40 dB other side, BC absent)



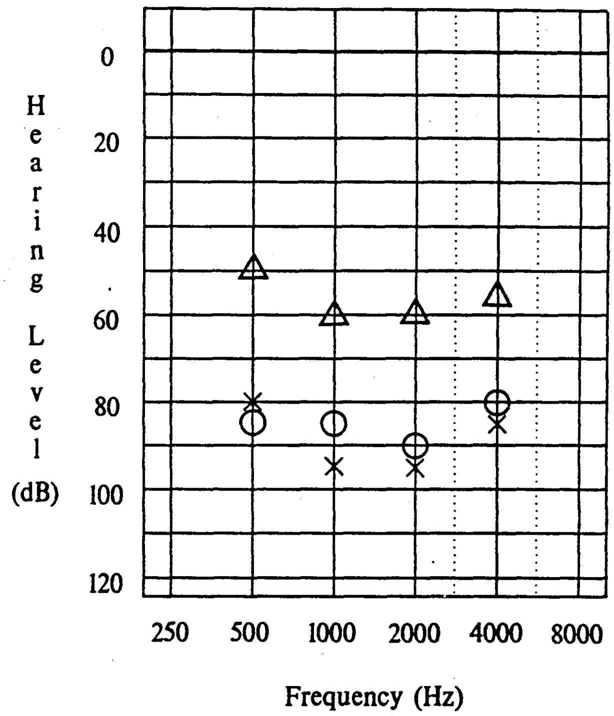
Audio 3A (gap < 15 dB one side, > 40 dB other side, BC present)



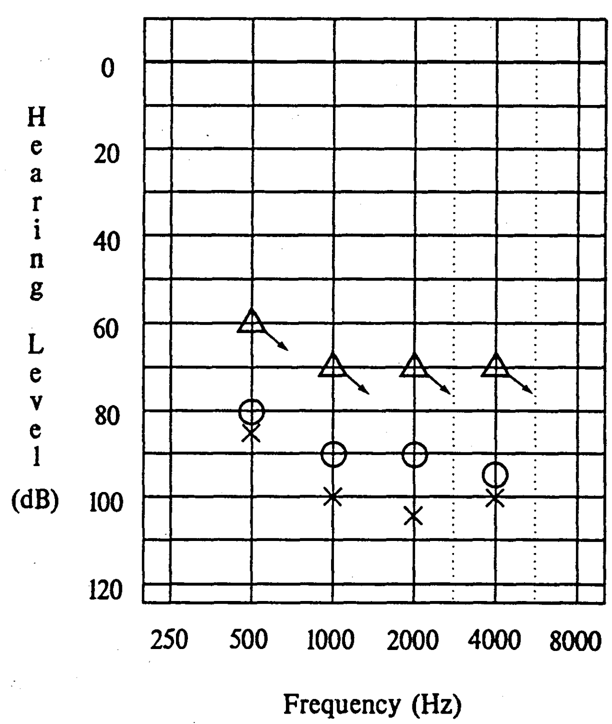
Audio 3B (gap < 15 dB one side, > 40 dB other side, BC absent)



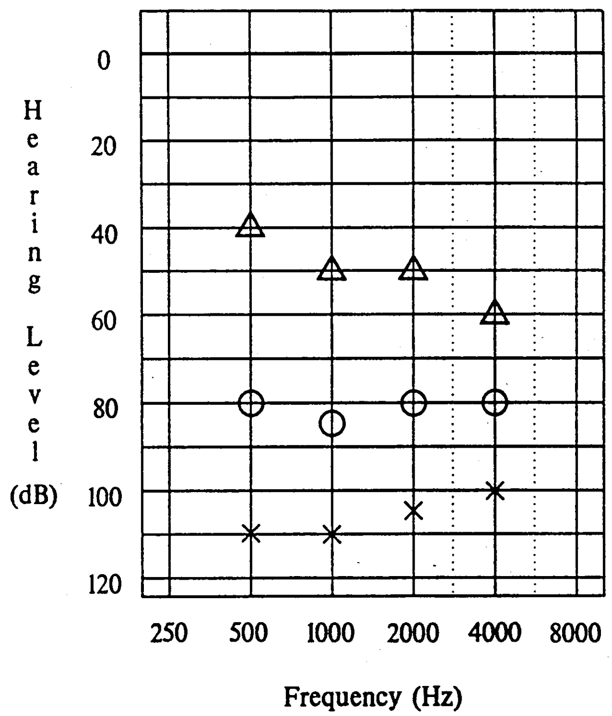
Audio 4A (gaps 15–40 dB both sides, BC present)



