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THE ISTHMUS OF THE EUSTACHIAN TUBE. A CONTRI- BUTION TO THE PATHOLOGY AND TREATMENT OF MIDDLE-EAR DISEASES.

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The Eustachian Tube has hitherto been described as consisting of two portions, the cartilaginous or pharyngeal portion, and the bony or tympanic portion. The narrowest part of the tube lies at the junction of these two portions, and is called the isthmus. Although these two portions have been considered as parts of the same anatomical structure, they have very few, if any, characteristics in common. On the other hand, the differences between them, from either an anatomical, histological or pathological standpoint, are very many, and by beginning the description of the two portions at their meeting point, the isthmus, these differences may be more clearly emphasized.

The Cartilaginous Portion, which is directed downwards, inwards and forwards from the isthmus, is situated entirely outside the bony skull; in fact, it lies entirely within the cavity of the nasopharynx. It does not come into relation with any part of the auditory apparatus at any point except at the isthmus. The walls of this portion consist of elastic cartilage, which is present over only a part of its circumference, the remainder consisting of fibrous tissue; the lumen is therefore not constant, but varies with the contraction of the muscles, which are inserted into it. Under normal conditions the lumen is closed; it increases in size from the isthmus

to the naso-pharynx in a trumpet-shaped manner, so that the line of transition between the interior of the tube and the naso-pharynx is not distinctly marked.

The mucous membrane is thick and thrown into folds, especially near the pharyngeal orifice; it is a separate structure from the perichondrium of the surrounding cartilage, and is freely movable upon it; it contains numerous mucous glands and some lymphoid follicles, which increase in number toward the pharyngeal orifice, where the lymph follicles may be heaped up into more or less distinct adenoid masses. From the isthmus to the pharyngeal orifice, therefore, the characteristics of the tubal mucous membrane become more and more similar to the characteristics of the naso-pharyngeal mucous membrane, with which it is continuous.

It is a well recognized fact that practically all acute as well as chronic inflammatory conditions of the tubal mucous membrane are due to extension from the naso-pharyngeal mucous membrane, and convalescence cannot be established in the tube until the mucous membrane of the naso-pharynx has been restored to a condition approaching the normal.

From every point of view, therefore, the pharyngeal portion of the tube is homologous with the naso-pharynx, of which it must be considered a part.

The Tympanic Portion of the tube is directed backwards, upwards and outwards from the isthmus, and lies wholly within the bony structure of the skull. Its lumen is therefore constant and is normally open. It increases in size from the isthmus toward the tympanic cavity, into which it merges in an imperceptible manner, so that there is no distinct line at which the tube ends and the tympanic cavity begins. It lies in immediate relation with the most important part of the auditory apparatus, the cochlea, whose bony capsule forms its posterior wall. Its superior wall is formed by the bony canal for the Tensor Tympani muscle, another important auditory structure. Its floor, which is at the same time the roof of the carotid canal, is frequently irregular, and contains depressions or small pockets. In temporal bones having a markedly pneumatic structure, it is frequently found that the mastoid cells extend along the floor of the tympanic cavity; such cells may extend so far forward that they underlie the floor of the tympanic portion, and are known as tubal cells.

The mucous membrane is thin and smooth; contains few mucous glands and no adenoid tissue; its deeper layer constitutes the

periosteum of the surrounding bony walls; in all these respects it is similar to the mucous membrane of the tympanic cavity.

In all acute and chronic inflammatory conditions of the tympanic cavity the bony portion of the tube is also involved, and measures directed to the cure of middle-ear diseases have often been without avail because the tympanic portion of the tube has not received appropriate treatment.

From every point of view, therefore, the tympanic portion of the tube is homologous with the tympanic cavity, and it should be regarded as a part of the same.

The views here enumerated entail some slight changes in the usual conception of the anatomy of the middle-ear. Instead of regarding the middle-ear as a sort of drum-shaped box, having a superior, inferior, external, internal, anterior and posterior wall, it should be regarded as an almond-shaped cavity, extending from the aditus ad antrum above, behind, and externally, in a downward, forward and inward direction, as far as the isthmus. In other words, at the isthmus the middle-ear ends and the naso-pharynx begins. Everything internal to the isthmus is naso-pharynx, everything external to it, middle-ear. The isthmus is the natural orifice of the middle-ear, and is analogous to the natural orifices of the accessory cavities of the nose.

While nomenclature is perhaps a matter of secondary importance, it would add to the clearness with which this conception is understood, if the names were made to express the true relations of the parts. The term "tympanic orifice" or the tube, which is only an arbitrary location, should be abandoned altogether; and just as the upper portion of the tympanic cavity is known as the epitympanum, and the lower part as the hypotympanum, so the part hitherto known as the bony portion of the tube could appropriately be called the *pretympanum*.

Starting with this hypothesis, this conception gives to the isthmus the point at which the middle-ear empties into the naso-pharynx, a degree of interest and importance which it has not hitherto possessed. In the following pages, therefore, the writer will discuss the influence of this region in certain important diseases of the ear; the instruments which he has devised for the purpose of approaching it for diagnosis as well as for the treatment of these diseases; the technic of operative procedures upon the isthmus; and the results of clinical experience, which, though limited in amount, are so striking in character, that there is every reason to

believe that they will be confirmed by the larger experience of the profession.

The isthmus of the tube may be reached for diagnostic or operative purposes by two different routes:

First, from the pharyngeal side through the Eustachian catheter, and,

Second, through the external auditory canal, through an incision made for this purpose in the anterior part of the drum membrane, or through a perforation previously existing as the result of disease.

PART I.—THE ROUTE THROUGH THE EUSTACHIAN CATHETER.—THE INSTRUMENTS.

The Catheter. (Figure 1). As the mouth of the Eustachian tube is a conical opening, a slender catheter will go further into the tube than a thicker one; hence the distance from the end of the catheter to the isthmus will vary with the thickness of the catheter, so that it is necessary to adopt a catheter of standard thickness. Its lumen

Figure 1.

must be large enough to accommodate the largest instrument which may be passed through it. Its end must be well rounded, to avoid injury to the tube. The distance to which any instrument is advanced beyond the end of the catheter must always be measured; this is accomplished by means of a scale which is read at the proximal end of the catheter; hence the catheter must be of standard length. The one which I use has an internal diameter of 2 mm.; the external diameter at the bulbous end, 3.5 mm.; the length, 14 cm. The proximal end has a conical expansion to fit various connections. It is made of virgin silver.

Figure 2.

The Eustachian Applicator. (Figure 2). This instrument consists of a metal tube about 1.5 mm. in thickness and 10 cm. long, provided with a set-screw at one end. It is marked with the scale above referred to. Through this tube a wire is passed and secured by means of the set-screw in such a position, that when passed through the catheter up to the beginning of the scale, the end of

the wire corresponds to the end of the catheter. The wire is made of a double strand of very thin steel wire twisted together. At the distal end, the two strands form a tiny loop, so that the end is smooth and rounded. This construction was devised, first, because it gives us a perfectly straight wire, which is much more flexible than a single wire of the same thickness, and second, because the loop at the end (Figure 3) is of slightly larger diameter than the body of the wire, and this, together with the screw-like form, enables us to load the end with a tuft of cotton in a firm and safe manner. The cotton is first wound around the end of the wire in a manner similar to a nasal applicator. The end is not left soft and fluffy,

Figure 3.

Figure 4.

Figure 5.

Figure 6.

Figure 7.

Figures 3, 4, 5, 6 and 7 are magnified about two diameters.

however, but is twisted firmly beyond the end of the wire (Figure 4). The projecting part is then bent at right angles (Figure 5), cut off with scissors close to the wire (Figure 6) and then smoothly rounded off between the fingers (Figure 7). It is saturated with the desired solution and then passed the required distance into the tube. There is no danger of losing the cotton. In fact, it cannot be removed from the wire unless it is scraped off with a knife. During the last two years I have made nearly one thousand applications with this applicator, up to and beyond the isthmus, without once losing the cotton, or even having it become loose on the wire.

The Eustachian Bougie. (Figure 8). Bougies are made of celluloid whalebone or gum-elastic material. The larger sizes of celluloid and whalebone bougies are too rigid, and the smaller sizes do not accomplish the desired purpose. Gum-elastic bougies are

more satisfactory in this respect. All bougies are olive-pointed, a fact of which advantage is taken for diagnostic purposes. They should be provided with a scale like the applicators.

Eustachian Sounds. (Figure 9). These instruments bear the same relation to the bougies that urethral sounds bear to the Bougie à Boule. They are of uniform diameter throughout, but are slightly conical and rounded at the point. They are made of a woven tube, covered with an elastic material, and then coated with a soft smooth varnish, which permits their being boiled. They are very soft and silky to the touch, but may be made more rigid by filling their lumen with silkworm-gut. Their texture enables them to be passed without pain, and almost without sensation, on the part of the patient. Owing to their flexibility, it is impossible to exert enough force in introducing them to injure the lining of the tube.

Figure 8.

Figure 9.

Figure 10.

Their color is a bright brick-red, which is a decided advantage, as it makes them easily visible through the drum-membrane. They are provided with a scale like the other instruments.

The Scale. (Figure 10). Whatever instrument is passed through the Eustachian tube, it is a matter of the first importance to know beyond any doubt that the instrument lies within the lumen of the tube, and that it has not made a false passage or been bent back upon itself at the isthmus. The sense of touch is not a positive guide even in experienced hands, and the so-called "tympanic expression" is not elicited when the tube has been cocaineized. The only positive way to ascertain that the instrument has been properly passed, is to advance it so far that its end becomes visible behind the anterior margin of the drum-membrane. As the distance between the anterior margin of the drum and the handle of the malleus is about 4 mm., the instrument must be advanced beyond the isthmus with great caution, 1 or 2 mm. at a time, the drum being inspected after each advance. Moreover, while the distance from the end of the

catheter to the isthmus is about 25 mm., and does not vary much in adults, the distance to which an instrument may project from the catheter until its end becomes visible behind the anterior margin of the drum, varies from 27 to 37 mm. It is therefore necessary to provide all such instruments with a scale which shall indicate single millimeters, at least for all distances beyond the isthmus point. As these instruments are too small to permit of printing a numerical scale upon them, the following device has been adopted with entire satisfaction. Bands, of a color contrasting with the color of the instrument, are painted around its shank. When the instrument is passed into the catheter up to the beginning of the first band, the end of the instrument is flush with the end of the catheter. This first band is 10 mm. long. It is followed by a space of 10 mm., beyond which a second band, 5 mm. long, is situated. The end of this band marks 25 mm., the usual situation of the isthmus. Beyond the isthmus point there are three narrow bands, 2 mm. wide, separated by spaces of 2 mm. The junction of bands and spaces therefore marks the odd millimeters, up to 37 mm., the center of a space or band, the even millimeters. The use of such a scale enables us to pass the bougie or sound into the middle-ear with perfect safety, as the exact distance to which it has been introduced is always known and can be easily controlled. When once the measurement for a given patient is known, the instrument can be reintroduced, to the previously ascertained point, with perfect assurance that it will lie in exactly the same position. When applications are to be made to the isthmus or to the region just beyond the isthmus, the position of the applicator can be known exactly by this means, and only by this means. Experience has convinced me that the passage of any instrument into the tube without a carefully-graduated scale to indicate its position, is not only crude guess-work, but is actually dangerous to the drum-membrane and to the chain of ossicles, and should never be attempted by the careful surgeon.

