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Eyelid opening in preterm neonates

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SUMMARY The frequency and patterns of eyelid opening were examined in a group of neonates (gestational age 24–35 weeks). Observations were spread over the 24 hour period to obtain a complete pattern of events. Mean eyelid closure was 74%. When babies were grouped by gestational age, however, differences became apparent, babies of less than 26 weeks having their eyes shut for only 55% of observations compared with 93% at 28 weeks. Trend analysis confirmed that eyelid closure reached a peak at 28 weeks. Neonates exposed to a day/night regimen, opened their eyes significantly more than those exposed to continuous illumination. We suggest that frequency of eyelid opening may be related both to the infant's developmental state (postmenstrual age) and the illumination of the neonatal unit. Frequency of eyelid opening should therefore be considered when calculating the ocular light exposure of preterm neonates.

Patterns of eyelid opening in neonates, particularly if they are born prematurely, are largely unknown. There are only two specific reports on this topic. Berman *et al*[1] estimated that eyelids remained closed for 80% of the time and considered that eyelid closure was a significant factor in limiting the exposure to light of infants at risk of retinopathy of prematurity. Details of the gestational ages of their subjects were not provided. Moseley *et al* investigated the effect of varying illumination on a small group of neonates ranging from 33 to 40 weeks' postmenstrual age,[2] and also observed that eyelids remained closed for about 80% of the time. In this study observations were carried out in a small quiet room immediately after a feed, with observations limited to a three hour study period. To date the pattern of eyelid opening in neonates over a complete 24 hour period has not been reported; this may be relevant to visual development, ocular protection, and growth.

We report an investigation of eyelid opening in preterm neonates. All observations were made in the cots with no interventions of any sort by the observer. This permitted the study of even the most immature preterm neonates. The association between degree of eyelid opening, behavioural state, illumination, and other external events are discussed.

Subjects and methods

Observations were carried out in two neonatal units in the East Midlands: unit A (Leicester Royal Infirmary) and unit B (City Hospital, Nottingham). Both units are divided into high and low dependency nurseries. Artificial lighting is maintained over the 24 hour period in unit A and in the high dependency rooms of unit B. In the low dependency area of unit B, however, artificial illumination is reduced between 2000 and 0700 hours each day. A regimen of reducing night time illumination and noise has been maintained in this area since a previous study[3] attributed improvements in sleep and feeding patterns to these changes. The illumination of the two neonatal units was measured at a series of randomly selected times during a 24 hour period: light intensity in the high dependency nurseries was about 500 lx with no nocturnal decrease. Similarly, the low dependency nurseries had a light level of 500 lx during the day. When the lights had been dimmed in unit B, however, the measured intensity of illumination fell to 1 lx compared with the 500 lx recorded in unit A.

The subjects were 49 preterm infants born between 24 and 35 weeks' gestational age (table 1). All babies of less than 36 weeks' gestation are routinely admitted to the neonatal units studied. Ill babies born at greater than 35 weeks' gestational age are also admitted. Data collected from these older, sick neonates would not have been representative of infants in this age range and therefore observations were restricted to preterm infants. The two groups of babies studied did not differ in the proportion of infants being ventilated (16%) or the proportion being nursed in incubators as opposed to cots (18%).

Table 1 *Details of subjects*

Gestational age (weeks)	*No of infants*	*Birth weight (g)*	
		Median	*(range)*
24	2	0790	0760–0820
25	5	0750	0620–0880
26	7	0855	0650–0980
27	2	1045	1030–1060
28	4	1095	1030–1410
29	11	1370	1020–2120
30	3	1015	0740–1620
31	2	1570	1520–1620
32	5	1750	1220–1859
33	4	1650	1320–2140
34	3	1990	1520–2500
35	1	2320	

SCORING PROCEDURE

Eyelid opening, behavioural state, position of the infant, and amount of handling were recorded. No interventions were made by the observer (JR). The infants were clothed, positioned, fed, and so on, by the mother or nurse and no attempt was made to alter or standardise these variables or to change any baby's schedule in any way.

The scale used to score the degree of eyelid opening was that described by Haith[4] and consisted of a four point scale ranging from 1 (eyelid fully closed) to IV (opening to strain). Scoring of behavioural state was by a four point abbreviated version of the Brazelton scale[5] previously used by Moseley *et al* (table 2).[2] Handling was categorised into: none, feed, nursing procedures, medical interventions, or holding. Position of the infant was recorded as either lying on the left, right, front, back, or being held.

