The Air-bone Gap as a Criterion for Identification of Hearing Losses

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Research reports (*6, 7, 9, 10, 11, 13*) indicate that there is a greater incidence of hearing loss in the cleft palate population than in the normal population. These losses are primarily of the conductive type and they are most usually bilateral. It has been hypothesized that the losses originate with infection and/or obstruction in the Eustachian tube and may subsequently involve the rest of the middle ear structures. Although the increased incidence of hearing loss has been recognized, there seems to be little agreement regarding the general extent of such losses. This lack of agreement most likely reflects the use by various investigators of different criteria and different testing techniques.

Most studies concerning hearing loss in the cleft palate population have dealt only with the degree of air conduction loss relative to audiometric zero[1] and not relative to bone conduction thresholds (*4, 13*). Few studies have considered the total air-bone gap. Miller (*10*) states that a bone conduction test was performed whenever the air conduction loss was greater than 25 dB but no results were reported. Halfond and Ballenger (*6*) reported that some of their cleft palate subjects demonstrated very slight air conduction losses. Significant differences were obtained, however, between air and bone conduction test results which suggested middle-ear pathologies in a group which had previously been defined as being "without hearing losses".

The primary purpose of the present project was to design a method for assessing the actual air-bone gap and to evaluate the usefulness of such a technique. Conventional audiometers, calibrated in terms of 1951 ASA standards, test bone conduction to a limit of −10 dB. Such a level would appear to be sufficient to test bone conduction responses adequately. In

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This research report is supported in part by PHS Research Grant DE-00853, National Institute of Dental Research.

[1] All thresholds are reported in terms of 1951 American Standards Association reference thresholds, unless otherwise stated.

dealing with children, however, hearing sensitivity is considerably better than with adults, and so different equipment may be desired in order to measure this greater sensitivity.

In studies conducted by Eagles and Wishik (*3*) and by Jordon and Eagles (*8*), air conduction thresholds were obtained in a normal school-age population under ideal testing situations with accurately calibrated equipment. It was observed that air conduction thresholds among children with otologically normal ears ranged from −10.2 dB at 250 Hz to −0.7 dB at the "higher frequencies". However, in cases where an otologic abnormality was evident, the air conduction loss ranged from +12.8 to −8.2 dB, depending upon the type of pathology. (The authors did not state what frequencies these values represented.) Thus, otologic abnormalities are frequently evident even when a child has better than 0 dB hearing by air conduction. For the otologically abnormal children, with better than 0 dB air conduction thresholds, it might be assumed that an air-bone gap was present. However, such a gap could not be measured with conventional equipment.

A second purpose of the present study was to suggest a more useful operational definition of hearing loss for children. Traditionally, hearing loss has been defined in terms of its medical or educational significance. Thus, a hearing loss of 10 dB might be considered medically significant. Hearing loss also has to be defined in terms of the frequencies tested. Indeed, Spriestersbach and his associates (*13*) indicated that the incidence of hearing loss ranged from 74.19 to 3.23% depending upon the type of definition employed.

Procedure

Subjects. Cleft palate subjects were chosen from patients who were under care in the Department of Otolaryngology and Maxillofacial Surgery, University Hospitals, University of Iowa. Subjects included 52 females and 55 males. The age of the subjects ranged from 4 years, 0 months to 25 years, 4 months. Table 1 indicates the distribution of subjects according to age and type of cleft.

