taken with acute ethmoiditis following a cold which he contracted in St. Louis. He came to Omaha. I found complete blindness in the right eye and that he could count the fingers with the left eye at not farther than 2 feet. The skiagram showed both sphenoids filled with pus. On opening both sides the condition at once cleared up.

DR. W. R. PARKER, Detroit: Dr. Shambaugh's cases illustrate well the point I wished to make. Two patients were without eye symptoms and one undoubtedly showed eye symptoms of sinus origin. I think these conditions are possible, but rare. I did not include in the paper inflammatory conditions of the conjunctiva or cellular tissue of the orbit, nor did I include reflex headaches, or cases of corneal ulcerations which depend on affections of the lacrimal apparatus. Cases of this kind are more common and well understood. My experience agrees with that of Dr. Dwight. In large student bodies we do meet cases of reflex headaches due to eye or nose affections. In these cases congestion of the mucous membrane of the nose, of the sinus and of the ethmoid cells may be found. A low-grade retinitis or a "fluffy chorioid" may also be found. You may refract and re-refract in these cases, but you will not cure them. If you relieve the nose and sinus condition, the patient will at once feel better. The trouble is not, it seems to me, due to the use of the brain, but rather to a relaxed condition of the mucous membrane incident to sedentary life. Get these persons out in the fresh air, with exercise and good food, and their symptoms will disappear.

THE MEASUREMENT OF AUDITORY ACUITY*

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The measurement of auditory acuteness is generally construed to be synonymous with the quantitative estimation of hearing and at first thought it would seem to be all that is implied by the term, and all that need be attempted in this method of examination. But a more comprehensive interpretation would compel us to include a qualitative as a really necessary part of a quantitative exploration of the auditory function, for in order that measurement of auditory acuity be complete, it should not be confined to the estimation of the power for the perception of one or even several tones, but the entire scale. According to the Helmholtz theory, each tone is separately perceived by its own particular cell and fibers which respond to this and no other. Therefore, the quantitative measurement in the usual restricted sense would test but a limited part of Corti's organ, leaving the rest unexplored.

Conversely, it is equally illogical to consider that the qualitative method can be completely divorced from the quantitative method of examination. Indeed, I maintain that actually it is impossible to do so, because we know, in both health and disease, the capacity to perceive tones of different pitch in different degrees of power, so that it can never be a question of perception only, but must also be a question of the amount of energy necessary to produce an excitation at the threshold of each and every tone.

At the two extremities of the scale points will be reached, of course, at which tone perception fails, no matter how powerful the stimulus, because the organ of Corti contains no elements which are capable of responding at all to sound-waves slower than twelve or sixteen or twenty, or more rapid than thirty or forty or fifty thousand vibrations per second, as the case

may be, and, therefore, amplitude of the waves beyond such limits are of no concern.

Occasionally too, in the midst of the scale a hiatus will exist where perception for certain tones is completely lacking. But we believe that in reality the hiatuses are seldom absolute, but consist rather in a lessening of the auditory power for the tones in question, which might be still excited to auditory perception by sound-waves of adequate amplitude.

Let us consider specifically the most commonly used methods of examination of auditory capacity with a view to determining their value and their relative advantages and disadvantages.

SPEECH

The voice in speech is regarded by many authors as the ideal instrument for the measurement of hearing on the ground that we thereby test the auditory organ in what is really its chief function.

The singing voice of an average individual has a compass of about two octaves; the average speaking voice that of a few semi-tones. The normal audition, as we know, extends over a range of about eleven octaves. Speech, therefore, can test it in but a small proportion of its full extent. This being in the most used and perfected part of the cochlear organ, will therefore represent its most sensitive area.

If our purposes are merely practical, such consideration would recommend the speech test as a desirable method. But otologic science cannot be satisfied except by a more analytic method of mensuration. Moreover, the speech method of testing is of all the least accurate. As we have no means of graduating the intensity of the voice, we endeavor to start with a given vocal power and measure auditory acuity by varying the distance between patient and examiner.

But unfortunately such a method of testing audition is open to several sources of error. In the first place a uniform standard of intensity is not possible of realization. Voices differ not only in pitch, but also very materially in their clang-tint or quality, due to the presence of harmonics. Voices whose fundamental tones might be of the same intensity would, therefore, be heard differently according to their particular harmonic character.

