The illumination intensity in the neonatal intensive care unit

MAREK SZCZEPAŃSKI, MONIKA KAMIANOWSKA

Abstract

Objective: The aim of this study was the description of the Neonatal Intensive Care Unit light environment. Patient and methods: Using the luxometer, light intensity (lx) in open as well as closed incubators in standard, reduced and minimal night illumination and applying procedures reducing light transmission to neonate eyes was recorded. The measurements were performed in the NICU at the Department of Neonatology of Medical University in Białystok. Results: Standard night illumination generated light intensity of 325 ± 5.0 lx, reduced 31 ± 1.0 lx and minimal 1 ± 0.01 lx. Procedures reducing light transmission to neonate eyes reduced light intensity to 22 ± 1.0 lx in standard illumination and to 3 ± 0.7 lx in reduced illumination. Conclusion: Minimal night illumination generates light intensity which is consistent with recommendations for NICU, standard and reduced night illumination exceeds permissible levels. Applying illumination reducing procedures in NICU, restricts night light transmission to neonate eyes, reducing the risk of visual system disorders and circadian rhythm disturbances in the hospitalized neonates.

Key words: neonatal intensive care unit, illumination intensity

Introduction

The development of the sight organ starts at the end of the 3rd week of intrauterine life. At the 5th week, the plate of the lens is situated on the top of the primary optic vesicle, of which the retina is formed. Nervous and glia elements are transformed into the optical nerve. At about the 10th week of gestation, the lids merge as two folds of superficial ectoderm and the eye fissure arises only at about the 26th week. The development of the eyes and sight is not finished at the moment of birth and is influenced by environmental optical stimuli. The axial length of the eyeballs, the cornea curvature and the lens thickness change in infancy. Total myelinization of the optic nerve may last up to the age of 2 years, and the spot field up to the age of 5 [1, 2].

Light inducing visual sensation is electromagnetic radiation of 400-780 nm wave length. Illumination intensity, that is luminous flux density on the illuminated surface, is expressed in lux (lx) [3]. Light plays a major role in the postnatal development of the sight organ (eyeball growth, peripheral retina parts development) and supports vision processes (visual acuity, colour vision) [4].

Exposure to high illumination may lead to structural changes in the vision organ [5]. The changes, located most of all in the external segments of the retina, and dependent on the time and continuity of the exposure, illumination and night activity, are generated in the mechanism of thermal, mechanical and photochemical (oxidation) damage [6]. Deformation, vacuolization and fragmentation of rods and cones progress leading to the complete destruction of the photosensitive layer of the retina [6]. It has been suggested that degenerative changes induced by the light of high intensity are developed in apoptosis mechanism [7]. According to Abramow et al. impaired colour and space vision (without a dysfunction of rods) is observed in the neonate in the NICU [8]. In his earlier studies, Hamer et. al. did not prove the influence of continuous light exposure on the functioning of retina sensor cells in the neonate staying in the NICU [9]. According to Kennedy et. al. and Roy et al. the preventive light reduction does not impair the development of the retina [10] and [11]. Animal studies prove an unfavourable effect of continuous light exposure on the growth of the eyeball, leading to the impaired eye refraction [12]. Recent studies exclude the influence of light on the incidence, intensity degree, and the course of retinopathy in premature infants [13].

Circadian rhythms induced by the rotation of the Earth generated by the light-induced biologic clock located in the hypothalamic suprachiasmatic nuclei synchronise physiological processes of the organism during the 24hr light/dark cycle, conditioning the health [14]. After birth, the circadian rhythm of the fetus is regulated by the mother’s day/night activation. It depends on the environmental illumination (regular and irregular light/dark cycles), feeding (breast milk, instant formula) and intrauterine age [15]. Rivkees’s et al. studies demonstrated a higher activity in premature infants during the day than at night, in comparison with those staying continuously in reduced illumination [14].

The influence of light on physiological processes in neonates, evaluated by many authors is not explicit. According to Jung, the cycled lighting used for 10 days increases the neonate’s body mass and saturation, decreases the heart beat, not affecting the respiration rate, behaviour stability and the body weight [16]. Brandon et al. observed a beneficial influence of the cycled light on the weight gain in neonates [17]. Boo et al. did not confirm these observations [18].

Neonates hospitalised in the NICU are exposed to natural and artificial illumination (illumination of the ward room, procedural illumination, phototherapy, ophthalmoscopy) [19]. The physical properties of light, physiological factors (lid thickness, opening of the eyes, pupil diameter), and environmental factors (type of incubator, methods reducing illumination in-
Intensity used, location in the NICU room) affect the amount of light that the neonate is exposed to [19] and [20]. The examinations suggest that an increase in the level of illumination decreases the frequency of the opening of the lids in neonates, which may impair the process of vision development (sight fixation) and lead to phototoxicity [21]. The aim of the study was the description of illumination in the NICU at night.

Material and methods

Illumination intensity was measured by a luxometer L-0A (producer – PPUH SONOPAN, Poland) and expressed in lux (lx). The examinations were performed in one of the NICU rooms of the Department of Neonatology of the Medical University of Białystok, Poland.