Table 2 *Description of behaviour and state of eyelids*

Behavioural state:	
Category I	Asleep—(Brazelton states 1 and 2): deep or light sleep, little or no motor activity
Category II	Drowsy—(Brazelton state 3): activity variable with mild startles from time to time, movements usually smooth, dazed look when infant is not processing information
Category III	Alert—(Brazelton states 4 and 5): bright look, attention focused, brief fuzzy noises
Category IV	Crying (Brazelton state 6): crying, high degree of motor activity
State of eyelids:	
Category I	Closed—eyelid fully closed
Category II	Chink—partial eyelid opening
Category III	Open—eyelid open, pupil exposed
Category IV	Open to strain—eyelid open, sclera visible above and below the iris

PROCEDURES AND SAMPLING

A maximum of four neonates were studied during each sampling period, which lasted for four hours, because pilot observations had shown that this included a complete cycle between feeds, the most regular disturbance for every neonate.

Each minute during the sampling period, the observer moved round the room and recorded the behavioural state, degree of eyelid opening for each eye, incidence of handling, and position in the cot or isolette for each of the neonates being studied. Care was taken to record handling only if a person was in physical contact with the baby at the moment the observer arrived at the isolette, incubator, or cot. A total of 240 observations (one each minute) was made under each category heading during each four hour sampling period for each baby being observed. If less than four infants were being observed the observer still only allocated 15 seconds to each infant (this included the time taken to travel from cot to cot). Two hundred and eight sampling periods were included in this study (unit A—152; unit B—56). To obtain a complete pattern of events throughout the 24 hour period, the start time of the sampling period was varied throughout the day and night.

The infants were enrolled into the study before the first period of observation, thus it was possible that they could be undergoing phototherapy during the sampling period. In this case the infants were still studied and a note was made if the eyes were covered with phototherapy eyeshields. The data about eyelid opening collected from these infants was not included in the main analysis as an assessment of eyelid state could not be made every minute. After each observation period the health of each infant was graded according to the criteria given in table 3.

ANALYSIS

In each unit eyelid opening was correlated with the occurrence and regularity of interventions and with the infants' behavioural state.

Mean eyelid closure for each age studied (gestational and postmenstrual) was calculated by computing the total number of times that each category of eyelid opening was observed; this value was then divided by the total number of observations made of the state of the eyelids in babies of that age.

Data were then reduced to give one value for each measure for each hour for each infant studied. For example frequency of lid closure was determined by summing the number of observations of eyelid closure (category 1) over each hourly period and then dividing by 60; this value was then converted to a percentage. Data about eyelid state, behavioural

Table 3 *Factors affecting illness score*

	Score
Respiratory support:	
Ventilated	3
Oxygen by headbox or in incubator	2
Breathing air	1
Cardiac support:	
Drugs (for example, dopamine)	1
None	0
Neurological state:	
Paralysed	4
Convulsions, treated	3
Convulsions, untreated	2
Abnormal movements	1
Normal	0
Feeding:	
Gastric feeds	0
Intravenous feeding	1
Phototherapy:	
Yes	1
No	0
Apnoeas:	
No action	1
Requiring stimulation with or without oxygen	2
Bradycardias:	
No action	1
Requiring stimulation with or without oxygen	2

Possible range of scores 0 to 14.

state, and handling were always based on 60 observations each hour. Frequency of occurrence of handling of various types was determined by computing the mean percentage of all observations in which handling was recorded for each hour for each infant.

Results

Mean eyelid closure (category 1) obtained in the first postnatal week (24 to 36 weeks' gestational age) are plotted in fig 1. In general, neonates born between 27 and 31 weeks' gestation had their eyes closed for more than 80% of the total number of the observations. Mean percentage lid closure declined from 80% at 30 weeks' gestation to 60% at 35 weeks' gestation (fig 1). The very immature neonates (24–25 weeks' gestation) opened their eyes for a greater percentage of the time than the older neonates (fig 1), mean percentage eyelid closure at 24 weeks' gestation being 55%. Considerable individual variation was noted in the most immature, however, with values ranging from 60% to 90% for babies born at 26 weeks' gestation. Analysis of trend confirmed that eyelid closure rises to a peak at 28 weeks' gestation (93%). No significant differences were found between eyelid closure as a function of gestational age (observations were made in the first postnatal week) or postmenstrual age (gestational plus postnatal age) (fig 2).

