Some stapedius reflex parameters in normal and pathological conditions

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It is widely recognized that the introduction into routine audiology of methods for recording intratympanic muscle contractions, as changes in acoustic impedance of the middle ear, has become of great and irreplaceable value in providing differential diagnostic information of some hearing impairments (Klockhoff, 1961; Zwislocki, 1963; Liden, 1969; Anderson *et al.*, 1970; Jerger, 1970).

The need for a precise and accurate recording, for clinical purposes, of relative dynamic changes in acoustic impedance has induced us to build an 'impedance adaptor' which allows the connection of both the pressure and compliance out-puts of the Madsen zo 70 electro-acoustic bridge to a two-channel electronystagmographic apparatus (Babighian and Colletti, in press). (Please refer to the quoted paper for technical details.) Here we call attention to the fact that, in order to obtain a more discriminative evaluation of the dynamic parameters of the middle ear muscle reflexes, we use a higher sensitivity than in the one usually adopted in recording pressure-compliance function.

This practical and sensitive recording system has given us the opportunity to perform a series of studies on the behaviour of the stapedius reflex in normal and pathological conditions, without limiting our evaluation to the assessment of the stapedius threshold, but trying to define other parameters such as: latency time; rise time; amplitude; adaptation; and difference limen of intensity of the reflex.

This paper is meant to be a preliminary report of some results of our research. In order to define the clinico-diagnostic possibilities of our methodology, we have focused our attention on normally hearing subjects and on a few known cochlear and retrocochlear pathological conditions, i.e. patients with Ménière's disease, with cochlear hydrops, and patients suffering from multiple sclerosis.

It is known, in fact, from comparative clinico-pathological studies (Dix, 1965) that, while in Ménière's disease the pathological process involves mainly the hair cells of Corti's organ, in multiple sclerosis, (due to the anatomo-pathological peculiarities of the disease) the lesions of the auditory system, when present, are strictly retrocochlear, as histopathologically demonstrated by Leidler (1917) and by Ward *et al.* (1965).

It thus seemed worthwhile to attempt an evaluation of these two

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opposite and definite pathological conditions from the particular point of view of the stapedius reflex parameters, in order to determine whether this methodology can predict a particular type or localization of the lesion.

Subjects and procedures

Three groups of subjects were submitted to our test procedures. The first group consisted of sixteen healthy subjects selected mostly from medical students. They all had normal hearing and denied progressive and/or actual otological pathology. The age ranged from 16 to 32 years.

The second group consisted of thirty-six patients varying in age from 24 to 58 years; twenty-four of them were suffering from Ménière's disease with typical symptomatology (recurrent episodes of vertigo, clearly associated with fluctuating sensorineural hearing loss and tinnitus), and twelve presented audiological signs of 'cochlear hydrops' without vestibular symptoms. The evaluation of audiometric findings (A.B.L.B., S.I.S.I. test, T.D.T.) clearly indicated this type of cochlear involvement. All patients had normal roentgenograms of the internal auditory meati and negative neurological examination. The patients were studied during their stay at our E.N.T. Department where they had been admitted for treatment of the deafness.

The third group consisted of thirteen patients suffering from multiple sclerosis admitted at the 2nd Neurological Department of the University of Padua, in Verona. In these patients, the main localization at the brain stem had been confirmed, prior to our test, by a complete neurological study and by the typical findings of vestibular examination.

In order to avoid false findings, always possible in the presence of even small alterations of the tympano-ossicular system, only patients with normal middle ear pressure and mobility of the ear drum and middle ear function, as revealed by tympanometry, cuti-stapedius and tensor tympani reflex were accepted for investigation.

All the subjects have undergone the following measurements of the stapedius parameters for frequencies at 500, 1000, 2000, and 4000 Hz.:

1—*reflex threshold:* both ascending and descending stimuli.

2—*reflex amplitude:* performed at 10 dB SL (refer to the reflex threshold).

3—*reflex decay:* performed at 10 dB SL (refer to the reflex threshold and lasting 10 seconds).

4—*difference limen of intensity of the reflex (D.L.I. of the reflex):* performed by superimposing a modulated tone of decreasing intensity from 5 to 0·25 dB with a periodicity of 1 c/sec., on the carrier tone (+10 dB SL) eliciting the reflex.

As already mentioned, the basic apparatus consists mainly in a Madsen zo 70 electroacoustic impedance bridge connected by an impedance

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adaptor to an electronystagmographic apparatus. The sound eliciting the stapedius reflex was delivered in the controlateral ear by an Amplifon 300 audiometer.

