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THE NOISE EXPOSURE OF INFANTS IN INCUBATORS

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1. INTRODUCTION

In general about 1% of the population have hearing problems stemming from child hood. However, for premature infants the incidence of incipient hearing loss is about 10%. Johnsen[1], in 1952, first drew attention to this anomaly in a study of 39 children with perceptive deafness. Most of the hearing loss reported in premature infants can be attributed to such causes as material rubella and neonatal asphyxia but as yet about 30% is unexplained. Campanelli et al [2] investigated a sample of 44 premature infants and found that 15.9% had a sensorineural hearing impairment. The mean of the audiograms of the group with this impairment exhibited a dip at 4 kHz typical of Noise Induced Hearing Loss (N.I.H.L.)

Seleny and Strezyn[3] measured noise levels in infant incubators and concluded that they were close to danger level. Douek et al[4] found the noise level in one of a group of 6 incubators was 80 dB(A). Guinea pigs were subjected to this level of noise and cochear damage was evidenced in the infant guinea pigs but none in the adult guinea pigs. Noise in incubators was also studied by Blennow et al[5] who found the highest levels in incubators powered by electric motors. Only a slight difference in levels was reported between empty and occupied incubators. However, Falk and Woods[6] in a treatise on hospital noise, whilst including data on noise levels in incubators, separately noted that a child crying produced 80 dB(A) - 86 dB(A).

Consequently, the aims of this investigation were:- (i) To obtain more information on the noise levels which exist in incubators due to the fan/motor system. (ii) An assessment of the contribution made by the infants to the noise climate in incubators. (iii) To determine the possible extent of hearing damage in premature infants due to noise exposure in incubators, and (iv) To estimate a design criterion for noise levels due to incubator services.

2. METHODS AND EQUIPMENT

2.1 Incubator Services Noise

S.P.L's were measured in 45 incubators from three main sources (Groups A, B, and C) in Northern Ireland. The measurements were made with the incubators operating in the normal mode (i.e. with fan and heater on) and with the microphone placed at the infants head position. Both SPL's and Octave Band Spectra were recorded. A Bruel and Kjaer SLM type 2209 with octave band filter type 1613 was used in the survey.

2.2 Noise Levels in Occupied Incubators

The peak hold facility of the SLM was used to monitor maximum levels produced by an infant crying in an incubator. In addition the 24 hour noise exposure of infants in incubators was measured at one centre (Group B) over a period of 12 months using two B & K personal Noise Dosimeters type 4230 (suitably adapted) and a CEL noise average meter type 144. The survey embraced a total

of 305 incubator days and involved measurements on 69 infants. Further investigation of the pattern of noise in the Group B incubators was made by using a B & K noise level analyzer (N.L.A.) type 4426.

3. EXPERIMENTAL RESULTS

3.1 Incubator Services Noise

Noise levels due to the fan/motor system are summarized in Table 1 for incubators from each of the three main sources and for all the Northern Ireland incubators. Table 1 includes a statistical summary of services noise levels for 60 incubators studied by Watts[7] in the Kent area. For all groups, with a total of 105 incubators, the mean SPL is 56.6 dB(A) and the corresponding standard deviation 4.72 dB(A). These values are in contrast with similar data derived from estimates of the SPL's for the incubators tested by Douek et al[4].

Table 1 - Statistical Summary of Services Noise

GROUP	No of Incubators	L_A dB(A)	σ db(A)	$L_{max}=L_A+3\sigma$ dB(A)
A	11	58.2	6.25	77.0
B	17	57.1	4.65	71.0
C	17	56.6	2.47	64.0
All groups	45	57.4	4.79	71.8
Watts (22)	60	56.0	4.77	70.3
Douek et al (16)	6	62.0	15.18	107.5

Octave band analysis gave frequency spectra broadly in agreement with those obtained by Watts[7] and by previous workers (3,5,6). None of the incubators sampled exhibited high levels at frequencies greater than 0.5 kHz as was found by Douek et al[4].

3.2 Noise Levels in Occupied Incubators

With the use of the peak hold facility of the SLM the maximum levels recorded were 113 dB(LIN) and 107 dB(A). Such levels are of a magnitude likely to cause hearing damage in adults after relatively short daily exposures.

The L_{eq}-24 hour measurements which were taken independant of incubator or infant were processed statistically when the resultant distribution was essentially normal with a mean L_{eq}-24 hour = 64.8 dB(A) and a Standard Deviation (σ) = 4.35 dB(A). These figures indicate that the maximum exposures to be expected for an infant in an incubator is 77.8 dB(A). This notional maximum was exceeded on one occasion during the survey when an L_{eq}-24 hour of 79.5 dB(A) was recorded.