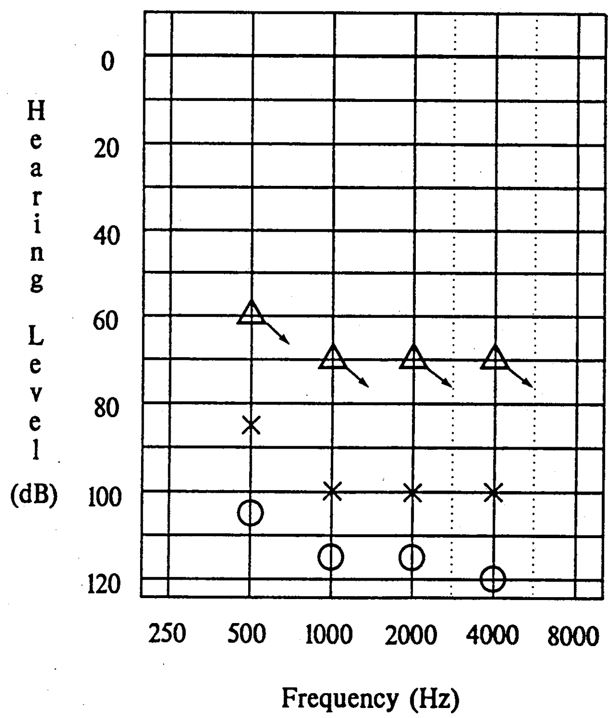
Audio 4B (gaps 15–40 dB both sides, BC absent)



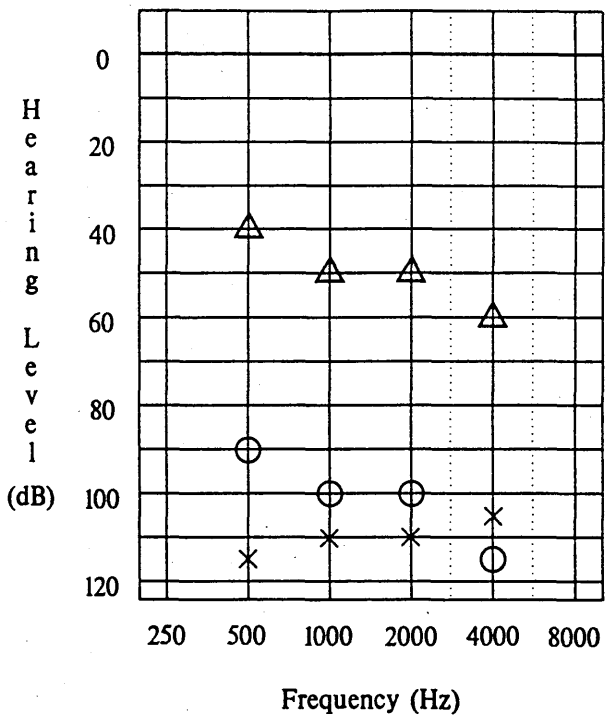
Audio 5A (gap 15–40 dB one side, > 40 dB other side, BC present)



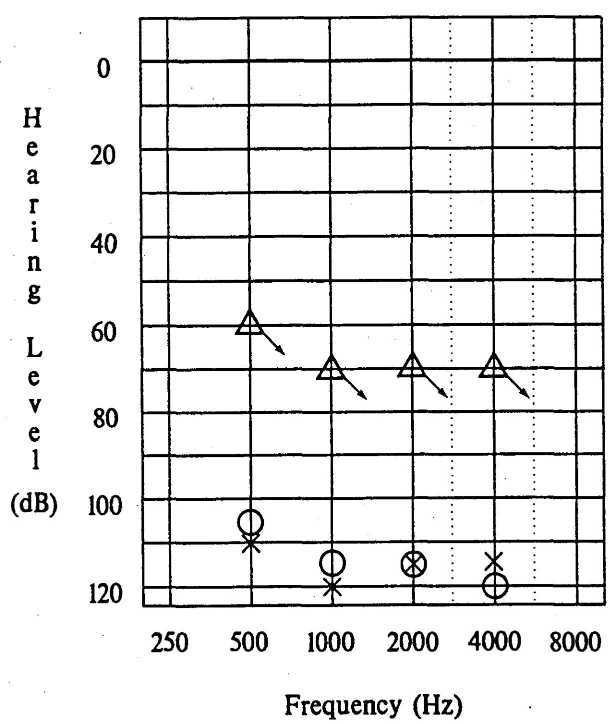
Audio 5B (gap 15–40 dB one side, > 40 dB other side, BC absent)