THE USE OF THESE INSTRUMENTS FOR DIAGNOSTIC PURPOSES.

The Eustachian Applicator: In chronic catarrhal conditions of the middle-ear, the mucous membrane of the middle-ear and tube is swollen and thickened. A slight amount of thickening in the cartilaginous portion of the tube will not interfere seriously with the ventilation of the middle-ear, as the cartilage is yielding and the tube is actively opened by muscular contraction; but in the narrow part of the unyielding bony canal, just to the outer side of the

isthmus, the slightest amount of swelling will cause obstruction. The only method which has been known up to the present time, of applying cocaine or adrenalin or both, to the tubal mucous membrane, consists of injecting the solution into the catheter and blowing it into the tube. Even when the tube is patent, it is difficult to inject such solutions beyond the isthmus unless undue force is employed. When there is obstruction in the tube, it is almost impossible to accomplish this result at all; at any rate it is quite impossible to know definitely that the solutions have reached the desired point, the region just beyond the isthmus. With the use of the Eustachian applicator, however, this procedure becomes at once simple, easy and certain.

The applicator, having been charged with a solution containing 5 per cent cocaine and 1 to 2,000 adrenalin, is passed into the tube for a distance not exceeding 25 mm., and allowed to rest there for a moment until the solution has had time to take effect. The applicator is then advanced one or two millimeters into the obstruction and again allowed to rest. Advancing slowly in this manner, the obstruction will be found to yield gradually before the applicator, and the tube becomes patent. If the ear has been inflated before the application, and the inflation is repeated afterward with the same air-pressure, a considerable difference in the sound heard in the auscultation tube will be perceived.

This procedure not only informs us that the mucous membrane of the pretympaum is swollen, but it enables us to determine the nature of the swelling. If the swelling is due to congestion, dilatation of the blood-vessels, or edema, it will disappear after cocaine-ization; but if the swelling be due to an exudation of leucocytes, fibrous tissue or cicatricial contraction, no reduction of the swelling takes place. In other words, the application of cocaine to the bony portion of the tube beyond the isthmus is necessary in order to distinguish between simple swelling and organic stricture.

The fact that cocaine and adrenalin, applied by means of the applicator to the region beyond the isthmus renders inflation more effective, is also of importance in prognosis. If inflation is attempted when the tube is swollen, the air will either not enter the middle-ear at all, or will enter it in insufficient amount, and no improvement in hearing follows. If great force is used, the air will enter the ear, but in such excessive amount that it will be under positive pressure and the drum will bulge outwards; for the obstructed tube will prevent the excess of air from escaping as

well as it will prevent the air from entering. In this case also no improvement in hearing follows. In such cases it is customary to decide that treatment will be unavailing. The true effectiveness of inflation cannot be determined unless the tube is known to be patent at the time, so that after inflation a true balance of air-pressure on both sides of the drum-membrane is assured. One of the most valuable uses of the Eustachian applicator in my hands has been to enable me to avoid this very common error.

The applicator serves a useful purpose in determining the shape of the isthmus. If an applicator which has been allowed to lie in the isthmus for a few minutes be examined, it will be found that the cotton tuft has assumed the shape of the passage. Generally the cross-section of the isthmus is round or irregularly triangular; occasionally, however, the cotton tuft will be found to be flat or crescentic in shape, showing that the isthmus has a slit-like form. The recognition of an isthmus of such shape is very important, as a slit-like isthmus will not permit a large-sized bougie to pass, even after it has been thoroughly cocainized and adrenalized. Unless it is known that one is dealing with a slit-like isthmus, a mistaken diagnosis of stricture is unavoidable, and an erroneous prognosis and much useless treatment is the result. The possibility of the presence of a slit-like isthmus and its importance in the diagnosis of stricture, has not hitherto been published. A recognition of the shape of the isthmus is also of value in selecting the instruments necessary for operative procedures upon the isthmus, to be described later.

Bougies. The ordinary Eustachian bougie, which is provided with a scale, may be used to determine the location of the isthmus, which can always be recognized by the increased resistance at this point, even when the tube has been cocainized. The increased resistance caused by the normal isthmus begins rather suddenly at a distance from the end of the catheter of from 20 to 25 mm., and ends when the bulb of the bougie has passed this point. When the bulb of the bougie is short, this resistance will end more abruptly.

When the increased resistance extends over a greater length than can be accounted for by the length of the bulb, the presence of swelling of the mucous membrane of the tube beyond the isthmus may be assumed. This diagnosis must be verified, however, by the disappearance of the increased length of the resisting area after this part of the tube has been cocainized. Thus, if a given bougie,

which has been found to pass a normal isthmus with an increased resistance for 3 mm. of its course, is passed into a diseased isthmus, and is found to meet with increased resistance at 23 mm., and to leave the area of increased resistance at 29 mm.; but after cocaineization enters at 23 mm. and leaves at 26 mm., it may be considered as proven that the tube is swollen for a distance of 3 mm. beyond the isthmus. When such a measurement has been determined, it is used as a guide for the introduction of remedial agents by means of the applicator.

When the tube has been cocaineized and adrenalized, and, by observation of the applicator, the presence of a slit-like isthmus has been excluded, the diagnosis of stricture is made when a bougie of normal size, 1.5 mm., fails to pass. Rigid bougies, such as those made of celluloid or whalebone, especially the larger sizes, are apt to lead to error. For, when a bougie passes through the tube, it must assume the curvature of the tube; this curvature has the shape of the letter S; hence the bougie must be bent twice in its passage. Now, having assumed a given curvature, even a rigid bougie may be advanced a limited distance without change of curvature; when advanced further, however, it must change its form; this means increased force, which is interpreted as increased resistance, and so an erroneous diagnosis of multiple stricture, a most rare condition, might be possible. The more flexible bougies will accommodate themselves to the curvature of the tube without evident change of resistance, and by using such bougies this error may be avoided.

THE USE OF THESE INSTRUMENTS FOR THERAPEUTIC PURPOSES.

The Eustachian Applicator is employed for the purpose of applying medicinal agents to the entire interior of the tube. Cocaine, when used to reduce swelling, need not be stronger than 5 per cent; stronger solutions are apt to produce a reaction after 6 to 8 hours, when the anesthetic effect has passed off. The same is true of adrenalin when used stronger than 1 to 2,000.

Various drugs have been tried for therapeutic purposes. Solutions of alum, aluminum acetate, tannic acid, iodine, and nitrate of silver, when applied to the tube, cause a characteristic pain, which usually lasts for about twelve hours. It is a continuous, dull, neuralgic ache, felt in the side of the neck along the anterior border of the sterno-mastoid muscle, from the ear to the larynx. When cocaine has been used previous to the application, the pain comes on about an hour after the treatment.

The writer has found argyrol to be a most valuable drug. Not only is its use entirely free from pain, in as high concentration as 50 per cent, even without the previous use of cocaine, but its antiseptic and astringent qualities are apparently as efficient in the Eustachian tube as they have been found to be in the eye.

Inflammation of the middle-ear has never followed as the result of the somewhat heroic treatment occasionally applied to the isthmus of the tube.

In acute inflammations of the middle-ear, which usually arise by extension from the naso-pharynx, the mucous membrane of the interior of the tube as well as that surrounding the pharyngeal orifice is swollen and edematous, and it is impossible to pass any instrument into the tube. If, however, the inferior meatus of the nose is thoroughly cocainized, and through this, cocaine and adrenalin are applied to the mouth of the tube with a nasal applicator, the catheter may be passed without pain. If an Eustachian applicator, charged with cocaine and adrenalin is now passed through the catheter, it will meet with resistance from the swollen mucous membrane of the interior of the tube; but if it be allowed to rest in this position, the swelling will recede and a slight advance can be made. If the advance be made slowly, giving the drugs time to act, the entire tube can be made patent without occasioning any pain to the patient. An application of 25 per cent argyrol solution may now be made with another applicator, as far as the isthmus.

Following this procedure, there is an immediate cessation of the throbbing earache and tinnitus, the predominant symptoms. If the inflammation be of a mild degree of virulence, or if the case be seen in its earliest stages, before redness and bulging of the drum-membrane are present, the relief obtained will be permanent and the disease will be brought to an immediate and abrupt termination, often by one single application. When, however, redness and bulging of the drum-membrane indicate the probable presence of pus in the middle-ear, the relief of the symptoms, though equally pronounced at the time, and though accompanied by a diminution in the degree of redness of the drum and a partial recession of the bulging, will not be permanent; in the few cases in which the writer has tried it, the symptoms returned after 6 to 8 hours, so that paracentesis had to be done on the following day.

The writer is of the opinion that it would be perfectly possible to abort an acute inflammation of the middle-ear in adults, even

after suppuration has become established, by repeating such applications at intervals of six hours; but this would require close observation and control of the patient in a hospital bed.

The writer has attempted to shorten the period of suppuration in acute otitis media by maintaining the patency of the tube, but has not succeeded in materially influencing the duration of the discharge in any of the cases.

On the other hand, in the terminal stages of the disease when the discharge has ceased and the perforation has closed, but when deafness, tinnitus, fullness in the ears, etc., persist, the use of intratubal applications of argyrol has yielded prompt and definite results. Cases which have done badly under the usual methods of treatment, have undergone immediate and rapid improvement as soon as the use of these applications was added to the treatment, while cases in which such applications have been begun as soon as perforation had closed, have been relieved of the terminal symptoms in a relatively short time.

