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ORIGINAL COMMUNICATIONS.

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FURTHER STUDIES IN THE FUNCTIONAL EXAMINATION OF THE ACUITY OF HEARING AND ITS RELATION TO THE PERCEPTION OF SOUNDS OF DIFFERENT PITCHES PRODUCED BY THE NEW ELECTRIC ACUMETER.*

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In the functional examination of our sense organs we are striving to ascertain principally two facts: (1) The amount of the specific function of the sense organ; in hearing, the amount of hearing power which the patient has at his disposal, and (2) in an affection of this sense organ, we endeavor by the functional examination to ascertain the seat of the affection, and as far as possible its treatment.

In most cases of diminished hearing, the patient is concerned primarily with his hearing power for the spoken word. But inasmuch as the measurement of the acuity of hearing for conversational speech is encountered with great difficulties, we have to resort to different substitutional methods, as whisper, watch, tuning fork, Galton whistle, monochord, etc. Before a gathering of this kind it is unnecessary for me to point out in detail all the inaccuracies and shortcomings of each and every one of the above-mentioned methods. Neither the initial intensity of the sound, nor its graduation is employed with any degree of constancy and exactness. None

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of these methods alone indicates a dependable relation to the hearing power for speech. In order to arrive at a positive judgment of the hearing power for speech, we have to take into consideration the results of the combined employment of all these methods.

I therefore fully endorse the statement made by Dr. Hays in an article which appeared in the *Annals of Otology, Rhinology and Laryngology* in December, 1921, in which he says: "Tests of hearing acuity by means of tuning fork as well as by the watch, whisper and spoken voice are a part of our usual procedure. But the more I have recourse to such examination the less value I place upon it."

It is true that a normal ear possesses a superabundance of hearing power for ordinary social intercourse. A person with about one-half of normal hearing power is seldom considered hard of hearing or deaf for speech by his acquaintances, yet for diagnostic or scientific purposes it is very desirable that even small deficiencies be measured by the most exact and refined methods of examination possible. Only when our methods of examination will register even minute changes, can we hope that our diagnostic ability as well as our therapeutic measures will show some degree of advancement.

In a previous paper which I read last year before this section, I described an Electric Acumeter, by the use of which I could obtain more exact results than by the employment of present-day methods. The principal advantages claimed for the Electric Acumeter are: (1) that we can produce sounds of various pitches from about 50 to about 20,000 d.v. per second; (2) that we can very finely and minutely graduate the intensity of each pitch; (3) that we can reproduce with great exactness any pitch as well as intensity within the range of the instrument. None of the methods now commonly used, singly or in combination, can claim these advantages.

In addition to the above, the use of my instrument has the following further advantages:

(a) We can place the patient in a silent booth, thereby eliminating interfering outside noises, and thus render the examination more exact. This cannot easily be done in the commonly used methods, because there the graduation of the intensity of sound is effected by the variation of the distance of the source of sound from the ear, while in the acumeter the graduation of the intensity is accomplished by increasing or decreasing the amount of energy created by the electric current. The distance of the source of sound from the ear is very short and remains stationary.

The source of the sound being near to the ear and stationary, unilateral examination of the hearing power can be more easily ac-

complished than formerly, where in order to exclude the good ear from hearing, a Barany noise apparatus had to be inserted. A Barany noise apparatus, however, eliminates not only the perception of sound of the good ear, but interferes and to a great extent diminishes also the hearing power of the ear which is to be examined, thus causing inexactness of the examination.

(b) A switch which may cut out the electric current and thereby the sound, serves as a check upon the statements of the patient.

(c) With the use of a second telephone receiver the examiner may at all times listen in to the sound heard by the patient without interfering with the examination.

(d) The results obtained by the instrument can be graphically plotted on a chart, the abscissa designating the frequency of double vibration of sound per second, and the ordinate the intensity of same.

Where on account of a great diminution of hearing power the ordinary intensity of sound is not sufficient I produce a sound of greater intensity which is about four times greater than the normal, by eliminating some resistance in the apparatus.

As will be seen from the charts, a sound of the frequency of about 1000 d.v. per second is heard by the normal ear with the least degree of intensity, which must be increased as we proceed towards both ends of the tone scale.

The second great object of the functional examination as stated above, is the determination of the seat of lesion and its treatment. According to our present knowledge the disease can be located either peripherally in the sound conducting apparatus, or centrally in the sound perceiving apparatus, viz., in the labyrinth, cochlear nerve or brain centres. To come to a precise diagnosis, we again have to employ numerous methods of examination, because no single method will positively and without including several exceptions, point to a definite diagnosis.