TABLE 1. Distribution of subjects according to age and type of cleft.

age (months)	*lip and palate*			*palate only*	*total*
	bilateral	*unilateral*	*total*		
26–71	6	10	16	10	26
72–109	24	15	39	9	48
110–167	6	7	13	6	19
168+	5	7	12	2	14
total	41	39	80	27	107

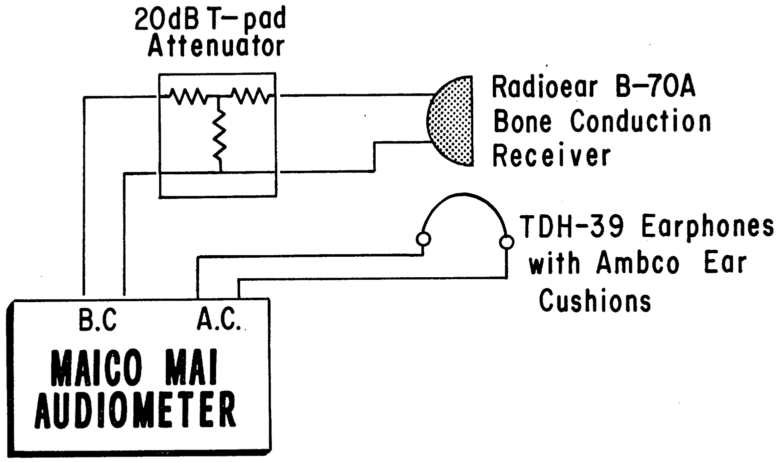

FIGURE 1. Diagram of apparatus.

AUDIOLOGIC EVALUATION. A Maico MA 1 audiometer was used for all air-conduction and bone-conduction tests. Testing was done in a sound treated room, and all subjects were tested by the same audiologist. Through the use of a 20 dB T-pad attenuator network (Figure 1), it was possible to test bone conduction responses to a limit of −30 dB relative to 0 dB hearing loss, rather than the usual limit of −10 dB. The T-pad was linear in frequency response and there were no audible clicks in the circuitry as judged by the senior author.

The air conduction stimulus was calibrated by means of an Allison Model 300 Audiometer Calibrating Unit. Bone conduction calibration was maintained by using the Carhart method of matching air conduction with bone conduction thresholds of patients with long-standing sensori-neural hearing losses (*1*).

All bone conduction thresholds were obtained using only the 20 dB pad. When reporting air-bone gaps the algebraic difference between the air-conduction threshold and the minimum bone-conduction threshold was computed. In reporting air-bone gaps in terms of traditional bone conduction levels (a minimum limit of −10 dB), the −10 dB level was the best hearing level that could be reported. For example, if a subject had an air conduction level of 30 dB and a bone conduction level of −25 dB (using the 20 dB pad), the total air bone gap would be 55 dB. When giving the results in terms of the conventional bone conduction testing, the air-bone gap would only be 40 dB because −10 dB is the best bone conduction level obtainable. When reporting the degree of loss relative to 0 dB, 0 dB will be considered to be the minimum bone conduction obtainable. Thus, the air conduction loss was used as a method of defining the air-bone gap although no actual bone conduction level was tested.

Most subjects were tested for the octave frequencies between 250 and

4000 Hz by air and bone conduction. The first frequency tested was 1000 Hz, followed by 500, 250, 2000, and then 4000 Hz. With younger children, because of short attention span, it was sometimes impossible to obtain a complete audiometric evaluation. For such subjects, only 500, 1000, and 2000 Hz were tested.

Older children were instructed to either raise their hand or to signal with the "response" button when they thought they heard a sound. Younger children were conditioned to drop marbles in response to the stimulus. Threshold was defined as the lowest level at which there was a response to the stimulus 50% of the time on a descending trial. If a reliable test was not obtained, the subject was not included in the study.

Results

General Description of Hearing Test Results. This study was generally patterned after the research by Spriestersbach and his associates (*13*); they, too, were concerned with the effect of definition of hearing loss upon the reported incidence of hearing loss. It would appear that the two samples were taken generally from the same type of population of cleft palate patients being seen at the University of Iowa Hospitals. However, the two samples were collected at different times and therefore represent different children. In addition, techniques for medical treatment have probably shown considerable improvement in the ten years which have lapsed since the earlier study. Although the Spriestersbach study had a slightly greater number of subjects (163) than the present investigation (107), the proportion of representation of the sexes, types of cleft, and age ranges was similar. Audiologic evaluation was completed in essentially the same manner, except that Spriestersbach did not report his bone conduction tests. For purposes of comparison, then, in this part of the report, only the degree of air conduction loss (relative to audiometric zero) will be discussed (see Table 2).