In subacute inflammation of the middle-ear the application of argyrol solutions to the interior of the tube is employed from the beginning of the treatment. Such applications have been found to be especially efficacious in that form of subacute otitis characterized by the presence of serous or sero-mucous fluid in the tympanic cavity, cases which have hitherto been found to be particularly obstinate to the usual methods of treatment. By restoring the patency of the tube by means of intratubal applications of cocaine and adrenalin, and maintaining this patency by the use of 50 per cent solution of argyrol applied well beyond the isthmus, the fluid, and with it the subjective symptoms, have been found to disappear in as many days as it would otherwise have taken weeks.

In the treatment of that class of diseases known variously as chronic catarrhal otitis, chronic dry otitis, or adhesive middle-ear catarrh, the object has been, first, to reduce the swelling of the mucous membrane of the middle-ear directly by proper inflation; and, secondly, to restore the physiological ventilation of the middle-ear, i. e., the normal exchange of air between the ear and the naso-pharynx.

By proper inflation of the middle-ear, it is meant that the air is driven into the ear gradually, beginning at the lowest possible pressure, gradually increasing to the desired maximum pressure, and maintaining this maximum pressure for a definite time. This

procedure must be followed by complete *deflation* of the ear; that is to say, the pressure is gradually lowered as far as possible, and the excess of air still remaining in the ear is allowed to pass off through the tube. (This procedure requires the use of compressed air, a regulator and gauge, and a cut-off which permits of turning the air on gradually. The so-called instantaneous cut-off should never be used for inflation.)

In order to carry out inflation in this manner, it is absolutely necessary that the tube should be entirely patent at the time. In the cases under consideration, however, there is always some degree of tubal obstruction; for when the mucous membrane of the middle ear is swollen, that of the pretympanum (the tympanic portion of the tube) partakes of the swelling. In the narrow part of the passage, just beyond the isthmus, the slightest amount of swelling will cause obstruction and interfere with inflation. Hence it becomes necessary to precede the inflation by temporarily restoring the patency of the tube by the application of cocaine and adrenalin solution to the region just beyond the isthmus, by means of the Eustachian applicator.

If the diagnosis of organic swelling has been made, in which case the use of cocaine and adrenalin will not restore the patency of the tube, the application of these drugs is followed by the passage of the Eustachian sound. The use of the sound in preference to the bougie is to be emphasized. The purpose of the instrument is to cause dilatation. Now, the bougie has a bulbous end, and if the stricture will permit the head of the bougie to pass, the narrow neck behind it can cause no dilatation. On the other hand, sounds, such as described above, have a uniform diameter close to the tip, and when the largest possible size has been passed, and has been allowed to remain in the tube for 5 or 10 minutes, the necessary dilatation will be accomplished.

In order to restore the normal ventilation of the middle-ear, the patency of the tube must be made permanent. Such a result may at times be accomplished by the methods thus far described, if they are repeated at regular and sufficiently frequent intervals. Much more rapid and satisfactory results are obtained, however, if after each treatment as described, an application of 50 per cent solution of argyrol is made to the region beyond the isthmus, by means of the Eustachian applicator.

The writer has thus devised a routine plan of treating the isthmus of the tube, which may be summed up as follows: 1. The application of cocaine and adrenalin solution to the region just

beyond the isthmus. 2. The passage of the largest possible sound for 5 or 10 minutes. 3. The application of 50 per cent solution of argyrol to the region beyond the isthmus. 4. Inflation and deflation as above described, with or without the addition of medicated vapor to the air.

In the case of old and firm strictures, the use of sounds must be more frequent and prolonged. If the form of sound above described is used, it may be passed daily without causing any unpleasant reaction. The sound must be left in situ for at least 15 minutes. When this has been done a few times, it will be found that when it is removed a larger-sized instrument may be passed. Eventually, the larger size will pass without the previous use of the smaller, and in this way the size of the sound can be gradually increased. When the largest sound passes easily, the interval between the treatments is prolonged, but it will probably be necessary to pass the sound occasionally about once in two or three months, for the rest of the patient's life.

I have devised an instrument by means of which these strictures can be cut, which will be described in the second part of the paper.

I have refrained from reciting detailed case histories, first, in the interest of brevity, and secondly, because their value would be limited by the fact that applications to the tube have not been the only factor in the treatment of any of the cases. Most of this work was done in private practice, and in each case every known method of influencing the middle-ear condition was employed. The fact, however, that many of these cases have previously been in the hands of able otologists, who have not failed to employ every hitherto known method of treatment, both direct and indirect, but without result; that practically the only addition which I have made to the treatment has been in the use of the Eustachian applicator; and that such patients have enjoyed a prompt and decided improvement in their hearing power; these facts justify, to my mind, the conclusion that the Eustachian tube is much more tolerant to manipulation and local treatment than is generally supposed, and that the Eustachian applicator is an indispensable addition to the armamentarium of the otologist.

PART II.—THE ROUTE THROUGH THE EXTERNAL AUDITORY CANAL.— THE INSTRUMENTS.

In order to ascertain the possibility of instrumental treatment of the isthmus of the tube from the external auditory canal, either through an incision made for the purpose, or through a perforation

already existing as the result of disease, as well as to determine the character of such an instrument, it was first necessary to know the exact relation of the parts from this point of view. A section of a fresh anatomical specimen was therefore made by passing a vertical saw-cut through the center of the external auditory canal, the middle-ear, and the tube. Such a cut was found to be, not a flat surface, but a section of a cylinder, the concavity of which is directed outwards and forwards. (Figure 14.) This section, viewed from the front, showed that the external auditory canal, the middle-ear, and the tube, form a continuous curved line, the concavity of which is directed outwards and downwards, the mid-

Figure 14.

dle-ear occupying the highest point of the curve. (Figure 13). A simple instrument, such as a probe, bent to conform to the curve, can be easily passed into the tube of the cadaver as far as the isthmus; in the living subject it is impossible to pass such an instrument, because, in order to obtain a view of the middle-ear it is necessary to straighten out the canal by drawing the auricle upwards and backwards. By reversing the procedure, however, namely, by fixing the auricle in the cadaver in the position which it occupies during examination, shaping the probe to lie in the passage so fixed, and then studying the best way to withdraw it, an instrument was devised which could readily be passed as far as and through the isthmus in the living subject. Such an instrument consists of a shank about 7 cm. long, of which 2 cm. at the end are curved to a form which nearly corresponds to an arc of a circle 5 cm. in diameter; it is attached to a suitable handle. The

writer has placed in the hands of the instrument-maker a templet of this curve, so that its exact form can always be reproduced.

The technic of introducing the instrument is as follows: A short aural speculum is introduced into the external auditory meatus without making traction upon the auricle, and the instrument is introduced into the canal as far as the eye can see. Traction is now made upon the auricle in an upward and backward direction, the instrument being advanced at the same time under the guidance of the eye. When the tympanic cavity is reached, the instrument is

Figure 13.

A. Pharyngeal Orifice. B. Isthmus. C. Carotid Artery. D. Drum Membrana.
E. Styloid Process. F. External Auditory Canal.

rotated, so as to bring its end into the anterior part of the cavity, and as soon as the opening of the tube is brought into view the end of the instrument is introduced into it. Traction upon the auricle is continued, and the instrument finds its way into the tube without difficulty, until the entire curved portion of the instrument has passed out of view beyond the anterior margin of the drum-membrane. In this position the end of the instrument is a few millimeters beyond the isthmus. It is not fixed, but slight lateral and rotary movements may be carried out. All operative procedures must, of course, be guided by the sense of touch alone. The withdrawal of the instrument is accomplished by reversing the movement of introduction.

Applicators: Ordinary nasal applicators may be bent to conform to the required curve, and are used to make applications of cocaine, adrenalin, etc., to the isthmus.

The Salpingeal Probe. (Figure 11). This is an ordinary probe fixed in a handle, and bent to the required curve. It is used to determine the exact direction of the bony passage. The presence of a soft place, indicating the existence of a dehiscence of the bony wall of the tube, can be detected with the probe. It also indicates the presence of denuded or carious bone, which is occasionally found on the floor of the tube.

The Salpingotome. (Figure 12). This instrument consists of a shank about 1 mm. in diameter, and of the same length and curvature as the other salpingeal instruments. For a distance of about 5 mm. from the end, it is sharpened to a keen knife edge. The extreme end is blunt and probe pointed. The position of the

Figure 11.

Figure 12.

Figure 15.

knife edge is such that when introduced into the isthmus, the edge is directed upwards and forwards. The instrument is intended to cut obstinate strictures of the tube at the isthmus, and in this direction there would be least danger of injuring important structures.

The Salpingeal Curette. (Figure 15). This instrument consists of a shank which is curved like the other instruments, and surmounted by a hemispherical head, the flat side of the hemisphere being directed toward the handle. It will be described in detail below.

DISEASES WHICH MAY BE INFLUENCED BY TREATMENT OF THE ISTHMUS THROUGH THE EXTERNAL AUDITORY CANAL.

Strictures of the Eustachian tube at the isthmus. The operation of salpingotomy consists of cutting a stricture of the tube at the isthmus by means of the salpingotome. An incision about 3 mm.

long is made in the anterior part of the drum membrane about 1 mm. from its anterior border, its lower end being at the level of the umbo. Through this incision an application of cocaine and adrenalin is made with the applicator, the pharyngeal portion of the tube having been previously cocainized by means of the Eustachian applicator. The salpingotome is then introduced and advanced through the isthmus. By pressing the handle backward and downward, the knife-edge is forced into the mucous membrane. The instrument is now withdrawn, and in so doing the mucous membrane is incised down to the bone. After proving, upon the cadaver, that this operation was actually feasible, the writer performed it in one case, the history of which follows:

The patient, a woman 36 years old, who came under my care a number of years ago, stated that she had noticed a gradual loss of hearing for some years. Upon examination it was found that the hearing was diminished in both ears to a very marked degree, so that ordinary conversation could only be heard at a distance of about 4 inches. The hearing was diminished for all tuning-forks, more for air-conduction than for bone-conduction, as the low forks could be heard equally by bone and air. The loudness of the forks was not influenced by compressing the air in the external meatus.

The hearing was somewhat better on the left side than on the right, and examination of both tubes showed that on the right side there was a stricture of the tube at the isthmus, which was so extreme that only a very fine bougie could be passed even after the isthmus was cocainized. The left tube was patent. Under treatment it was possible to dilate the stricture so that a moderate-sized sound could be passed, but the dilatation could not be maintained for any length of time without passing the sound frequently. When the tube was dilated, speech could be heard at 24 inches.