Results and discussion

The data collected from our study are schematically presented in Table I. The patients of each group are listed according to the extent of

TABLE I.

Group of patients	Stapedius reflex parameters		
	Threshold	Decay	D.L.I.
I.—Normally hearing subj. (16) 32 ears	— (29) + (3)	— (32)	— (32) + (2)
II.—Cochlear hydrops subj. (12) 5 mild H. loss	— (5)	— (5)	— (3) ⊖ (2)
7 moderate H. loss	— (5) + (2)	— (7)	— (3) ⊖ (4)
—Ménière's disease subj. (24) 8 mild H. loss	— (7) + (1)	— (8)	— (5) ⊖ (3)
9 moderate H. loss	— (6) + (3)	— (9)	— (5) ⊖ (4)
7 moderately severe H. loss	— (2) + (3) ++ (2)	— (6) + (1)	— (3) ⊖ (2) + (2)
III.—Multiple sclerosis subj. (13) 5 normally hearing	— (4) + (1)	— (5)	— (4) + (1)
4 mild H. loss at 4–8 KHz.	+ (1) ++ (1) +++ (2)	+ (2) not performable	— (1) + (1)
2 moderate H. loss	+++ (2)	+ (2)	+ (2)
2 moderately severe H. loss	absent	not performable	

LEGEND:

Threshold Values		*Decay* Values		*D.L.I.* Ampl. mod.	
normal	(75–95 dB) = —	normal	= —	1–0, 85 dB	= —
pathological	(95–105 dB) = +	pathological	= +	0,85–0,50	= ⊖
,,	(105–115 dB) = ++	(4 to 7 sec.)		3–1	= +
,,	(115–125 dB) = +++				

the hearing loss based on the 1964 I.S.O. reference. The Table shows the parameters concerning the threshold, the decay and the D.L.I. of the stapedius reflex. Only mean values of 500 and 1000 Hz. are considered in the Table.

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Stapedius reflex parameters

It is generally agreed (Metz, 1952; Jepsen, 1963; Anderson and Wedenberg, 1968; Peterson and Liden, 1972) that the stapedius reflex threshold for pure tones in normally hearing subjects lies between 75 and 95 dB for frequencies from 250 to 4000 Hz., with an average value around 85 dB HL. The most sensitive threshold, according to Peterson and Lidén (1972), is found by using a 220 Hz. probe tone rather than a 625 or 800 Hz one. It is likewise known that the amplitude of the reflex contraction, in normal ears, increases progressively with increasing acoustic stimulation. Data collected from our previous research (Colletti, 1972*a*) by means of a 220 Hz. probe tone in a group of 32 normal ears agree with the statements of the authors cited above. Moreover, our findings allowed us to assert that at 10 dB SL (refer to the reflex threshold) the stapedius is in partial contraction and this is the best level for testing variations in its tonicity, while at about 20 dB SL the maximal contraction related to sound intensity is reached (Fig.1).

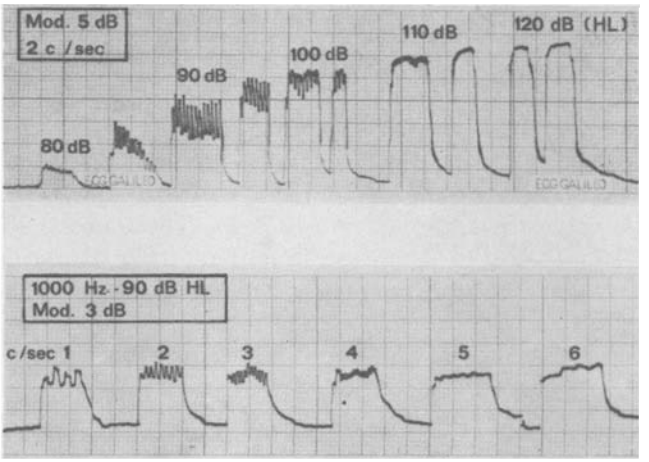


FIG. 1.

Upper track: assessment of the best *carrier tone* intensity for evoking variations of stapedius contraction in a normal ear. The periodicity (2 c/sec.) and the modulated tone (5 dB) are kept constant while the carrier tone intensity is increased in 5 dB steps from reflex threshold.

Lower track: assessment of the best *periodicity* (c/sec.) for evoking variations of stapedius contractions. The carrier tone intensity (90 dB HL = 10 dB above reflex threshold) is kept constant as well as the intensity of the modulated tone (3 dB).

