CLINICAL BONE - CONDUCTION STANDARD VALUES FOR THE BRUEL AND KJAER 4930 ARTIFICIAL MASTOID

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Calibration of any measuring instrument is a major prerequisite for its use and Audiology as a scientific discipline respects precision in clinical and research measurements. Accurate audiometric calibration is crucial in clinical audiology in that the results of audiological evaluations are critical for diagnosis, treatment and rehabilitation of hearing problems. "Without calibrated earphones and bone-conduction receivers it is impossible : (1) to know whether thresholds of patients are contaminated by faulty equipment ; (2) to know whether apparent changes in hearing over time for a patient are due to true differences in his performance or to variations in the equipment ; and (3) to accurately compare results obtained in one clinic or laboratory with those found in another clinic or laboratory" (Wilber and Goodhill, 1967a).

Though stable acoustic devices, such as the 2cc and 6cc couplers, have been developed for calibration of air-conduction receivers in audiometers, no comparable instruments are available for bone-vibrator calibration. For many years, the clinician had only a choice of three biological calibration methods: (1) A loudness-balancing procedure advocated by Beranek (1949) as a means of transferring air-conduction norms to a bone-conduction system. (2) Averaging the bone thresholds exhibited by subjects with normal hearing and applying the appropriate correction if their air-conduction thresholds deviate from ASA, 1951 or ISO, 1964 norms for air conduction (AMA, 1951; Hedgecock, 1961). (3) Testing subjects with pure sensori-neural losses for air and bone-conduction thresholds using an audiometer with a calibrated air-conduction system. The discrepancies between the average bone and air thresholds at each frequency represents the correction to be applied to the bone-conduction vibrator (Carhart, 1950 ; Roach and Carhart, 1956). The rationale for the last two methods is based principally on the theory that air-and bone conduction thresholds are essentially equivalent among persons with normal hearing or among patients with "pure" sensori-neural losses.

All the above methods have their limitations, apart from variability of procedures adopted by the testers and variability of responses of the listeners. The procedures also require that a large group of individuals be tested.

Physical calibration of bone-conduction vibrators has been attempted for many years, but there were great difficulties in constructing artificial mastoids which simulate the human bone-conduction system. At present there are two artificial mastoids commonly in use : the Beltone artificial mastoid (Weiss, 1960) and the British artificial mastoid (BS4009, 1966). The British artificial mastoid utilizes a viscoelastic pad which the developers indicate is relatively

Abstract and Guide : Mr. M. N. Vyasamurthy immune to aging and temperature. The Beltone artificial mastoid departs substantially from the earlier-designed artificial mastoids and uses an air damping technique to simulate the mechanical impedance of the human mastoid. Stability of these artificial mastoids has been determined by various investigators (Sanders and Olsen, 1964 : Studebaker, 1967a: Whittle, 1965: and Wilber and Goodhill, 1967b). The general conclusion has been that the variability of bone-vibrator measurements made on the artificial mastoid is no larger than that observed with air-conduction receiver measurements utilizing 6cc couplers.

"The lack of acceptable bone-conducton thresholds and means for determining them has been a serious problem for atleast thirty years. The need is becoming increasingly acute. The possibility of realizing standardization has been greatly enhanced by the development of one or more artificial mastoids capable of measuring force values into known mechanical impedance and by the current availability of stable bone receivers for audiometric testing" (Lybarger 1966a).

The problem of bone-threshold standardization is being carefully studied by the Working Group 1/TC43 of the International Organisation for Standardization (ISO). In 1964, in the United States, the Hearing Aid Industry Conference (HAIC) Standards Committee recommended a uniform interim bone threshold standard to be adopted till an international standard become effective. All threshold data for these norms were reported in force values obtained from calibrations performed at the front surface of the Beltone artificial mastoid. Data from eight laboratories were used to establish the norm, and the averaged results were published by Lybarger (1966a). Later, publications by Dirks et al (1968), Olsen (1969), Sanders and Olsen (1964), Studebaker (1967b), Weston et al (1967), and Wilber and Goodhill (1967b) attested to the usefulness of the HAIC norm. Robinson and Whittle (1967) compared the HAIC interim threshold values with values obtained on the British artificial mastoid, BS4009, and found close agreement between the equivalent force thresholds.