The primary disparity among the various reports regarding the extent of hearing loss in the cleft palate population is that there is no common definition as to what constitutes a hearing loss. The Spriestersbach study pointed out the necessity of defining hearing loss according to the frequencies tested and the degree of hearing loss which was considered to be significant. Table 2 presents the percentages of subjects with hearing loss (air conduction) in the present and in the Spriestersbach study. The current investigation indicates that the percentage of subjects with hearing loss varies from 1.03% to 52.34% for the better ear and from 14.95% to 81.31% for the poorer ear, depending upon the frequencies used to represent the hearing loss and the degree of loss considered to be significant. From the data in Table 2, it can be observed that a disproportionate percentage of hearing losses is noted when the single frequency representing the greatest hearing loss is reported. The three-frequency and the five-frequency averages yield essentially the same

TABLE 2. Percentages of subjects with hearing loss (air conduction) by various definitions. Data from the Spriestersbach study (*13*) are presented in parenthesis for easy comparison. Note that for definition 2, Spriestersbach also considered the loss at 8000 Hz. For definition 3, the Spriestersbach study did not include those subjects on whom they could not get a complete test. However, the present study did.

definition of hearing loss, air conduction only	*N*	*percentage with a hearing loss*	
		better ear	*poorer ear*
1. average of 500, 1000, 2000 Hz	107 (163)		
10 dB		21.49 (28.83)	46.73 (61.96)
20 dB		4.50 (11.66)	29.91 (36.81)
30 dB		2.71 (5.52)	14.95 (18.40)
2. average of 250, 500, 1000, 2000, and 4000 Hz	97 (124)		
10 dB		27.84 (19.35)	56.70 (50.81)
20 dB		5.15 (7.26)	31.96 (26.61)
30 dB		1.03 (3.23)	15.46 (12.90)
3. frequency showing the greatest loss	107 (124)		
10 dB		52.34 (43.54)	81.31 (74.19)
20 dB		30.84 (16.13)	56.08 (40.32)
30 dB		8.41 (7.26)	32.71 (20.97)

findings and appear to be more representative of the percentages of hearing losses present. Since most readers are familiar with results reported in terms of the three frequency average, that definition will be used for the remainder of the discussion.

Table 3 presents the mean hearing loss of the cleft palate subjects according to age, sex, and type of cleft. The data regarding age is in agreement, roughly, with previous studies (*4, 5, 10, 12, 13*) in that there is a tendency for the older children to show less severe hearing losses than the younger ones. As indicated in other studies (*4, 13*), there appears to be no consistent differences between sexes. In contrast to most previous studies, which have demonstrated a trend to higher incidence of hearing loss in the palate-only group, there is a tendency in the present study for the cleft lip and palate group to show a greater loss than the palate-only group when the criterion is the threshold for the poorer ear.

AIR-BONE GAPS. In this section of the report, results will be discussed in terms of the bone conduction thresholds obtained by traditional methods of bone conduction testing and by use of the 20 dB pad.

The percentage of subjects exhibiting a specified air-bone gap, for the total group of cleft palate subjects as well as for the two cleft-type subgroups, is shown by the histograms in Figure 2. The parameters include (a) the air-bone gap for the better and the poorer ear, (b) the three methods of defining an air-bone gap, and (c) the various air-bone gaps which are considered to be significant, that is, whether they are 10 dB and greater, 20 dB and greater, or 30 dB and greater.

TABLE 3. Comparison of mean air conduction thresholds for different ages, sexes, and cleft types. Thresholds were computed from the average of 500, 1000, and 2000 Hz. The Spriestersbach data are presented in parenthesis.