It is not possible except in an approximate way to determine the dynamics of the voice. Our qualifying adjectives, "low," "soft," "loud," "ordinary conversational," as applied to speech, it must be admitted, constitute inexact expressions, which cannot serve as definite guides for intensity.

An ordinary conversational voice of one person may have a carrying power very different from the conversational voice of another, and even the same individual cannot be certain that it will be the same at different tests. It will not only fail, therefore, to serve as a standard comparable among different examiners, but even for the same examiner when testing the same case at different times.

In employing the voice as a means of testing hearing we may make use of phrases or sentences, of different words, of numbers, or of nonsense syllables.

The use of phrases or sentences is open to the obvious disadvantage that the individual examined will supplement his defect in hearing by his apperceptive faculties and guess what has been said by the context, aided by the emphasis and inflection of the speaker. Results, therefore, will depend greatly on the intelligence and education of the person being examined.

* Because of lack of space, this article is abbreviated in *THE JOURNAL*. The complete article appears in the *Transactions of the Section* and in the author's reprints.

The use of disparate words will lessen the errors arising in this way, but the apperceptive factor is still to be considered. Words will be grasped in accordance with the hearer's familiarity with them, and one's familiarity with different words will vary with age, training and education, profession and environment. Moreover, the auditory value of words differs considerably with the letters or elements of which they are made up. O. Wolfe, who made a detailed study of the elements of speech, came to some rather surprising conclusions with regard to the hearing distances for different letters. Vowels are heard much better than consonants, and, therefore, for a given word the vowel is the index of the range or hearing distance for that word. The extremes of distance are illustrated in the statement that a *a* in "father" is heard over 250 meters, while aspirate *h* is heard less than ten meters. Sibilant *s* could be heard 175 meters, while lingual *r* is heard only forty meters.

The use of numbers or nonsense syllables precludes some of the disadvantages of using words and sentences, but they still have the chief fault of all voice or speech tests, namely, the lack of a uniform and comparable standard of intensity.

Agreeing to an approximate standard of intensity as acceptable for our purpose, however, we still have to object to the method of measuring auditory acuity by varying the distance from the source of sound.

Andrews made experiments by which he obtained the percentage of accuracy of hearing of individuals placed at different ranges who had a series of specially selected lists of numbers spoken to them, and reached the conclusion that, while there is a general decrease in audibility as distance increases, yet the decrease is neither constant nor uniform.

These inequalities were attributed to the reflection or absorption of the sound-waves, which differed for different parts of the room. As it is impossible to avoid these acoustic phenomena in any ordinary testing-room, we must be prepared for such a source of error in all conclusions based on the correlation of auditory capacity with distance.

To mention finally another source of possible error in testing with a loud or even ordinary conversational voice, it must not be forgotten that, if one ear has still good hearing, it is impossible to eliminate it completely in the test. Though held tightly closed with the finger, or with a wad of cotton, it participates in the hearing.

There is the likelihood, therefore, of attributing to the ear tested a degree of audition which it does not really possess, but which has, in fact, been exercised by the other or normal ear.

WHISPER

The use of whisper for testing audition has advantages and partly avoids certain of the errors of conversational speech. It is more satisfactory for testing unilateral deafness as the unaffected ear is less likely to take part in the hearing. We can also come nearer with whispered speech to securing a uniform standard of intensity. This we do by following the instruction to utilize for our whisper test the residual air of the lungs after a forced expiration. It is likely too that the acoustic properties of the room do less to invalidate the estimation based on distance than in the case with loud speech. These are all advantages, relatively speaking, for the faults persist, though in less degree.

The absence of a uniform intensity is exemplified in the distance given as the normal hearing distance

for whispered speech by different observers. They vary all the way from the estimate of Jasskau of ten or twelve meters for words and fourteen or fifteen meters for numbers, up to the estimate of thirty-five to forty meters given by Matte and Schultes.

We all realize how the result will be influenced by the acoustic properties of the room and its freedom or not from disturbing noises. In a room that looks on the street, the range of hearing will be materially reduced.