Audio 6A (gaps > 40 dB both sides, BC present)



Audio 6B (gaps > 40 dB both sides, BC absent)



APPENDIX C

THE ELECTROACOUSTIC CHARACTERISTICS OF HIGH-POWERED NHS HEARING AIDS USED IN THE STUDY.

Tables 1 and 2 show the outputs of all hearing aids measured with a 2cc coupler using a Bruel and Kjaer 2118 audio test station with an input of 75 dB SPL and the aid gain set to maximum.
The figure quoted are averages over 0.5,1 and 2 kHz given in dB SPL and are the means from three different aids.

TABLE 1 : BODY WORN AIDS

Aid	Receiver	Gain(dB)	Output(dB SPL)
BW81	6022	62	137
	6023	64	139
BW61	6022	59	134

TABLE 2 : EAR LEVEL AIDS

Aid	Gain(dB)	Output(dB SPL)
BE53	55	130
BE34	50	125

Tables 3 and 4 give the manufacturers specifications which are much higher than those measured above. Max gain is measured with an input of 50 dB SPL and the max output is with the aid at full saturation as specified in IEC publication 118-7.

TABLE 3 : BODY WORN AIDS

Aid	Receiver	Max gain(dB)	Max output(dB SPL)
BW81	6022	88	146
	6023	93	148
BW61	6022	71	144

TABLE 4 : EAR LEVEL AIDS

Aid	Max gain(dB)	Max output(dB SPL)
BE53	65	137
BE34	60	133

APPENDIX D

FASIN - AN AUDIOVISUAL SENTENCE IN NOISE TEST

developed by Graham A Day, George G Browning and Stuart Gatehouse.

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British Journal of Audiology, 1988, **22**, 179–182

An audiovisual test of hearing disability using free-field sentences in noise

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(*Received 23 November* 1987, *and in revised form 5 February 1988*)

Abstract

An audiovisual test, using BKB sentences in noise, has been developed to assess hearing disability, unaided and aided with a hearing aid(s), in severely hearing-impaired individuals. After a single practice list, no significant further increases in performance were detected. The test is reproducible within and between test sessions.

Introduction

Many different methods of assessing the benefit an individual gains from a hearing aid have been suggested. A questionnaire is convenient and will assess mostly how satisfied a patient is with an aid overall, but questionnaire responses can be heavily influenced by psychological factors that are difficult to control. A performance test is desirable which quantifies the benefit and is relevant to real life. These could include binaural listening to speech with or without vision, with or without competing noise and requiring or not requiring localisation. No single test can embrace all these conditions and a test battery would be impracticable and in many instances pointless to administer. A compromise has to be arrived at, and in research the style of tests will be dictated by the objectives of the study. In individuals with a severe hearing impairment (pure-tone average worse than 65 dB HL over 0.5, 1, 2 and 4 kHz) in their better-hearing ear, some degree of speech-reading is required under most circumstances, so amplification by a hearing aid is best evaluated in the context of speech-reading. Likewise, most difficulty is encountered in understanding running speech in a background of noise. Thus, for this group an appropriate test would be to assess their ability to identify, unaided and aided, sentences in a background of noise, with a view of the speaker.

Our aim was to develop an audiovisual test of hearing disability using free-field sentences in noise which could be used to assess benefit from hearing aid provision. As speakers can differ markedly in their speech readability, and as there may even be speaker-by-perceiver interactions it was considered both realistic and likely to enhance validity if several speakers were incorporated. No standardised audiovisual test of this type was available in 1985 when the associated study of benefit from binaural hearing aids (Day *et al.*, 1987) was formulated, and the Rosen–Corcoran recording (Rosen and Corcoran, 1982) was not available for both vision alone and audiovisual presentation.