Category	*N*	*mean hearing thresholds*	
		better ear	*poorer ear*
age (in months)			
26–71	26 (56)	3.21 (11.91)	13.10 (22.20)
72–119	48 (54)	4.72 (4.67)	16.42 (12.76)
120–167	19 (30)	.31 (6.47)	12.05 (15.23)
168+	14 (23)	−.78 (5.43)	5.21 (14.52)
sex			
male	55 (100)	2.72 (7.36)	15.66 (17.04)
female	52 (63)	2.68 (7.97)	11.60 (16.17)
cleft type			
lip and palate	80 (120)	2.20 (6.75)	13.27 (15.81)
palate only	27 (43)	1.24 (9.95)	4.72 (19.21)

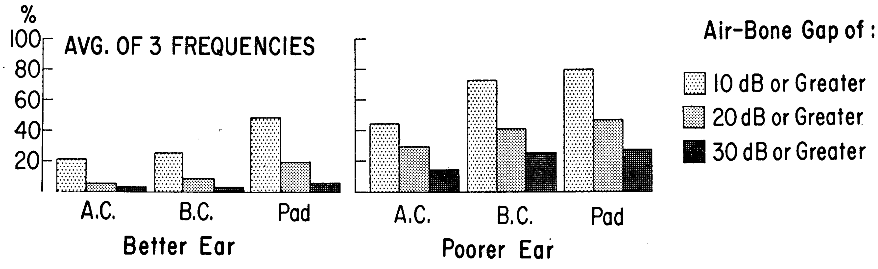

FIGURE 2. Percentage of the total group of subjects exhibiting air-bone gaps, measured by the following criteria: A.C., air conduction loss re 0 dB bone conduction; B.C., air conduction loss re −10 dB bone conduction; Pad, air conduction loss re −30 dB bone conduction. Measures represent the average of three frequencies (500, 1000, and 2000 Hz).

In considering only the better ear, using the criterion of an air-bone gap of 10 dB or greater, the percentage of subjects showing such a gap ranges from 22% (when 0 dB is the bone conduction reference threshold) to 51% (when −30 dB is the bone conduction reference). However, in considering the percentage of subjects showing a gap of 30 dB or greater, there is little difference in these percentages no matter which definition is employed. The same general trend is observed to be true for the poorer ear. The more stringent the criterion, in terms of definition of air-bone gap or in terms of degree of gap considered to be significant, the greater the percentage of subjects showing an air-bone gap. Thus 85% of the subjects tested with the 20 dB pad (30 dB reference) displayed an air-bone gap of 10 dB or greater for the poorer ear. Again, even using conventional bone conduction testing (bone conduction reference of −10 dB), 78% demonstrated an air-bone gap of greater than 10 dB.

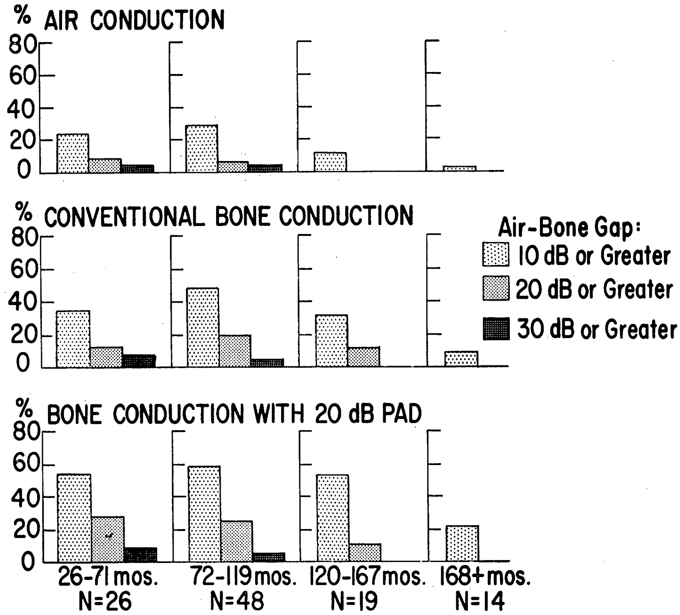

FIGURE 3. Percentage of subjects exhibiting air-bone gaps in the better ear for four age groups: *air conduction,* air conduction responses re 0 dB bone conduction; conventional *bone conduction,* air conduction responses re possible maximum of −10 dB bone conduction; and *bone conduction with 20 dB pad,* air conduction responses re possible maximum of −30 dB for bone conduction responses.