The pattern and frequency of eyelid opening in the high dependency regions of units A or B were not significantly different. Similarly, during the day, there were no significant differences in eyelid opening in either of the low dependency nurseries. Differences were, however, observed in the fre-

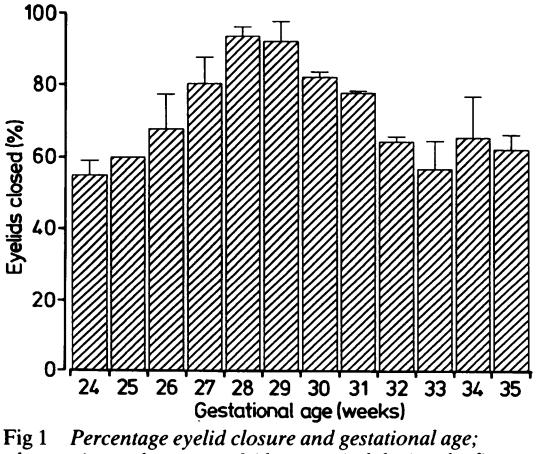

Fig 1 *Percentage eyelid closure and gestational age; observations taken over a 24 hour period during the first week of life are expressed as mean (SEM).*

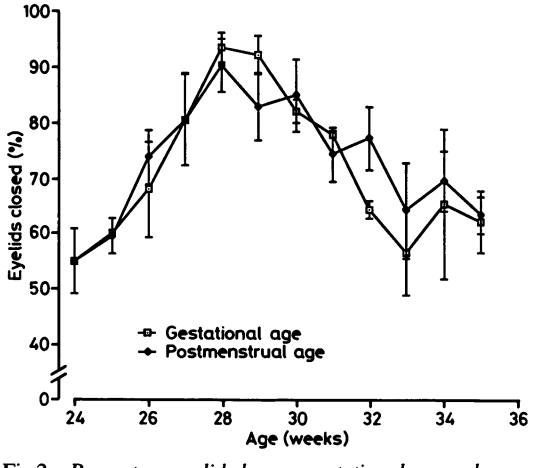

Fig 2 *Percentage eyelid closure, gestational age and postmenstrual age; observations taken over a 24 hour period are expressed as mean (SEM).*