Method

Test design

Sentence material. The BKB material (Bench and Bamford, 1979) consists of 21 lists each containing sensible sentences constructed from words familiar to the majority of English-speaking individuals. They are scored by the keyword method, 3 or 4 to a sentence, giving a potential total score of 50 per list. It is recognised that for audition-alone presentation of sentences in noise, 14 of the lists are of approximately equal difficulty (Pearce, 1980). However, they are not balanced for speech-reading difficulty, so an evaluation of the audio-visual inter-list difficulty was necessary.

Speakers and recording. Four speakers with varied speech characteristics were chosen. On informal inspection, two were considered visually clear and two visually unclear speakers. Two were male and two female. Two had Scottish accents and two non-regional British accents. Each

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speaker spoke a sentence in turn in a non-reverberant room, and the sentence lists were recorded on a Sony U-matic video player, good lighting of the mouth being ensured. The visual image included the full head and neck region. Each speaker spoke 4 sentences from each 16-sentence list.

Competing noise. Speech-shaped noise was mixed with the sentence material, enabling an adjustable signal-to-noise (S/N) ratio with a large range.

Test presentation. All the subjects were tested in a sound-deadened room, seated 2 m in front of a 26" video monitor. The mixed signal and noise were presented at 70 dBA with a S/N +5 dB, for the hearing-impaired subjects and −5 dB for the normal hearing listeners. The mixed signal was presented from two loudspeakers at 45° to the frontal azimuth. Performance was defined as the percentage of the 50 keywords in each sentence list correctly identified verbally, using strict scoring.

Standardisation of sentence lists

From informal inspection 11 of the 14 BKB sentence lists were considered to be audiovisually suitable. One list was used for practice, leaving 10 lists to be normalised. This was done both audiovisually and for vision alone. Ten normally hearing (pure-tone average better than 15 dB HL over 0.5, 1, 2 and 4 kHz in the poorer-hearing ear) and normally sighted (either with corrected or uncorrected vision) individuals were employed. The list order was balanced and performance scores obtained for the lists under audiovisual and vision-alone conditions.

The mean audiovisual and vision-alone scores for each list is shown in Figure 1. Weighting factors were calculated by comparing the mean score for each list separately with the average score of all 10 lists. The weighting factor for an individual list is the value which, when multiplied by the mean score for that list, brings it to the average score across all lists. A subject's score on a specific list can then be multiplied by this factor to give a corrected score, irrespective of the level of performance. The weighting factors for each of the 10 lists are shown in Table I, both for audiovisual and vision-alone presentation. Table I also shows that the correction factors for the vision-alone presentation are similar to those reported by Rosen and Corcoran (1982) for the same sentence lists, the correlation factor being 0.88.

The effects of using 4 speakers can be seen in Figure 2 by the range of scores each subject had for each speaker. In some instances, the order of ability to read a speaker changed between subjects. For example, speaker 2 for subject 5 was the easiest of the 4 to speech-read, whereas the same speaker was the one that subject 6 found most difficult. Insofar as the inclusion of 4 speakers with a range of audiovisual 'clarity' reduces the effect of subjects having particular difficulty with 1 speaker, the dynamic range of the list may be extended.

Reliability

The repeatability of a test is best assessed on its particular target population. The audiovisual scores in 29 of the patients with a severe hearing impairment being investigated for benefit from hearing aid amplification (Day *et al.*, 1987) were studied to determine repeatability within and between sessions. Each patient at their first visit had one practice list followed by one audiovisual, monaurally aided (list 1), one vision-alone (list 2), one audiovisual-aided (list 3) and another audiovisual monaurally aided list (list 4) and a final monaurally aided, audition-alone list (list 5). The list numbers correspond to the sequence of sentence lists that were used, rather than to BKB list identifiers. Practice effects can be evaluated by

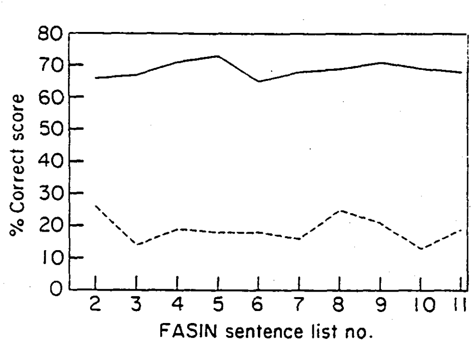

Fig. 1. Mean inter-list audiovisual and vision-alone scores for 9 normal subjects. ——, Audiovisual; ----, vision alone.