The quality and intensity of the constituent elements have been found to differ for whispered speech no less than for the loud voice. Quix, who has investigated this subject very thoroughly, has divided whispered speech into zones of pitch represented by the low, the high and the mixed zones. For the purpose of testing audition he finds it necessary to employ certain groups of words, which are what he calls isozonal and equi-intensive, for he finds that one group differs considerably from another in the distance at which the words are heard by the same individual. So that it appears that while whispered speech has advantages over the ordinary conversational voice as a means of testing hearing, it still falls short of being an accurate and reliable method.

THE WATCH

With regard to the watch, the committee of the Bordeaux congress says:

"Notwithstanding that it has not been possible to obtain from manufacturers a type giving about the same tone and having the same intensity, its employment is so convenient and the indications furnished relative to the auditory perception by the bony route so valuable that we believe it should be maintained as an acoumetric measure until we possess an instrument more exact.

Andrews says that one may hear the watch at a considerable range and yet be relatively deaf for speech and vice versa, for the ratio between the range of hearing for speech and that for a single tone of noise is not necessarily constant even in the same individual. This is an objection which can be equally urged against all tests which are confined to the estimation of hearing of a single tone or click or involve the perception of only a restricted portion of the basilar membrane.

In employing a watch as a test faulty technique may lead into erroneous results. A watch will give a sound of greater or less intensity depending on whether it is open or closed, nearly run down or newly wound up, whether it is held free or against the palm of the hand, and depending on its relation to the wall or other reflecting surfaces.

It has seemed to me that erroneous results attributable to the psychic element plays a greater rôle in the watch test than in any others. The watch click is a familiar one of such a rhythmic character that when it has just been heard, one can very easily imagine that he continues to hear it, thus deceiving both himself and the examiner. One will obtain results that differ greatly according to whether the watch is gradually removed from the ear until it attains the extreme range of hearing, or whether one follows the contrary course of beginning outside of the range and gradually approaching until the threshold of excitation is attained.

THE ACOUMETER

Many acoumeters have been designed, all aimed to present a method which might gain universal approval and adoption as a uniform method of auditory mensuration. The only one that has approached success in

this ambition is that devised by Politzer. In this instrument one endeavors to assure a constant and uniform intensity by the regulated extent of the fall of the hammer on a metal cylinder. The Bordeaux committee on acoustics recommends a little different method of using from that which is recommended by Politzer and which has been the method in general vogue. Instead of raising the striker at the end of the index finger to let it fall again, they advise letting it hang freely, causing the striker to take a swinging movement such as one uses in ringing a bell.

The objections to the acoustometer are very much the same as those to a watch, and one is liable to fall into many of the same pitfalls and errors in using it to measure audition.

Neither uniformity of intensity nor of pitch can be relied on in the different instruments which one finds in the shops, and besides many inaccuracies necessarily result, as I have pointed out in speaking of the speech tests, in which an attempt is made to correlate auditory power with the distance between the subject and the examiner. Furthermore, the click of the instrument is so loud that it is impossible to eliminate a normal and fairly well-hearing ear, and it is not applicable, therefore, in unilateral deafness.

TUNING-FORKS

The tuning-fork as an instrument of well-defined pitch and of relatively pure tone would seem to be the ideal one for testing the auditory functions. Its harmonics are few and far removed from the fundamental and generally die out quickly. They can be constructed to produce notes below the usual inferior limit and from there through the whole range upward to the highest perceptible tones. Nevertheless, by reason of the unlike intensity of forks of different pitch, we find that insurmountable difficulties arise in an attempt to apply them for either quantitatively or qualitatively testing audition.

In the deepest tones it is very difficult to get a satisfactory instrument. The vibration originating from within and without the prongs have opposite phases, which tend to produce interference. The forks, therefore, in their low pitches are so feeble that they must be held very near to the ear to be appreciated. As Politzer stated, the effect is to produce a sensation which may be mistaken for sound and give misleading results.

In employing tuning-forks to test the hearing, one attempts by various methods to get some basis for the estimation of the intensity. Three ways are possible: (1) to attempt to get a uniform initial intensity by using a uniform physical impact; (2) to calculate the intensity from the amplitude of the vibration; (3) to infer the intensity from the duration of the vibration.