In the patients with cochlear lesions the reflex threshold was found to be within normal limits in twenty-five subjects. In eleven cases the threshold was pathologically elevated: in nine patients oscillating from 95 to 105 dB, in two from 105 to 115 dB.

In the group of patients suffering from multiple sclerosis, four normally hearing subjects presented reflex thresholds at normal values. One patient,

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despite a normal hearing threshold, showed a pathological reflex threshold. In six cases, with mild hearing loss mainly at high frequencies, the stapedius reflex threshold was pathologically elevated for each frequency examined. Temporary absence of the acoustic reflex has been encountered in two patients who had developed, in a few days, a sensorineural hearing loss averaging 50–60 dB and mainly affecting high frequencies; subsequent audiological investigation made it possible to demonstrate the appearance of the reflex even though at clearly pathologically elevated levels. This could be observed only from 30 to 60 days after complete recovery of the hearing threshold. Besides, peculiar alterations of the reflex rise time were noted in both cases. Detailed descriptions of the audiological patterns of these patients can be found in case reports published elsewhere (Colletti, 1972*b*, 1973).

Now, evidence has been furnished from several studies that loudness recruitment is present in a hypoacusic ear when the stapedius reflex can be elicited at the same sound level as in normal ears, or, in more general terms, when the normal gap (60–70 dB) between pure tone and reflex thresholds is decreased (Kristensen and Jepsen, 1952; Metz, 1952; Thomsen, 1955; Djupesland *et al.*, 1967; Lidén, 1970.)

The results of our study indicate that in 69·4 per cent of the cochlear lesion group the threshold of the reflex is within normal values, while in the remaining 30·6 per cent it occurs at pathological levels. In all cases the gap between the stapedius and pure tone threshold was lower than 60 dB (between 20 and 55 dB). Hence these data indicate a rather good agreement between psychoacoustic recruitment tests and the METZ test in cochlear end-organ lesions. They confirm the experiences of the authors quoted above, that a narrowing of the gap between reflex and pure tone threshold is indicative of cochlear disease.

Quite different results were obtained in multiple sclerosis: only 30 per cent of the cases showed a stapedius reflex threshold within normal values, while in 70 per cent the threshold was at pathological levels, with a gap between reflex and pure tone threshold which varied from 75 to 105 dB. Our findings clearly show that in 70 per cent of the patients the loudness function is altered, and, more precisely, that in 40 per cent loudness recruitment is absent and in 30 per cent a particular phenomenon called 'loudness reversal' (Dix, 1965) is observable. Such pathological conditions of the stapedius reflex can therefore be regarded as expressions of retrocochlear lesions due to the disease process of multiple sclerosis.

The conclusion that can thus be drawn from this study of the stapedius threshold, in these two different and opposite pathological conditions, is that the reflex seems to be related to loudness function rather than to intensity of the acoustic stimulation. In these terms, it seems possible to diagnose, in an objective way, the presence of a disorder of the loudness

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function, whether it be in the absence or presence of loudness recruitment and whether in the presence of loudness reversal.

Pathological reflex decay

Djupesland *et al.* (1967) and Johansson *et al.* (1967) have demonstrated that, while physiological decay is observable rather soon at high frequences, this does not occur at 500 and 1000 Hz. Anderson *et al.* (1970) have introduced, and emphasized the value of studying, reflex decay in the differential audiological diagnosis of sensorineural hearing impairments. The above authors suggest that the phenomenon of reflex decay be defined as the time in seconds for the response amplitude to be reduced by 50 per cent; a reflex decay is thus classified as pathological when the half-life of the response amplitude is below 5 seconds, on stimulation with 500 and 1000 Hz.

The results obtained in our groups of subjects, following the methodology suggested by Anderson *et al.* (1970), reveal pathological decay in only five out of sixty-three subjects examined. Four of them, suffering from multiple sclerosis, had a hearing loss varying from mild to moderate. One patient suffering from Ménière's disease presented a hearing impairment averaging 70–80 dB. It must be mentioned that in four cases of multiple sclerosis it was not possible to perform such an investigation due to an abnormally small reflex amplitude. None of the remaining subjects with normal hearing, cochlear lesions and multiple sclerosis demonstrated any measurable alteration of the reflex decay. In the five patients with pathological decay the halving time of the reflex fluctuated between 4 and 7 seconds (Fig. 2). Even if some of these values are longer than the ones reported by Anderson *et al.* (1970) in their cases of acoustic tumours,