About a year ago treatment was discontinued altogether, and when the patient returned in the early part of this year her hearing was again as bad as when I first saw her.

On February 14, 1910, it was possible to pass only a very small sound, and it was decided to cut the stricture. The isthmus was thoroughly cocainized with the Eustachian applicator. An incision 3 mm. long was then made near the anterior border of the drum-membrane at about the level of the end of the hammer-handle, and through this an application of cocaine and adrenalin was made to the tympanic side of the isthmus. The salpingotome was intro-

duced through this incision into the tube, and the stricture cut. Immediately afterwards it was possible to pass a sound 1.4 mm. in diameter, which was allowed to remain for 5 minutes. The external auditory canal was then filled with cotton. For 10 hours after the operation there was considerable pain along the side of the neck, referable to the tube.

On the following day there was no local reaction in the middle-ear, but the edges of the incision had not united. On the third day the incision was still open, its edges were dry, the drum-membrane in its immediate neighborhood was not reddened, but was clear and transparent. An attempt was made to pass the Eustachian applicator into the tube, but it was not possible to enter it more than 18 mm. An application of 50 per cent argyrol was made. On the seventh day the incision was still open and its edges clean, dry and transparent. An application of cocaine and adrenalin was now made to the isthmus; a sound 1 mm. in diameter passed, and an application of argyrol was made. The procedure was painless and no pain followed afterwards. On the tenth day the opening in the drum-membrane no longer had a linear form, but was small and round, its edges were moist and granulating, the surrounding drum-membrane was opaque and covered with mucus. A sound 1.4 mm. in diameter was passed and an application of argyrol made. On the fourteenth day the perforation was reduced to a pin-point opening, and the drum-membrane had a cloudy appearance. Sounds were passed and argyrol applied on the eighteenth day and on the twenty-second day. On the twenty-sixth day the perforation was permanently closed, and it was possible to introduce a sound 1.4 mm. in diameter. At the present writing it is six weeks since the operation. It is now possible to pass the sound after cocainization of the tube. The drum-membrane has lost some of its cloudy appearance, and is becoming clearer. The hearing for speech is 24 inches.

From this case we may conclude that the operation of cutting the stricture was followed by swelling of the tubal mucous membrane lasting about two weeks, sufficiently pronounced to cause complete obstruction. During this time there was not the slightest tendency to the formation of granulation tissue on the edges of the drum-membrane. As soon as the tube became patent, the perforation began to granulate, and finally closed after two weeks more. After six weeks all that remained was some cloudiness of the drum-membrane. In six weeks, therefore, the patency of the

tube was restored and the hearing was increased to as great a degree as could previously be accomplished only after many months of patient treatment.

Chronic suppurative otitis media presents such a variety of aspects that no single method of classifying the various cases has as yet received general acceptance. A classification based upon clinical experience may therefore be of practical value. From a clinical standpoint we can distinguish two different forms of the disease. In one class of cases the only symptom which is evident to the patient is the constant discharge from the ear. This discharge may vary in character and in quantity from time to time, but not infrequently the patient gives a history of many years' standing.

In contra-distinction to this class of purely chronic cases, other patients give histories of repeated attacks of acute inflammation in the middle-ear or mastoid cavity. Whether these acute exacerbations are mild or severe, the distinction between these cases and the purely chronic ones is important, because it is becoming more and more clearly recognized that the large majority of labyrinthine and intra-cranial complications of middle-ear disease occur as the result of acute exacerbations of chronic suppuration. Nor is the distinction between these two classes of cases merely a matter of empirical observation, but is in reality dependent upon the vital surgical principle of drainage. For it is in those cases in which drainage is obstructed that there is retention of pus under pressure, resulting in acute inflammatory symptoms and progressive extension of the suppurative cavity. These cases generally come under observation during an acute exacerbation, and should be regarded as cases of acute mastoiditis rather than as cases of chronic suppuration.

On the other hand, if in all cases in which there are no acute symptoms, the drainage is sufficiently good to prevent retention of pus, then we should expect these cases to get well if sufficient time be allowed and they be kept reasonably clean. For the pathology of the suppurative process is in no wise different from bone abscess elsewhere in the body; and a bone abscess in any other part of the body, as large as the mastoid cavity, which is draining well and which is kept clean, in a patient otherwise in good health, will invariably be cured *in time*. On the other hand, even though the sclerotic process in the mastoid bone and the lining of the bone cavity with granulations indicate an effort on the part of nature to heal the abscess cavity, nevertheless a suppurating ear, in spite of

the most painstaking local treatment, will not be cured and remain permanently well, but will frequently last during the whole of the patient's life. We must therefore seek another cause, in addition to the local suppurative process, to account for the *persistence* of aural suppuration.

Now, this additional cause is to be found in the constant re-infection of the middle-ear through the Eustachian tube, and in spite of the academic simplicity of this explanation it may be of interest to study the exact mechanism of this re-infection in detail.

Under normal conditions, when the drum-membrane is intact, it is a matter of some difficulty to blow foreign substances through the Eustachian tube into the middle-ear. It does not usually occur during the ordinary acts of swallowing, blowing the nose or sneezing. On the other hand, when the drum-membrane is perforated, it is very easy to propel particles of mucus, etc., through the tube. The difference may be well illustrated by the experiment of blowing smoke into a narrow-necked bottle. It will be found that it is almost impossible to fill the bottle with smoke; but if a hole is made in the opposite side of the bottle, it is very easy to fill it with smoke. In like manner, the intact drum-membrane prevents the passage of strong air currents through the tube, while the presence of a perforation permits and facilitates it. This protective action of the drum-membrane, although very evident, is not mentioned in literature among the functions of this organ. It is equally as important as the auditory function, if not more so; for the drum-membrane is not indispensable for the purpose of hearing, as it is quite possible to hear when the drum has been destroyed; but an intact drum is indispensable for the protection of the middle-ear, as it has hitherto been practically impossible to prevent suppuration of the middle-ear, when the continuity of the drum has been permanently destroyed. The mere presence of a perforation, therefore greatly facilitates the communication between the middle-ear and the naso-pharynx and all the changing bacterial flora of this infected region are constantly being added to the already existing sepsis in the drum cavity.

Not only are germs transmitted from the naso-pharynx to the ear, but particles of mucus are propelled bodily through the tube, and add their bulk to the secretion actually formed in the ear itself. The quantity of mucus which may thus be directly transmitted is unknown; but the quantity of the aural discharge varies

synchronously with the naso-pharyngeal secretion, and it can be seen with such regularity in the mouth of the tube and on the floor of the middle-ear, that it is probably much larger than is generally suspected. The fact, therefore, that the amount of the aural discharge is too great to have been formed in the middle-ear cannot be considered as indicating, as is generally supposed, that it must have come from diseased mastoid cells, as ulcerated bone secretes pus, whereas the aural secretion consists in large part of mucus, which could only be derived from the naso-pharynx.

The presence of naso-pharyngeal mucus in the middle-ear keeps it in a state of moisture, and in addition, with every act of swallowing, the warm moist air of the naso-pharynx sweeps through the middle-ear cavity and helps to maintain, in the diseased organ, all those conditions which are favorable to the development and propagation of the infectious agencies.

Now, if this hypothesis be correct, then it must follow as a necessary corollary, that if the communicating passage between the middle-ear and the naso-pharynx be obliterated by producing artificial atresia of the Eustachian tube, the suppurative process must become capable of early resolution, at least in a large percentage of the purely chronic cases.

During the last few years it has become clearly recognized by all otologists, that in order to ensure successful healing after the radical operation an attempt must be made before concluding the operation to effect the closure of the Eustachian tube by curetting its tympanic orifice. Before this fact was recognized, the majority of radical operations resulted in failure. Since the closure of the tube has become the regular practice, the majority of radical operations are successful. The difference between failure and success, therefore, consists in closing the tube. The only question is whether the cart has not been placed before the horse. The writer is of the opinion that if the Eustachian tube be closed in the proper manner, the rest of the radical operation will, at least in a majority of the purely chronic cases, be superfluous and unnecessary.

The method which has been employed for closing the tube at the end of the radical operation consists either of curetting the neighborhood of the so-called tympanic orifice, or of utilizing the remnants of the drum-membrane to cover the opening. In as much as the tympanic orifice of the tube is a purely arbitrary location, these methods are equivalent to an attempt to construct a diaphragm across the middle-ear cavity. This procedure is apt to fail

because of insufficient curettage of the small tubal cells of the floor of this region, through which communication may be re-established between the pretympa-num and the middle-ear, or because the diaphragm closes the passage above, but in the lower part becomes continuous with a cicatricial bridge, which forms between the lower margin of the drum-membrane and the promontory, leaving a fistulous tract along the floor of the middle-ear communicating with the Eustachian tube. Such a fistulous tract is occasionally present as the result of the disease itself, and may extend as far back as the aditus ad antrum, where it communicates by a small opening with the upper part of the tympanic cavity. For these reasons, the so-called tympanic orifice is an uncertain and unreliable location for producing atresia of the tube.

On the other hand there are many reasons why the isthmus of the tube is the most favorable location for this purpose. Not only is it the natural orifice of the middle-ear, and the termination of the middle-ear cavity, but it is the narrowest part of the entire passage. In addition, the isthmus is a situation at which cartilage is joined to bone, and like other such places, as the epiphyseal lines of growing bones, the chondro-costal articulations and the suture lines of the nasal septum, constitutes a *locus minoris resistentiae*, where irritation quickly results in stimulating granulation and the production of new bone. (It is for this reason that the isthmus is the most frequent site for the occurrence of strictures of the tube.)