Table 4 *State of eyelids in low dependency regions between 2000 and 0700*

	State of eyelids (%)		
	Shut	*Chink*	*Open*
Unit A	77	5	18
Unit B	64	7	29

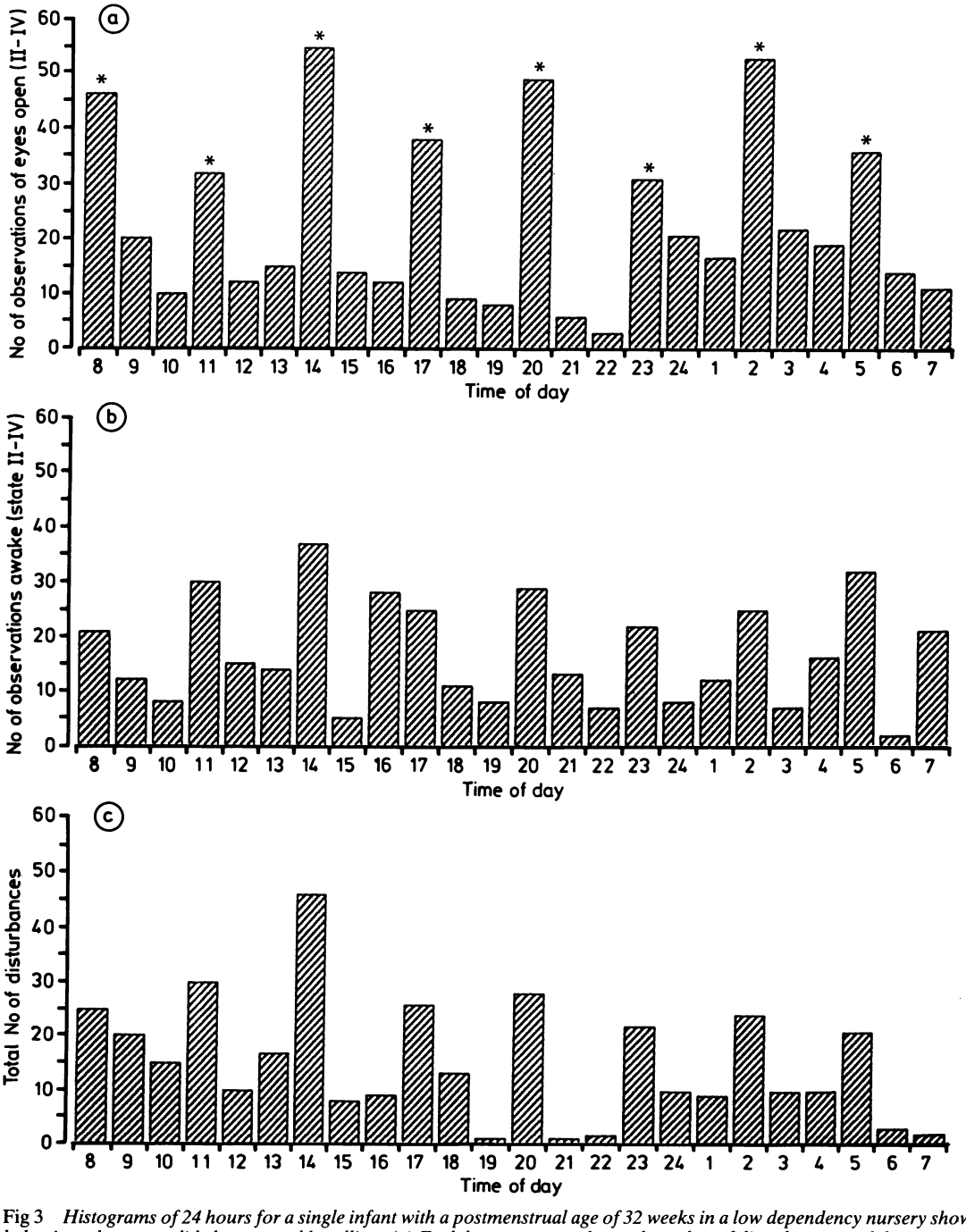

Fig 3 *Histograms of 24 hours for a single infant with a postmenstrual age of 32 weeks in a low dependency nursery showing behavioural state, eyelid closure, and handling. (a) Each bar represents the total number of disturbances each hour; *indicates the times of feeds. (b) Each bar represents the total number of observations of eyelid opening (categories II-IV) each hour. (c) Each bar represents the total number of observations in which the infant was categorised as being awake (states II-IV) in each hour.*

quency of eyelid opening at night between the low dependency nurseries (table 4). Firstly, as the lights were dimmed, babies in unit B responded to the reduction in light with a transient period of eyelid opening lasting about two minutes. Secondly, these infants spent a smaller proportion of the time with their eyes closed (table 4). This difference in mean eyelid closure for unit A (mean 77%, range 47–100%) and unit B (mean 64%, range 23–96%) was significantly ($p<0{\cdot}002$) when compared by multivariate analysis which took the subject's age and health variation into consideration. In addition, the mean duration of periods of eyelid opening intervals (categories II to IV) was similar in units A and B during the day but when the lights in unit B had been dimmed, the average length of time in which the eyes were open increased from 3 to 11 minutes ($p<0{\cdot}001$).

Neonates in unit A were observed to lie with their heads turned to the right for greater than 80% of the observations, while those in unit B spent about half of the time lying on either side.

Analysis of the disturbances to each infant suggested that there was a periodic pattern of events throughout the day with respect to feeds, nursing procedures, and holding, with medical interventions being made as required for the treatment of the babies. A typical summary for a single infant compiled from a series of four hour sampling periods made during the first week of life is shown in fig 3.

During such 24 hour periods infants undergoing intensive care were medically disturbed on average 25 times, while the healthier infants were disturbed less often (10 times) ($p<0{\cdot}005$). No significant differences were found in the number of non-medical interventions between the two high dependency units studied. Both units have a policy of minimal handling—that is, as many disturbances as possible are grouped—even so, these neonates were disturbed more than 100 times each day. Babies in the low dependency region of unit B were held significantly more than the corresponding neonates in unit A during the daylight hours ($p<0{\cdot}002$). No differences were apparent at night.

Neonates within the high dependency areas were asleep (Brazelton states I-II) for 76% of the time. Periods of wakefulness were associated predominantly with either nursing or medical procedures. The maximum number of consecutive observations of 'asleep' was 11—thus the maximum period of uninterrupted sleep was only 11 mintues in either unit, while infants in the low dependency areas had longer periods of uninterrupted sleep (mean 34 minutes).

All infants undergoing phototherapy initially had their eyes covered with protective eye shields. During this study we noted that these shields did not fully cover the babies eyes for 56% of observations (9292 out of 16615) made while neonates were undergoing phototherapy in either of the units studied.

