

# A Procedure to Obtain the Recruitment Using Cochlear Microphonic Potentials

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**Objective:** To present an objective procedure for recruitment measure. Nowadays all recruitment methods are based on the patients' subjective responses. This procedure is based on the ratio between an increase in the cochlear microphonic potential and the increase in stimuli intensity. The system allows recruitment to be measured down to one tenth of a decibel; the precision necessary to differentiate the auditory capacity of patients.

**Method:** We used a specific technique to detect cochlear microphonic potentials. We have compared the results obtained with this new technique with those determined by the Lüscher method. We present 10 adults with no statistic aim. We first tested the physical accuracy followed by measures with laboratory animals and humans.

**Results:** We obtained a maximum deviation of 0.3 dB with respect to the patients' subjective appreciation. During the repetition of the objective measure with the same patients, we obtained identical results, whereas significant differences were observed with the repetitions in the subjective study.

**Conclusions:** The possibility of an objective measurement for recruitment opens up new perspectives for early diagnosis. This technique may be of assistance in the decision to place an implant or how to adapt a hearing aid. Through automatic volume control as well as the correct adjustment of the selective gain in frequency, we can also obtain the threshold audiometric profile simultaneously.

**Key words:** Objective audiometric method. Microphonic cochlear potentials and recruitment. Early diagnosis. Differential intensity value.

## Procedimiento para obtener el reclutamiento mediante potenciales microfónicos cocleares

**Objetivo:** Aportar un procedimiento objetivo para la obtención del factor de reclutamiento (*recruitment*). En la actualidad todos los métodos están basados en la respuesta subjetiva del paciente. La relación entre el aumento del potencial microfónico coclear (MC) y el incremento del estímulo es la base de esta aportación. El sistema permite la apreciación de décimas de decibelio, precisión necesaria para determinar el poder diferencial de amplitud auditiva en los pacientes.

**Método:** Se ha empleado un equipo específico para el estudio de los potenciales MC. Hemos comparado los resultados obtenidos con esta nueva técnica con los determinados subjetivamente por el método de Lüscher. Se presenta a 10 adultos sin propósito estadístico. Previamente se comprobó la precisión física del equipo, y luego se practicaron determinaciones en animales de experimentación y, por último, en humanos.

**Resultados:** Obtenemos mediante MC una desviación máxima de 0,3 dB respecto a la apreciación subjetiva de los pacientes. En la repetición de la prueba objetiva se obtienen idénticos resultados en el mismo paciente, mientras que en el estudio subjetivo se observan discrepancias en las repeticiones.

**Conclusiones:** La posibilidad de estudiar el reclutamiento objetivamente abre nuevas perspectivas en diagnóstico precoz y nos capacita para optar más acertadamente respecto a la colocación de un implante o la adaptación de un audífono, con un control automático de volumen correcto unido al ajuste de la ganancia selectiva en frecuencia, ya que obtenemos simultáneamente el perfil audiométrico umbral.

**Palabras clave:** Reclutamiento por método objetivo. Microfónicos cocleares y reclutamiento. Reclutamiento en diagnóstico precoz. Valor diferencial de intensidad.

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Received September 26, 2007.

Accepted for publication December 12, 2007.

## INTRODUCTION

The loss of proportionality between a sound of given physical intensity and the sensation it produces is known as recruitment. At present, determination of the differential

intensity value has been carried out by subjective evidence. The supraliminal tests aimed at detecting recruitment seek the disproportion between the objective intensity of the stimulus (dB) and the subjective intensity (sonority). These include Fowler's, Sisi's, Lüscher's, Reger's, and Jerger's tests. Another useful battery is the one formulated in 1952 by Metz, with which he found the appearance of the stapedial reflex to be near 60 dB while its normal level is between 70 and 90 dB. A narrowing of the dynamic field leads us to admit a lesser magnitude of the differential level of intensity, in other words, a reduced subjective dB, equivalent to positive recruitment. If we consider that a cochlear injury has caused hearing loss through which sounds begin to produce discomfort at lower than normal intensities, then we must admit that the auditory field has been narrowed.