The writer has already shown that it is not difficult to reach the isthmus with instruments passed through the external auditory canal, and it would have been a simple matter to construct various instruments for the purpose of producing atresia at this point. For instance, it would not be difficult to construct a caustic carrier, by means of which any kind of chemical caustic might be deposited at the isthmus. In like manner, a galvano-cautery point could be made to cauterize the isthmus by means of heat. The writer has refrained from even constructing such instruments, for the following reasons: All caustics, whether chemical or thermal, produce their effect by causing local gangrene of the tissues. The dead tissue becomes outlined by a line of demarcation and is then separated from the healthy tissue underneath by a process of sup-puration, even when the parts can be kept in an aseptic condition, which, of course, in the case under consideration could not be done. Now, the depth to which a given caustic will burn can not be controlled, as a caustic of a given strength will burn deeper in one

individual than in another. In the presence of dehiscences of the bony wall of the tube, when such vital structures as the carotid artery might lie directly under the mucous membrane, it would be extremely dangerous to induce a suppurative process of unknown and uncontrollable severity. On the other hand, the mechanical removal of the mucous membrane, carried out under surgically clean conditions and followed by healthy granulation and cicatrization, seemed to be the most scientific as well as the least dangerous method, especially as the instrument which the writer has constructed for this purpose has been carefully designed so as to avoid wounding any of the important structures in the neighborhood.

The instrument, which has been briefly described above as the salpingeal curette, consists of a shank having the same length and curvature as the other salpingeal instruments, attached to a suitable handle. Its end is surmounted by a hemispherical head with the flat side toward the shank. The circular cutting-edge is sharp, having a cutting-angle of about 60° , which is directed backwards, so that it cuts only in this direction. This fact, together with the rounded outline of the distal side of the head, prevents the instrument from wounding the parts during its introduction, so that it can neither make a false passage nor be plunged through a dehiscence in the bony wall and into the carotid artery. The proximal side of the head is flat and placed at right angles to the shaft. If this surface were made conical, i. e., projecting into the head, the edge would cut better; but such a cutting-edge would have what mechanics call a "positive rake," which would give it a tendency to penetrate into the tissues of its own accord. By making this surface flat, the edge has no "rake," and hence can not penetrate into the tissues unless it is forced into them. In other words, the depth of the cut is under the constant control of the operator. The projection of the cutting-edge from the shank has been adjusted to correspond to the thickness of the mucous membrane. In the smallest curette, this projection is one-quarter of a millimeter, to correspond to the thickness of the mucous membrane of a small isthmus and of the angles of a slit-like isthmus; in the largest size, one-half millimeter. As the instrument cuts towards the shank, the shank always rests upon uncut tissue; hence the edge can never lie deeper than the under surface of the mucous membrane. The cutting-angle of the edge, 60° , is sufficiently large to prevent it from penetrating the bone unless undue pressure is made. Constructed in this careful manner, the instrument has thus far proven itself to be, in the hands of the writer, perfectly safe and reliable.

The technic of the operation which the writer has performed for the purpose of producing atresia of the Eustachian tube at the isthmus is as follows: The external canal and middle-ear are first irrigated with a saturated solution of boric acid. The solution is contained in the author's wash-bottle, which is connected with the compressed air apparatus, so that the pressure of the stream can be regulated. At first the straight cannula is used, then the attic and hypotympanum are irrigated with appropriate cannulae. An application of a solution containing 10 per cent of cocaine and 1 to 2000 adrenalin is then made to the inner tympanic wall, and, by means of the salpingeal applicator, to the tympanic side of the isthmus. The Eustachian catheter is then introduced, and through this the pharyngeal side of the isthmus, and the isthmus itself, are cocainized with the same solution. The applicator is allowed to remain in the isthmus for about 3 minutes, and upon its withdrawal, the shape of the isthmus is noted. The irrigating bottle is then connected with the catheter, and under a pressure of about 10 pounds, the boric acid solution is driven through the tube. The greater part of the fluid returns through the nose and mouth, but the irrigation is continued until a sufficient quantity has passed out of the ear to thoroughly remove all mucus and secretion from the tube.

When the parts have thus been anesthetized, cleaned and dried, the largest curette which will pass the isthmus is inserted through the canal and into the tube according to the technic above described. By a circular motion, the cutting-edge is forced through the mucous membrane down to the bone on all sides of the isthmus, so as to sever it completely from the mucous membrane of the pharyngeal portion. By an inward and outward movement of the instrument, the mucous membrane is then separated from the bone all around the tube for a distance of about 3 mm.; the isthmus is then again encircled, so as to separate the mucous membrane for about 5 mm. all around the tube. The curette is then sharply withdrawn, bringing the separated mucous membrane out with it; i. e., the mucous membrane is inverted like the finger of a glove, the cut-end becoming visible in the middle-ear. When the isthmus is fairly large and round, this procedure will usually be successful; when it is angular or slit-like, the mucous membrane cannot be inverted successfully; in such cases the smallest curette is introduced and the angles and corners thoroughly curetted, so as to destroy or completely remove the mucous membrane therefrom. The ear is then powdered with iodoform or similar powder, and the canal plugged with gauze.

On the following day the gauze is removed, and the ear treated according to the usual conservative methods. The writer has operated in this way upon 21 ears in 17 patients, the histories of which are of sufficient interest to be given in detail, as follows:

Case I. A woman, 42 years old, came under my care 5 years ago, stating that her left ear had been discharging since an attack of measles when she was 3 years old. For some time there had been a distinct odor and white, cheesy masses began to appear in the secretion.

Upon examination a large perforation was found involving the upper half of the drum-membrane; the ossicles had disappeared from the attic, which was filled with cholesteatomatous masses; there was a small granuloma in the anterior part of the attic. The lower half of the drum-membrane was adherent to the promontory, and a small portion of the hammer-handle was attached to it. Radical operation was refused. Under conservative treatment, including the removal of the granuloma and of the remnant of the hammer-handle, the odor disappeared, but the suppuration and the discharge of cholesteatoma continued, the quantity varying from time to time.

On August 28, 1907, the ear was operated upon. The lower part of the drum-membrane was separated from the promontory with an angular knife, and the region of the Eustachian tube exposed. The orifice of the tube was filled with pus. After cleansing the ear as thoroughly as possible, the tube was curetted as above described, dusted with iodoform, and the canal filled with gauze. On the following day the inner tympanic wall was found swollen and slightly reddened, the discharge in the ear consisting of thin sero-purulent fluid, containing small masses of cholesteatoma. The swelling of the inner tympanic wall lasted two weeks; during this time there was very little secretion, and the ear was treated with insufflations of boric acid powder. After this the patient used instillations of alcohol, and was not seen again until October, when there was still some discharge, but the secretion no longer contained cholesteatomatous particles. In January, 1908, four months after closing the tube, the ear was quite dry and clean, the inner tympanic wall having the dry appearance of skin. The adhesion between the drum-membrane and the promontory had not recurred; the edge of the drum had retracted, so that the entire middle-ear activity was freely open.

Two years later, on March 5, 1910, the patient was again examined. She stated that no treatment of any kind had been neces-

sary during the interval, and upon examining the ear it was found entirely well.

Case 2. A young man, 22 years old, who came under my care November 3, 1907, stated that his left ear had been discharging since he was 8 years old, from unknown cause. Since then the discharge has been continuous, profuse, and purulent in character; there were occasional pains in the mastoid region, but these had not been noticed during the past year. Polypi had been removed from his ear on several occasions.

Examination showed the presence of a large aural polyp filling the entire canal and obstructing the view of the middle-ear. After shrinking the polyp with cocaine and adrenalin, part of it was removed, sufficient to give access to the tubal region. The tube was then curetted. After the operation the discharge became muco-purulent, but was so abundant that another portion of the polyp had to be removed to obtain drainage. The patient was using instillations of alcohol, which had been previously prescribed for him, and he was allowed to continue them, but applications of 10 per cent solution of nitrate of silver were made to the polyp twice a week. The discharge from the ear became very slight, and the polyp became gradually smaller. On March 1, 1908, four months after closing the tube, examination showed that the ear had become quite dry and clean, the polyp having entirely disappeared. He was kept under observation for a few weeks, and remained well during that time.

On March 5, 1910, two years later, he reappeared at my request for examination. He stated that he had not paid any attention to his ear during these two years, and upon examination the ear was found to be dry and clean, there was no sign of polyp and the edges of the drum-membrane had retracted so that they were nearly flush with the walls of the canal. The ossicles still remained.

Case 3. Male, 28 years old. The patient stated that he has had a discharge from his right ear for over a year, which resulted from an acute otitis, following a sea-bath. Upon examination a large perforation was found, involving about three-quarters of the drum; the ossicles were present.

On December 1, 1907, the tube was curetted. When the packing was removed on the following day, the inner tympanic wall was found swollen and red, and the discharge had assumed a thin watery character. The patient was in the habit of using instillations of boric acid solution, and he was allowed to continue them. The swelling of the mucous membrane lasted two weeks, but the ear

did not become dry until January 12, 1908, six weeks after closing the tube. The patient has not been seen since.

Cases 4 and 5. Male, 27 years old. The patient, who came under my care March 7, 1908, stated that both his ears had been discharging profusely since an attack of typhoid fever in his seventh year. Upon examination there was found a profuse discharge from both ears, muco-purulent in character, without odor. A large perforation existed in both drum-membranes, involving the lower two-thirds. There were no polypi, but the edges of the perforations were covered with granulations, especially in the upper part near the remaining hammer-handle.

The left tube was curetted in the manner described. On the following day, when the packing was removed, there was considerable swelling of the inner tympanic wall, with some redness. There was a discharge of thin, slightly turbid mucus. The ear was powdered with iodoform. One week later, on March 15, there was still some swelling of the inner tympanic wall and a discharge of thin watery mucus. On March 22, two weeks after operation, the ear had become dry and the swelling of the mucous membrane had disappeared. The granulations on the edge of the drum were reduced in size.

The patient was not seen again until February 5, 1910, two years after closing the tube. The ear which had been operated upon, the left ear, was found to be quite dry and free from secretion; the edge of the drum-membrane had healed completely, and the perforation had increased in size, so that the entire hammer-handle was exposed. The right ear was still discharging freely, and there was a mass of granulation tissue in the upper anterior part, just under the short process. The tube was curetted and the ear packed. On the following day there was a considerable reaction, the inner tympanic wall being swollen and pink in color. There was a discharge of thin watery mucus. The ear was powdered with iodoform. On February 16, there was still a slight amount of clear watery discharge, but the swelling had disappeared. On March 25, 1910, the ear was clean and free from pus, and upon wiping the middle-ear with an applicator, the cotton did not become moist; but the mucous membrane still had a moist appearance.