As indicated previously, the data show that there are less severe degrees of hearing loss as a function of increasing age. Figures 3 and 4 show the percentage of subjects showing gaps for the better and the poorer ears, respectively, for different age groups. The middle histogram (conventional bone conduction) and the bottom histogram (bone conduction with the 20 dB pad), in Figure 3, indicate that 8 per cent of the 26 children in the 26–71 month age bracket possess an air-bone gap of greater than 30 dB. However, using the same criteria for the two older age groups, none of the subjects exhibited such losses. The same general trend is observed for the data in Figure 4, which relates to the poorer ear. However, as would be expected, the percentages of subjects showing losses are greater than those reported for the better ear.

Since this study was completed in a medical setting and with a group of subjects known to possess hearing losses, it seems appropriate to discuss the results in light of the identification of medically significant losses. For the purposes of this report, a medically significant loss is defined as an air-bone gap of greater than 10 dB rather than the traditional definition of an air conduction loss of greater than 10 dB.[2] For the better ear, using the 20 dB pad (bottom histogram in Figure 3), 54% of

[2] A pure sensori-neural loss of 10 dB or greater would still be considered medically significant although there is no air-bone gap present.

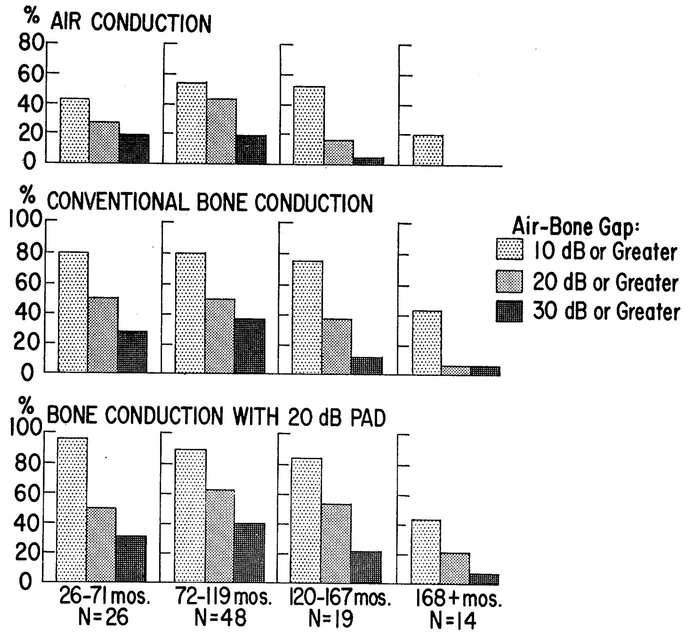

FIGURE 4. Percentage of subjects exhibiting air-bone gaps in the poorer ear for four age groups: *air conduction,* air conduction responses re 0 dB bone conduction; conventional *bone conduction,* air conduction responses re possible maximum of −10 dB for bone conduction responses; and *bone conduction with 20 dB pad,* air conduction responses re possible maximum of −30 dB for bone conduction responses.

the 26 children, 26–71 months in age, exhibited a medically significant gap. For the oldest group of children, only 21% of the group of 14 showed such a gap. For the poorer ear (Figure 4), there are distinct differences in the proportion of children in the youngest age group showing medically significant air-bone gaps, whether air conduction thresholds, conventional air-bone gaps, or air-bone gaps with the 20 dB pad, are used as the criteria. It is particularly important to note that in the poorer ear, the 26 to 71 month age group shows 54% more air-bone gaps with the use of the pad (bottom histogram) than with just an air conduction test using 0 dB as the reference threshold (top histogram). For the same age group, 16% more air-bone gaps were identified with the pad than with conventional bone conduction testing (middle histogram).