Recruitment is observed in intelligibility tests which are distributed in a "bell" shape as a result of sensory saturation, where the dynamic limit decreases. It also appears in the few retrocochlear injuries, probably due to pathological interaction of efferent fibres with the cochlea. The frequent decrease in the pain threshold shows a narrowing of the hearing dynamic. With a magnitude of sound pressure <0.8 dB, patients already find differences that amount to recruitment or, if preferred, a reduction of the differential intensity threshold. In endocochlear injuries, such as acoustic trauma, we see that cochlear microphones (CM) acquire an early curvature depending on the degree of involvement.<sup>1</sup> Recruitment is evident in the large number of hearing aids that are adapted with automatic volume control in sensorineural disorders.

The sole purpose of this study is to describe for the first time an objective method for the study of recruitment and to obtain its parameters accurately. We start from the assumption that the recruitment factor lies in the sensory receptor. Under normal conditions, the outer ciliate cells bioelectrically copy faithfully the sound pressure waves in both frequency and amplitude. In presumably normal infants, with prior selection of families with no history of hearing problems and no incidents during birth, we found microphonic potentials that faithfully follow the changes in sound pressure of the stimulus, in other words, with zero recruitment.

## MATERIAL AND METHOD

We used specific instrumentation for the study of CM: the MC/07 set from Electrónica General Española. This instrumentation consists of the following parts (Figure 1) described in other works.<sup>2-6</sup>

The stimulus generator can be seen as a conventional elementary audiometer which consists of 2 controls, one for the selection of frequencies (250, 500, 1000, 2000, and 4000 Hz) and one for intensities between 30 and 120 dB. Calibration follows UNE rules for audiometers. It has a switch that activates or deactivates stimulus to the patient. In addition, this unit generates a phase-matching trigger signal for each wave of the stimulus intended for treatment of the

microphonic response so that it can be processed by the computer to produce averages that clean up the results.

### Amplification Line

This is designed to reject all disturbing signals with a frequency other than that of the stimulus. At the end of it is the CM masked by the artefacts of its same frequency. The software eliminates these by synchrony of the microphone phase marked by the trigger. In this way, it is possible to obtain the response of the outer ciliate cells cleanly, with precision of >0.1 dB in absolute frequency and amplitude. This has enabled us to establish the procedure we present to determine the differential level of intensity in patients.

### Computer Line

The computer, after cleaning up the last artefacts from the CM, processes the results and feeds them into the CM audiometric graph to create a profile that matches the subjective audiometry. It also collates the data for the presentation of the differential intensity threshold.