Table I. Sentence list weighting factors

FASIN, list no.	FASIN, audiovisual	FASIN, vision alone (lip-reading)	Rosen and Corcoran, vision alone (lip-reading)
2	1.04	0.75	0.8
3	1.03	1.25	1.09
4	0.96	0.92	0.95
5	0.92	0.95	1.04
6	1.05	1.03	1.19
7	1.02	1.10	0.99
8	1.00	0.75	0.8
9	0.95	0.89	0.9
10	1.00	1.35	1.30
11	1.02	0.99	1.02

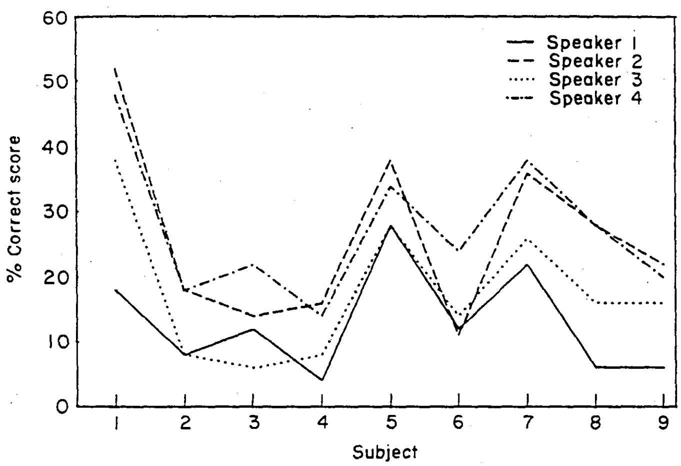

Fig. 2. Mean vision-alone scores in 9 normal subjects across 10 lists, resolved for each speaker. Speaker 1, English female. Speaker 2, Scots male. Speaker 3, Scots female. Speaker 4, English male.

comparing the corrected scores on list 1 (repetition 1) and list 4 (repetition 2). Figure 3 shows a plot to the corrected scores on repetition 2 against those on repetition 1. Improvement in performance with practice would result in a grouping to the left of the 45° line. This did not occur. The mean corrected score on repetition 1 was 63.8 (s.d. 20.8) and on repetition 2 was 64.5 (s.d. 20.3). There was no significant improvement in performance between repetitions. Figure 3 also shows that for 23 of the 29 subjects, the 2 scores fell within the arbitrarily chosen test/retest range of ±12.5%.

Differences of this magnitude or less are of material clinical interest, for example the difference to be expected between 2 aid provisions. Thus, a single presentation of the FASIN (free-field audiovisual sentence-in-noise) test in each of 2 conditions (e.g. aid A and aid B) will be insufficiently stable to differentiate between them for an individual subject. The standard deviation of the difference in score between repetition 1 and repetition 2 was 10.6. Such a difference implies that the FASIN test when performed at the same session would require 35 subjects to reliably distinguish between 2 conditions with a true performance difference of 5% at a significance level of $P < 0.05$. Certain assumptions are inherent in the above calculation (e.g. normally distributed differences and independent observations), and the figure of 35 subjects should be treated as a minimum number when planning an experiment.

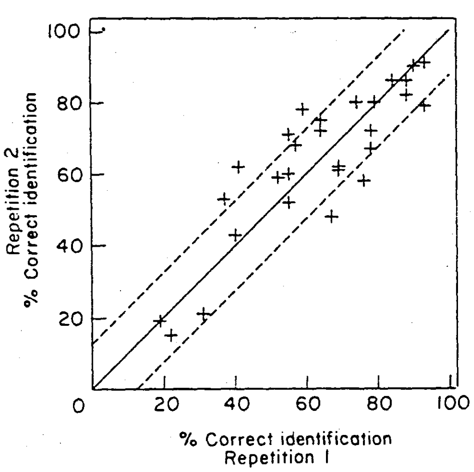

Fig. 3. Repeatability of FASIN within a session.

