COMPARISON OF PROMONTORY STIMULATION TEST RESULTS BETWEEN DIFFERENT SUBSETS OF PATIENTS WITH HEARING LOSS: A NEW APPROACH IN NEUROTOLOGIC DIAGNOSIS

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Abstract - *Promontory stimulation testing is both a valuable diagnostic tool and a crucial step in candidate selection for cochlear implantation. In this study we have compared the promontory stimulation test results between different subsets of patients with hearing loss in order to clarify the aspects of promontory stimulation which correlate best with the patients'characteristics. Patients with severe to profound hearing loss underwent Promontory Stimulation as well as a number of other diagnostic tests. One hundred and eighty eight ears comprised the study population and were grouped into congenital, non-congenital, cochlear, retrocochlear, sudden, and progressive hearing loss groups. The congenital group (CG) (n=36) had lower hearing thresholds and greater dynamic ranges than the non-congenital group (NG) (n=71). Gap detection and temporal difference limen results were also significantly better in this group. The cochlear group (CO) (n=15) had better hearing thresholds than retrocochlear (RC) (n=20). The sudden-onset (SN) (n=14) group had worse dynamic ranges as compared to progressive group (PR) (n=22) but did better on gap detection and temporal difference limen. Dynamic ranges decreased with age in all groups.*

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Key words: Promontory stimulation, hearing loss, congenital, cochlear, retrocochlear

INTRODUCTION

Promontory stimulation testing (PS) is accepted as a routine part of candidate selection for cochlear implantation in many centers (1 - 4) since a good estimate of neuron survival can be made using this test (11). Thus it could be predicted with an acceptable confidence, whether the candidate would be able to experience hearing with electrical stimulation (3, 5). Subjective tests such as hearing thresholds, and dynamic range of hearing verify that some response will be elicited by the prosthesis. Cochlear implantation is not recommended for the patients with poor results on this test (3, 5) especially on gap detection and temporal difference limen discrimination (3) although false negative results have been reported (6, 7). The nature of the correlation between PS test results and number of surviving neurons is not quite clear but has made this test a valuable predictor of prognosis since 1970's (3, 7, 8). Determination of the exact site of the lesion in a deaf ear is a diagnostic obstacle and will lead to expensive and complicated procedures such as computerized tomography (CT) scan or sometimes MRI(9). PS is a relatively inexpensive and uncomplicated test which heralds better results in neurotologic diagnosis (9, 10). In this study we have tried to determine which aspects of PS best correlate with known lesions of the auditory pathway or other known characteristics of patients.

MATERIALS AND METHODS

This study was carried out on 139 patients referred for evaluation for profound hearing loss. Etiology of deafness was determined on history, physical examination, audiologic tests, diferent imaging techniques and surgery. Also PS was carried out for all of the patients. It should be noted that throughout this study each ear was considered one subject and if both ears of a patient were tested he or she was considered as two subjects. The nucleus promontory stimulator (model Z 10012, Cochlear Corporation, Melbourne Australia) was used for all testings. The electrical stimulus was delivered transtympanically with a blunt needle onto the promontory after attaining anesthesia of tympanic membrane. The stimulator delivers an electrically isolated constant current square wave stimulus that can vary in amplitude from 0 μA to 500 μA. The square wave could be varied in discrete frequency steps from 50 Hz to 1600 Hz. Patients were instructed about different steps of the test. PS consisted of three different tests. In the first test the dynamic range was evaluated. The purpose of this test was to determine whether a patient will obtain auditory sensations from electrical stimulation and if there will be growth in perceptual loudness as stimulus current is increased. In order to determine the dynamic range, hearing thresholds and maximum acceptable levels (MAL) were established for each tested frequency (i.e, 50, 100, 200, 400, 800 and 1600 Hz). The dynamic range (DYN) was calculated as the difference between threshold and MAL. No attempts were made to establish the threshold with higher amplitudes if a patient experienced pain before obtaining a hearing threshold. Second test, Gap detection (GAP), was performed to assess the temporal processing ability of the subject by determining the point at which the patient could no longer reliably detect a gap between two signals. This was done by presenting two signals at the aforementioned frequencies at MAL. The gap intervals started at 250 ms and were decreased by 50 ms decrements to 50 ms and then down to 10 ms by 10 ms decrements. Temporal difference limen test (TDL) was the third test. The point at which the patient could no longer reliably identify the longer of the two stimuli of different duration, was determined by this test.