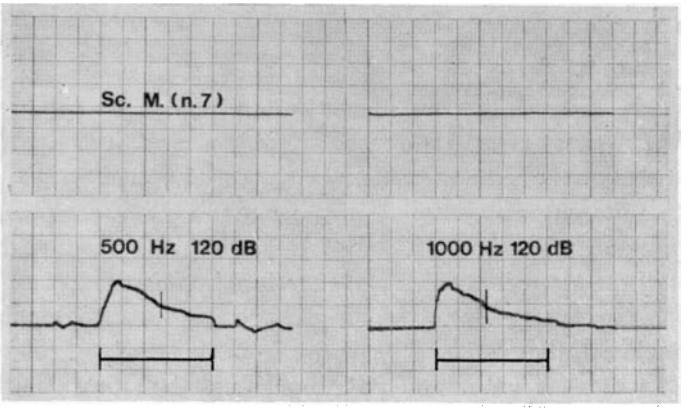


FIG. 2.

Recording of the *stapedius reflex decay* at 500 and 1000 Hz. in a patient (n. 7) suffering from multiple sclerosis. The halving time of the reflex is in the order of 5·5 and 4·5 seconds respectively.

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nevertheless, we think that in patients suffering from multiple sclerosis they can be interpreted as the result of a retrocochlear lesion due to the disease process. The possible existence of typical alterations in multiple sclerosis involving the root of the VIIIth nerve has been demonstrated histopathologically as well (Ward *et al.*, 1965).

Concerning the only case of reflex decay encountered in the patients suffering from Ménière's disease, it must be mentioned that he had normal roentgenograms of the internal auditory meatus and a normal corneal reflex, and that neither neurological nor vestibular examination provided evidence of an acoustic cerebellopontine angle tumour. The finding of a pathological reflex decay in a severe hearing impairment must not, according to Anderson *et al.* (1970), necessarily lead to suspicion of an expansive process, but should rather be considered as a result of retrograde degenerative process due to severe damage to the hair cells. A particular pattern of the stapedius reflex has been encountered in three patients suffering from multiple sclerosis: namely, a pathological rise time (Fig. 3). As is known, in routine clinical techniques, the rise time of the reflex is not evaluated; and, as far as our own experience is concerned, in normally

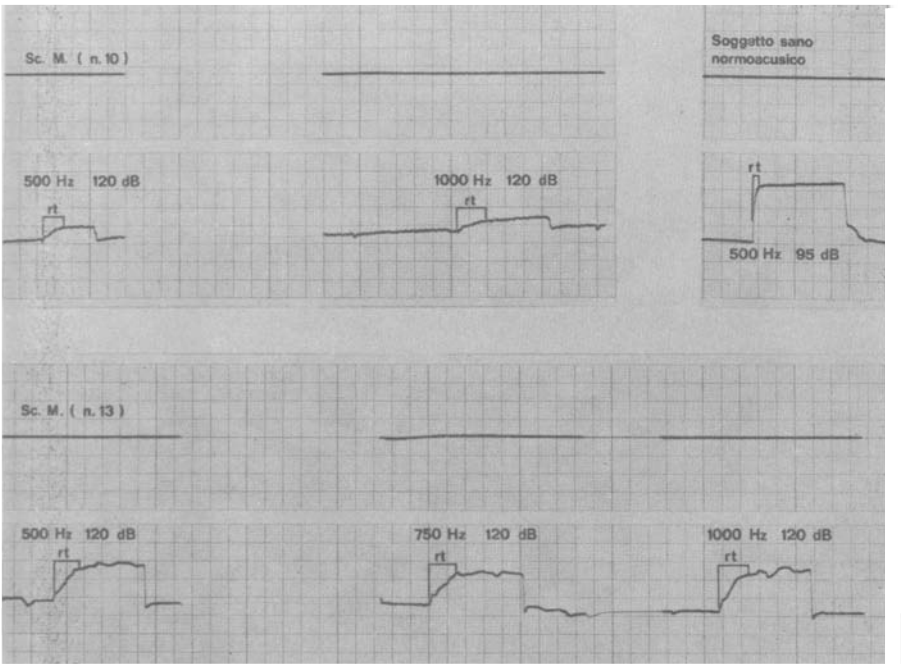


FIG. 3.

Recording of *pathological reflex rise time* in patients (n. 10 and n. 13) suffering from multiple sclerosis. The rise time of the reflex practically negligible in normal ears (see upper right track) is oscillating from 2 to 3 seconds at the examined frequencies.