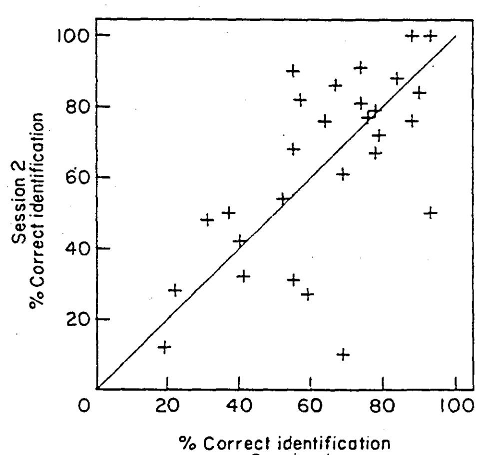

Fig. 4. Repeatability of FASIN between sessions (average 3 months difference).

On the patient's second visit, the monaurally aided condition was repeated and can be compared with the previous score (Day *et al*., 1987). Figure 4 shows a plot of the corrected score of session 2 against that of session 1. The mean scores were 63.8 and 64.2 for sessions 1 and 2, respectively, suggesting that the mean performance is stable over time. However, the standard deviation of the difference score was 20.0 (as opposed to 10.6 for the within-session difference). Thus, using the FASIN test on a group of 35 subjects would only be able to resolve a difference of 10% between conditions if the testing had to be performed on separate sessions (for example, when comparing the benefits of a hearing aid and surgery).

Discussion

FASIN would appear to be an acceptable audiovisual test of disability to test groups of severely hearing-impaired individuals. One practice list of 16 sentences is used prior to testing, and each sentence list takes 5 min to play. Calculations from the within-session standard deviations of the score difference suggest that the test is sufficiently powerful to resolve differences between conditions that have a 5% score difference. This is a value of material clinical interest in studying variations in hearing aid provision.

FASIN can be performed with audition alone, vision alone or audiovisually. In the latter mode, there is a wide range of scores when individuals with a severe hearing impairment are tested wearing a hearing aid and undue floor and ceiling effects can be avoided with a +5 dB S/N ratio.

The use of more than 1 speaker in audiovisual tests has the potential of avoiding bias due to familiarity with the speaker's accent or to a particular ability to speech-read a specific speaker. In FASIN, the use of 2 Scots speakers with regional accents might require its weighting factors to be recalculated if it were to be applied to individuals less familar with such accents.

In conclusion, FASIN is a test with little practice effect. To date, it has been used to assess the benefit from hearing aids in severely hearing-impaired individuals. It could be adapted to evaluate individuals with mild-to-moderate impairments by using a less favourable S/N ratio.

Copies of the tapes are available from Dr G. A. Day at the Audiology Department, Royal Infirmary, Glasgow G31 2ER, for the cost of a blank cassette plus postage. Please state which video-replay system is required.

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APPENDIX E

QUESTIONNAIRE

This is a sample questionnaire which was issued to all patients who completed the study.

Name ....

Date ....

HEARING QUESTIONNAIRE

Please fill out this questionnaire and post it back to us in the stamped addressed envelope provided. Your answers will help us understand more about hearing problems patients you have. You can be sure your answers will be kept strictly confidential.

To answer the questions please ring the response you think applies most to you.

Example Question:

How good is your eyesight ?

1. Normal
2. Fairly good
3. Bad
4. Very bad

Section A.

We want to obtain your own estimate of your hearing ability **WITHOUT THE HELP OF HEARING AIDS.**

1. Imagine that a normal young person has a hearing ability of 100 and a person who is totally deaf has a hearing ability of 0

We would like you to circle the number that best indicates the state of your hearing for each ear.

Left ear		Right ear
100	Normal	100
90		90
80		80
70		70
60		60
50		50
40		40
30		30
20		20
10		10
0	totally deaf	0

2. How much better or worse do you think your hearing is than the average for people of your age.

1. Much worse
2. Slightly worse
3. About the same
4. Slightly better
5. Much better

Section B

This section is concerned with obtaining general information on how you spend your time.

