Value of the tuning-fork in the diagnosis of disease of the auditory nerve / by Thomas Barr.

Reprinted from "The Glasgow Medical Journal," October, 1

VALUE OF THE TUNING-FORK IN THE
OF DISEASE OF THE AUDITORY N

By THOMAS BARR, M.D.,
Aural Surgeon to the Glasgow Western Infirm

I PROPOSE, to-day, to discuss the value of the
a test of the perceptive capacity of the audit
to consider whether we are able, by its use, to
in abnormal conditions of the organ of hearing,
conducting apparatus from diseases of the senti
organ. This is an enquiry of great interest and
the surgeon, as well as of weighty significance
to the disturbed function of the organ due to a hi
transmission of sound from the exterior to the
structures, or is it due to pathological changes in th
either at its origin in the brain, in its stem, or in
and terminations in the labyrinth? These are qu
must seriously engage our attention when called
an opinion as to the prospects of a case of diseas
tory apparatus, and, even in general medical d
consideration is often demanded when disturbance
tion of hearing is one of the symptoms present.

The impression of sound reaches our conscio
specific excitation of the terminations of the ner
The simplest idea of this is got from the arrangem
the lower fishes, in which there is no conducting
sound, as in the case of the mammalia. The org
consists, in these creatures, of a simple membranou
with fluid. The inner surface of this bag is lin
having small hair-like appendages projecting in
These cells receive the terminal fibres of the au
and when the waves of sound which fall upon t

* Lecture delivered at the Aural Clinique, Glasgow Weste

Reprinted from "The Glasgow Medical Journal," October, 1879.]

VALUE OF THE TUNING-FORK IN THE DIAGNOSIS OF DISEASE OF THE AUDITORY NERVE.*

By THOMAS BARR, M.D.,
Aural Surgeon to the Glasgow Western Infirmary.

I PROPOSE, to-day, to discuss the value of the tuning-fork as a test of the perceptive capacity of the auditory nerve, and to consider whether we are able, by its use, to discriminate, in abnormal conditions of the organ of hearing, diseases of the conducting apparatus from diseases of the sentient part of the organ. This is an enquiry of great interest and importance to the surgeon, as well as of weighty significance to the patient. Is the disturbed function of the organ due to a hindrance to the transmission of sound from the exterior to the terminal nerve structures, or is it due to pathological changes in the nerve itself, either at its origin in the brain, in its stem, or in its expansions and terminations in the labyrinth? These are questions which must seriously engage our attention when called upon to give an opinion as to the prospects of a case of disease of the auditory apparatus, and, even in general medical diagnosis, their consideration is often demanded when disturbance of the function of hearing is one of the symptoms present.

The impression of sound reaches our consciousness by a specific excitation of the terminations of the nerve of hearing. The simplest idea of this is got from the arrangement found in the lower fishes, in which there is no conducting apparatus for the sound, as in the case of the mammalia. The organ of hearing consists, in these creatures, of a simple membranous bag, filled with fluid. The inner surface of this bag is lined with cells having small hair-like appendages projecting into the fluid. These cells receive the terminal fibres of the auditory nerve, and when the waves of sound which fall upon the firm parts

* Lecture delivered at the Aural Clinique, Glasgow Western Infirmary.

of the head are propagated to the fluid in the bag, sympathetic vibrations are set up in the minute hair-like processes, and, the terminations of the nerve being thus stimulated, the sensation of sound is experienced. The simple membranous bag found in these primitive forms of life becomes evolved, in the higher animals, into the complicated arrangements of the membranous labyrinth in the vestibule, semicircular canals, and cochlea. This membranous structure is bathed in fluid, and supports the ramifications of the nerves which are also supposed to terminate in cells with hair-like appendages found at certain parts of the membrane.

Sonorous vibrations may reach the terminal nerve-structures in the following different ways:—1st. By the special sound-conducting apparatus provided in man, and in all air breathing animals. This is sometimes called "air conduction of sound," because the waves of sound, originating in the vibrating body, are transmitted through the medium of the air to the tympanic membrane, the vibrations of which are conducted to the fluid in the labyrinth through the malleus, incus, stapes, and membrane of the fenestra ovalis. 2nd. Sonorous vibrations may reach the nerve by the bones of the head, either from direct contact of the vibrating body—direct osseous conduction, or by the waves of sound reaching the surface of the head through the air—indirect osseous conduction. In either case the vibrations are propagated to the osseous walls of the labyrinth, tympanum, and external auditory canal. The vibrations which reach the osseous walls of the labyrinth are transmitted in part to the perilymph of the vestibule, and thence to the terminations of the nerve, but many also reach the nerve directly through the osseous lamina of the cochlea; while those from the walls of the external auditory canal and tympanum pass to the tympanic membrane, to the ossicles, and to the air contained in the external auditory canal and tympanum, and by these media reach the fluid of the labyrinth through the foramen ovale.

