Acoustic reflex threshold and loudness discomfort

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ABSTRACT

Objective: Trying to find an accurate relation between loudness discomfort level and acoustic reflex threshold.

Methods: Seventy patients were involved in this study. Ten normal patients, 30 patients of unilateral conductive hearing loss and 30 patients of unilateral or bilateral, mild to moderate sensorinearal hearing loss were tested by 1, 2, KH_2 pure tones, 0.5, 1, 2, 4, 8 KHz narrow band noise, wide band noise and speech noise stimuli to get loudness discomfort level and acoustic reflex threshold in each ear for each stimulus.

Results: Ninety two percent of predicted loudness discomfort levels occurred within ± 6 of acoustic reflex threshold rescaled data, when least squares regression method was applied.

Conclusion: It is apparent that predicted results are statically significant. They are not constant value, but vary according to the acoustic reflex threshold change, stimulus used and hearing situation (normal, conductive or perceptive loss).

Keywords: Acoustic reflex threshold and loudness discomfort.

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Traditionally, amplification requirements for the hearing imparied ear have been based in part upon loudness discomfort level (LDL). By this level, output limitation of hearing aid is determined. It is generally believed that saturation level should be adjusted so that the hearing aid cannot produce uncomfortably loud sounds.[1-7] Perhaps the most critical determinant of a successful hearing aid fitting is the output limitation imposed.[8]

For unresponsive children, an objective method to get LDL, via acoustic reflex threshold (ART), was needed and tried, but the results have not been in agreement.

Several investigators[9-14] have identified a relationship between LDL & ART. Others[15-21] questioned this relation and this controversy was explained by Ritter[21] by the inconsistent factors during estimation of ART & LDL.

Objective evaluation of loudness perception, by using hearing threshold, has been tried by some investigators such as Marzinzik et al,[22] who got applicable loudness model compared to Launer et al[23] who found weak correlation between loudness functions and audiometric thresholds.

In this study we tried to find accurate relations between LDL & ART.

Methods. Our subjects were 10 normal hearing youths of American National Standards Institute specifications,[24] with bilateral normal middle ear function, 30 individuals with unilateral conductive hearing impairment and other normal ear of the previous group criteria and 30 individuals of mild to moderate, unilateral or bilateral sensorineural hearing loss, with bilateral normal middle ear function.

Nine stimuli were used to get ART & LDL in each ear for each stimulus. These stimuli, were 1KHz and 2KHz pure tone (stimuli 2, 3), 0.5, 1, 2, 4, 8 KHz narrow band noise (stimuli 4-8), wide band noise (stimulus 1) and speech noise (stimulus 9). Low frequency pure tones were not used because of the

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Table 1 - Estimations of the LDL from ART for the normal group.

Stimulus	Corr	Predicted models to all data points	P value	Corr	Predicted models to rescaled data	P value
1	0.21	LDL=99.60+0.15ART	>0.05	0.86	LDL=105.39+0.12ART	<0.0001
2	0.34	LDL=90.58+0.24ART	<0.001	0.97	LDL=79.80+0.39ART	<0.0001
3	0.58	LDL=59.62+0.57ART	<0.001	0.98	LDL=56.0+0.61ART	<0.0001
4	0.10	LDL=88.91+0.06ART	>0.05	0.82	LDL=80.90+0.18ART	<0.0001
5	-.28	LDL=106.5-0.20ART	>0.05	-0.76	LDL=99.70-0.10ART	<0.0001
6	-.38	LDL=118.3-0.37ART	<0.001	-0.63	LDL=113.20-0.24ART	<0.001
7	0.87	LDL=41.67+0.50ART	<0.0001	0.71	LDL=42.5+0.50ART	<0.001
8	0.20	LDL=88.42+0.03ART	>0.05	0.76	LDL=80.60+0.19ART	<0.0001
9	0.10	LDL=81.70+0.07ART	>0.05	0.98	LDL=58.00+0.43ART	<0.0001

p>0.05=insignificant, p<0.05=significant, p<0.001=significant p<0.0001=significant, corr=correlation coefficient

artifactual responses at high levels[25] and higher frequencies were not used because of the inconsistent ART.[26-28]

Results. LDL results of stimulus 7 (NBN of 8 KHz) , should be excluded, as it was recorded only in 15% of the normals, 42% of perceptives and none of the conductive group. At first, the mean differences between LDL and ART across stimuli were investigated to see whether or not their means differed significantly. The tests of significance indicated that the means of LDL and ART were found to be significantly different at all stimuli at 0.05 level of significance except at stimuli 4, 5 and 8 of the conductive group and at stimulus 7 of the perceptive group.