One may either employ the maximal strike in setting a tuning-fork in vibration or secure a uniform intensity by a device such as that of Lucac. This consists in a hammer attached to the prong of the fork by means of a spring. It must be remembered in using tuning-forks that the more forcible the strike the greater the harmonics which tend to cover the fundamental tone. It is best that the fork be struck gently with a covered hammer and near the middle of the prong if one would eliminate as much as possible disturbing overtones. With regard to a uniform initial physical energy, it must be understood that even though this could be satisfactorily secured not much is gained, because the effect is different with each fork and the intensity must be estimated by varying the distance on counting the time of vibration, methods both of which are open to serious objection on their own account.

With regard to the estimation of sound intensity by means of amplitude, there are different opinions, and doubt is expressed of the validity of the claim of a simple relation existing between the two. It is generally asserted that sound energy is in direct proportion to the square of the amplitude, but this is denied by some authors. At any rate it is possible to estimate intensity from amplitude only in forks of low pitch; above the second octaves amplitudes are practically indeterminable. Ingenious optic methods of determining amplitudes have been devised by Gradenigo, Bonnier and Ostman, but they are similarly applicable only to forks of low pitch.

The third method of using tuning-forks, by duration of perceptible vibration, is the one most commonly employed. A serious arithmetical mistake is made, however, in stating auditory power in terms of duration, because the loss of intensity is not directly proportionate with time and is different for forks of different pitch.

Deep tuning-forks vibrate for a long time with a feeble intensity which diminishes slowly, while forks of high pitch vibrate a short time with great intensity at the beginning which rapidly diminishes. Bezold, Edelman, Gradenigo, Quix, Struycken, Dundas-Grant, Schmieglow and others have been at great pains to establish for the different forks their curves of decrement, but the calculations on which they are based are complex, and there is no agreement as to results.

After all, according to Quix, duration curves are determinable only for tuning-forks which test the sensitive zones of audition; "beyond these," he says, "one falls into the domain of hypothesis."

AUDIOMETERS

We have discussed all the methods of measuring auditory acuity which are in common usage, but, in addition to these, other methods have been proposed and certain special instruments devised for carrying them out. But none have so far been sufficiently free from all objection to gain general recognition or adoption.

The term "audiometer" has been arbitrarily applied to that type of apparatus which is placed at a fixed distance from the subject, and in which, instead of varying distances, certain special arrangements are provided for varying the intensity of the sound by increasing or lessening the physical energy which produces it. It is indispensable, of course, to be able to start with an intensity below the threshold of normal hearing and to raise it to reach the threshold of the very deaf, and it is essential that the energy be of a kind that can be readily measured in all its gradations.

Some of the earliest instruments designed to measure audition were of this type. Wolke, in 1802, employed a metal hammer falling from different heights on a sonorous metal plate, and the same principle is utilized in one of the latest audiometers, that of Toulouse and Vasehide, who substitute for the hammer drops of water, which are let fall from different heights.

Itard, in 1842, measured hearing by the strike of a small spherical mass, suspended like a pendulum, which could be made to strike a circle of copper from different points of removal. The distance of the swing was indicated on a dial which was therefore considered a measure of auditory power.

Again employing this principle an instrument has been very recently proposed by two Italians distinguished in this branch of otology—Stefanini and Gradenigo. The use of electricity to vary the physical energy

of the sound has been attempted by several authors, the most notable being the audiometer of Hughes and that of Seashore.

The chief difficulty with instruments of this type, if they are intended to secure universal adoption, is that it is not possible to realize uniformity in the different examples; their chief defect consists in the fact that they test but a restricted area of the cochlear field.

I have been experimenting recently at the government Bureau of Standards with a special machine which enables us to test the auditory function over a fairly wide area, namely, from 60 vibrations per second up to 3,000 per second, conducted to the ear by means of a sensitive telephone. An alternating current is passed through the primary of a variable mutual inductance whereby it can be readily varied in intensity. The different gradations of intensity can be accurately measured. I am thus able to produce sounds of varying intensity as well as of varying pitch fairly free from harmonics and thus combine, as we believe ought to be done, the qualitative and quantitative methods.

I have not progressed far enough as yet to feel justified in establishing any definite proposition, but I feel that such a method of testing audition embodies the right principles and will, if it can be simplified, become eventually the method of auditory mensuration *par excellence*.