The first, the air conduction of sound, is the ordinary mode of hearing in man, and produces a more powerful impression on the nerve than osseous conduction. This may be easily tested if we place a vibrating tuning-fork on the vertex, and, the moment the vibrations cease to be audible, transfer the fork to a point an inch or two from the ear, when the sound will be heard for some time longer. Vibrations received from the air by the bones of the head have the least effect upon the nerve. This is to be expected if we consider with what difficulty sonorous vibrations are transmitted from air to solids,

where they are not only diminished in intensity, but many of them are also reflected from the surface of the solid. Politzer has found that though both ear passages are filled with glycerine and plugged firmly with caoutchouc, while the mouth and nose are securely closed, a loud spoken voice may be heard two feet from the person, though with dulled sound. It is also well known that in those who have congenital absence of the external auditory canals, a certain amount of hearing still exists. I had lately the opportunity, through the kindness of Dr. H. C. Cameron, of making an examination of a child in whom there is total absence of the auricles, and of the external passages of the ear, and I was convinced, both from my own observations and the statements of the mother, that an appreciable amount of hearing is possessed by the child. Professor Allen Thomson, in two able papers, in which this subject is fully discussed, in the *Edinburgh Medical Journal* for 1847, relates the cases of several persons with congenital closure of the external auditory canals, who were capable of hearing speech in a moderately loud voice.

In the investigation, however, of the state of the auditory nerve, conduction by the bones of the skull, when the sound-producing body is placed in contact with some part of the head, most requires our attention. The savage takes advantage of this direct conduction of sound by the bones of the head, when he prostrates himself on the ground and applies the side of his head to the earth in order to hear the tread of the distant enemy. If a vibrating tuning-fork be held close to the ear, but not touching it, the sound will be perceived in its fullest intensity; the vibrations, being conducted by the air to the tympanic membrane, produce the maximum amount of impression on the nerve; if the sounding fork be now placed on the top of the head, it will be heard clearly and distinctly in both ears, although not quite so loud nor so prolonged as by the first experiment. If we now close both meatuses with the fingers, and hold the vibrating fork opposite the ear, only a very faint sound will be appreciated; but if we transfer it to the vertex, the tuning-fork will be heard sounding nearly twice as intensely as with the ears open. Again, allow one ear only to be closed, and place the sounding fork in contact with the cranial bones and the effect will be very striking—the sound heard in the closed ear will be very much louder than in the open one—indeed, it will be so intensified on the closed side as to give the impression that no sound is perceived in the open ear at all. Even though the fork, still in contact with the head, be moved close to the unoccluded ear the sound

will still be heard almost exclusively on the closed side. Similar exaggeration of the impression of sound may be noted in our own persons when, in the act of speaking, we close our auditory meatuses—the vibrations of our vocal apparatus, transmitted by the cranial bones, will then affect our auditory nerves much more strongly. Lastly, by placing a watch in the mouth, between the teeth of the upper and lower jaws, the sound of the ticking will be heard with much greater intensity when we close the ears with the fingers. It is noteworthy that, in stopping the ears, if the finger be pressed into the canal of the ear *very firmly*, the increase of sound is less marked than when there is closure with only slight pressure, or the sound, instead of being increased, may be actually diminished. The interesting fact, to which Weber was the first to direct attention, that when a vibrating tuning-fork is placed on the vertex, and the external auditory canal of one side is closed with the finger, the sound on that side is much intensified, affords a basis for the application of the tuning fork for the purpose of differential diagnosis. A great amount of labour, by way of experiment and otherwise, has been expended to explain this phenomenon. Politzer, in his recently published volume, gives the following explanation of the increased loudness of the sound on the occluded side:—1st, The increased resonance of the external auditory canal, and the reflection upon the tympanic membrane and ossicles of the vibrations transmitted by the bones of the head to the air in the external passage. 2nd, The hindrance to the passing away from the ear of the waves of sound conducted by the bones of the head to the labyrinth and tympanum. 3rd, The altered tension of the membrane and ossicular chain. This subject is fully treated of, along with that of the effect of very firm pressure in the meatus on osseous conduction, by Politzer, in the *Archiv für Ohrenheilkunde* of 1864.