Cases 6 and 7. Annie B., 27 years old, came under my care October 6, 1908. Both ears began to discharge after measles at 9 years of age, and had been discharging profusely since, especially in damp weather. Both drum-membranes had completely disap-

peared, but the remains of the ossicles were present. Both tubes were curetted at one sitting. After the removal of the packing, the inner tympanic walls on both sides were swollen, but not reddened; the discharge was slight in amount, and consisted of clear mucus. On February 6, 1910, 16 months later, the left ear was dry and clean, the mucous membrane having the dry appearance of skin rather than of mucous membrane; the right ear contained a slight amount of clear mucus. The patient was in the habit of inserting a cotton-tipped toothpick into this ear, and wiping the canal, several times a day. When her attention was called to the harmfulness of this practice, she discontinued it, and the ear has since become dry.

Cases 8 and 9. Anna H., 45 years old, came under my care October 8, 1908, stating that both her ears had been discharging since childhood, as long as she could remember. About ten years ago she began to suffer from tinnitus and vertigo, associated with pains in the head on the right side. She then had an operation performed on the right ear, following which there was no change in the amount of aural discharge, nor in the other symptoms. Since that time she has been under constant treatment at various hospitals.

Examination showed a profuse foul-smelling discharge from both ears; both drum-membranes had disappeared, but the remains of the ossicles could be seen on both sides. Behind the right ear there was a scar from an ordinary mastoid operation not like the scar from a radical operation. There was no scar in the concha or canal wall. Ordinary conversation could be heard at six feet on both sides.

Both tubes were operated upon in the manner described. The packing was removed on the following day. There was considerable swelling of the inner tympanic wall, the color was pale red, with a thin serous discharge in both ears. October 15, both ears were free from discharge and the mucous membrane of the inner tympanic wall had resumed its normal appearance. The patient was not seen again until February 6, 1910, 16 months after closure of the tubes. No treatment of any kind had been carried out during the interval, yet both ears were dry and clean, the inner tympanic wall having the pale, dry appearance of skin rather than of mucous membrane.

Cases 10 and 11. Jennie P., aged 15, states that at the age of 2 years, double paracentesis was performed during an acute illness; following this there has been constant profuse discharge from both

ears, often accompanied by odor, which was not alleviated by local treatment at various clinics.

Examination showed that there was profuse purulent discharge in both ears. Both drum-membranes had disappeared, but remnants of the ossicles were present on both sides. On the right side there was a polyp of moderate size, filling about three-quarters of the lumen of the canal.

On October 8, 1908, the right ear was operated upon. Enough of the polyp was removed to expose the anterior region of the drum-cavity, and the tube curetted. When the packing was removed on the following day, the inner tympanic wall was swollen and somewhat red, and there was a thin mucous discharge in the ear, but no pus. The remains of the polyp was touched with 10 per cent solution of nitrate of silver.

Previous to the operation, the patient was in the habit of instilling peroxide of hydrogen into her ears, and she was allowed to continue this practice. She was seen twice a week, and the polyp was touched with the silver solution. It became gradually smaller, and the discharge remained of a mucous character.

On November 9, the left ear, which had continued to suppurate during this time, was operated upon. The operation was followed by the same reaction as occurred in the right ear, and lasted about two weeks. The polyp on the right side disappeared completely after two months, but both ears continued to secrete turbid mucus until the beginning of April, 1909, when both ears became dry; the inner tympanic wall on both sides now had the smooth dry appearance of skin. The ears have remained dry since then.

Case 12. Ernest B., 11 years old, has had discharge from both ears for the last five years, following scarlet fever. In the left ear the drum-membrane had disappeared entirely, but the discharge was only slight and disappeared promptly upon local treatment. In the right ear there was a perforation in the posterior inferior quadrant, involving about one-quarter of the drum-membrane; with it a continuous discharge of pus, which was usually quite abundant and occasionally had an odor, resisting continuous treatment at the hands of skilled specialists. Local treatment, including the irrigation of the tube through the catheter, succeeded in reducing the amount of the discharge and freeing it from odor, but it could not be made to disappear entirely. Attempts to close the perforation with trichloracetic acid also failed. Radical operation was refused.

On October 15, 1908, the tube was curetted in the manner described. The same reaction followed which has been described in the other cases, and after three weeks, the ear became dry and clean. The perforation in the drum-membrane became gradually larger, until after a few months it included nearly the entire drum-membrane. The ear has remained dry up to the present time.

Case 13. Rebecca S., aged 19, stated that her left ear had been discharging since early infancy. During the past four years the discharge assumed a creamy consistency, became very profuse, and frequently had a foul odor. There was occasional tinnitus, and vertigo occurred upon slight provocation, especially upon attempting to syringe the ear. The hearing, however, had remained good.

After cleansing the ear, examination showed that the inner part of the canal was filled with a polyp, so that the middle-ear could not be seen. An application of strong cocaine and adrenalin solution caused the polyp to shrink, so that it occupied the posterior half of the tympanic cavity. It was attached by a broad pedicle to the posterior inferior part of the promontory. Owing to the presence of vertigo, and the location of the polyp, its removal was deemed inadvisable and as the anterior part of the middle-ear cavity was exposed by shrinking the polyp with cocaine; its removal was unnecessary.

Examination of the anterior part of the cavity showed that a cicatricial adhesion had formed across the tubal orifice, shutting off the tube from the middle-ear. A bougie, passed into the tube, was stopped by this membrane, and could be seen under it. When this membrane was incised, a drop of pus escaped; and the presence of a fistulous tract could be determined, running from the Eustachian tube along the floor of the middle-ear as far as the posterior wall. The introduction of the salpingeal probe disclosed the presence of carious bone on the floor of the tube and along the hypotympanum.

The entire tympanic portion of the tube from the isthmus outwards was thoroughly curetted with the salpingeal curette, the carious bone on its floor being carefully removed, as well as the carious bone on the floor of the middle-ear. The ear was then dusted with iodoform powder, and packed.

When the packing was removed on the following day, the ear was filled with a purulent discharge of a much thinner consistency than before the operation, and the inner tympanic wall was swollen

and red. The polyp was again shrunken with cocaine and the silver solution was again applied. This was repeated every few days, the polyp becoming rapidly smaller, and the amount of the discharge becoming less.

Six weeks after operation there was only a slight amount of secretion in the ear, but this was of purulent character; the polyp had shrunken until all that was left of it was a small nodule on the promontory. Examination now showed that the pus came from the region of the attic, the Eustachian tube being closed, and the floor of the tympanum quite healed. The use of the intratympanic mirror disclosed the presence of a black mass in the attic, just internal to the short process, which was exceedingly painful to the touch and felt hard and bony to the probe. It was evidently the incus, in a necrotic condition. Operation for its removal was proposed but was refused. The ear was treated by insufflation of dry powders, at interval for three months, when the patient awoke one morning with a sharp pain in the ear followed by an increase of the discharge, which all that day was tinged with blood. When the ear was seen on the following day, it was found that the black mass had disappeared from the attic. The probe could be moved about freely in the attic, and pain was elicited only in the neighborhood of its outer wall.

The discharge now began to diminish rapidly but a small crust continued to form near the short process, upon the removal of which a small drop of pus escaped. At first this crust would re-form in a few days, but the interval became gradually longer; the last crust was removed in the early part of January of this year, and it has not reappeared since.

The ear is now entirely free from secretion, the inner tympanic wall having assumed the dry appearance of skin. The point on the promontory from which the polyp had grown has become converted into a shallow pit or depression. The tinnitus has disappeared and vertigo is only occasionally present. The hearing remains as good as before the operation.

Case 14. Tony O., aged 27 years, stated that her left ear had been discharging since childhood, from causes unknown to her. The discharge was usually quite abundant and occasionally there was an odor. Examination showed a profuse discharge, purulent in character. The drum-membrane had nearly disappeared, but remnants of the ossicles were present. A small polyp, as large as a pea, was attached to the malleus, near the short process. The polyp

was removed with the snare, but as it returned in a few days, the ossicles were removed, together with the outer attic wall, under local anesthesia, on July 24, 1909. The tube was then curetted and the ear dusted with iodoform, and packed. On the following day the inner tympanic wall was swollen and slightly congested, and there was a thin mucous discharge in the ear. The swelling of the inner tympanic wall lasted about ten days when it receded and the ear became dry. It has remained so since.

Case 15. Elsa H., 30 years old, stated that her left ear had been discharging since childhood. The ear was neglected until about 5 years ago, when she came under the care of a competent otologist. Radical operation having been refused, she was put under conservative treatment, which resulted in diminishing the amount of the discharge, especially during the warm weather. In the winter the discharge was always profuse, purulent, and usually had a bad odor. The hearing was considerably diminished, whisper being audible at four inches. Examination showed that the upper half of the drum-membrane had disappeared, but the remains of the ossicles were still present. The lower part of the drum-membrane had become adherent to the promontory; anteriorly, this adhesion terminated in a small opening, by which the space underneath communicated with the middle-ear proper, while posteriorly the adhesion extended as far as the aditus ad antrum. A bougie passed through the Eustachian tube could be seen under the adherent membrane.

On November 8, 1909, the ear was operated upon. The adhesion was severed by an incision extending along its entire length. A small amount of pus escaped. This was wiped away, especially in the region of the round window, when it was found that the hearing-distance had improved so that whisper could now be heard at a distance of 6 feet. The tube was curetted, the ear dusted with iodoform, and packed. On the following day the inner tympanic wall was swollen, and there was a discharge of thin mucopurulent secretion in the middle-ear. This reaction persisted for 3 weeks, when the swelling had completely subsided and the ear had become dry, and has remained so since. The adhesion in the lower half of the drum has not returned. The edges of the incision have completely retracted, so that the hypotympanum is freely exposed. The gain in the hearing which was made at the time of the operation has been maintained up to the present time. The patient has since had an acute empyema of the antrum of Highmore, without affecting the ear:

Case 16. William K., 21 years old, stated that he had had a constant, profuse discharge from his ear for the last 14 years, usually with a foul odor. The tube was curetted on May 6, 1909. On the following day the mucous membrane of the inner tympanic wall was swollen and the discharge was slight and mucous in character. On May 11, the swelling had gone down, but there was still some discharge of clear watery mucus.

The patient has not been seen since, but I had a communication from him on March 5, 1910, when he stated that his ear had remained entirely free from secretion during the summer, but after a sea-bath a slight discharge again appeared for a few days. During the following winter there has occasionally been a slight amount of moisture, but it did not persist for more than a day or two at a time.

Case 17. A. B., a man 19 years old, stated that his right ear had been discharging since early infancy, following an attack of measles. The discharge was profuse and, when it was neglected, would acquire an offensive odor. He had been under treatment at intervals all his life.