### Method

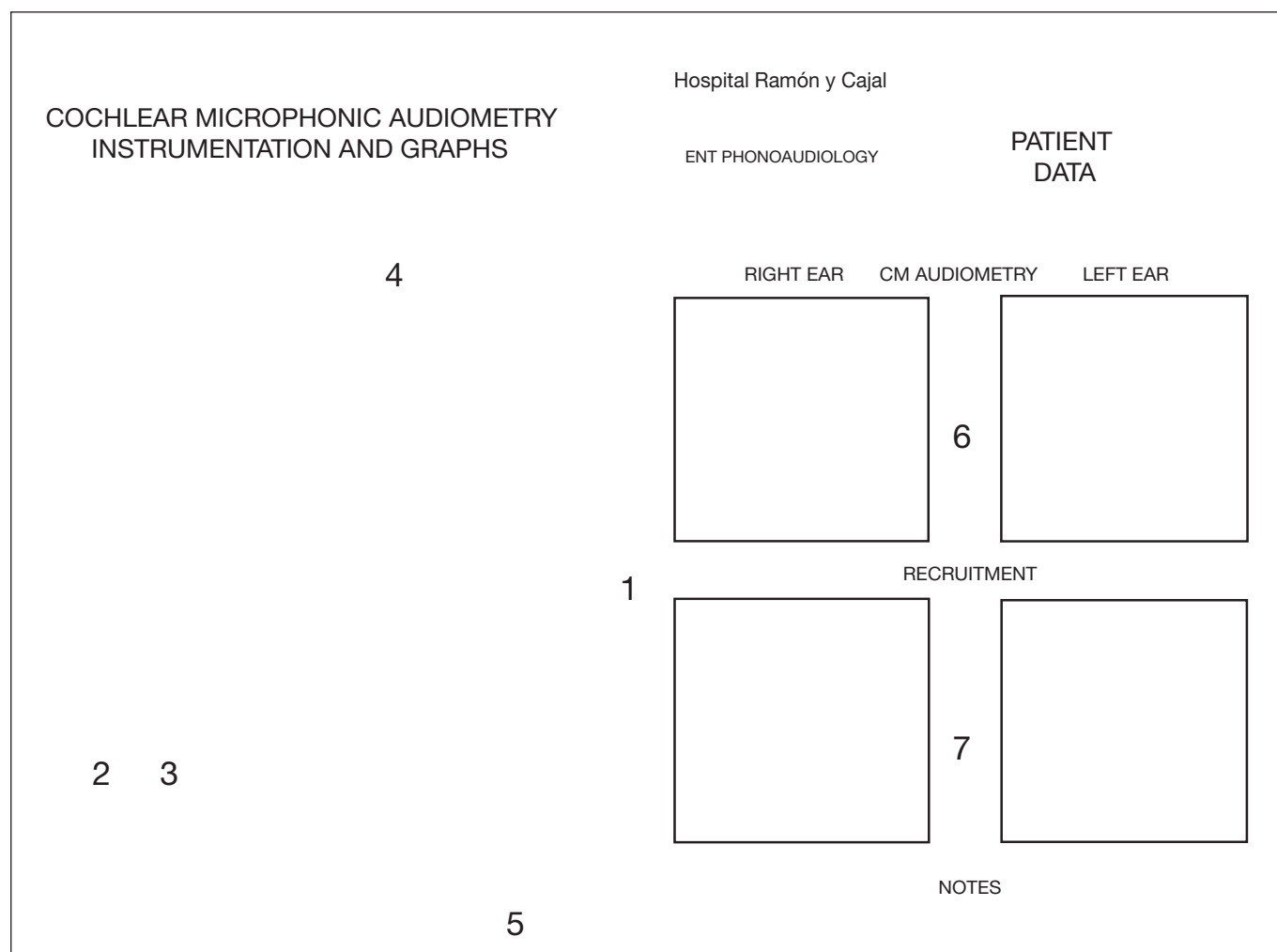
Prior to this study, the system was verified through a physical simulator of microphonic potentials and we ensured the linearity of the instrumentation. For this study, we worked with 20 pigmented rats of the Long-Evans strain, all of them bred and stored with the correct conditions for research, from the animal reserve at the Hospital Ramón y Cajal. The audiometric profile between them did not exceed differences of >3 dB and the study of CM recruitment at 1000 Hz virtually overlapped in all cases.

The stimulus from the transducer is transmitted through a tube that ends in an olive, applicable to the external auditory canal, which cannot be changed in its physical characteristics, as it would alter the level of sound pressure perceived by the patient. The placement of electrodes on both mastoids and the forehead followed the usual procedure for registering evoked auditory potentials.

With the patient prepared, we conducted a study of the existing "noise" without giving stimulus, so that the software could treat this as the zero line. Next, we generated a stimulus and observed the result on the monitor. More or less intensity was applied until a definite response was obtained. The same procedure was followed for all frequencies to complete the chart. For the study of recruitment, 2 determinations were carried out with each frequency separated by 10 dB of intensity. The same procedure was followed with the other ear.

### Foundations

Previous studies<sup>7-9</sup> confirmed that the threshold of CM response runs below and parallel to that of the subjective audiometry, that is, there is a consistently small gap between the 2 responses. Once this differential is known, we subtract it from the results obtained in the study of the CM amplitude. Thus we get, at all frequencies, a track that overlaps the conventional subjective audiometry which we call cochlear microphonic audiometry (CMA). The application of a correction gap is a normal procedure. In audiometers it is



**Figure 1.** 1: differential amplifier rejecting disturbances <250 and >4000 Hz. To the right of the image is the cochlear microphonic audiometry. 2: amplifier equipped with filters for the frequencies studied. 3: stimulus and trigger generator. 4: computer fitted with averaging card and appropriate software. 5: input of sound stimulus, at present through a tube and olive.

used to represent the current audiogram in a straight line, correcting isophonic curves, and also a quantitative correction is carried out to superimpose the bone channel on the air channel.

We run the results through the following algorithm to obtain the CMA profile:  $dB = (e - r) - \text{gap}$ , where dB is the value presented as threshold in the CMA graph, e corresponds to the stimulus applied, and r is the value of the response obtained, both in dB.

From the result, we subtract the gap established as a constant, currently 30 dB.