Using just the degree of air conduction loss relative to audiometric zero, it was reported earlier in the Spriestersbach study that differences between the cleft lip and palate and the cleft palate only subjects were observed. For the poorer ear, the lip and palate group showed a mean loss of 13.27 dB while the palate only group showed a mean loss of 4.72 dB. For the present study, Figure 5 indicates the differences between these two groups when the air conduction loss, conventional bone conduction testing, and the 20 dB pad are considered as defining the degree

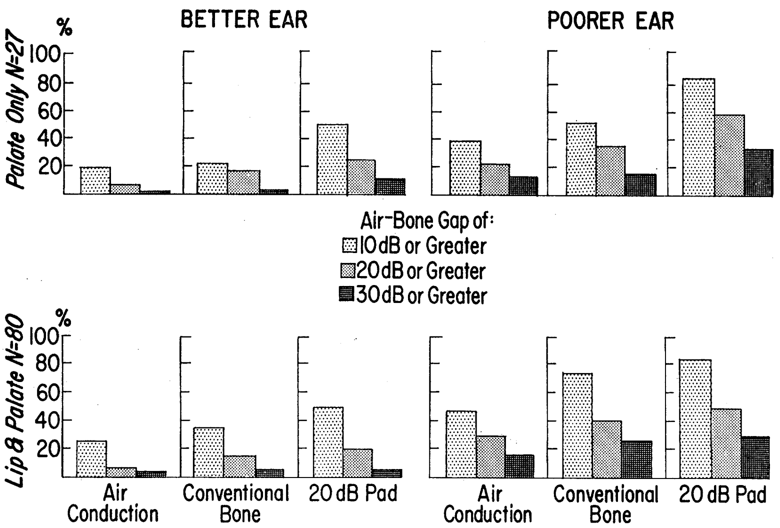

FIGURE 5. Percentage of subjects according to cleft type exhibiting air-bone gaps for the better and poorer ear employing the three definitions for air-gap, described in the legend for Figure 4.

of air-bone gap. In terms of the percentage of subjects demonstrating a specified air-bone gap, there does not appear to be a great deal of difference between the two groups.

Discussion

The literature indicates that the cleft palate population has a greater incidence of hearing loss than the normal population. However, because of various definitions as to what constitutes a hearing loss, the ability to compare different research reports proves to be difficult. Three factors appear to be important in terms of defining hearing losses: (a) the frequency or frequencies used in computing the hearing loss, (b) the degree of loss considered to be important, that is, whether medically or educationally significant, and (c) the method of defining the extent of the air-bone gap. The inability to compare research results concerning the first two factors is primarily due to a lack of uniformity among various investigations. There is little consistency among reports as to the frequencies that should be used in computing a loss or as to what degree of loss constitutes a significant loss. In considering medically significant losses, the first two factors may be considered to be of little consequence. However, as has been shown, the method used to compute the air-bone gap may be of great importance.

These results indicate that testing a child for air conduction only, if his air conduction loss is 0 dB, is not sufficient. The extent of the air-bone gap should also be investigated, whether conventional bone conduction or special techniques are used, as in the present study. A child with 0 dB via air conduction threshold might exhibit an ear pathology upon otoscopic examination, yet the hearing threshold would not be considered to indicate a medically significant problem. The same child might have a bone conduction threshold of −10 dB, indicating a 10 dB air-bone gap, which would be considered, as defined in this study, to constitute a loss of medical significance.