1. Do you live on your own?

    1. Yes
    2. No

2. During a normal week how many hours do you spend on the following activities?

    a) Watching T.V. ..... hours/week

    b) Listening to radio or records ..... hours/week

    c) In a club or pub ..... hours/week

3. During a normal month how many times do you do the following?

a) Attend meetings, talks or church ..... times/month

b) Go to cinema, bingo or other entertainment ..... times/month

4. During a normal week how many times do you use the telephone?

a) At work ..... times/week

b) At home ..... times/week

Section C

This section is concerned with situations in which some people have difficulty understanding speech. Answer them as it would be **WHEN WEARING HEARING AIDS.**

1. Can you follow the television news when the volume is turned up only enough to suit other people?

    1. Easily
    2. With some difficulty
    3. With great difficulty
    4. Not at all

2. Can you make out what people are saying on the telephone with the earpiece to your left ear?

    1. Not at all
    2. With great difficulty
    3. With some difficulty
    4. Easily
    5. Do not use the telephone

3. Can you make out what people are saying on the telephone with the earpiece to your right ear?

   1. Not at all
   2. With great difficulty
   3. With some difficulty
   4. Easily
   5. Do not use the telephone

4. Can you follow what is being said on the radio news when the volume is turned up only enough to suit other people?

   1. Not at all
   2. With great difficulty
   3. With some difficulty
   4. Easily

5. Do you turn your head the wrong way when someone calls to you ?

   1. Never
   2. Rarely
   3. Quite often
   4. Very often

6. If you are with a group of people and someone you can't see starts to speak, are you able to tell where the person is sitting?

   1. Usually
   2. Sometimes
   3. Not usually

7. How difficult do you usually find it to follow somebody's conversation when other people are talking close by?

   1. Great difficulty
   2. Some difficulty
   3. No difficulty

8. When talking in a quiet room with someone who is a clear speaker, how much difficulty do you have in understanding what they are saying?

   1. No difficulty
   2. Some difficulty
   3. Great difficulty

9. How often does your hearing problem restrict your enjoyment of social and personal life, compared to others around you?

1. Never
2. Rarely
3. Quite often
4. Very often

10. Do you get a feeling of being cut off from things because of difficulty in hearing?

1. Very often
2. Quite often
3. Rarely
4. Never

11. Do any hearing difficulties you may have lead to embarrassment?

1. Never
2. Rarely
3. Quite often
4. Very often

12. Do you feel embarrassed at having to wear a hearing aid?

1. Never
2. Rarely
3. Quite often
4. Very often

13. When you cross the road, can you hear the bleeps of the pelican crossing?

1. Easily
2. With some difficulty
3. With great difficulty
4. Never

14. If you are in a noisy room (e.g. with the TV on) does it prevent you from joining in any conversation?

1. Never
2. Occasionally
3. Frequently
4. Always

15. Do members of your family leave you out of conversations it you are having trouble hearing them?

1. Never
2. Occasionally
3. Frequently
4. Always

16. Has your problem with hearing caused you to stop taking part in group activities that you previously enjoyed? (e.g. bingo or church or social club)

1. All
2. Most
3. Some
4. None

17. Do you watch peoples lip movements in order to understand what is being said?

1. Never
2. Occasionally
3. Frequently
4. Always

18. Do you ever get annoyed when people do not speak clearly?

1. Never
2. Occasionally
3. Frequently
4. Always

19. Do you think people working at the hearing clinics understand your difficulties?

1. Not at all
2. A little
3. Mostly
4. Understand fully

20. Mark the number between 0 and 10 which you feel represents the amount of help that your hearing aid(s) give you.

where : 0 = NO HELP and 10 = FULL HELP

NO help FULL help

0 1 2 3 4 5 6 7 8 9 10

21. Mark the number between 0 and 10 which you feel represents how disabled you are by your hearing loss.

where : 0 = Not disabled at all

and 10 = Totally disabled

Not disabled at all Totally disabled

0 1 2 3 4 5 6 7 8 9 10

22. How much help have the hospital services been in helping you with your hearing difficulties?

1. No help at all
2. A little help
3. A moderate amount of help
4. Extremely helpful

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