CONCLUSIONS

From this general review of the chief methods of measuring auditory acuity, it is very evident that, as at present employed, they fall very short of the perfection greatly to be desired. They are both defective and deficient; no one of them is equal to all the demands of a complete acoumetry, and in what they attempt they are erroneous and easily lead to faulty interpretations.

The difficulties with which we have to contend are of two kinds, those which arise from the nature of the function being explored, and others connected with the various tests themselves and the manner in which they are conducted.

Strictly speaking we cannot really measure auditory sensation at all, because it is not a quantity divisible into equal units. We arrive at estimation of the power circuitously by measuring the energy employed in producing a given sensation, on the ground that auditory power is in inverse proportion to the intensity of the stimulus. We take as the criterion or standard of measure the lowest energy which we find is needed to produce just an appreciable perception of sound. This we call the liminal value, or from the standpoint of the ear, the threshold of excitation.

As we are obliged to depend on the interpretation and response of the subject, results will vary with degrees of intelligence and especially of aptness and attention. In testing with speech, for example, in which case the apperceptive faculties play an important rôle, education, training and environment greatly influence the response. Expectation and suggestion are psychologic factors which may vitiate the validity of tests otherwise carefully carried out, and in children it is necessary to eliminate as far as possible fear, nervousness and anxiety.

In some recent experiments I have shown that the ear by being continuously exposed to sounds readily shows fatigue which, of course, markedly lowers the threshold of excitation. This was found to occur with greater readiness with sounds at the two extremes of the trial scale, but especially with those of the upper limit. It has been proved that general fatigue of the

body will lessen the acuity of the senses—including that of audition.

With regard to the tests themselves, there are many and various sources of error. These should be well understood and carefully borne in mind, if we would avoid the fallacies of too implicit faith in their accuracy and reliability. Of all the sources of error the one which is most carefully to be guarded against is that of depending on distance as a reliable means of estimating sound intensity. In the first place, if there is a relation existing at all it is not a simple one, as might be inferred from the common practice of expressing auditory acuity by a fraction in which the normal hearing distance is taken as a denominator and the distance at which it is heard as the numerator.

The fact is the intensity of sound diminishes with distance geometrically and not arithmetically. Suppose, therefore, a loud watch which can be heard normally at 100 inches is heard at only forty, individual hearing power is not correctly expressed as 40 per cent., but as 16 per cent.; while if the patient hears at only thirty inches his hearing acuity, instead of being 30 per cent., is really reduced to 9 per cent. But, unfortunately, when distance is used as a means of arriving at the intensity of the stimulus, the law of geometric diminution is upset by other disturbing factors. The absorption and reflection of sound-waves, the influence of extraneous noises and the participation of the other ear in tests made with loud sounds, especially when the latter are of high pitch, may each, singly or jointly, upset all calculations. Errors flowing from such causes enter especially into the commonly employed tests made with the tuning-fork, the watch, the acoumeter and speech and, therefore, seriously affect the validity of the results which are obtained.

The errors arising from the lack of a uniform initial intensity are encountered in those tests in which this is depended on. It is one of the drawbacks in the use of the human voice, the intensity of which can be only roughly gauged, and differs even with the choice of vowels and their arrangement, and also in the use of the tuning-forks whose intensity must be estimated by calculations that are complex and faulty. The presence of harmonics is a bad fault in many instruments used in acoumetry. They tend to cover the fundamental tones and so lead to erroneous conclusions.

Nearly all the tests which are in general use are open to the objection that they apply to only limited portions of the whole auditory field and cannot therefore be regarded as giving a complete measure of auditory power. It is this that explains the observation which has been frequently made that a person may seem to have a good hearing for the watch and at the same time have great difficulty in hearing speech.

Tests used with the idea of covering a great part of the auditory field, including the upper and lower limits—the so-called qualitative tests—are often applied without regard to the function of intensity. As I have pointed out, the limits of sound perception might be extended and apparent hiatus disappear by merely employing greater intensity. It might be useful to know the amount of intensity necessary to get the threshold of excitation for different notes of the scale.

A general survey of the subject of auditory mensuration leads to the inevitable conclusion that there is great need of a system that will meet the exacting requirements of otologic purposes.

The ideal instrument for testing audition, from an otologist's standpoint, would be one capable of produc-

ing all the notes of the scale, from the highest to the lowest, in pure tones free from harmonics and capable of giving these notes in intensities readily measurable and varying from a point below the threshold of excitation of the most sensitive hearing up to a degree necessary to awake sensation in persons suffering from the most profound deafness.