The following consideration is essential: the software places the audiometric threshold at the same point regardless of the intensity we apply to the patient. It is only necessary to find a definite CM response. The following example will help to clarify this fortunate peculiarity:

– We give a hypothetical patient a 60 dB stimulus at 1000 Hz and obtain a CM of 5 dB. By applying the formula described above, we obtain:  $60 - 5 - 30 = 25$  dB, the threshold value

– If this same patient is given 70 dB, ie, 10 dB more, we obtain a CM response of 15 dB, which also represents an increase of 10 dB. Applying the formula gives  $70 - 15 - 30 = 25$  dB, ie, the threshold does not change by increasing the stimulus

This is the rationale behind our paper. This is true only if the patient has zero recruitment; any deviation in the response between the 2 stimuli supplied indicates a change in the differential intensity level: positive or negative recruitment.

Therefore, to find the CM recruitment factor (CMR), another algorithm is used with the introduction of 2 separate determinations at each frequency separated by 10 dB.

Algorithm for obtaining recruitment and CMA (Figure 1):

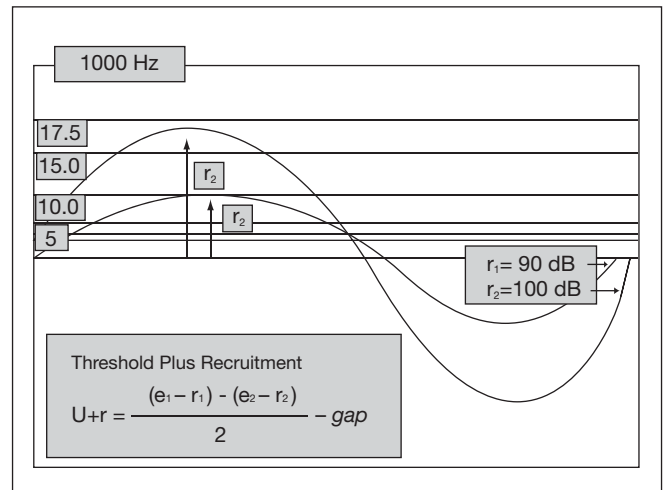
$$[(e_1 - r_1) + (e_2 - r_2)] / 2 - \text{gap}$$

where  $e_1$  and  $r_1$  are the results of the first determination while  $e_2$  and  $r_2$  correspond to a stimulus and response that are 10 dB greater between the 2 tests carried out one after the other.

We present the results of 5 collaborators with normal hearing from our department and another 5 patients with evident subjective recruitment. No statistical confirmation is intended; our intention is only to show the results as originally obtained. We studied the recruitment only at 1000 Hz. The reason for this restriction is that, at this frequency, measurements in dB are equivalent to those of sonority in phon units, and therefore there is no need to introduce any differential correction for each frequency, which may be necessary in the future if the study is carried out with absolute scientific rigour using higher or lower frequency values. The wide variety of factors involved in the differential power of intensity for each frequency and sound pressure level compels us to present in this work only the methodology reached, leaving the statistical studies and implementation for future contributions.

## RESULTS

We present data from a patient whose results correspond to 2 CM responses obtained at 1000 Hz with stimuli at 90 Hz and 100 dB, respectively (Figure 2). The differential result between the 2 is 7 dB, so they differ by 3 dB with respect to the added stimulus, which was 10 dB. We see that the response has been "compressed," so the value of recruitment is  $7/10=0.7$ . Regardless of the above example, the recruitment CM for all frequencies without taking into account future correction is represented in the chart (Figure 1), under the CMA. The normality margins according to Lüscher, ie, between 0.8 and 1.5 dB, have been added in the top right section. For the future, there is the possibility of extending the study rigorously to all audiometric frequencies, determining the relationship with respect to isophonic curves and seeking clinical applications.