Statistical analyses were performed using statistical software SPSS/PC+ (ver 5.1). T-test, and Mann-Whitney U test were used in addition to descriptive measures for comparing group differences as convenient. A confidence interval of 95% was selected and $p<0.05$ was considered significant in all testings.

RESULTS

One hundred and thirty nine patients comprised the study population and 188 ears were studied on the whole as both ears of some patients were tested. Exclusion criteria were as follows: undetermined type of hearing loss, central hearing loss (HFHL and LFHL), hearing loss due to trauma, infection or ototoxic drugs, tinnitus (as the chief complaint), conductive hearing loss and stimulation of the round window instead of the promontory. One hundred and seven ears, were included in the study. PS did not result in any complications in any of the subjects. Some characteristics of the study population are presented in

Table 1. Some of the study population characteristics (Only cases with valid values were included)

	Mean±SD	Min	Max
Age	28.33±15.4	1	69
TH at 200 Hz	187.82±163.31	32	888
MAL at 200 Hz	325.90±248.35	60	960
DYN at 200 Hz	169.26±163.36	10	929
GAP at 200 Hz	228.95±58.46	50	250
TDL at 200 Hz	239.71±41.63	50	250

Table 2. Education level

	No	Percent
Illiterate	1	1.9%
Elementary	17	32.7%
Less than high school	10	19.2%
High school	13	25%
University	11	21.2%

Table 3. Perception of stimulus

	No	percent
Sound	52	70.3%
Pain	16	21.6%
Other	6	8.1%

Table 4. Primary Diagnosis

	No	Percent
Neurinoma	9	8.4%
Meningioma	4	3.7%
Retrocochlear hearing loss	2	1.9%
Cochlear hearing loss	5	4.7%
Meniere's disease	15	14.0%
Progressive hearing loss	22	20.6%
Sudden hearing loss	14	13.1%
Congenital hearing loss	36	33.6%

Table 5. Study groups

	No	Percent
Retrocochlear hearing loss	15	14.0%
Cochlear hearing loss (CO)	20	18.7%
Progressive hearing loss (PR)	22	20.6%
Sudden hearing loss (SN)	14	13.1%
Congenital hearing loss(CG)	36	33.6%
Non-congenital hearing loss(NC)§	71	66.4%

§ This group includes all the first four groups

tables 1 to 4. Figure 1 represents the type of response to stimulus while obtaining thresholds for different frequencies. As shown in table 5, subjects were divided into five groups according to the nature of their hearing loss: retrocochlear (RC), cochlear (CO), progressive (PR),sudden (SN) and congenital (CG) hearing loss. The first four groups comprised the non congenital hearing loss group (NC) together.

We performed four consecutive analyses to compare test results between different sets of subjects.

First analysis

In this step subjects were grouped into CG (n=36) and NC (n = 71).

Threshold, MAL and DYN: Hearing thresholds were lower in the CG group in low freqencies. As the frequency increased this difference decreased and was reversed at 800 Hz (Fig. 2). MAL did not show any significant difference across groups but tended to be lower in low frequencies and higher in high frequencies in the CG group than the NC group (Fig. 3). DYN showed the same trend as the hearing thresholds. It should be noted that all the means presented in figures 2 and 3 reflect the cases in which a threshold was obtainable. Fig. 4 compares the percent of subjects in whom a hearing threshold could be established between the two groups. This data shows that hearing thresholds were obtainable more frequently in the CG than the NC group.

Gap detection: We compared the percent of subjects in each groups in whom no GAP could be detected at first. There were fewer subjects with no GAP in the CG group as compared to the NC group. This difference increased with frequency and reached a significant level at 800 Hz (2 tailedp=0.0073 for 1600 Hz, Fig. 5). Mean GAP of the two groups were