In 1969, Bruel and Kjaer brought out an artificial mastoid, Type 4930, which conformed with the British Standard, BS4009 (1966), and had specifications in accordance with the IEC R373 raft.

Wilber (1972a) Compared the Beltone 5A and B & K 4930 artificial mastoids using four Radio ear B-70-A bone vibrators and found that neither conformed exactly to the impedance values in the new ANSI Standard S3. 13-1972 "for an artificial headbone for the calibration of audiometer bone vibrators." Dirks and Kamm (1975) and Lybarger (1971) also studied the difference between vibrator outputs as measured on the B & K 4930 and Beltone artificial mastoids. In general, the studies showed that the B & K artificial mastoid yielded lower force levels than did the Beltone for the same electricial input voltage to the bone vibrator. This is due, in part, to the differences in mechanical impedance of the artificial mastoids used.

It is thus indicated that different norms must be used when calibrating bone vibrators on different types of artificial mastoids. Differences in vibrator output have also been attributed to differences in the physical characteristics of the bone vibrators. Hence, several authors (Dirks and Kamm, 1975; Studebaker, 1967a: Weston, et al., 1967) state that different types of vibrators must have different norms, as is the case with earphones. Hence, the present study aims at establishing clinical bone-conduction standard values for the B & K 4930 artificial mastoid, using the bone vibrator provided with the Madsen TBN 60 audiometer (Denmark). These values can be used in calibrating similar bone vibrators on the B & K artificial mastoid.

Plan of the Study

A bone vibrator (X. 120, Denmark) provided with the Madsen TBN 60 audiometer was calibrated using thirty-one subjects with bilateral sensori-neural hearing loss, with the procedure recommended by Carhart (1950). The corrections obtained in this manner were applied to the vibrator output which was measured periodically on the Bruel & Kjaer 4930 artificial mastoid, connected to a B & K frequency analyzer (2107). The corrected output values for each frequency are reported in dB re-one Micro Volt. To examine whether these values could be applied to other types of bone vibrators, three vibrators (Radioear B. 70-A; a vibrator, M66, provided with the Madsen 0 B 70 audiometer and a vibrator, A39, provided with another Madsen TBN 60 audiometer) were calibrated on the B & K 4930 artificial mastoid using the obtained norms. Four of the sensori-neural loss subjects tested earlier, were retested on these vibrators and their bone-conduction thresholds compared.

The values obtained in the study can be used as a standard for calibrating bone vibrators on the Bruel & Kjaer 4930 artificial mastoid in the clinic.

METHODOLOGY

Subjects

A total of thirty-one bilateral mild to moderate sensorineural hearing loss cases were tested in the present study. There were eleven cases of presbycusis, four with congenital impairments, four with noise induced hearing loss two with hearing loss due to ototoxicity, one with Meniere's disease, one with hearing loss due to head injury, and eight due to miscellaneous or unknown causes. No attempt was made to control the sex or age distribution of the group. The group included twenty-one men aud ten women. The age was from eleven to sixty-nine years, with a mean age of 44.6 years.

Criteria of Selection: (1) The subjects did not have any history of ear discharge or infection. (2) They were identified as having bilateral sensori-neural loss, with no conductive involvement, by an otologist. (Cases with loss of cone of light and a dull tympanic membrane were also rejected) (3) They were found to have bilateral acoustic reflex at reduced sensation levels as determined on a Madsen ZO70 or Madsen ZO72 Acoustic Impedance Bridge.