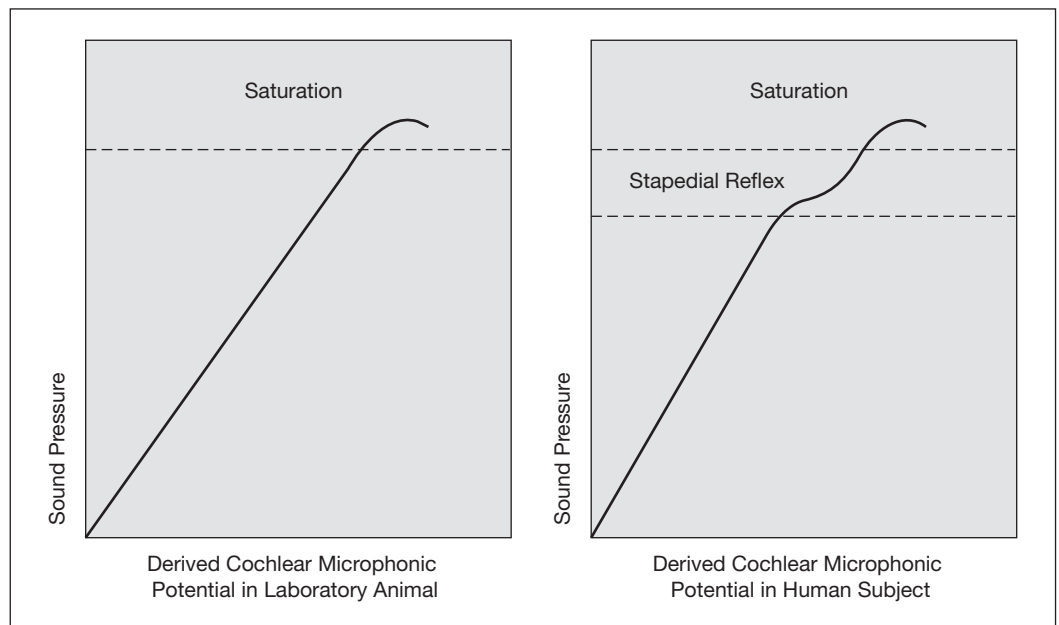


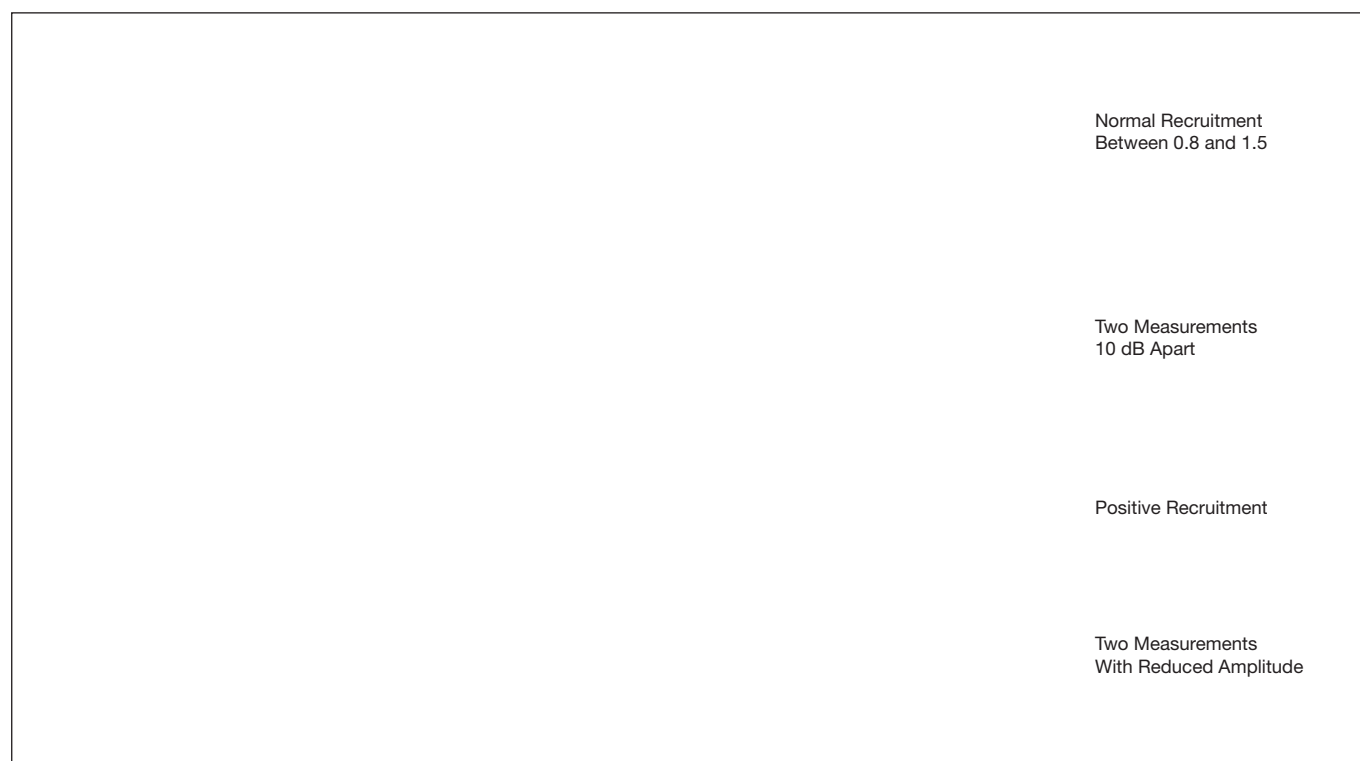
**Figure 2.** Two cochlear microphonic responses corresponding to 2 stimuli of 90 and 100 dB respectively. They differ by 7 dB. This algorithm determines the recruitment and audiometric trace.