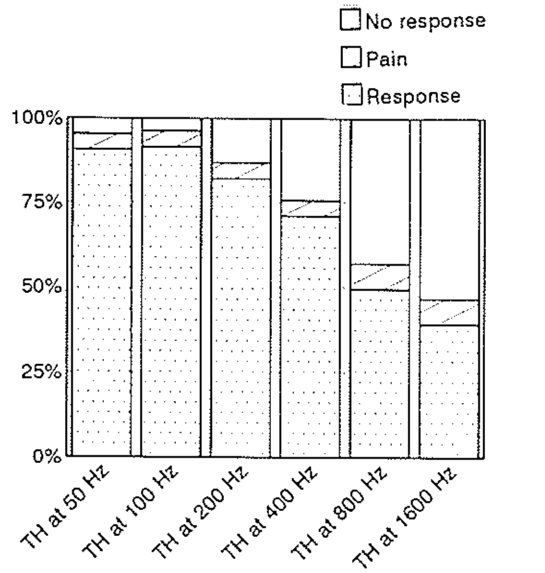
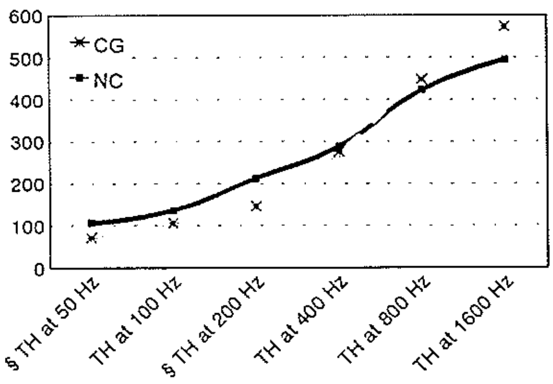


Fig. 1. Stimulus perception at different frequencies when measuring hearing threshold

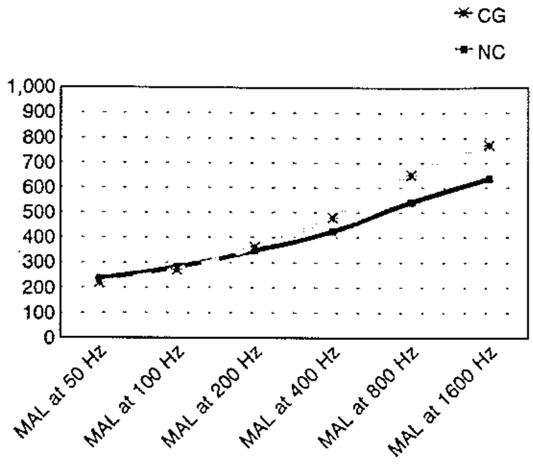


CG	72.33	106.36	146.12	275.22	449.17	573.23
NC	107.13	137.15	212.83	289.08	423.2	495.76

Fig. 2. Comparison of hearing threshold between CG and NC groups § Denotes significant differenes at 0.05 level

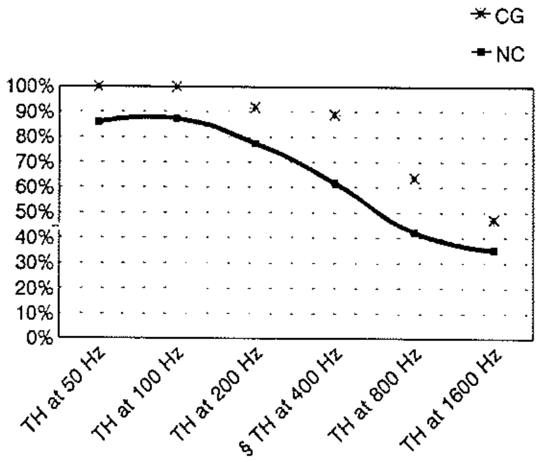
compared for the rest of the subjects with a measurable GAP (Fig. 6). GAP was higher in CG than NC at all frequencies, though not significantly.

Temporal difference limen: There were fewer subjects with measurable TDL in the NC than the CG group, a difference which was statistically significant at 400 Hz and 1600 Hz (2 tailed p = 0.0138, Fig. 7) and



CG	219.13	272.03	361.91	481.31	650.91	772.23
NC	236.13	281.97	347.68	426.02	542.68	636.55

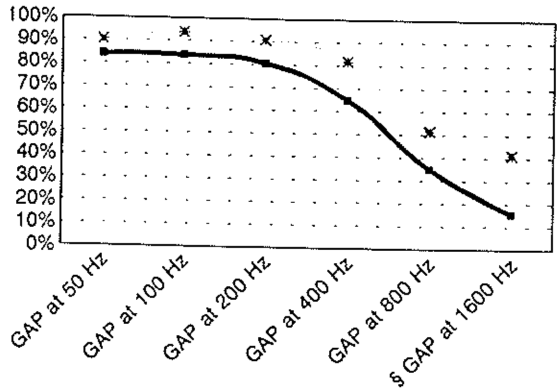
Fig. 3. Comparison MAL between CG and NC groups
No significant differences at 0.05 level was noted