The last criterion was included since many investigators (Ewertsen, et al., 1958; Jepsen, 1963; Kristensen, et al., 1952; Lamb, 1968; Metz 1952; Thomsen, 1955) have shown that in cases with cochlear involvement, impedance changes are found to occur by stimulating with signals less than 70 dB sensation level (the reflex threshold level in normal hearing adults_ Jepsen, 1963), which has been explained as showing loudness recruitment of the stimulating signal. It has also been shown that minimal conductive hearing loss or seventh nerve patholgy will usually prevent impedance changes from occurring (Jepsen, 1951; Klockhoff, 1961).

Equipment

Acoustic reflex measurements were made on a calibrated Madsen Acoustic Impedance Bridge, either Model ZO70 or Model ZO72 connected to a calibrated Beltone 12D audiometer.

Thresholds of subjects for establishing calibration norms were measured on a Madsen TBN60 Portable Audiometer (Denmark), fitted with TDH39 earphones in MX14/AR cushions and a bone vibrator (X-120, Denmark), having a contact tip area of approximately 3 85 cm^2.

Comparison of bone-conduction thresholds on audiometers calibrated with the obtained norms was done with the following three audiometers: (1) A second Madsen TBN60 portable audiometer, with a similar bone vibrator (A-39, Denmark), having a contact tip area of approximately 3.85 cm^2. (2) A Madsen 0B70 audiometer with its bone vibrator (M66), having a contact-tip area of approximately 2.9 cm^2. and (3) A Beltone 12D audiometer with a Radio ear B-70-A vibrator, having a contact tip area of approximately 3.85 cm^2 .

Air-conduction calibration was done on a Bruel & Kjaer artificial ear, Type 4152, which contained a 6cc coupler (NBS9-A) and a B & K condenser microphone, Type 4132, coupled to a B & K sound level meter, Type 2203, and a B & K octave filter set, Type 1613.

Bone-vibrator calibration was done on a Bruel & Kjaer artificial mastoid, Type 4930, connected to a B & K frequency analyzer, Type 2107. Harmonic distortion of the bone vibrators was measured on the B & K artificial mastoid, Type 4930, connected to a B & K sound level meter, Type 2203, and a B & K octave filter set, Type 1613.

Test Environment :

Thresholds of the subjects were tested in a sound treated room, where the ambient noise levels (Table 1) were within the maximum permissible noise levels proposed (Hirschorn, 1971) for audiometers calibrated to ISO (1964) standards. Permissible noise levels for bone-conduction testing are also given in Table 1.

Table 1

Ambient Noise Levels in the Audiometric Room.

Octaves in Hz	Attenuation characteristics of MX41/AR cushions (dB) Harvard report, 1946.	Maximum allowable SPLs for on masking above the Zero of the audiometer (dB) Air conduction ASA 1960	ISO values	Bone Conuetion	SPLs in the audiometric room used (dB)
75-150	—	40	41	—	18.5
150-300	3	40	25	22	16.5
300-600	9	40	26	17	13.5
600-1200	15	40	30	15	10.0
1200-2400	24	47	38	14	14.0
2400-4800	37	57	51	14	11.0
4800-9600	—	62	51	—	10.0

Note: Column 4 is derived by subtracting the difference between the ASA 1951 and ISO 1964, reference threshold values (Appendix II, Table C), from the values specified in the ASA S3 1-1960 report (Column 3). Column 5 is derived by subtracting the values of Column 2 from Column 4 (Martin, 1975).

Procedure

The bone-conduction system of the first Madsen TBN60 audiometer was calibrated using the procedure advocated by Carhart (1950) and Roach and Carhart (1956). This method has decided advantages over the procedure utilizing the responses of normal hearing subjects, though the latter has been widely used. Firstly, a moderate hearing loss offers protection against the masking effect of mild ambient noise. Secondly, in testing normal hearing subjects, the thresholds of some subjects might fall below the audiometric limits. Lastly, in testing the normal hearing subjects, participation of the non-test ear has to be ruled out by masking. This entails all the difficulties encountered in trying to effectively mask the non-test ear. Also, there is the need to account for central masking. In testing bilateral sensorineural loss subjects, only responses of the better ear are taken into consideration. Consequently, there is no need for masking the non-test ear ; and hence, the above difficulties do not arise. With these points in view, it seemed advisable to use the responses of sensori-neural loss subjects.