The rule which is most constant and shows the least number of exceptions is, that we consider the cause for diminished hearing to be located peripherally in the sound conducting apparatus, when bone conduction is increased and the perception of low pitched sounds is diminished, whereas the diagnosis of a central affection is made, when bone conduction as well as the perception of high pitched notes is diminished.

The latter rule harbors numerous difficulties because diminished bone conduction compared to air conduction is encountered in a normal ear as well, particularly in older people, and the unilateral examination for diminished perception of high pitched sounds as

stated above, is almost impossible because the perception of sound of the second ear cannot be excluded satisfactorily.

The main reliance therefore for the diagnosis of the seat of the affection must be laid upon the precise measurement of the perception of the low as well as of the high sounds, which in the writer's opinion can best be accomplished by the electric acumeter.

In peripheral affections the demonstration of increased bone conduction will only corroborate the findings of the acumeter.

My limited experience proved to me that affection of the sound conducting apparatus will show not only a very decided diminution of hearing power for the low, but also for the high pitched sounds. Far advanced affections of the sound perceiving apparatus show a diminished perception of the high as well as of the low pitched notes. In the beginning of a central affection, however, the perception of the high pitched sounds will be more markedly affected, for nerves are more vulnerable and more easily injured.

To a similar conclusion came also Dr. Dean, who states, cochlear involvement is indicated when there is a diminution of the hearing power for the high notes, more marked for the low.

As will be seen from the charts, there exists a fairly constant relation between the results obtained by the old method of examination and the results obtained by the electric acumeter. Diminished perception for the loud and whispered voice will usually correspond to a diminished perception of a sound with the frequency of about 1000 d.v. per second. Noises in the ear and diminished perception for the watch will usually coincide with diminished hearing for high notes. Rinne negative will coincide with diminished perception of low notes, provided that the factor of old age does not interfere.

I did not consider Schwabach's test, because I believe it is less reliable than Rinne's. In Rinne's test the comparison is made between the air and bone conduction of the same individual, while in Schwabach's test the bone conduction of the patient is compared with the bone conduction of a second individual, whose age, mental or physical condition may be responsible for the differences.

To summarize my experience as visualized by the charts, the following conclusions can be drawn:

- (1) Diminution of hearing power for the spoken word will correspond to a lowering of the curve representing the whole field of audition, especially the sound with the frequency of about 1000 d.v. per second.

- (2) Affections of the sound conducting apparatus will show a diminished perception mainly of the low pitched sounds, but the

high pitched sounds will also be frequently affected, though to a less degree.

(3) Affections of the sound perceiving apparatus will show a diminished perception of high pitched sounds, and in advanced cases of the whole field of audition.

(4) There exists a correlation of the hearing power of the two ears. It is well known that, as Politzer says, "the perception of the cochlear nerve for weak intensities is very changeable." Repeated examinations therefore may not always give uniform results, still the relation of the hearing power of the two ears remains remarkably constant, possibly because the underlying cause for the change is identical.

(5) Permanent perforations of the drum membrane, as well as retracted drum membranes caused by organized exudates with connective tissue formations in the tympanic cavity as seen in progressive o.m.c.c., produce very great diminutions of hearing power.

(6) In a case of sequellae of o.m.p.c. with a dry tympanic cavity, the hearing will be more diminished than in a case of o.m.p.c. where the purulent process is still active with succulent granulations.

(7) Calcareous deposits on the drum membrane do not always materially diminish the hearing power.

(8) Nerve deafness is sometimes combined with catarrhal deafness when Rinne will be found to be negative.

(9) Otosclerosis sometimes shows a very great diminution not only of the low but of the high notes also.

It is admitted that repeated examinations may give varying results owing to physical or mental changes on the part of the patient. It is believed, however, that the above mentioned method of examination gives promise of yielding more exact information than we have been able to obtain hitherto, and with more study and experience not only our diagnostic but also our therapeutic ability will be amplified in this special branch of otology.

Conventional signs used in plates: V, conversational voice; v, whispered voice; h, watch; W, Weber; R, Rinne; mt, membrana tympani; Au, both ears; AD, right ear; AS, left ear; Ac, ad concham; 10' X - more than 10 feet; M, male; F, female. Fraction following V and v designates feet. Fraction following h designates centimetres. The numerator of the fraction indicates the right ear. The denominator of the fraction indicates the left ear.

In the curve the solid line represents the hearing power of the right ear, the dashed line the hearing power of the left ear, and the dotted line the normal hearing power.

EXPLANATION OF PLATES.

PLATE I.

Represents the normal curve obtained by averaging the results of examination of a number of persons with normal hearing.

The abscissa represents the number of double vibrations per second and the ordinate the acuity of hearing, which is in inverse ratio to the intensity. The minimum of hearing power is at 0. The peak of the curve is at about 1000 d.v. per second, showing that this pitch can be heard by the normal ear with the least amount of intensity.