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hearing subjects and in patients with cochlear lesion it is practically negligible. Therefore, the finding of a rise time lasting from 2 to 3 seconds seems rather remarkable for its theoretical implications. We are still studying this aspect in correlation with other research endeavouring to determine the latency of the reflex. Though it is difficult to formulate a possible clue as to the mechanism underlying this particular aspect, we think that the site of the causative disease process can be regarded at the level of the polysynaptic circuits of the reflex in the brain stem.

Difference limen of intensity of the stapedius reflex

In a previous paper we have described the patho-physiological data of the method we use to assess the difference limen of intensity of the stapedius reflex (Colletti, 1972*a*). The test is performed by superimposing a modulated tone (with a periodicity of 1 c./sec. with decreasing intensity from 5 to 0·25 dB), on to the carrier tone (+ 10 dB) eliciting the reflex. The reasons which induced us to standardize the methodology as mentioned, can be summarized as follows:

1. The optimal intensity of the carrier tone eliciting a stapedius reflex capable of delivering a modulated contraction lies around 10 dB above the stapedius threshold. As shown in Figure 1 (upper track) at higher or lower intensities the modulated contraction, even if present, is minimal. This leads us to think that, at intensities lower than 10 dB, the stapedius is in partial contraction which does not permit wide variations of the muscular tonicity induced by the modulated tone. At intensities over 10 dB, it may be assumed that the maximal contraction of the stapedius induced by the carrier tone, produces a similar tetanic muscular situation which does not allow further variations of the contraction, at least with the apparatus at our disposal.
2. The periodicity of the modulated tone which we adopted for our routine clinical investigation is 1 c./sec. Figure 1 (lower track) shows that it is possible anyway to record a modulated reflex even for 2–3–4 c./sec. Over 5 c./sec. a linear track is obtained.

The results of the test, performed in the three groups of subjects, are as follows:

In fourteen out of sixteen normal subjects the difference limen of intensity (D.L.I.) of the stapedius reflex lay between 1 and 0·85 dB modulation amplitude, while in the remaining two subjects it was found at 2 dB.

In the group of cochlear lesions, fifteen patients presented a D.L.I. between 0·85 and 0·50 dB; only two subjects had a D.L.I. between 3 and 1 dB modulation amplitude, while the remaining cases revealed a D.L.I. within normal limits. Let us remember that all the patients of this group were selected from a wide group of patients with cochlear

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lesions on the basis of complete and uniform positive recruitment tests.

The patients with multiple sclerosis displayed different results, the difference limen of intensity being never found at modulation amplitudes lower than 0·85 dB; in five patients the D.L.I. of the reflex ranged within normal values; in four cases the D.L.I. was at 3 dB modulation amplitude; in the remaining patients the test could not be performed owing to an abnormally small reflex amplitude.

As known, the assessment of the difference limen of intensity is broadly used in audiometry in order to obtain differential diagnostic clues in auditory disorders. Leaving apart, intentionally, any discussion on the relationship between small D.L.s and the presence of loudness recruitment,