There were 4 incubators placed peripherally (two at each side of the room) sized 5.9 × 4.6 m. The walls of the room were covered with tiles to the height of 1.6 m, the floor had a covering, two windows sized 150 × 200 cm were screened with roller-blinds (impregnated linen), the desk and cabinets were placed peripherally. Standard illumination of the room included 3 fluorescent lamps placed under the ceiling turned on with the separate switcher. Procedural illumination (100 W) and the bedside lamp were the additional source of light. The measurements were performed after twilight. The lightning was switched on for about 30 min before measurement and the phototropic receiver was illuminated for at least 5 min with the measured light intensity (according to PN – 84 E – 02033 Interior illumination with electric lighting). Each measurement was done three times, the mean and standard deviation were calculated. The measurements were carried out in the closed incubator (ISOLETTE, Air – Shield, Vickers, GB) and the open incubator (Bab ytherm 8000, Dräger, Medizintechnik GmbH, Germany) situated at 0.6 m from the wall.

![Fig. 1. Method of illumination intensity measurement](image)

The photoelectric receiver of the luxometer was placed on a doll’s head at the level of its eyes.

The measurements were performed in the conditions of standard illumination of the NICU room (3 fluorescent lamps switched on), reduced illumination (1 fluorescent lamp) minimal illumination (1 bedside lamp on the desk) and procedural illumination (extra source of light) and phototherapy. The procedures reducing the light amount that the neonate was exposed to, were applied (the change in a doll’s position in the incubator, a one- or four-ply cover on the incubator, eye-patches for phototherapy) (a producer PRO – OPTICS, INC., PALATINE, IL, USA).

Results

The illumination intensity measured in the NICU, in the open and closed incubator at the standard, reduced and minimal night lighting is presented in Table 1.

<table>
<thead>
<tr>
<th>Type of illumination</th>
<th>Closed incubator</th>
<th>Open incubator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard illumination</td>
<td>325 ± 5.0</td>
<td>200 ± 5.8</td>
</tr>
<tr>
<td>Reduced (night)</td>
<td>31 ± 1.0</td>
<td>31 ± 2.1</td>
</tr>
<tr>
<td>Minimal illumination</td>
<td>1 ± 0.01</td>
<td>1 ± 0.01</td>
</tr>
</tbody>
</table>

It is worth mentioning that the structure of the open incubator provided darkening in the field of measurement, due to which the result obtained (200 ± 5.8 lx) was significantly lower in comparison with the results taken in the closed incubator (325 ± 5.0 lx).

The amount of light that the neonate is exposed to is modified by its positioning in the incubator and under the incubator cover. In the conditions of both standard and reduced illumination, if the incubator is uncovered, the illumination intensity taken at the height of the neonate’s eyes is lower when the doll is positioned on the side in comparison with the supine position on its back. However, the cover on the incubator reduces more significantly the amount of light the neonate is exposed to from above than from the side (Tab. 2).

<table>
<thead>
<tr>
<th>Type of illumination</th>
<th>Position on the back</th>
<th>Position on the side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard illumination</td>
<td></td>
<td></td>
</tr>
<tr>
<td>incubator without the cover</td>
<td>325 ± 5.0</td>
<td>253 ± 6.0</td>
</tr>
<tr>
<td>incubator with the cover</td>
<td>47 ± 7.0</td>
<td>108 ± 9.6</td>
</tr>
<tr>
<td>one-ply fabric</td>
<td>22 ± 1.0</td>
<td>100 ± 3.0</td>
</tr>
<tr>
<td>four-ply fabric</td>
<td></td>
<td></td>
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<tr>
<td>Reduced illumination</td>
<td></td>
<td></td>
</tr>
<tr>
<td>incubator without the cover</td>
<td>31 ± 1.0</td>
<td>24 ± 2.5</td>
</tr>
<tr>
<td>incubator with the cover</td>
<td>3 ± 0.7</td>
<td>18 ± 1.1</td>
</tr>
</tbody>
</table>

An increase in the thickness of the fabric used to sew the incubator cover reduces the standard illumination intensity from 47 ± 7.0 lx in case of one-ply fabric and 22 ± 1.0 lx, when four-ply fabric was used, when the doll was positioned on the back position. When the doll was positioned on the side position, the incubator cover reduces the standard illumination from 108 ± 9.6 lx to 100 ± 3.0 lx respectively (Tab. 2).
Applying extra light sources (procedural lighting or lamps for phototherapy) used in the NICU increases markedly the amount of the light the neonate’s eyes are exposed to (Tab. 3).

Table 3. Illumination intensity with using extra light sources (lx)

<table>
<thead>
<tr>
<th></th>
<th>Open incubator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard illumination</td>
<td>200-325*</td>
</tr>
<tr>
<td>Procedural illumination</td>
<td>533-1280**</td>
</tr>
<tr>
<td>Phototherapy</td>
<td></td>
</tr>
<tr>
<td>without eye-patches</td>
<td>3860-8560***</td>
</tr>
<tr>
<td>with eye-patches</td>
<td>120-211***</td>
</tr>
</tbody>
</table>

* with regard to the type of the incubator  
** with regard to the type of light source  
*** with regard to a model of the lamp used for phototherapy

Eye-patches used in phototherapy reduce the illumination intensity from 3860-8560 lx to 120-211 lx depending on the model of the lamp used.