CG	100%	100%	91.7%	88.9%	63.9%	47.2%
NC	85.9%	87.3%	77.5%	62%	42.3%	35.2%

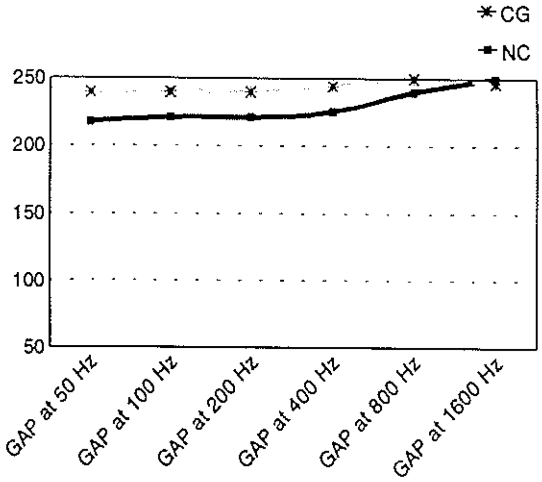
Fig. 4. Comparison cases with measurable hearing threshold between CG and NC
§ a significant difference was noted

Other results: Interestingly all of the subjects in the CG group had perceived the stimulus as sound but this happened in only half of the subjects in the NC group and the rest of them had perceived the stimulus as pain or other perceptions ($p = 0.0005$).



CG	90.6%	93.8%	90.9%	81.8%	51.5%	41.2%
NC	84.2%	83.9%	80.7%	64.9%	35.1%	15.8%

Fig. 5. Comparison cases with measurable GAP between CG and NC (only cases in which the test was done were included)
§ a significant difference was noted

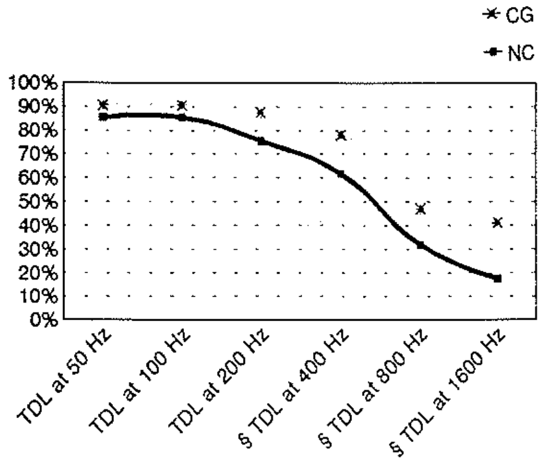


CG	239.6	240	240	244.4	250	246.4
NC	217.7	221.2	221.2	225.6	240	250

Fig. 6. Comparing GAP between CG and NC groups No significant differences at 0.05 level was noted

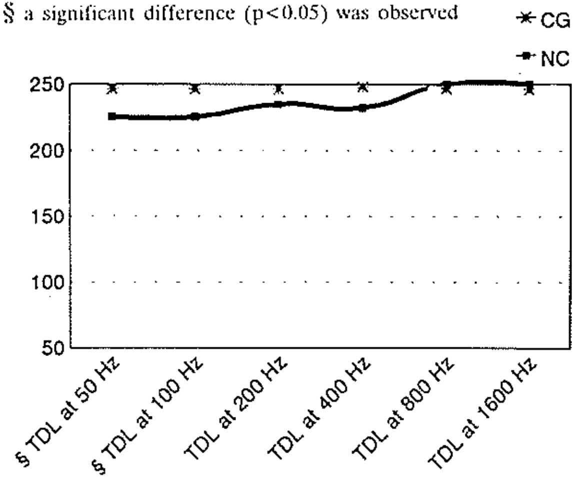
Second Analysis

In this analysis subjects with cochlear etiology of hearing loss (CO, n = 15) and subjects with retrocochlear etiology of hearing loss (RC, n= 20) were compared. The rest of the subjects were not