While testing air-conduction thresholds, only one of the earphones was used and its calibration was checked periodically. Corrections to the exact sound pressure level (for TDH39 earphones in MX41/AR cushions) according to the 1964 ISO standard were made. Calibration was done using a 500gm load on the artificial ear and, as recommended in the manual, with the grid on the condenser microphone.

Each subject was tested for air and bone-conduction thresholds (no masking was used). The ascending method (Carhart and Jerger, 1959) was used for obtaining the thresholds. Only data of each subject's better ear was used. To obtain bone measurements, the vibrator was first positioned at the point on the mastoid yielding maximum sensitivity, with 1000Hz as the stimulus. Thresholds for all frequencies were then determined without shifting the vibrator. The clinical headband provided with the audiometer was used to fix the vibrator against the mastoid. No attempt was made to control the force of application of the vibrator. Air and bone-conduction thresholds were obtained from sixteen subjects at 250HZ, twenty-three at 500 Hz, twenty-three at 1000 Hz, nineteen at 2000 Hz, and seventeen at 4000 Hz. The difference between the mean air and bone thresholds for each frequency was then found.

The output of the bone vibrator was measured on the Bruel and Kjaer 4930 artificial mastoid connected to a B & K frequency analyzer, Type 2107. Measurements were made every week over a period of four months during which the study was conducted. The frequency analyzer was calibrated using internal reference voltage, as indicated in the Instruction Manual.

The Input Switch	Was set to	"Direct"
Function Selector		"Selective Section off"
Weighting Network		"Linear 20-40000"
Meter Switch		"RMS Fast"
Meter Range		"Ref"
Range Multiplier		"OdB (xl)"

After allowing the instrument to warm up, the meter deflection was adjusted to the red mark on the meter scale When thus calibrated, the analyzer read 94dB for an input of 50mv. Thus for any reading on the decibel scale, the reference voltage was 1μv The analyzer's indication was given by the meter indication (dB) + meter range setting (dB) + range multiplier setting (dB), in dB re : 1μv.

The output of the vibrator was then measured for each frequency. Measurements were made at a dial setting of 40dB on the audiometer, since at the zero setting, the circuit noise of the analyzer might have interfered with the readings. Since the attenuation system of the audiometer was found to be linear, readings for zero setting of the audiometer could be conveniently calculated by subtracting 40dB from the measured output.

The mean output of the vibrator for each frequency was found. The difference between the mean air and bone-conduction thresholds was then applied as correction to the measured output at each frequency. Thus the corrections obtained from biological calibration were applied to the vibrator output to establish the norms. For example, at 1000Hz, the mean bone-vibrator output at 40dB dial setting, was 71.07dB re : 1μ v. The mean air-bone difference at this frequency was 8.33 dB. Hence the corrected output was (71.07-8.33) = 62.74dB re : 1μ v.

Harmonic distortion of the vibrator was measured on the Bruel and Kjaer 4930 artificial mastoid connected to a B & K sound level meter, Type 2203, and a B & K octave filter set. Type 1613. The sound level meter was calibrated using internal reference voltage. Out puts for the fundamental and second and third harmonics were measured at 40 dB dial setting of the audiometer.

The norms obtained in the above manner were used to calibrate the bone vibrators of three other audiometers: (1) a second Madsen TBN60 audiometer (A-39, Denmark vibrator); (2) a Madsen B70 audiometre (M66 vibrator); and (3) a Beltone 12D audiometer (Radioear B-70-A vibrator). The norms obtained were applied to correct the outputs of these vibrators as measured on the B & K 4930 artificial mastoid. For example, at 1000Hz. at 40dB dial setting BC out put was 54 dB re : 1μ v. The output according to the norms obtained was 62.7dB. Hence, a correction of-10dB was applied to the bone-conduction thresholds obtained at 1000Hz on the Beltone 12D audiometer. Harmonic distortion of the three vibrators was also measured.