As our objective was to estimate the LDL from ART and to discuss the possibility of developing an applicable model that may be used in similar situations, the linear regression model: LDL= B_0+B_1 ART + error-term was considered throughout this study, where B_0 and B_1 are the constant term (or the intercept) and the slope that would be resulted from estimating LDL from ART.

When the linear model was fitted to the data sets of the normal, conductive and perceptive groups, the results were given in Tables 1, 2 and 3. Two procedures of fitting these data sets were considered,

Table 2 - Estimations of the LDL from ART for the conductive group.

Stimulus	Corr	Predicted models to all data points	P value	Corr	Predicted models to rescaled data	P value
1	0.40	LDL=102.84+0.16ART	<0.05	0.97	LDL=58.20+0.56ART	<0.0001
2	0.45	LDL=90.19+0.29ART	<0.001	0.95	LDL=78.80+0.39ART	<0.0001
3	0.28	LDL=97.80+0.20ART	>0.05	0.96	LDL=86.14+0.31ART	<0.0001
4	0.37	LDL=81.69+0.13ART	<0.05	0.85	LDL=69.40+0.28ART	<0.0001
5	0.81	LDL=58.85+0.41ART	<0.0001	0.91	LDL=66.39+0.33ART	<0.0001
6	-.11	LDL=100.23-0.03ART	>0.05	0.97	LDL=77.00+0.22ART	<0.0001
7	-	Not enough data				
8	-.10	LDL=94.13-0.01ART	>0.05	0.77	LDL=89.38+0.08ART	<0.0001
9	0.04	LDL=89.90+0.02ART	>0.05	0.97	LDL=40.46+0.56ART	<0.0001

p>0.05=insignificant, p<0.05=significant, p<0.001=significant p<0.0001=significant, corr=correlation coefficient

Table 3 - Estimations of the LDL from ART for the perceptive group.

Stimulus	Corr	Predicted models to all data points	P value	Corr	Predicted models to rescaled data	P value
1	0.53	LDL=94.82+0.19ART	<0.001	0.95	LDL=92.47+0.22ART	<0.0001
2	0.37	LDL=85.99+0.22ART	<0.05	0.81	LDL=94.35+0.14ART	<0.0001
3	0.49	LDL=85.44+0.21ART	<0.001	0.97	LDL=87.22+0.19ART	<0.0001
4	0.53	LDL=74.03+0.21ART	<0.001	0.95	LDL=76.82+0.18ART	<0.0001
5	0.45	LDL=70.63+0.25ART	<0.001	0.93	LDL=78.40+0.23ART	<0.0001
6	0.42	LDL=71.77+0.27ART	<0.001	0.81	LDL=65.33+0.36ART	<0.0001
7		Not enough data				
8	0.32	LDL=77.75+0.13ART	<0.05	0.81	LDL=73.10+0.26ART	<0.0001
9	0.38	LDL=65.30+0.26ART	<0.05	0.95	LDL=60.20+0.34ART	<0.0001
p>0.05=insignificant, p<0.05=significant, p<0.001=significant p<0.0001=significant, corr=correlation coefficient						

Table 4 - ART, LDL and predicted LDL from ART observations for the normal group.

Stimulus	ART, LDL and predicted IDL from ART observations for the normal group								
1	ART	70	75	80	85	90	95	105	115
	LDL	115	115	115	115	115	116	118	120
	LDL	113	114	115	116	117	118	120	121
2	ART	80	85	90	100	110	115		
	LDL	112	113	114	120	123	125		
	LDL	111	113	115	119	123	125		
3	ART	80	85	90	95	110	115		
	LDL	106	108	108	115	125	125		
	LDL	105	108	111	114	123	126		
4	ART	50	60	75	80	85	90		
	LDL	90	93	93	93	95	100		
	LDL	90	92	94	95	96	97		
5	ART	50	55	60	70	75	80		
	LDL	95	95	95	95	92	93		
	LDL	95	94	94	93	92	92		
6	ART	55	65	70	75	80			
	LDL	95	100	93	96	95			
	LDL	100	98	96	95	94			
7	ART	65	70	70	75				
	LDL	75	75	80	80				
	LDL	75	78	78	80				
8	ART	50	55	60	70	75	80	85	
	LDL	90	90	95	90	95	95	98	
	LDL	90	91	92	94	95	96	97	
9	ART	40	50	60	70	75	80		
	LDL	80	90	90	85	90	100		
	LDL	81	85	89	91	93	96		

Table 5 - ART, LDL and predicted LDL from ART observations for the conductive group.