The tuning-fork most useful for our purpose should be large sized, and of the pitch C, with 512 vibrations in the second, fitted to produce a sound sufficiently long continued to ensure that the patient has time to recognise on which side he hears the sound best. It yields two simultaneous tones—the fundamental or deep tone, and the overtone or high tone. The overtone is usually appreciated more distinctly when the fork is held some distance from the ear; the fundamental tone predominates when it is held nearer. The clear overtone is a source of fallacy with some patients suffering from one-sided deafness, as, when the sounding fork is placed on the head, the overtone, from its great clearness, seems to be heard very distinctly on

the deaf side, and the patient has the impression that he hears the tuning-fork better on that side. This difficulty has been removed by the observation, first made by Politzer, that the overtone is in great measure destroyed when the limbs of the tuning-fork are grasped by two brass clamps. When these are attached, only one tone is appreciated, and that one, on account of the number of vibrations per second being diminished, is much lower in the scale. By shifting the clamps towards the handle we render the pitch higher, until, when we reach the lower end of the limbs of the fork, it is raised a complete octave. In this way one tuning-fork, with the addition of these clamps, can produce a variety of notes by simply altering the position of the clamps.

In applying the tuning-fork, when we wish to compare the relative susceptibility of the two nerves, we may select any point in the middle line of the head, such as the vertex, forehead, bridge of the nose, upper lip, or directly the central incisors of the upper or lower jaw. The position in which the vibrations are heard loudest is over the upper central incisors when the jaws are apart, but as at this place the sensation of the vibrations is very unpleasant to the patient, the forehead or bridge of the nose is usually selected. The temple or the mastoid region is chosen when our object is to determine the actual perceptive capacity of the nerve, and not to make a comparison of one side with the other. We may form a very fair estimate of this by comparing the patient's appreciation of the tuning-fork applied to the head with that of our own, provided that our nerves of hearing are normal. It may be assumed that the perceptive power of the patient is fairly good if, the moment he has ceased to hear the sounding fork applied to his mastoid process, we quickly transfer it to our own and also fail to perceive it or hear it only slightly. If, on the other hand, we can distinguish it clearly and for some time after the patient no longer hears it, we may conclude that his auditory nerves have lost their normal susceptibility to sound.

I would here point out an important disadvantage under which we labour in testing the nerve of hearing, namely, our dependence in great measure upon subjective symptoms. The ophthalmologist, in his examination of the optic nerve, bases his diagnosis mainly upon actual inspection, and not on the statements of patients, which we know often afford very insufficient data on which to form an opinion. In trusting mainly to objective phenomena, he enjoys important advantages, and consequently, the knowledge of the varied pathological changes

in the optic nerve has attained an exactness which we can never hope to reach in the case of the auditory nerve. We cannot see the ramifications of the auditory nerve, and can never attain the precision which attends purely objective examination. In the meantime we are very much dependent on the intelligence and correctness of our patients for material to form a just conception of the case. It is true that by the auscultation tube (a three limbed tube of india-rubber connecting our ear with the ears of the patient) we may often objectively ascertain on which side the sound is heard most distinctly. Politzer recommends that the ends of an india-rubber tube four feet in length be inserted into the two meatuses of the patient, while the one end of another shorter tube is attached to the middle of the former, the other end being inserted into the ear of the observer. While the vibrating fork is placed on the vertex, the sound passing out of the external auditory canals of the patient is communicated to the arms of the tube and conveyed to the ear of the examiner. By alternately pressing upon the two limbs attached to the patient's ears, and thus shutting off the vibrations, we can determine the strength of tone in each side of the patient. This method must be employed with a care which renders it unsuitable for ordinary use, and is found practically to be, in most cases, less valuable than the usual mode of trusting to the patient's sensations.

I would mention a source of error against which we must be on our guard. The patient being preoccupied by the thought that he *should* hear the tuning-fork better on the good side, and worse on the deaf one, will probably, if not cautioned before, at first say that he hears it better on the healthy side. In most cases, however, with moderately intelligent patients, we will, by a little exercise of patience, succeed in getting an accurate description.

The same effect which is brought about by the physiological experiment of stopping the ear with the finger, is produced by many of the diseases of the sound-conducting apparatus. The obstructions, due to pathological changes in the external auditory canal and tympanum, which prevent the entrance of the waves of sound to the fluid of the labyrinth, also intercept, in their passage outwards, those vibrations which have been conducted to the labyrinth by the bones of the head, and these vibrations being reflected back on the nerve, intensify the sound of the tuning-fork. Hence, the vibrating fork may be only faintly heard, when held opposite the dull ear, but, when transferred to the bones of the head, it will sound much more strongly, or even exclusively, on that side; but if the healthy

ear be now closed with the finger we shall often find that the sound of the fork stops in the defective side, and is now only heard in the healthy though closed ear—when the finger is removed the perception of the sound again springs to the deaf side. This osseous conduction of sound, when the conducting part of the organ of hearing is diseased, may be turned to profitable account by patients, and so we find that some persons with chronic tympanic disease can understand the spoken voice only when their hand is touching the shoulder of the speaker. In like manner, the tones of a musical instrument, such as the piano, may sometimes be appreciated by a very deaf person, if a rod of wood, in contact at one end with some part of the instrument, be held at the other end between the teeth of the patient—in this way a melody, which would be a confused mass of sound under ordinary circumstances, may be heard clearly.