The curves in Figure 3 correspond to the linear growth of the CM in terms of sound pressure until saturation. The study was conducted in guinea pigs that do not present any stapedial reflex as their ossicular chain consists of a columella starting at the eardrum and ending at the stapes without a tensor muscle. We also confirmed that in humans the increase is linear until the, very imprecise, appearance of the stapedial reflex and then until saturation. We do not always find a reasonable correlation between the data of subjective recruitment and those obtained by this objective procedure.

In Figure 4, we give an example of another form of representation: primary CM response with deduction of the recruitment factor. Any differences, which we leave for the

**Figure 3.** Growth behaviour of the cochlear microphonic potential depending on the stimulus. The stapedial reflex can be observed in the human subject, but this alteration cannot be seen in the isophonic curves, and finally saturation is reached. In the guinea pig, the response is linear for the reasons given in the text.





**Figure 4.** Sample presentations of 5 normal responses for primary cochlear microphonic potentials and the corresponding deduction for the recruitment factor. Five are within the normal range and the other 5 show recruitment.

statistical study, are attributed mostly to the difficulty of subjective response by the patient and audiometrist. Since it is sometimes difficult for the patients to determine with certainty their hearing threshold with a 5 dB separation on the audiometers, we can imagine the difficulty in perceiving tenths of a decibel in the recruitment study.

## DISCUSSION

There is a notable discrepancy in our work with regard to the normally accepted isophonic curves. No alteration in the path is seen at the frequency of 1000 Hz, which precisely matches equal increments even for stimuli that correspond to the emergence of the stapedial reflex. This can be attributed to the variability of sound pressure necessary to cause muscle contraction in the stapes, which masks the statistical result that led to the establishment of the isophonic curves, and also the price for the convenience of having a reasonable frequency for central reference.

The accuracy of the system to differentiate tenths of a decibel is possible thanks to the fact that software linearly analyzes the CM response, which comes from a logarithmic stimulus. The logarithmic scale in decibels goes in 130 increments of 1 dB each from the sensory threshold to the painful level, reflecting a linear increase in micropascals of sound pressure between 20 (hearing threshold) and 100 000 000  $\mu\text{Pa}$  (corresponding to the pain threshold).

The study of recruitment requires special care. Results must be checked by repetition. We have shifted from the widespread denial of the possibility of obtaining microphonic potentials in man by humane procedures to the graphic determination of the audiometric profile threshold and its appreciation in tenths of a decibel for the study of recruitment.

Like any new technique, it will require on-going studies to establish its usefulness and limitations.

## CONCLUSION

We report the first objective method for determining recruitment.

The combination of the audiometric curve (CMA) and the CMR study provides valuable data to decide more precisely on the implementation of a cochlear implant or adapting a hearing aid and, where appropriate, adjust characteristics such as band pass or automatic volume control.

The discrepancy already pointed out regarding the lack of correspondence in the levels of isophonic lines before the advent of stapedial reflex leads us to consider the inaccuracy of the subjective methods used in the course of these statistics, and the acceptance of inaccurate results, but with undeniable usefulness both clinically and physically. The method we propose offers accuracy and a broad spectrum of new possibilities, which we will try to analyze in future and which we now put within reach of other researchers.

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