Another purpose of the present study was to discuss the feasibility of using the 20 dB pad for the measurement of air-bone gaps in a more precise way. The design of such an attenuator is quite simple and is easily adapted to audiometric equipment which may already be in use. The use of such a pad, however, is necessary only when it can be presupposed that a loss is conductive in nature, and when air conduction thresholds are 0 dB or better. There is no necessity to use a pad on a patient who has a sensori-neural hearing loss.

Although the investigation of hearing losses in the cleft palate population was of primary concern in this paper, it would seem logical that the technique discussed would be applicable to all children. Previous research (*3*, *8*) has indicated that even in the presence of otological abnormalities of the middle ear, children may still exhibit better than "normal" hearing. Thus, there should be an emphasis placed upon the administration of bone conduction tests even for those children who show 0 dB hearing by air conduction.

The question of agreement between the degree of air-bone gap and otologic pathologies is pertinent and deserves careful consideration before the significance of the air-bone gaps, such as those studied here, can be fully interpreted. Further research involving comparisons of air-bone gap data and otologic findings is needed.

All thresholds reported in the present study are relative to the 1951 American Standards Association reference thresholds. In actuality, the stringent criteria imposed by the use of the 20 dB pad for bone conduction may not be necessary with the adoption of the 1964 International Standards Organization standards (*2*). For example, 0 dB 1964 ISO at 500 Hz is comparable to −14 dB on 1951 ASA standards. Although on the 1951 ASA standards, many of the children in the study obtained bone conduction thresholds of −20 dB, this would be only slightly better than the 1964 ISO limits. Thus, with the use of the 20 dB pad we were essentially imposing the new 1964 ISO standards upon the bone conduction loss. If it would be desirable to place a pad on the audiometers calibrated in terms of the new standards, the attenuator would need only to provide a possible additional attenuation of 10 dB.

The findings reported here indicate that the lip-and-palate subjects have poorer hearing than the palate-only subjects. The findings of Spriestersbach and associates (*13*) indicate the opposite; that is, palate-only subjects have poorer hearing than lip-and-palate subjects. One explanation of this difference may be related to the high incidence of hearing loss in young children and the distribution of age of subject in the two cleft-type groups in the two studies. For example, if a large proportion of the palate-only subjects by Spriestersbach had been younger than six years old, the high incidence of hearing loss in that palate-only group may have been due not to the type of cleft but to the age of subject. Unfortunately, that possibility cannot be evaluated since distribution of age of subject according to cleft type is not reported by Spriestersbach and his associates (*13*). In the present study, only 20% of the lip-and-palate subjects are younger than six years of age and so the possibility of an interaction between cleft-type and age of subjects seems unlikely but additional research is needed.

A final word of caution seems appropriate in generalizing from this study with regard to the general level of hearing sensitivity demonstrated by the cleft palate population. Cleft palate subjects used as the sample in this investigation were for one reason or another under medical care at the time of study and, furthermore, the probabilities are high that they have had continued medical surveillance over a period of years. They may or may not be different in level of hearing sensitivity from other cleft palate subjects who are not under medical care or who have not had medical surveillance for a number of years.

Summary

A total of 107 cleft palate patients were given audiometric tests for air conduction and bone conduction. Bone conduction thresholds were obtained by inserting an additional 20 dB attenuation into the circuitry of the audiometer. Three factors were considered important in defining the percentage of subjects exhibiting a loss: (a) frequency or frequencies used in computing the loss, (b) degree of loss, and (c) method of defining the air-bone gap. Findings of the present study agreed with previous investigators in terms of the relatively high incidence of hearing loss in the cleft palate population. One difference was that the cleft-lip-and-palate group showed a worse mean air conduction loss than the palate-only group. The study points out that more thorough bone conduction measures should be reported in research concerning the incidence of hearing loss in the cleft palate population. With the use of the 20 dB pad, it was possible to define more accurately the existence of the air-bone gaps. Also, the use of the 20 dB pad in bone conduction testing might well be applied to the hearing testing of other than cleft palate children.

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