Moreover, in order that such an apparatus may deserve universal acceptance, it must be possible to construct as many others as are wanted of the same type, each constant for itself and precisely similar to the others. It is only then that we can hope to make it available for a uniform notation comparable among different observers.

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TONSILLECTOMY BY THE SLUDER METHOD

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It is a matter of pride to us that, though total removal of tonsils has been advocated and occasionally practiced for decades, laryngologists within the last dozen years have established enucleation in capsule as the operation of choice and clearly defined the indications for it. As a result of their effort, with its leadership in America, general practitioners and laymen alike are fast coming to demand this procedure. Quick to appreciate its value, they are equally alert to detect faulty work and ready to condemn its author.

We will all admit that enucleation is being well done by sharp or blunt dissection, by the aid of scissors or knives and forceps of various designs, in most of which combinations the snare figures prominently, and that the performance of tonsillectomy will by any method demand much study and practice. On the other hand, we must concede that there is much bungling work being done to discredit legitimate tonsil surgery and that the question of how tonsils can best be removed is still an open one.

It is opportune, therefore, to emphasize the value of an operation with which you are all more or less familiar, but which, in spite of its merits, has not yet received the recognition that is bound, I believe, to place it foremost of all methods for tonsil removal.

The large percentage of unsatisfactory results following the operation on the tonsils by use of the guillotine has done much to bring discredit on this operation. When, therefore, Dr. Sluder advocated the use of this instrument, modified in certain particulars, for the operation of tonsillectomy, most of the men doing this work were not prepared to accept offhand his statement regarding the effectiveness of his operation.

The clear descriptions of the Sluder technic make it unnecessary to dwell on it here. The essence of this new idea is that the tonsil, when scooped up by the ringed margin of a fenestra in one end of a stout shaft, introduced below and behind the gland, pressing it upward and forward and outward toward the rigid alveolar eminence of the jaw, can be put entirely through this opening, especially if counter-pressure is made on the tonsil with the finger inserted in the mouth and applied to the outside of the palatoglossus. When thus put through the fenestra the gland can be quickly separated from its attachments outside the capsule by guillotine, pushed as with Dr. Sluder's instrument and

its modifications, or pulled as with the ring guillotine suggested recently by Dr. Jennings of St. Louis, or with Dr. Beck's snare or those of others, or severed by scissors or knife. One may do this operation by utilizing the ring in the handle of a strong pair of forceps and a snare.

In view of the simplicity of this method it seems strange that the guillotine was not used for tonsillectomy long ago.

I would emphasize several points of technic. First, it is essential to keep the shaft of the guillotine oblique across the buccopharyngeal cavity, with the ringed end pressed with sufficient force well below the lower extremity of the tonsil to insure the presence of the entire gland in front of the ring as it is brought upward and forward. Secondly, the importance of pushing the last vestige of the gland through the fenestra by judicious massage with the fingers is fundamental. To make sure of complete dissection—this is the key. Thirdly, the blade should not be too sharp, lest it unduly buttonhole the capsule and slice the tonsil itself. A sharp blade may be effectually blunted by taking off its edge with any metal object, care being taken that

A. M. Corwin's Improved Sluder-Ballenger guillotine.

the knife margin accurately fits the ring against which it is to be thrust. Neither should the blade be too dull, since it requires undue leverage to force it home, and it does not dissect so well. The matter of hemorrhage, as between the use of sharp or blunt dissection, is, in our experience, negligible, bleeding in any event being controlled according to indications. Fourthly, after final pressure on the blade, the lingering attachments of mucous membrane and fibrous shreds should be severed with the finger so that the guillotine comes away easily without dragging on the tissues; and it always holds the removed tonsil in its grip, necessitating no use of forceps.

As an adjunct of this method, which has become an essential part of my technic for two years, I wish to commend the routine use of a pair of tonsil hemostats, of which there are several forms on the market. This one of my own design is simple, quickly adjustable and when in place is out of the way. The patient being asleep on his back, as soon as the first gland is removed, which takes but a few seconds, one of the hemostats is applied, immediately reducing bleeding to a minimum and allowing the removal of the opposite tonsil without