Four subjects, who were tested in the earlier part of the study, were then retested for bone-conduction responses, in the same manner as described earlier, on the above three calibrated audiometers. The bone-conduction thresholds of these subjects revealed an estimate of the applicability of the obtained norms to other bone vibrators.

RESULTS AND DISCUSSION

The data obtained in the present study were analyzed and bone-conduction standard values for the Bruel and Kjaer 4930 artificial mastoid were established, using the vibrator of the Madsen TBN60 audiometer (X-120, Denmark). The applicability of these norms to other vibrators was also studied.

The air-conduction thresholds of thirty-one ears with sensori-neural loss are shown in Table 2. These values were obtained after applying the exact corrections to the measured thresholds on the audiometer (Madsen TBN60); the corrections (re : ISO, 1964) on a Bruel and Kjaer 4132 artificial ear, containing a 6cc coupler, and connected to a B & K 2203 sound level meter and B &K 1613 octave filter set. The corresponding bone-conduction thresholds of the thirty-one ears with sensori-neural loss, obtained on the same audiometer, are shown in Table 3 .

Table 4 gives the mean air and bone thresholds of the thirty-one ears with sensori-neural loss, for each frequency. The differences between the mean air and bone thresholds are shown in the last column of the table 4.

TABLE 2

Air-Conduction thresholds of Thirty-one Ears with Sensori Neural Loss (in dB re : ISO 1964).

Frequency in Hz

250	500	1000	2000	4000
39.5	33.0	33.0	32.0	47.5
29.5	43.0	43.0	47.0	42.5
34.5	48.0	48.0	42.0	52.5
39.5	53.0	58.0	32.0	42.5
29.5	28.0	63.0	32.0	42.5
54.5	58.0	48.0	32.0	52.5
44.5	38.0	43.0	47.0	52.5
49.5	48.0	53.0	47.0	32.5
39.5	48.0	48.0	37.0	57.5
44.5	68.0	48.0	37.0	32.5
34.5	48.0	63.0	47.0	57.5
34.5	53.0	48.0	62.0	57.5
54.5	43.0	63.0	52.0	37.5
52.0	43.0	48.0	57.0	51.0
42.0	33.0	53.0	37.0	31.0
47.0	53.0	48.0	67.0	26.0
	38.0	28.0	60.5	56.0
	53.0	53.0	35.5	
	33.0	48.0	50.5	
	48.0	53.0		
	61.0	60.5		
	51.0	55.5		
	41.0	40.5		

TABLE 3

Bone-Conduction Thresholds of Thirty-one Ears with Sensorineural Loss (in dB re : zero of the audiometer)

Frequency in Hz

250	500	1000	2000	4000
25	40	15	30	30
30	55	35	40	25
35	35	35	45	50
40	50	40	20	25
15	45	60	25	30
40	45	35	40	40
40	55	40	50	25
35	40	45	45	45
35	35	55	40	35
30	60	45	30	25
40	45	55	45	50
20	55	30	50	30

35	60	60	50	25
40	60	40	45	45
20	60	45	25	50
30	35	40	55	35
	50	25	60	50
	60	35	25	
	30	40	45	
	55	50		
	55	50		
	40	55		
	35	25		
N 16	23	23	19	17

TABLE 4

Mean Air-and Bone-Conduction Thresholds of Thirty-one Ears with Sensori-Neural Loss (dB re : zero of audiometer)

Frequency in Hz.	Air (corrected to ISO 1964)	Bone	Difference Air-Bone.
250	41.84	31.88	9.96
500	46.22	48.70	-2.48
1000	49.85	41.52	8.33
2000	44.92	40.26	4.66
4000	45.38	36.18	9.20

These represent the correction to be applied to the bone vibrator (Madsen Z-120, Denmark). The assumption is that in sensori-neural loss, the air and bone thresholds do not differ. Since the air-conduction system was in calibration, the air-bone differences obtained can be wholly attributed to the bone vibrator.