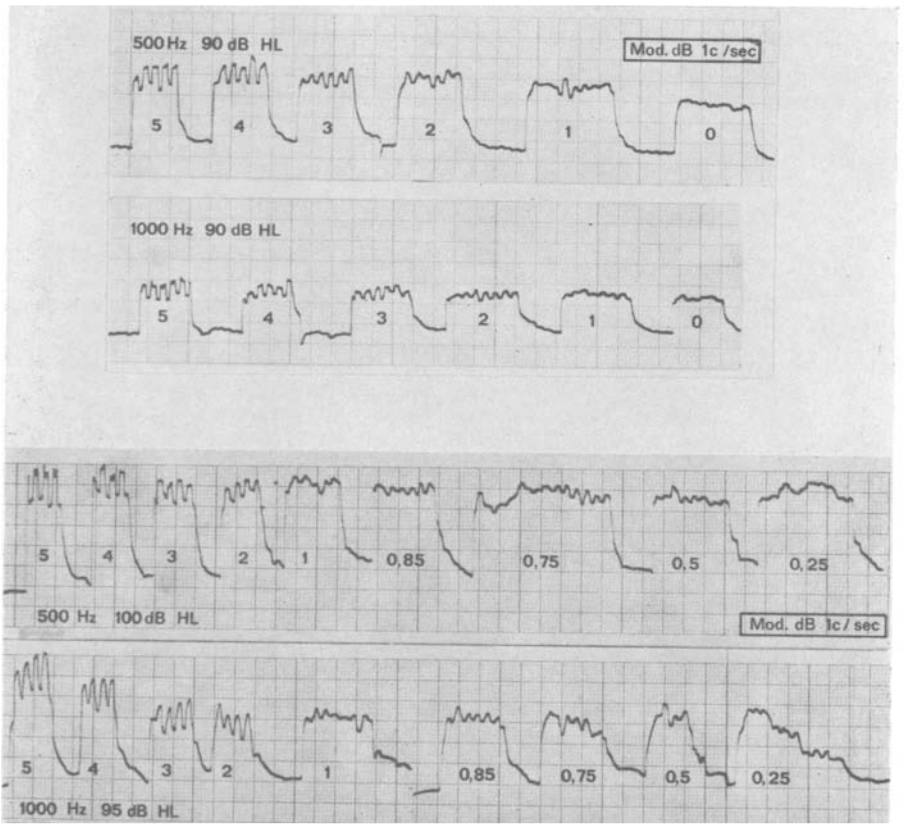


FIG. 4.

Assessment of the *difference limen of intensity of the stapedius reflex* (D.L.I. of the reflex) in a normally hearing subject (upper tracks) and in a sensorineural hearing loss of cochlear origin (lower tracks) at 500 and 1000 Hz.

The *D.L.I. of the reflex* is found at 1 dB modulation amplitude for both frequencies in the normal subject while at 0·5 and 0·25 modulation amplitude respectively in the cochlear lesion subject.

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we should like to underline that our methodology, exceeding some of the limitations connected with the assessment of the D.L.I. in clinical psychoacoustic tests (state of attention, influence of guessing, rhythm effects etc.) may assess the D.L.I. of the reflex in a rapid, accurate and objective way (Figs. 4 and 5).

In this connection, two observations seem to be of a certain value: firstly, only 42 per cent of the patients with cochlear lesions showed reflex D.L.s clearly inferior of the normal values; and secondly, only 38 per cent of the patients suffering from multiple sclerosis presented D.L.I. values within normal limits. Furthermore, 30 per cent of this latter group revealed a threshold value of 3 dB modulation amplitude. These abnormally high values of the D.L.I. revealable by means of the stapedius reflex seem rather remarkable both for their theoretical and practical implications. They recall the phenomenon of 'decruitment' which, according to Simmons and Dixon (1966) and to Tillman (1969), may well be a part of the symptomatology of retrocochlear or VIIIth nerve pathology.

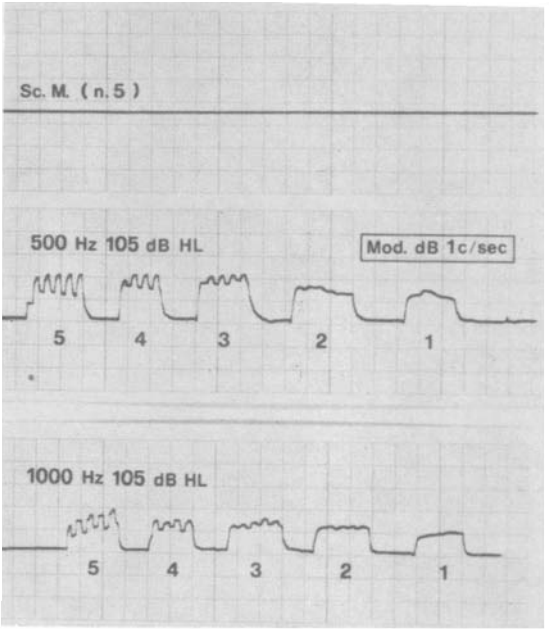


FIG. 5.

Difference limen of intensity of the stapedius reflex at 500 and 1000 Hz. in a patient (n. 5) suffering from multiple sclerosis.
The D.L.I. of the reflex is found at 3 dB modulation amplitude for both frequencies. (RECRUITMENT.)

Summary

In the present paper we have presented the results of an analysis of some stapedius reflex parameters in a few known pathological conditions

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of cochlear and retrocochlear sites. The number of patients examined is too small to allow definite conclusions; nevertheless, we think that a complete and accurate analysis of the stapedius reflex parameters can furnish a valid contribution to routine audiological tests in order to define disorders of loudness function and adaptation and thus offer valuable, objective information on the site of a lesion affecting the auditory system.

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