Discussion

During early development the eyelids are fused, usually beginning to open during the sixth month of gestation (24–25 weeks). We found that preterm neonates (24–26 weeks' gestation) had their eyes shut for only 55% of the time, while older neonates opened their eyes less often (fig 1). Little is known about the effects of early exposure to the environment on the developing visual system, this has been reviewed by Fielder *et al.*[6]

The association between gestational age and percentage of time spent with eyelids closed (category I) suggests that neonates of 28–31 weeks' gestation have their eyes shut for more than 80% of the time. This confirms values quoted by Berman *et al* in a study of low birthweight infants of unspecified gestational age.[1] In contrast to Moseley *et al*,[2] who reported that babies of postmenstrual ages ranging from 33 to 40 weeks had their eyes shut for more than 80% of observations, we noted that neonates of 35 weeks' postmenstrual age had their eyes closed for only 55% of observations (fig 1). This apparent difference may be explained by variations in the sampling techniques used in the two studies. Firstly, Moseley *et al* moved the neonates to a small, quiet side room within the neonatal unit for the duration of the study interval immediately after a feed.[2] We noted that the bulk of eyelid opening occurred just before feeds in babies of more than 32 weeks (fig 3), and this would have not been taken into account in the former study.

The changes in the proportion of time spent with eyelids closed (category 1) with increasing postmenstrual age may be attributed to two factors: the development of the lid closure reflex, and the onset of a circadian rhythm. Light causes a reflex closure of the eyelids.[7] Finnstrom has suggested that this reflex may develop around 29–31 weeks' gestation,[8] which corresponds with the maximum percentage eyelid closure found in this study (fig 1). As no significant differences were noted between the pattern of eyelid opening when plotted as either a function of gestational or postmenstrual age (fig 2) this may suggest that exposure to light has not hastened the development of the lid closure reflex in the most immature. If this is the case, the very immature preterm infant (24 to 26 weeks' gestation) may not be able to react to the light stimulus.

The reduction in the amount of eyelid closure after 31 weeks noted in this investigation may reflect

the gradual development of a circadian sleep wake rhythm in neonates. Support for this hypothesis is provided by the observation that preterm babies on 'demand' feeding (usually at more than 36 weeks' postmenstrual age) wake and thus open their eyes before feeds. There is evidence that an endogenous circadian rhythm develops spontaneously in the human infant.[9] Booth *et al* have shown that as preterm infants mature they spend a smaller percentage of the time in active sleep, and their quiet sleep periods lengthen.[10] Sleep-wake cycles have been identified in babies from 32 weeks' gestation.[11]

The two neonatal units studied differed in their lighting regimens. Unit B has a policy of reducing the illumination in the low dependency nurseries each evening. We noted that preterm neonates exposed to this 'day/night' regimen opened their eyes more than those subjected to continuous illumination (table 4). This confirms previous observation that neonates often close their eyes when not asleep if in a brightly lit room.[12 13] The observation that neonates also respond immediately to a reduction in illumination with a transient period of eyelid opening confirms a previous study,[2] although these authors were unable to demonstrate the longer term effects that we have identified. Eyelid opening (categories II to IV) for neonates within the low dependency areas, however, occurred particularly in the period before feeds (fig 3)—a period in which observations were not performed by Moseley *et al*,[2] and this may explain the differences between the two studies.

Our results show that the time neonates spend with their eyelids closed is related to gestational (fig 1) or postmenstrual (fig 2) age, and to the level of ambient illumination in the neonatal units in older infants (table 4). The possibility that early exposure to light may be deleterious to the eyes of preterm neonates has recently received much attention.[14] Hamer *et al*,[15] have made an attempt to estimate the retinal irradiance in the eye of an infant of 34 weeks' postmenstrual age undergoing treatment in a neonatal unit. Their calculated value was small relative to those shown to cause retinal damage in animal studies, but did not take into account factors such as eyelid closure and random shading. Our findings suggest that because it occurs so often, estimates of eyelid closure are a prerequisite for calculating the ocular light exposure of neonates.

Quantifying eyelid opening is also relevant to two further topics. First, corneal temperature is lowered by eyelid opening.[16] As most ocular growth occurs between 28 and 40 weeks' gestation,[17] with the cornea in particular flattening during this period, perhaps a thermal deficit may affect ocular development in general and the cornea in particular.[18] Second, visual development, and the early visual experience on this process. The visual experience of these preterm neonates can not be determined without knowledge of the frequency and duration of eyelid opening and clearly this information is a prerequisite to investigating the factors which may influence visual development.

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