PLATE II.

Diminished perception of pitch 1000 confirmed by:

3
v—
3

Diminished perception of high notes confirmed by:

ae
h—
ac

Normal perception of low notes confirmed by:

+
R—
+

PLATE III.

Diminished field of audition confirmed by:

1
v—
1

Diminished perception of high notes confirmed by:

o
h—
o

Perception of low notes not much diminished confirmed by:

+
R—
+

PLATE IV.

Curve of right ear below that of left ear as well as the reduction of the whole field of audition is confirmed by:

$\frac{1}{2}$ o
V— and v—
3 $\frac{1}{2}$

The lack of perception of upper notes above pitch 2000 confirmed by:

o
h—
o

Diminished perception of low notes confirmed by:

—
R—

PLATE V.

Diminution of whole field of audition, especially the diminished perception of high notes, does not coincide fully with the examination by the ordinary methods.

Diminution of low notes not sufficient to overcome factor of old age, therefore

+
R—
+

PLATE VI.

Slight bilateral diminution of upper notes may be pathognomonic for syphilis.

PLATE VII AND PLATE VIII.

Both plates show almost identical curves, due probably to the similarity of the ages of the patients.

The inferior position of the curve of right ear below that of the left ear in Plate VIII is confirmed by:

$$\begin{array}{ccc} 8 & 1 & ac \\ V- & v- & \text{and } h- \\ 10 & 2 & 1 \end{array}$$

Diminished perception of low notes cannot overcome factor of their ages, therefore

$$\begin{array}{c} + \\ R- \\ + \end{array}$$

PLATE IX.

Right curve below that of left curve confirmed by:

$$\begin{array}{ccc} 5 & 10 \\ V- & \text{and } h- \\ 10 & 30 \end{array}$$

Diminished perception of high notes and tinitus confirmed by:

$$\begin{array}{c} 10 \\ h- \\ 30 \end{array}$$

Diminished perception of low notes confirmed by:

$$\begin{array}{c} - \\ R- \\ - \end{array}$$

PLATE X.

Diminished field of audition, especially of right ear, confirmed by:

$$\begin{array}{c} \frac{1}{2} \\ V- \end{array}$$

Diminished perception of high notes on right ear confirmed by:

$$\begin{array}{c} 10 \\ h- \end{array}$$

Diminished perception of low notes on right ear confirmed by:

$$\begin{array}{c} - \\ R- \end{array}$$

Calcareous deposit on the left drum membrane did not affect very materially the hearing power of that ear.

PLATE XI.

AD: slightly diminished field of audition, probably caused by acute rhinopharyngitis.

AS: Diminished perception of high notes confirmed by:

$$\begin{array}{c} h- \\ 3 \end{array}$$

Diminished perception of low notes confirmed by:

$$\begin{array}{c} R- \\ - \end{array}$$

PLATE XII.

Represents the condition of the same ears as in Plate XI one week later and after having established a better drainage by trephining the left drum membrane. The perception of low as well as of high notes improved.

PLATE XIII.

AD: Hardly any perception of sound present as V^2 — probably heard by left ear.

AS: Diminished field of audition confirmed by:

$$\begin{array}{c} v- \\ 2 \end{array}$$

Diminished perception of upper notes confirmed by:

h—
ac

Diminished perception of low notes not sufficient to overcome factor of age, therefore

R—
+

PLATE XIV.

AD: Practically no hearing in this ear.

Lack of perception of low notes confirmed by:

R—
—

AS: Diminished perception of low notes not sufficient to overcome factor of age, therefore

R—
+

PLATE XV.

AD: Diminished field of audition and diminished perception of high notes confirmed by:

2 2 ac
V— v— and h—

Great diminution of low notes cannot be overcome by age, therefore

R—
—

AS: Hardly any perception of sound present.

PLATE XVI.

AD: Diminished field of audition confirmed by:

8 O
V— v—

Diminished perception of high notes confirmed by:

ac
h—

Diminished perception of low notes confirmed by:

R—
—

AS: Very little perception of sound present.

PLATE XVII.

AD: Diminished field of audition confirmed by:

$\frac{1}{2}$ O
V— and v—

Diminished perception of high notes confirmed by:

ac
h—

Diminished perception of low notes confirmed by:

R—
—

AS: Very little perception of sound present.

PLATE XVIII.

AD: Practically totally deaf.

AS: Shows a tone gap between tone pitch 2000-4000. The slight perception of the sound above 4000 is confirmed by:

h—
 $\frac{1}{2}$

Diminished perception of low notes confirmed by:

R—
—