Typical N.L.A. results in an incubator environment are shown in Fig 1. To emphasize the importance of the energy content at higher levels these graphical representations are plots of the logarithm of the arbitrary energy (E_{arb}) vs SPL (L_A) in dB(A), where log (E_{arb}) = log n + LA/10, n being the number of counts at the level L_A.

The Characteristic energy distribution for an empty incubator (Curve a) has a peak which occurs at the incubator services noise level as measured by a S.L.M. With a quiet infant in the incubator the distribution (Curve b) is similar but contains some noise at higher levels. However, when the infant was noisy the characteristic curve obtained (Curve c) exhibited a second larger peak at levels consistently between 90 dB(A) and 100 dB(A).

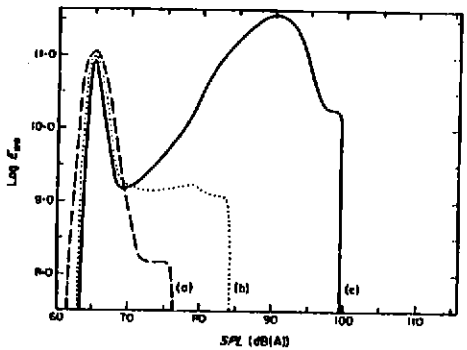

Figure 1: Comparison of characteristic energy distributions in an incubator with services on (a) when empty, (b) when occupied by a quiet infant and (c) when occupied by a noisy infant.

4. DISCUSSION

4.1 Noise Exposure and TTS

The high levels of noise measured in incubators in this survey indicate that noise cannot, as is suggested by Schulte and Stennert [8], be discounted as a cause of sensorineural deafness in premature infants. S.P.L.s reaching 107 dB(A) would, if sustained and repeated many times, be high enough to cause hearing loss in adults. Even if the exposure were of short duration, some TTS would be expected.

The exposures of infants in incubators have been compared with workers in industry by applying a normalizing factor of 6.2 dB(A) to the infants 24 hour exposure levels to correct to L_{eq}-8 hour values. Applying this correction to the N.L.A. data gives a Mean L_{eq}-8 hour of 71 dB(A) and a Maximum L_{eq}-8 hour of 84 dB(A). This maximum approaches the level at which damage might occur in adults. Table 2 contains estimates of the asymptotic threshold shifts (ATS) to be expected upon prolonged exposure at the maximum L_{eq}'s measured in incubators together with estimates of the percentage of infants in incubators likely to be affected by TTS and those whose recovery may be retarded by the services noise.

TABLE 2 - ESTIMATES OF ATS AND OF % INFANTS AFFECTED BY TTS

Incubator Noise Source	Maximum Exposure Level (dB(A))	Assumed Infant Susceptibility	ATS (dB)	% Infants affected by TTS	Recovery From TTS Retarded (% Infants)
Noisy Infants and Services	79.5	Adult	19	0.5	Not applicable
		Adult + 10 dB	60	39	
Services only (i.e. Infants only)	71.0	Adult	-	- -	1.7
		Adult + 10 dB	25	3.6	50

4.2 Incubator Services Design Criteria

Blennow et al (5) suggest that attention should be directed to the avoidance of high noise levels in new incubators. For this purpose a design criteria is necessary. Alternative starting points for estimating such a criterion are

(i) the introduction of TTS at 75 dB(A) for an 8 hour exposure; (ii) recovery from TTS is retarded at levels of 67 dB(A) or greater; (iii) vasonconstriction occurs at levels above 53 dB(A). In the deduction an allowance of 6 dB(A) is made for the fact that exposure in an incubator is for 24 hours per day. As before, an allowance of 10 dB is made for a possible hypersusceptibility to noise in premature infants and, to ensure that very few incubators exceed the danger level, an allowance of three times the standard deviation is made for the spread in incubator services noise levels. The resulting design levels range from 38 dB(A) to 45 dB(A). Most infants would be protected if a criterion of 45 dB(A) were to be used in incubator design. For existing incubators a maximum permissible level of 55 dB(A) would avoid any possibility of recovery from TTS being retarded by services noise.

3. CONCLUSIONS

The noise generated by infants in incubators has been shown to be the dominant source. Sufficiently high levels are generated by the infants to cause considerable TTS but no definite conclusion can be reached as to attributing the cause of some hearing loss in infants to incubator noise. The estimates of the numbers of infants likely to be affected by TTS due to exposure to incubator noise indicate that, if noise is responsible for all or part of the incidence of unexplained hearing loss in the infant population, then the infants must have a susceptibility to noise damage greater than that of adults. In such a case the incubator services noise would be partially cupable. It follows that reduction of services noise levels would be desirable both for new and at least some in-service incubators.

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