Table 5 shows the calibration readings for the output of the bone vibrator (Madsen X-120, Denmark), as measured on the Bruel and Kjaer 4930 artificial mastoid connected to a B & K 2107 frequency analyser. These were measured at 40 dB dial setting and expressed in dB re : 1 μ v. The measurements were made over a period of four months during which the study was conducted. In table 6 the means of these outputs for each frequency are given. The outputs were corrected by applying the corrections obtained from the biological calibration, i.e., the air-bone differences shown in Table 4.

TABLE 5

Output of the Madsen X-120, Denmark, Vibrator, at 40 dB Dial Setting over Four Months (in dB re : 1 μ v.)

Sl. No.	Frequency in Hz 250	500	1000	2000	4000
1.	79.0	65.0	72.0	59.5	53.5
2.	78.0	65.5	72.0	61.0	52.0
3.	77.0	65.5	71.0	62.0	52.5
4.	76.0	67.0	71.5	62.5	53.0
5.	78.0	66 5	71.0	61.0	53 5
6.	72 5	64.0	71.0	61.0	51.0
7.	69.0	61.5	69.0	60.5	53.0
8.	68 5	63 5	70.0	61.0	53.0
9.	76.0	64.5	71.0	62.0	52.0
10.	76.0	66.5	72.0	63.0	51.5
11.	78.5	66.5	72.0	61.0	50.0
12.	79.0	68.0	72.5	62.5	52.5
13.	78.5	67.5	71.5	62.0	52.0
14.	77.5	66.5	71.5	61.0	50.0
15.	78.0	65.5	71.0	60.0	50.0
16.	77.5	66.5	71.0	60.5	49.5
17.	78.0	67.0	71.0	61.0	50.5
18.	78.0	66.0	71.0	59.0	49.0
19.	78.0	66.5	70.5	59,0	48.5
20.	78.0	67.0	71.0	60.5	50.5
21.	78 5	64.5	70 0	58.5	49.0
22.	79.0	66.0	71.0	59.5	52.0
23.	80.0	65.0	70.0	57.0	50.0

TABLE 6

Mean output of the Madsen X-120, Denmark, Vibrator, at 40 dB Dial Setting (in dB re 1 μ v)

Frequency in Hz	Measured output	Air - Bone difference	Corrected output
250	76.90	9.96	66.94
500	65.74	-2.48	68 22
1000	71.07	8.33	62.74
2000	60.65	4.66	55.99
4000	51.20	9.20	42.00

Note : Column 4 is derived by subtracting the values of Column 3 from column 2

SUMMARY AND CONCLUSIONS

There are at present no adequate standards for bone-vibrator calibration, especially for the Bruel and Kjaer 4930 artificial mastoid. Further, most of the studies, use the bone-conduction responses of normal hearing subjects, and this method has some limitations. Hence, in the present study, responses of thirty-one bilateral sensori-neural loss subjects were used to calibrate a bone vibrator (X - 120, Denmark) provided with the Madsen TBN60 audiometer, in the manner suggested by Carhart (1950). The corrections obtained in this manner were applied to the vibrator output, which was measured periodically on the B & K 4930 artificial mastoid connected to a B & K frequency analyzer (2107). The corrected output values at 0dB dial setting were : -93.1, -91.8, -97.3, 104K-0, and -118.0 dB at 250, 500, 1000, 2000, and 4000Hz respectively (dB re : 1 μ v)

At 40 dB Hl, the corrected output values were (re : 1 μ v) : 66.94, 68.22, 62.74, 55.99, and 42.00 dB, at 250, 500, 1000, 2000, and 4000 Hz respectively.

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वाक्यदोषो नाम यथा स्वल्पस्मिन्नर्थे न्यूनं, अधिकं,
अनर्थकं, अपार्थकं, विरुद्धं चेति ।।

Speech is said to be defective where there is insufficiency redundancy or want of meaning a misjoinder in sayings.

(Charaka Samhita 3-8.55)