The obstructions in the auditory passages to the entrance or exit of waves of sound may consist simply of the presence of foreign substances, such as impacted cerumen or catarrhal exudations into the tympanic cavity. The same effect is produced, however, by any cause which interferes with the vibrating or oscillating power of the membrana tympani and ossicular chain, such as the increased tension of these parts caused by the stronger effects of the atmospheric pressure on the outer surface of the membrane in obstruction of the Eustachian tube, or in ankylosis of the ossicles to one another, or of the plate of the stapes to the edge of the foramen ovale. In these cases the waves of sound passing out from the labyrinth are impeded by the unyielding base of the stapes pressing on the fenestra ovalis. The conditions in the ear which are likely to be attended by increased perception of the tuning-fork, when applied to the cranial bones are, first, all obstructions in the external auditory canal, as impacted cerumen, accumulation of epidermis, foreign bodies, furuncular swellings, polypoid formations, exostoses, cicatricial narrowing and diffuse inflammatory thickening; secondly, most affections of the middle ear, as chronic thickness of the tympanic membrane, myringitis or inflammation of the tympanic membrane, exudations in the cavity of the tympanum, with or without perforation of the membrane, granulations or polypi in the tympanum, increased tension of the tympanic structures through obstruction of the Eustachian tube, adhesions between the ossicles and the walls of the tympanum, ankylosis of the ossicles, thickening of the mucous lining of the tympanum and of the fenestral membranes. In the case of perforation of the membrane, the

increased perception of sound, conducted by the bones, often observed, is due to other changes in the tympanum, such as thickening of the mucous membrane, rigidity of the ossicles, or presence of purulent secretion. *There are few exceptions to the rule that, if the vibrating tuning-fork, when applied to any point in the median line of the skull, is heard more strongly on the affected or deafer side, the nerve on that side is fairly healthy, and the patient is probably suffering from some one of the conditions just mentioned.*

But secondary disease may exist in the nerve, and although there is a decided affection of the conducting apparatus, there may be *diminished* perception by osseous conduction. It is well known that after disease has continued for some time in the tympanum, whether it be of a plastic or suppurative character, atrophic changes, and fatty or colloid degeneration often take place in the auditory nerve. Also, when a high degree of imperfect hearing has existed for a great length of time, the terminal apparatus of the nerve is apt to become atrophied from the absence of the special excitation. Even in the course of an acute disease of the middle ear, simultaneous exudation of serum or extravasation of blood may take place in the labyrinth. In these secondary affections of the sentient apparatus, the diminished sensibility of the nerve counteracts the effects which we generally find associated with an impediment to the passing out of the waves of sound, so that while examination shows, without doubt, that there are pathological changes in the tympanic structures, the osseous conduction of sound is more feeble on the deaf side than on the sound one, in consequence of the associated disease in the labyrinth. In these cases, besides the use of the tuning-fork, we must give careful consideration to the history and course of the disease, while such points as the age of the patient, the presence of subjective sounds in the ear, the influence of mental emotion on the deafness, the presence or absence of the syphilitic cachexia, and in females, the effect of the menstrual period, the state of pregnancy, or lactation, must be noted in order to help us in arriving at a correct diagnosis.

Again, in tympanic disease, *diminished* perception of the sound of the tuning-fork, when applied to the cranial bones, may be due to excessive pressure on the foramen rotundum or foramen ovale from the tympanic side, producing such an amount of tension of the labyrinthine fluid that the receptive power of the nerve, for the time being is much diminished. Such pressure may be caused by catarrhal or inflammatory products in contact with the inner wall of the tympanum, or

by extreme retraction of the membrane, or any other cause which may lead to pressure on the foramen ovale. This probably explains the occasionally intermittent character of the perception of osseous vibrations—at one time much diminished, and then, after a few days, again increased—varying from time to time in the course of the treatment with the improvement or aggravation in the tympanic disease. The subject of intermittent osseous conduction is treated of very fully by Dr. U. Bürkner, in the *Archiv für Ohrenheilkunde*, of Dec. 1878. Von Tröltsch has directed attention to the fact that in persons over 50 years of age, diminished perception of vibrations conveyed along the bones has not the same serious meaning as in younger people, as after that period of life it is often due to some change in the osseous tissue of the cranial bones which impairs their conducting power. On the other hand, senile degeneration of the auditory nerve in advanced age is common, and, of course, interferes with the receptive power of the nerve.