CG	90.6%	90.6%	87.5%	78.1%	47.1%	41.2%
NC	85.5%	85.5%	75.5%	61.8%	32.1%	17.5%

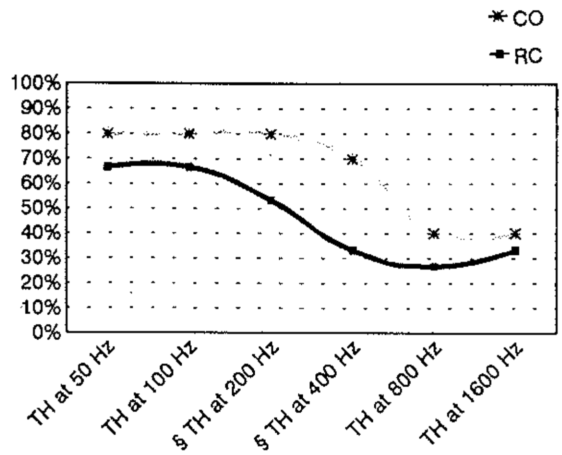
Fig. 7. Comparing cases with measurable TDL between CG and NC (only cases in which the test was done were included)
§ a significant difference (p<0.05) was observed



CG	246.5	246.5	246.5	248	246.8	246.4
NC	225.5	225.5	235	232.3	250	250

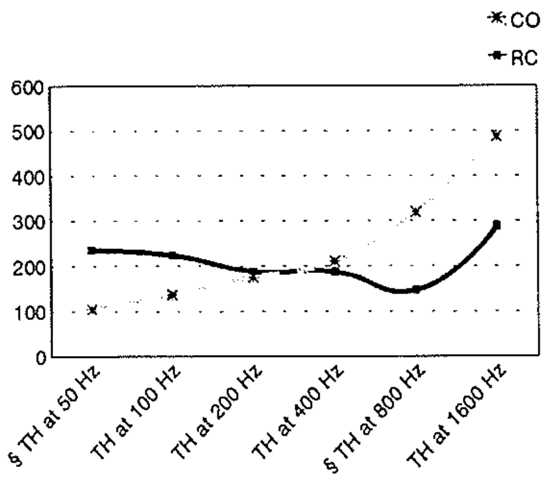
Fig. 8. Comparing TDL between CG and NC groups
§ A significant difference (p<0.05) was noted

included.Thresholds, MAL and DYN: Fig. 9 compares the percent of subjects with obtainable hearing thresholds for different frequencies. There were fewer subjects in whom a threshold would be established in the



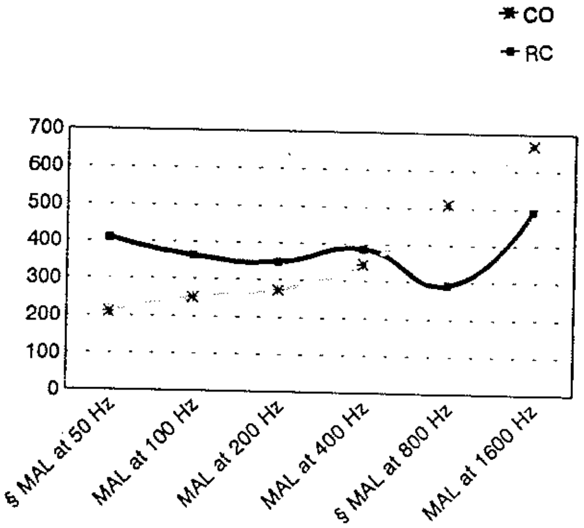
CO	80%	80%	80%	70%	40%	40%
RC	66.7%	66.7%	53.3%	33.3%	26.7%	33.3%

Fig. 9. Comparing cases with measurable hearing threshod between CO and RC
§ a significant difference (p<0.05) was noted