Stimulus	ART, LDL and predicted IDL from ART observations for the conductive group									
1	ART	75	80	85	90	95	100	105	110	120
	LDL	120	120	120	110	110	113	120	121	125
	LDL	100	103	106	109	111	117	120	123	125
2	ART	95	100	105	110	115				
	LDL	115	118	122	123	125				
	LDL	116	118	120	124	126				
3	ART	90	95	100	105	110	115	120		
	LDL	115	115	118	120	120	121	125		
	LDL	114	116	117	119	120	122	123		
4	ART	80	85	90	95	100				
	LDL	93	93	93	95	99				
	LDL	92	93	95	96	97				
5	ART	65	70	75	80	85	90	95	100	
	LDL	90	90	90	90	93	95	100	100	
	LDL	88	89	91	93	94	96	98	99	
6	ART	80	85	90	95	100				
	LDL	95	95	97	98	99				
	LDL	95	96	97	98	99				
7	ART									
	LDL									
	LDL									
8	ART	65	70	75	80	85	90	95		
	LDL	95	95	95	90	95	96	98		
	LDL	95	95	95	96	96	97	97		
9	ART	70	75	80	85	90	95	100		
	LDL	80	80	85	93	93	93	95		
	LDL	80	82	85	88	91	94	96		

one for the whole date and the other for the reduced (rescaled) data.

Rescaled data was simply based on the idea that those ART measurements which have the same record should be rescaled in such a way that the corresponding LDL measurements were to be represented by their mean values.

As can be seen from Tables 1, 2 and 3, the results for the whole data were found to be not that good, because of the effects of some outlying observations. Moreover, the linearity trend as explained by the correlation coefficients appeared to be poor in general. Therefore, in the presence of outliers, the statistical results obtained by the least squares method are often affected by these isolated data points. However, the results appeared statically significant by using rescaled data (Tables 1, 2 and 3). Using the appropriate statistical tests, the estimated linear models fitted to the rescaled data were all found to be adequate models. On the other hand, the correlation coefficients have been associated with large values which may reflect strong linear relationships between LDL & ART. However the rescaled scores of ART and the corresponding scores of LDL with their predictions, based on the predicted models, are given in Tables 4, 5 and 6.

Discussion. Comparing ART & LDL mean results of the normal group and the conductive one, all results of all stimuli were found higher in the conductive group, coinciding with Hawking,[29] who stated that conductive loss has a higher LDL.

Also comparing the mean differences between LDL and ART of the 2 groups, all stimuli were found to be less in the conductive group. These results of comparison indicates a less dynamic range in conducive loss.

Comparing the mean results of the normal and the perceptive groups, LDL was lower in the perceptive group except stimulus 6 (NBN of 4 KHz), which was 1.3 dB more. ART was higher in perceptives except at stimuli 2 (PT of 1 KHz) and 4 (NBN of 1 KHz), which was 5.3 dB and 0.7 dB lower, but in dB SL, ART was less in all stimuli.

Also LDL-ART difference is lower in the perceptives for all stimuli. All results of comparison,

Table 6 - ART, LDL and predicted IDL from ART observations for the perceptive group.