In order to exemplify the clinical value of the tuning-fork, we must distinguish two groups of cases. 1st, Those in which examination of the tympanic membrane shows no departure from health, where we might suspect a primary disease of the labyrinth or rigidity, or ankylosis of the ossicles. 2nd, Those in which examination of the tympanic membrane gives distinct evidence of tympanic disease—here we wish to know (*a*) if it is confined to the conducting apparatus, (*b*) if there is a secondary nerve affection, or (*c*) if there is caries of the osseous labyrinth.

1st, Cases in which careful examination of the external and middle ear yields negative results. Primary disease of the labyrinth is probable if the vibrating tuning-fork, when applied to the vertex, is heard weakly or not at all; this probability is increased if, when the patient stops both ears with the fingers, the sound of the tuning-fork is heard more strongly than before. This latter is really a method of magnifying the sound; the waves of sound are stopped as they try to pass out of the ear and, reverberating from the sides of the external auditory canal, are reflected back with increased intensity upon the partially insensitive terminations of the nerve. On the other hand if, after a long period of gradually increasing deafness, examination of the tympanic membrane gives little information, and if the tuning fork is distinctly heard, or, the affection being confined to one side, is heard better on the affected side, the probability is great that the disease is in the conducting part of the ear, and that it is a case of ankylosis of the ossicles. It may be

mentioned here that primary disease of the labyrinth generally involves both ears. Constitutional syphilis is by far the most common cause, but an attack of apoplexy, a blow on the head, the sudden and loud report of a gun in the vicinity of the ear, are also not infrequent causes. The most common lesions which are found are extravasation of blood or serous exudation, into the labyrinth or into some part of the auditory nerve outside of the labyrinth. The deafness is almost always sudden and complete; the patient is frequently unable to hear a loud voice close to the ear, while subjective noises in the ears of a more or less distressing character, resembling the ringing of bells, the noise of steam blowing off, &c., are almost always present.

2nd. Those cases in which examination of the tympanic membrane gives distinct evidence of tympanic disease. The affection is in the great majority of cases confined to the conducting apparatus, if the osseous vibrations be heard distinctly louder on the affected or worse side, or, both sides being equally affected, if the tuning-fork be heard as long as on our own persons,—our own auditory nerves being healthy. Secondary disease of the nerve is highly probable if we have an affection of the middle ear which has existed during a very long period, perhaps from childhood, and if the osseous vibrations are heard better on the healthy side; especially if we have the opportunity of tracing the course of the disease, and have noticed gradually increasing difficulty of hearing with gradually diminishing perception of the tuning-fork on the head. In short, the failure to hear the vibrations of the tuning-fork by osseous conduction, in chronic affections of the tympanum, especially if advancing and already with great deafness, is presumptive of the existence of secondary disease of the nerve. Practically, we may infer that if the perception by osseous conduction is good in long continued tympanic affections, the hearing capacity will not get worse rapidly; while, on the other hand, if after only short duration of disease in the tympanum, the perception by the bones markedly diminishes or disappears, there is a probability of quick increase of the deafness. In caries of parts of the temporal bone, we may assume that the bones of the labyrinth are not involved in the carious process, if the tuning-fork be heard better on the affected side. Lucœ of Berlin asserts that by this means we may determine, in acute or chronic suppuration of the middle ear, whether the brain is involved or not—that so long as the tuning-fork is heard more strongly on the affected side, the brain is not yet invaded by the disease in the ear. This is not, however, borne

out by the experience of others who have often observed that caries may lead to a partial destruction of the roof of the tympanum, and the consequent lighting up of a fatal meningitis, or the formation of a cerebral abscess, and yet the labyrinth be unaffected.

In concluding, I think it may be said, that tests applied to determine the acuteness of the perception of sound conducted by the bones of the head, are of the very greatest importance, both in diagnosis and prognosis, and that, in a very large proportion of cases, we are able to tell whether the seat of the disturbed function is in the labyrinth or in the tympanum, when the examination of the external auditory canal and the tympanic membrane, as well as the Eustachian tube, yields negative results; and, when disease of the middle ear likewise exists we can frequently tell whether the nerve is intact or involved in secondary disease.

GLASGOW: PRINTED BY ALEX. MACDOUGALL.