Discussion

The role of illumination in caring for hospitalised neonates (it maintains and influences the development of vision processes, regulates the circadian rhythm, enables professional care and parents’ visits) and taking into consideration the harmful effect of too bright light on the development of the vision organ and the circadian cycle, delineate the schemes for the recommended illumination in the NICU [4] and [5].

In the 1980s, the level of illumination intensity ranging from 600 to 1000 lx was commonly accepted [18]. Proving the harmfulness of high intensity illumination on the process of the vision organ development caused the reduction in the recommended illumination intensity to the level of 1-2 lx in the NICU, permitting at the same time an individual increase in the illumination for observation and procedures [22]. Taking into consideration the significance of the circadian rhythm for the physiological development of the neonate hospitalised in the NICU in 1998 in Great Britain, 50-100 lx was taken as a mean level in the indirect care and 1000 lx in the intensive therapy with the reduction in the illumination to 5 lx between 8 p.m. and 8 a.m. [19]. Similarly, in 1997 American Academy of Pediatrics (AAP) recommended introducing regular day/night cycles of illumination in the NICU [15]. Developing a physiological circadian rhythm in premature babies requires illumination intensity of 100-150 lx for 8 hours daily with a reduction in the evening and at night [22]. The concept of illumination assumes the individualisation of lighting underlying beneficial effects of the natural light [23].

Robinson et al. examined the conditions of illumination in 7 NICUs in Great Britain in 1990, proving a mean level of the illumination intensity at night (8 p.m.-8 a.m.) 348 lx (range192-690 lx), and during the day (7 a.m.-8 p.m.) 470 lx (236-905 lx). These results were lower than those obtained earlier by Landry et al. (285-1485 lx) [19]. The further reduction in the illumination in the NICU was recorded by Bullough et al. showing the illumination intensity of 184 lx during the day (1 p.m.) and at night (12.30 a.m.) – 34 lx [24]. In our study, the standard illumination of the NICU room had the intensity of 325 lx, reduced – 31 lx, minimal – 1 lx. According to the standards accepted in the Department of Neonatology of the Medical University of Białystok, referring the neonate’s minimal care and therapy, minimal illumination with the individualised illumination intensity in case of necessary procedures, was applied at night.

Walsh-Sukys et al. examined the effects of the reduced illumination, which is beneficial for the preterm neonate’s development, patients’ safety, medical staff’s perception and the costs of hospitalisation in the NICU of level III reference. Introducing the individualised illumination for each neonate caused the reduction in illumination from 193 lx to 12 lx, individual extra illumination, which could be compared to traditional (202 lx), was provided if necessary. The costs of the project were low. About 60% of the medical staff regarded new conditions to be beneficial for both neonates and caretakers.

No increase in the number of unwanted accidents, malpractice, accidental extubations, infections or in mortality rate was reported [22].

Phototherapy applied in the NICU generates the high illumination intensity. It is recommended to use eye-patches, mechanically stopping the light in order to protect the vision organ against damage (deformation, vacuolization, fragmentation of the rods and cones) [25] and [26]. Robinson et. al. proved that when using various protective patches for the eyes, the illumination was reduced up to 2% - 10% at the wavelength of 700 nm [25]. In Chin’s et al. study transmission of the light wavelength of 460 nm did not exceed 0.04% when eye-patches were used [26]. In the study, we reduced the illumination intensity using phototherapy eye-patches to 2.5-3.1% depending on a model of the lamp used.

Lee et. al. evaluated the influence of the incubator cover on the reduction of the light that the neonate was exposed to [27]. They proved that the incubator cover in dark colours reduced more of the light inside the incubator than the cover in light colours [27]. The further reduction in the illumination transmitted to the neonate can be achieved by an increase in thickness of the fabric used to sew the cover. When an incubator is covered, the neonate’s supine position on the back is favorable (22 ± 1.0 lx at a supine position on the back, and 100 ± 4.7 lx at the position on the side). In the uncovered incubator, a position on the side is more favorable (325 ± 5.0 lx in the position on the back and 253 ± 6.0 lx at the position on the side).

The reduction in the illumination that the neonate is exposed to in the incubator correlates with the thickness of the wall in the incubator. According to Kardson, an increase in the wall thickness, to diminish heat loss in the neonate, reduces the therapy light that the neonate is exposed to during more than 40% [28]. In our study, the illumination intensity was lower in the open incubator (200 ± 5.8 lx) in comparison with the intensity in the closed incubator (325 ± 5.0 lx). It resulted from the shadow of the open incubator structure cast on the measurement field.
Conclusion

Minimal night illumination generates the light intensity in accordance to the recommendations for the NICU. Application of the procedures reducing the illumination intensity in the NICU decreases night light transmission to the neonate’s eyes, which is especially important in the physiological development of the vision organs and circadian rhythm of neonates hospitalised in the NICU.

References


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