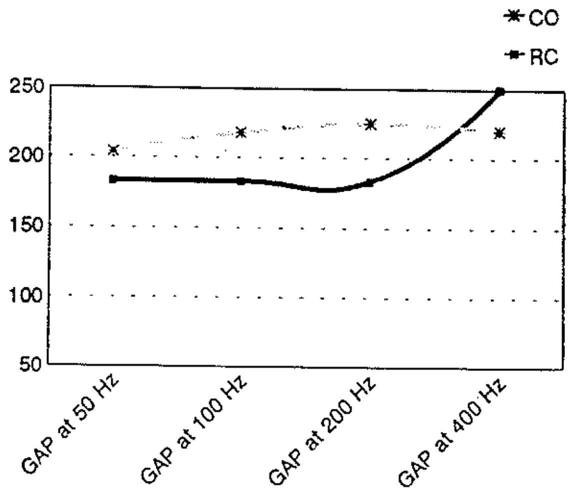
CO	104.9	137.26	175.52	211.02	319.27	488
RC	235.5	223.9	188.5	187.6	147.7	288

Fig. 10. Comparing of hearing threshod between CO and RC groups
§ Denotes significant difference at 0.05 level



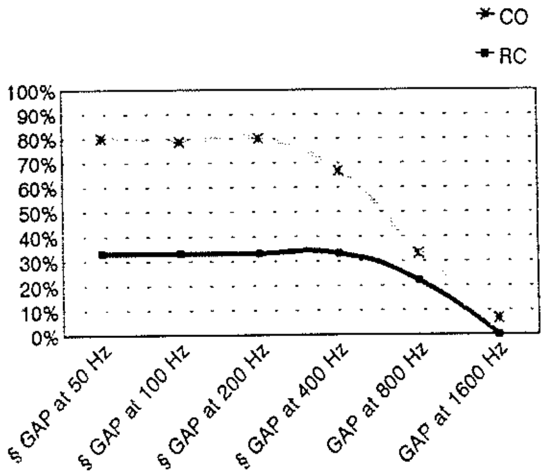
CO	211.3	250.4	272.8	344.7	509.5	668
RC	410.7	363.7	349.2	387	292.2	491.6

Fig. 11. Comparing MAL between CO and RC groups
§ A significant difference ($p<0.05$) was noted



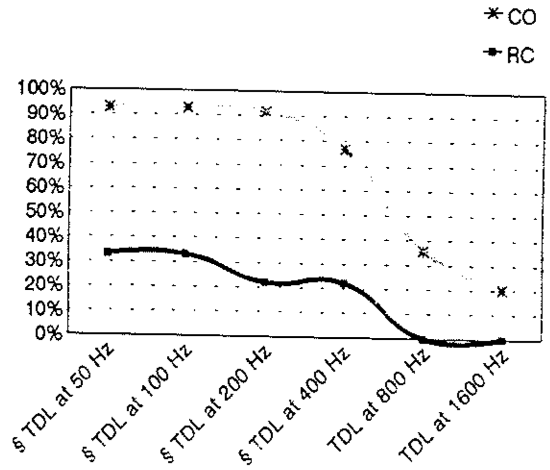
CO	204.1	218.1	225	220
RC	183.3	183.3	183.3	250

Fig. 13. Comparing GAP between CO and RC groups
No significant difference at 0.05 level was noted



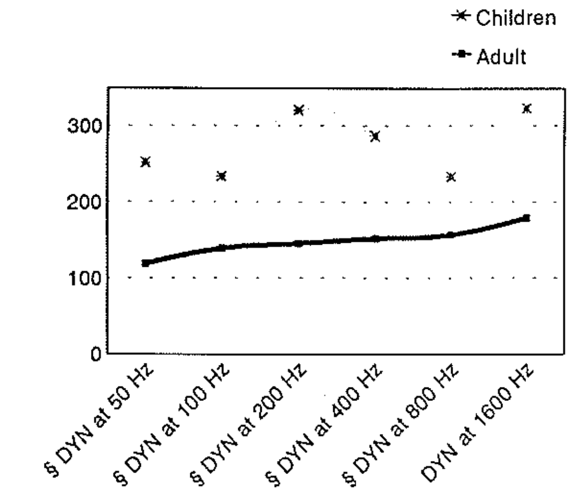
CO	80%	78.6%	80%	66.7%	33.3%	6.7%
RC	33.3%	33.3%	33.3%	33.3%	22.2%	0%

Fig. 12. Comparing cases with measurable GAP between CO and RC (only cases in which the test was done were included)
§ denotes significant ($p<0.05$) difference



CO	92.9%	92.9%	91.7%	76.9%	35.7%	20%
RC	33.3%	33.3%	22.2%	22.2%	0%	0%

Fig. 14. Comparing cases with measurable TDL between CO and RC (only cases in which the test was done were included)
§ a significant **difference** ($p<0.05$) was observed



Children	251.9	234	321.1	287.4	234.1	323.8
Adult	119.1	139.2	145.5	152.2	157.2	179.3

Fig. 15. Comparing Dynamic range between children and Adult groups

§ A significant difference ($p<0.05$) was noted

in these subjects (i.e. subjects with measurable TDL) mean TDL was lower in the NC in low frequencies. This was reversed at 800 Hz, although none of these differences were significant (Fig. 8).