Stimulus	ART, LDL and predicted LDL from ART observations for the perceptive group												
1	ART	55	60	70	75	80	85	90	95	110	105	110	115
	LDL	105	105	110	110	109	112	113	113	113	114	116	120
	LDL	104	106	108	109	110	111	112	113	114	115	117	118
2	ART	70	75	80	85	90	95	100	105	110	115	120	
	LDL	102	103	104	106	107	105	110	110	110	110	110	
	LDL	105	105	106	107	107	108	108	109	109	110	110	
3	ART	60	65	70	75	80	85	90	95	105	115	120	125
	LDL	100	100	100	103	104	105	106	108	110	110	110	110
	LDL	100	101	102	103	104	105	106	107	108	110	111	112
4	ART	50	55	60	65	70	75	80	85	90	95		
	LDL	85	88	88	88	89	95	90	93	92	95		
	LDL	86	87	87	88	89	90	91	92	93	94		
5	ART	50	55	60	65	70	75	80	85	90			
	LDL	85	85	88	84	89	81	91	91	94			
	LDL	84	85	86	87	89	89	90	91	92			
6	ART	45	50	55	65	70	75	80	85	90	95	100	
	LDL	80	80	80	100	93	94	91	97	92	100	100	
	LDL	82	83	85	88	91	92	94	96	98	100	101	
7	ART												
	LDL												
	LDL												
8	ART	45	50	55	60	65	70	75	80	85	90		
	LDL	85	85	90	87	88	90	90	93	93	95		
	LDL	85	86	87	89	90	91	93	94	95	97		
9	ART	45	50	55	60	65	70	75	80	85			
	LDL	75	75	80	82	85	85	86	87	88			
	LDL	75	77	78	80	82	83	85	87	88			

showed the decreased dynamic range of perceptive hearing loss.

In our results the mean of LDL of pure tone 1KHz and 2KHz (stimuli 2 and 3) of the normals were 113.3 and 110.3 and that of perceptives were 105.5 and 104.6, while that of Bentler and Pavlovic[30] were 104.2, 104.9, 97.5 and 101.1.

ART mean of stimulus 9 in the normals was 63 dB, near to 65 dB given by Northern & Gabbard,[31] while the mean of 1 and 2KHz pure tones was 91 dB from the results compared to 85dB.

After exclusion of the wide band noise stimulus from the 3 groups, LDL, and ART mean values were the highest for pure tones, then for narrow band noises, and the lowest for speech noise. This coincides with Northern & Gabbard,[31] who stated that ART reduced as the band width increased, and coincides with Moor BCJ et al,[32] who stated that loudness increased if band width increased.

Wide band noise stimulus was found to have the greatest mean value, in LDL of normal and perceptive groups and the next value in the conductive group, as well as in ART of perceptives and the next in other groups. This result is opposite to what is generally accepted, and can be explained only by calibration problems.[33]

The results (Tables 4, 5 and 6) revealed that the relation between ART and LDL differ according to the stimulus used coinciding with previous researchers, and differ according to the type of hearing loss.

The difference between ART and LDL is not constant, and differ according to the change of ART value.

In the 3 groups, for the 9 stimuli tested, the difference between ART and LDL decreased when ART increased. After exclusion of stimulus 7, the difference varied from 5 to 45 dB at stimulus 1 (wide band noise) and from 10 to 26 dB at stimulus 3 (2KHz pure tone) in normals. In the conductive group the difference varied from 5 to 45 dB at stimulus 1 and from 10 to 20 dB at stimulus 2 (1KHz pure tone), while in the perceptive group, the difference varied from 15 to 40 dB at stimulus 3 and from 3 to 30 dB at stimulus 9 (speech noise).

Always LDL was higher than ART, except in the perceptive group, it was less, until ART reached 115 dB at stimulus 1 and 2 ie. pure tones only.

From Tables 4-6 (25 stimuli) the predicted results of LDL occured within ±1 of the rescaled results at one stimulus, within ±2 at 9 stimuli, within ±3 at 17 stimuli, within ±4 at 17 stimuli, within ±5 at 20 stimuli, and within ±6 at 23 stimuli. Predicted results of 23 stimuli, out of 25 stimuli, (92%) occured within ±6 of the rescaled results.

In the perceptive group, important for the clinical application of the results, the least ART and LDL results were 85 and 88, at stimulus 9 (speech noise), indicating that the upper limit of the equipment would not exceed in more patients of higher hearing loss. For this reason and because all of its results occured within -3+2, speech noise was preferred for the clinical use, although some stated that it remained unclear what stimulus type should be used to elicit the discomfort level.[29,34-35]

All previous researches tried to get constant values for the difference between ART and LDL. To us, this difference change according to ART change, and according to the equations of the statistical analysis, so the researchers that did not find the relation between ART and LDL, may get another result by using the least squares regression method of statistical analysis. We believe that the method of analysis was a main factor in the researchers controversy.

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