Examination showed that the entire drum-membrane had disappeared; the remnants of the ossicles were present and felt carious to the probe. There was some granulation tissue around the orifice of the tube.

On April 4, 1909, the necrotic ossicles, together with a part of the external attic wall, were removed under local anesthesia, and the tube curetted at the same time. On the following day, when the packing was removed, the inner tympanic wall was found very much swollen, and there was some blood in the middle-ear. This was removed and the ear dusted with iodoform powder. On the next day there was some discharge in the middle-ear, but it was not purulent, but consisted of slightly turbid mucus. The swelling of the mucous membrane continued until one week after the operation, but slight moisture continued to collect in the ear for 4 weeks, when the ear became dry and clean, and the mucous membrane had assumed the appearance of skin.

During the following summer the patient was in the habit of bathing daily in the public bathing places near the city, but paid no attention to his ear. In the fall a slight discharge reappeared, but lasted only one week. It reappeared, however, during the winter every 6 or 8 weeks, lasting each time for a few days.

On February 5, 1910, the patient appeared at my office with such a recurrence of two days' standing. There was a small amount of muco-purulent secretion in the middle-ear. On wiping this away, it could be seen that an adhesion had formed in the upper anterior corner of the tympanic cavity, behind which a small pocket had formed, which contained pus. This was incised; the ear became dry in two days, and has remained so since.

Case 18. Sadie F., 17 years old, came under my care September 18, 1907. She stated that her left ear had been discharging since she was 2 years old, following measles. The discharge was usually very abundant and generally had a very foul odor.

Upon examination, the drum-membrane was found to have disappeared entirely, together with the ossicles, but a remnant of the hammer-handle could be seen attached to the outer wall of the attic. There were several small masses of granulation tissue around the margin of the drum-membrane. In the upper wall of the canal, at about its middle, there was a round opening which was filled with white cheesy masses. Upon removal of this material, the opening was found to lead to a large cavity in the region of the antrum, about as large as a hickory nut. Examination of the contents of this cavity showed that it consisted of epithelial cells and detritus, and an occasional crystal of cholesterin. It was therefore evident that this was a large cholesteatomatous cavity. The tube was curetted in the manner described, and the ear packed. Two days later the inner tympanic wall was found to be swollen and edematous and slightly red, and the cholesteatoma cavity had partly refilled. Irrigations of 1 to 5,000 solution of bichloride of mercury were ordered. The patient returned on September 31, when the ear was found clean and nearly dry, and the large cholesteatoma cavity was empty. On October 6 the ear was quite dry and clean. The patient was not seen again until February 2, 1910, 2 years and 4 months after closing the tube. During this time the ear had been neglected, although there was occasionally some moisture in the canal. Upon examination a plug of cerumen was found in the canal, upon the removal of which it was seen that the cholesteatomatous cavity was empty and its walls dry. It was considerably smaller than when last seen. The inner tympanic wall was not quite dry; upon touching it with a cotton applicator, the applicator became slightly moist, but there was not sufficient fluid to constitute a distinct drop. The granulation-tissue on the edges of the drum-membrane had entirely disappeared, the walls of the middle-ear cavity passing smoothly into those of the canal.

Case 19. Rose L., aged 50, states that $1\frac{1}{2}$ years before she came under my care a paracentesis was performed on her right ear for acute otitis media. The discharge which followed has never ceased, but has remained profuse and of a purulent character. A perforation involving about one-quarter of the drum existed in the lower part, the upper border of which embraced the handle of the malleus. She had been under constant local treatment without any result. As the upper border of the perforation was too low to permit the introduction of the instruments into her tube, a small incision, about 2 mm. long, was made in the upper border of the perforation near the anterior margin of the drum. On October 24, 1907, the tube was curetted. On the following day there was swelling of the mucous membrane of the inner tympanic wall, and a discharge of thin, slightly cloudy fluid. The swelling of the inner tympanic wall lasted three weeks, when it disappeared, and the discharge became less abundant. On November 17 there was still a very slight amount of moisture which could only be recognized by inserting an applicator. This condition persisted for a year, when the patient passed out of observation.

Although this ear did not become entirely dry, the behavior of the perforation is of special interest. After the upper border of the perforation was incised there remained on each side of the incision an angular-pointed tab of tissue. A week after the operation these tabs became rounded and finally merged into the general margin of the perforation. The perforation itself began gradually to enlarge, so that after a year it involved the greater part of the drum-membrane.

Case 20. Henrietta R., aged 23, stated that her ear had been discharging for the last 7 years, following an acute inflammation of the auricle and the side of the face. Examination showed that the entire drum-membrane had disappeared, the middle-ear and canal being filled with purulent secretion. After irrigation, a number of small granulomata were seen in the neighborhood of the tubal orifice. The tube was curetted and the granulations removed, November 16, 1907. After the reaction from the operation had passed away, the discharge of pus ceased, but a slight amount of clear mucus continued to be secreted in the ear as long as the patient remained under observation, February 10, 1908. The patient has not been seen since.

Case 21. Anna S., 21 years old, stated that her left ear had been discharging since early childhood, the secretion being very profuse

and often with foul odor. Examination showed that secretion was purulent in character, the drum-membrane and ossicles having entirely disappeared. The tube was curetted, in the manner described, on January 17, 1908. The discharge became very much less after the operation, and on February 11, 1908, had almost ceased. The patient was not seen after this date until February 5, 1910, when she stated that her ear had remained free from discharge for two months; after which it became as abundant as before the operation, and has continued so ever since.

Examination showed that a cicatricial drum-membrane had formed which nearly closed the middle-ear cavity, the opening in the membrane being about as large as the head of a pin. On testing the tube, by filling the canal with water, and inflating air through the Eustachian catheter, it was found that the tube was open; in other words, the operation performed two years ago had not succeeded in causing atresia of the tube. For a short time after the operation, while the mucous membrane of the tube was swollen, the discharge was lessened; as soon as the swelling subsided and the tube became patent, the discharge returned in its former intensity, and a cicatricial membrane had formed.

A second operation was therefore performed on February 14, 1910, but the cicatricial drum-membrane was not incised nor was the opening in it dilated. The reaction which followed was the same as had occurred in the other cases; the discharge on the following day was clear mucus. On February 21, the swelling of the inner tympanic wall had subsided, and the opening in the cicatricial drum-membrane had become considerably larger. On February 28 the opening in the membrane measured 5 mm. in diameter, about 3 times its original size. On March 20, the perforation measured about 7 mm. in diameter, so that the cicatricial membrane was reduced to a band of tissue around the canal wall not more than 2 mm. wide. The discharge has been reduced to a minimum. No treatment of any kind is carried out by the patient, and when she makes her weekly visits to my office, only a slight amount of secretion is found on the floor of the middle-ear.

In reviewing these cases, it must first be noted that no injurious results were caused at the time of the operation nor did any follow afterwards. The operation is painless under cocaine anesthesia, and only a few of the patients complained of post-operative pain. The operations were performed in the office, and the patients allowed to go home afterward. The hemorrhage at the time of the operation

was very slight, only a few drops of blood being lost, and there were no secondary hemorrhages. Swelling of the pharyngeal portion of the tube did not occur, nor was there any rise of temperature or any evidence of sepsis in the tube. Tinnitus did not follow in any of the cases, and when present before the operation was not increased afterwards. The hearing, which was tested by speech only, was neither improved nor diminished to a noticeable degree, the improvement which followed in one case being attributable to other causes.

My object in performing this series of operations was not to study the possibilities of conservative treatment of aural suppuration, but to determine, in as logical a manner as is possible in medicine, the exact influence which would be exerted upon the suppurative process by causing a permanent atresia of the Eustachian tube at the isthmus, and only such intratympanic surgery as was absolutely necessary was performed at the time of closing the tube. When the tube had already been closed, or partly closed, by adhesions at the tympanic orifice, these adhesions were cut, and the lumen of the tube obliterated at the isthmus. Ossicectomy was done in two cases only. When polypi were present, and were so large that even after the use of cocaine and adrenalin they still obstructed the view of the tubal region, enough of the polyp was removed to expose the field of operation. For the polypi which occur in aural suppuration are not true mucous polypi, but are merely exuberant granulations such as occur in bone-suppurations elsewhere in the body, and like these are amenable to treatment by astringent applications, especially after the infectious process has ceased. Such polypi were therefore treated by applications of 10 per cent solution of nitrate of silver. Most of the patients had some favorite method of treating their ears, such as the use of irrigations, instillations, etc., and they were allowed to continue the same form of treatment, more as a placebo than for any other reason. We may therefore state with logical accuracy that the results obtained were directly caused by closing the tube at the isthmus, and by this alone.

The suppuration had existed in all of the cases for a long time. In one case for a year, in one for $1\frac{1}{2}$ years, in a boy of 11 for 5 years; in the rest, all adults, since childhood. In all of the cases the closure of the Eustachian tube at the isthmus was followed immediately by a marked diminution in the quality of the secretion, a fact which in the opinion of the writer, proves the statement

made above, that in cases of profuse aural discharge the largest part of the bulk of the secretion is not formed in the middle-ear, or mastoid cells, but is derived from the naso-pharynx. Atresia of the tube was successfully accomplished by the first operation in all of the cases but one.

Of the 21 cases operated upon 13 were cured. Of these 12 were examined within the past month, and were found to have remained well, 2 for 3 months, 1 for 7 months, and the rest from 1 to 2 years.

Of the 8 cases which were recorded as not cured, 2 were operated upon in the spring, and in both the discharge ceased completely at the time. During the summer, however, they indulged in sea-bathing in the public bathing places, and recurrence took place. The amount of secretion was very slight and ceased readily upon local treatment.

Another patient was in the habit of inserting a cotton-tipped tooth-pick into her ear to see if it was discharging. The secretion which was present consisted of clear mucus, and when she was ordered to discontinue this practice, the ear promptly became dry.

The fourth case was the one with the large cholesteatoma cavity. This cavity has been free from cholesteatoma for $2\frac{1}{2}$ years, but there is still a slight amount of pus which can be obtained by wiping the floor of the middle-ear with an applicator.

In the fifth case the operation is of such recent date that it is too early to present results.

In the sixth case atresia of the tube was not accomplished, and recurrence was complete. The case is of special interest, however, because during the time that the patient was not under observation, a cicatricial membrane had formed, which disappeared spontaneously after the tube was closed by a second operation.

The remaining two cases did not reappear for observation, and their condition is unknown.