Other results: Interestingly all of the subjects in the CG group had perceived the stimulus as sound but this happened in only half of the subjects in the NC group and the rest of them had perceived the stimulus as pain or other perceptions ($p = 0.0005$).

Second Analysis

In this analysis subjects with cochlear hearing loss (CO, n = 15) and subjects with retrocochlear hearing loss (RC, n= 20) were compared. The rest of the subjects were not included.Thresholds, MAL and DYN: Fig. 9 compares the percent of subjects with obtainable hearing thresholds for different frequencies. There were fewer subjects in whom a threshold would be established in the RC group at all frequencies. Mean hearing threshold was then compared in this subset of subjects across the groups which revealed a lower threshold for the CO group at lower frequencies. This was reversed from 400 Hz up to 1600 Hz (Fig. 10). MAL was also lower in the CO group atlower frequencies and this trend was also reversed from 800 Hz (Fig. 11). RC group had a greater DYN at almost all frequencies, the difference was never significant, though. Gap detection: Figures 12 and 13 compare the percent of patients with measurable GAP and the mean GAP between groups, respectively. At lower frequencies the percent of patients with measurable GAP was significantly higher in CO group ($p=0.025$ at 50 Hz).

Temporal difference limen: The percent of subjects with measurable TDL was higher in CO group ($P=0.003$ at 50 Hz, Fig. 14) but no significant difference was revealed by comparing mean TDL between two groups.

Other results: Subjects in CO group had a significantly lower educational level than the RC group subjects ($p = 0.045$).

Third Analysis

This analysis compared subjects with sudden hearing loss (SN, n=14) with those who had suffered progressive hearing loss (PR, n=22). The rest of the subjects were not included. Thresholds, MAL and DYN: Thresholds, being almost the same for the two groups at lower frequencies, increased at higher frequencies. This increment was more pronounced in the PR group but never led to a significant difference. Also PR group had greater MAL and DYN at all frequencies also but again the differences were not significant except for DNY at 50 Hz (77.4 for SN vs. 161.9 for PR $p=0.038$).

Gap detection and TDL: Mean GAP was significantly lower in PR than in the SN group at 50 Hz to 400 Hz. The same was true for TDL at 200 Hz and 400 Hz frequencies (205.3ms vs 250ms $p = 0.048$).

Fourth Analysis

To demonstrate the effect of age on PS results we divided the study population into child (12 years old or younger, group C, n=17) and adult (older than 12 year, group A, n=83) groups for this analysis.

Thresholds, MAL and DYN: children had significantly higher MALs than the adults in all frequencies but similar thresholds. This resulted in significantly higher DYN for children than adults across all frequencies (Fig 15).

Gap detection and temporal difference limen: No significant difference was noted between the two groups regarding these tests except for a slightly (but significantly) lower TDL for children at 800 and 1600 Hz frequencies.

DISCUSSION

We have compared various PS test results across different sets of subjects to illuminate the correlation between PS test aspects and certain characteristics of the subjects.

In the first analysis we noted that congenitally deaf subjects had lower hearing thresholds and greater dynamic ranges than other subjects.

These patients also had better gap detections and temporal difference limens especially at higher frequencies.

The second analysis revealed that subjects in CO group had better hearing thresholds as reflected by the far more larger number of subjects with obtainable thresholds in this groups. This difference offsets the value of thresholds, MAL and DYN means for these groups and actually makes their comparison unreliable. CO group had a better gap detection and TDL, also, especially at lower frequencies.

As demonstrated the third analysis, SN group had lower DYN at low frequencies but the same group did better on GAP and TDL than the PR group. Dynamic ranges decreased with increasing age, this finding was consistent with previous studies (3, 9). Age did not have a considerable effect on GAP and TDL.

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