The operation was followed in practically all of the cases by two peculiar and interesting phenomena. The first of these is the swelling of the inner tympanic wall. This swelling was sometimes quite marked, so that it filled the entire middle-ear, but the mucous membrane never had the intensely red appearance of acute inflammation. There was frequently enough congestion to give it a pink color, but the swelling had more the nature of edema than of inflammation. Moreover, the swelling did not occur in the canal wall near the tympanic orifice, nor in the pharyngeal portion of the tube; it was not, therefore, the edema which might occur with any

traumatism, for it was limited entirely to the inner tympanic wall. Furthermore, the swelling always lasted for one or two weeks, and was accompanied during the whole of this time by a watery secretion; for the discharge which appeared in the ear during this time was either a thin, watery mucus or a diluted sero-purulent fluid.

These conditions might be considered to be of trophic or of vaso-motor origin, for the plexus of sympathetic nerves which surrounds the carotid artery sends a few fibres through the floor of the bony part of the tube, where they unite, under the mucous membrane with the tympanic branch of the glosso-pharyngeal and with the lesser superficial petrosal nerve, to form the tympanic plexus in the anterior part of the inner tympanic wall. These nerves are undoubtedly injured by the operation. On the other hand, it has been shown (A. Most, *Arch. für Ohrenh.*, Vol. 164, p. 241) that the lymphatics of the inner tympanic wall pass through the Eustachian tube and empty, together with those of the naso-pharynx into the deep cervical lymph glands. These lymphatics are injured by the operation, and the lymphatic stasis so caused would account for both the swelling and the transudation of serum. With the establishment of a collateral lymph circulation, both of these conditions disappear.

The second phenomenon of interest is the behavior of the drum-membrane. In all the cases in which the perforation involved only a part of the drum-membrane, the perforation invariably became larger after the operation; the edges of the drum-membrane became thinner and thinner, and gradually retracted toward the walls of the canal, so that after a month or two, all that remained of the drum-membrane was a narrow, white line. The ossicles, however, remained. The perforation never became smaller or showed the slightest tendency to close, but always became larger. The only case in which a cicatricial membrane did form, and in which it nearly closed off the middle-ear from the canal, was the case in which the tube remained open; as soon as the tube was closed by a second operation, the opening in this cicatricial membrane immediately began to grow larger, and the membrane eventually disappeared. In the case in which the structure was cut, the incision in the drum retained its linear form and showed no sign of granulating as long as the tube was closed by swelling of its mucous membrane; as soon as the tube became patent, the perforation immediately began to granulate, became round in form and soon closed entirely.

This tendency of the drum-membrane to spontaneous atrophy after the tube has been closed, might be attributed to a trophic

disturbance caused by the destruction of the sympathetic nerves in the floor of the tube; but there is no evidence to prove that the trophic nerve-supply of the drum-membrane is contained in these fibers. On the other hand, the writer fully believes that one of the important functions of the drum-membrane is to protect the middle-ear against infection from the naso-pharynx, in fact, this is the only function for which the drum is indispensable. When the lumen of the tube has been obliterated by organic atresia at the isthmus, the necessity for this protection no longer exists. Hence, in accordance with general physiological law, when the function of the drum-membrane has been abolished, the organ itself becomes atrophic.

Whatever may be the theoretical explanation, the fact remains as a matter of clinical observation, and it may be formulated into the rule or law, which is here propounded for the first time, namely: *When the Eustachian tube has been permanently closed by organic atresia at the isthmus, a perforation in the drum-membrane will never close, but will tend to become larger.* The fact that there are other reasons why a perforation in the drum-membrane may remain open does not in the least conflict with this rule.

Otosclerosis: It is a well-known fact that there are certain cases of otosclerosis in which the hearing is improved when a perforation is made in the drum-membrane. Some writers have stated that this happens only in those cases in which the drum-membrane is very much thickened; but this statement has not been borne out in my experience. On the other hand, Lucae, who has performed many of these operations, states that benefit may usually be expected in those cases in which the defective hearing is accompanied by a negative Rin test.

At several different periods in the history of otology, the attempt has been made to give such patients the benefit of the improved hearing so attained, but these operations have been abandoned because, however brilliant the results were immediately after the operation they did not remain permanent. The failure to maintain the improved hearing may be ascribed to three causes. In the first place, it was usually difficult and often impossible to keep the perforation open, in spite of the variety of methods employed and of the many ingenious devices which were invented for the purpose; even when the entire drum-membrane, together with the ossicles, were removed, cicatricial closure occurred in one-third of the cases within one year (Lucae). In the second place suppuration invariably set in sooner or later. In the third place, the procedure did

not exert any favorable influence on the disease itself, for the morbid process in the bone continued to advance in its usual course.

Now, from the experience which the writer had with the cases of chronic suppuration, he was led to believe that these three causes for failure could be avoided, if, after perforating or removing the drum-membrane, the Eustachian tube were closed at the isthmus, in the same manner as was done in the suppurating cases. For he was convinced that by closing the tube the tendency of the perforation in the drum-membrane to close would be overcome. Secondly, he was satisfied that suppuration would be prevented by the same means. And, thirdly, if the same lymphatic stasis occurred in the otosclerotics which took place in the suppurative cases, and if it were followed by the same dessication of the inner tympanic wall, it did not seem impossible to him that the marked changes which would be produced in the circulation of the parts, might exert a direct influence upon the diseased process itself; but he realized that the nature of this influence, whether favorable or unfavorable, could only be determined by the behavior of the hearing-power subsequently to the operation.

The first case to be operated upon in this manner was a woman, 60 years old. She gave a distinct family history of hereditary deafness extending through several generations. Her own hearing had become gradually poorer since early adult life. There was marked tinnitus, humming in character, in both ears. Upon examination it was found that the hearing was markedly diminished on both sides, whisper and ordinary conversation being inaudible. Loud conversation, close to the ear, was heard, more distinctly on the left side than on the right. Hearing for all tuning-forks was diminished for both bone and air-conduction, but the Rinne test was negative. The drum-membranes were thin and atrophic, somewhat retracted, and the ossicles were immovable. The right ear was operated upon on May 15, 1909. A probatory incision was made in the posterior inferior quadrant in the region corresponding to the round window, so as to admit the sound vibrations as directly as possible to this region. There was an immediate improvement in the hearing, as whisper could now be heard close to the ear.

The entire drum-membrane was then removed, including the malleus, but the incus was left in situ. The tube was then thoroughly curetted, the ear dusted with iodoform and packed. When the packing was removed on the following day, the inner tympanic wall was very much swollen, so as to fill the entire middle-ear cavity; it was pink in color; there was a secretion of thin watery fluid on the

floor of the canal. This reaction persisted for 3 weeks, after which the ear became dry and the swelling of the inner tympanic wall had completely receded.

In the middle of July, 2 months after the operation, the hearing had so improved that whisper could be heard at 2 inches and ordinary conversation at 10 inches. On November 3, whisper 3 inches, ordinary conversation 15 inches. It is now a year since the operation. The tinnitus in this ear has entirely disappeared. Not only has the patient kept the gain which resulted immediately upon opening the drum-membrane, but she has made additional gains since then, and the improvement is still going on. There has been no discharge from the ear at any time, the tympanic cavity being dry and clean. The opening in the drum-membrane has not shown the slightest sign of becoming smaller.

The second case was a girl, 25 years old, a daughter of the first patient. She stated that her hearing had been diminishing for about 5 years. She was under my care for some time previous to the operation. At first her hearing was markedly diminished for all tuning-forks, especially for the low ones. Rinne negative. Whisper, right ear 12 inches, left ear 3 inches. Occasional tinnitus especially left. There was considerable swelling of the tubal mucous membrane on the left side, as only a small bougie could be passed. The tube was dilated with the sound and applications of argyrol made to it, with the result that the hearing improved so that whisper could be heard at 24 inches. This result was not constant, however; the maximum hearing-distance varied from 16 to 24 inches, but could never be extended beyond the latter figure. On July 24, 1909, a probatory incision was made, when the distance for whisper increased to 3 feet. The drum-membrane and malleus were then removed, and the tube curetted. The reaction lasted about 2 weeks. Six weeks after operation, the hearing-distance for whisper had increased to 4 feet. Three months later, a further improvement had taken place, whisper being distinctly audible at 5 feet. In March, 1910, the distance was 6 feet.

There has been no discharge from the ear at any time, the tinnitus has entirely disappeared, and the perforation in the drum-membrane has shown no sign of becoming smaller.

The third patient was a man 38 years old, who had noticed increasing deafness for a number of years, for which he had been treated both here and abroad, without result. When he came under my care, in January, 1907, his hearing was very much reduced, for

all forks, both by bone-and air-conduction, but the Rin test was negative. Whisper could be heard in the right ear at 3 inches, in the left ear at 12 inches. Both ear drums were thin and transparent, and the promontory could be clearly seen through it (Schwartzs symptom). The ossicles were retracted and immovable. There was some tinnitus. The Eustachian tube was wide-open and inflation had no effect on the hearing. The only method of treatment which was of any benefit, was the use of Lucas pressure probe. Direct massage of the ossicles diminished the tinnitus and improved the hearing so that in the right ear he was able to hear whisper at 15 inches, in the left somewhat further; but in spite of his patient endurance of this form of treatment for a long time, no further advance could be made.

On November 5, 1909, it was decided to make a probatory incision in the drum-membrane; his hearing distance was immediately doubled, to 30 inches. The drum-membrane was then removed, and the tube curetted. When the reaction, which lasted nearly a month, had subsided, his hearing distance for whisper in the operated ear was 8 feet.

Although these cases are few in number, they indicate clearly that the destruction of the mucous membrane of the isthmus of the tube in cases of otosclerosis is followed by the same disturbance of the lymphatic circulation of the inner tympanic wall as occurs in the suppurative cases, and that when the swelling and transudation spaces off, the same dessication of the mucous membrane occurs. From the fact that these patients not only retained the increase of hearing which immediately succeeded the operation, but that they made additional gains afterwards, one case continuing to improve after one year, as well as from the fact that the tinnitus disappeared in all 3 cases, it seems to the writer that he is justified in drawing the conclusion that the changes produced in the inner tympanic wall have exerted a direct and favorable influence upon the otosclerotic process itself. If this conclusion is verified by similar results in other cases, it may indeed be true that a ray of hope may be extended to those sufferers whose unfortunate condition is the *bte noire* of otology.

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