Mist and water condensation inside incubators reduce the efficacy of phototherapy

Manoel de Carvalho, Carolina Turano Torrao, Maria Elisabeth Lopes Moreira

ABSTRACT

OBJECTIVE To measure the irradiance in humidified incubator under three different overhead phototherapy devices.

DESIGN/METHODS The effective irradiance of three phototherapy devices was assessed by taking a series of irradiance measurements in the illuminated field. Measurements were made with a fixed bandwidth broadband radiometer (380–530 nm). The distance between the light source and the radiometer was 35 cm for the daylight fluorescent lamp, 40 cm for the light emitting diode (LED) and 50 cm for the halogen phototherapy. A double-wall incubator was kept at 36°C and set at three different levels of humidity (60–70%, 80% and equal or above 90%).

RESULTS The irradiance under the overhead daylight fluorescent lamp phototherapy did not change with the increasing humidity. However, above 90% humidity, when water vapour inside the incubator was so saturated to the point of totally condensing in the incubator walls, the measured irradiance decreased 15% of the initial values with the blue LED phototherapy and 45% with the halogen spotlight phototherapy.

CONCLUSIONS Highly humidified incubators are frequently used to treat very low birthweight infants. Health professionals should be aware that mist and water condensation inside an incubator may significantly reduce the efficacy of treatment.

INTRODUCTION

Transepidermic water loss is high in very low birthweight infants (VLBW). In order to minimise this loss, new and modern incubators have been developed aiming at increasing relative air humidity inside them. This technology has allowed a more adequate control of hydroelectrolytic and thermal balance of VLBW infants. However, with humidity set at 90% or higher, the quantity of water vapour inside the incubator is so intense that it impairs visualisation of the patient.

In addition, VLBW infants often develop significant hyperbilirubinaemia needing efficient phototherapy. As the efficacy of phototherapy depends on the amount of light energy (irradiance) reaching the patient, it is argued that high humidity inside incubators may interfere with the effectiveness of the treatment.

The goal of this trial is to determine if mist and water condensation inside the incubator influence the irradiance delivered by phototherapy devices.

MATERIAL AND METHODS

An experimental trial using a double wall VISION incubator (model 2186; FANEM, São Paulo, Brazil) was performed. Incubator temperature varied from 34.7°C to 36.4°C, and external room temperature was kept constant at 25°C throughout the experiment. Measurements were performed in the same incubator without the presence of newborn infants.

Humidification of the incubator was selected in three levels (60–70%, 80% and equal or above 90%). A thermo-hygrometer model HT 208 manufactured by CIAL (FLUKE 5500A calibrator; gauged by Sigtron-INMETRO/RBC, São Paulo, Brazil) was used to assess confirmation of humidification levels inside the incubator. The level of humidification of 60–70% was considered as baseline, since relative air humidity in Rio de Janeiro is around it. This is the level found when the incubator has no humidification. For each 10% increase in humidification level, there was a waiting period of 90 minutes for temperature and humidity stabilisation. Irradiance emitted by the phototherapy device was measured with a Fanem radiometer model 2620–Brazil (reading band 380 nm and 530 nm, peak 460 nm) placed on the incubator mattress.

Three phototherapy models were tested: phototherapy with daylight fluorescent lamps, phototherapy equipped with halogen light source (Bilispot, model 006BP; FANEM, São Paulo, Brazil) and light emitting diode (LED) phototherapy (Bilitron, São Paulo, Brazil). Irradiance measurements were performed in triplicate at different
humidification levels. Each phototherapy model was tested separately with minimum interval of 90 minutes between measurements. Since the illuminated areas projected by these phototherapy devices are different and irradiance is not evenly distributed throughout the areas, we decided to measure the spectral irradiance of the whole illuminated area instead of a single point of measurement.

The daylight fluorescent lamp phototherapy device (FANEM model 007), was equipped with a set of six 20 W daylight fluorescent lamps and positioned at 35 cm from the incubator mattress as recommended by the manufacturer. For irradiance measurement, a white rectangular cardboard sheet was fixed on the mattress. The mattress area (42×34 cm) was divided in four predetermined points. Average spectral irradiance (ASI) was obtained by the arithmetic mean of these four points (figure 1).

The halogen phototherapy model (Bilispot) was equipped with a 12 V 75 W dichroic light bulb and positioned perpendicularly at 50 cm from the incubator mattress as recommended by the manufacturer. The light emitted by this device projected over a flat surface produces a bright circle (15 cm diameter) with clear edge. ASI of halogen phototherapy was obtained in the following way: The projected circle was drawn on a white cardboard and subdivided into three concentric areas obtained by the drawing of two additional ellipses dividing thus the illuminated surface in three areas (A, B and C) of 75.3 cm², 226.1 cm² and 377.2 cm², respectively. In each of these areas, four diametrically opposed points were marked to serve as irradiance measurement points (figure 1). The arithmetic means of these four points, once pondered with their respective areas and added up, gave the ASI according to the equation below:

\[
ASI_{\text{total}} = \frac{ASI \times 19.6}{176.7} + \frac{ASI \times 58.9}{176.7} + \frac{ASI \times 98.2}{176.7}
\]

The LED phototherapy device (Fanem model 3006-Brazil) was equipped with five SuperLED light bulbs and positioned 40 cm away from the incubator mattress surface as recommended by the manufacturer. At this distance, the light focus assumes an elliptic shape of 32×27 cm. ASI of this equipment was measured the following way: the projected ellipse was drawn on a white cardboard and subdivided into three concentric areas obtained by the drawing of two additional ellipses dividing thus the illuminated surface in three areas (A, B and C) of 57.3 cm², 226.1 cm² and 377.2 cm², respectively. In each of these areas, four diametrically opposed points were marked to serve as irradiance measurement points (figure 1). The arithmetic means of these four points, once pondered with their respective areas and added up, gave the ASI according to the equation below:

\[
ASI_{\text{total}} = \frac{ASI \times 19.6}{176.7} + \frac{ASI \times 58.9}{176.7} + \frac{ASI \times 98.2}{176.7}
\]

RESULTS
At the beginning of the study the maximum irradiance level for each of the three phototherapy models was 3.0±0.1 μW/cm²/nm, 20.5±3.8 μW/cm²/nm, 21.5±3.4 μW/cm²/nm for the daylight fluorescent lamps, LED and halogen phototherapy, respectively.

With humidification inside the incubator set at 60% and 70% there was no variation in irradiance in any of the three tested phototherapy models. When the level of humidification was increased to 80%, and subsequently ≥90%, there was an increasing of mist and water condensation on the walls of the incubator and a decrease in irradiance measured in the halogen and LED phototherapy devices (table 1). Measurements made with the LED phototherapy showed a decrease of 10% and 15% when the humidification was increased to 80% and ≥90%, respectively. The decrease of irradiance in the halogen phototherapy was even more pronounced. When the humidification level was increased to 80% and ≥90%, irradiance dropped, respectively, 29% and 45% from the initial values. Increase in mist and water condensation inside the incubator did not alter irradiance measured in the daylight fluorescent phototherapy model.

**Figure 1** Geometric areas used to calculate the irradiance of the phototherapy devices.
DISCUSSION
The skin of VLBW is structurally and functionally immature at birth predisposing the patient to great water and heat loss.7 Hydro electrolytic balance of these patients is more difficult and usually insensible water loss is inversely related to gestational age. To minimise water loss and prevent acute dehydration it is common practice to nurse these patients in humidified incubators during the first days after birth.8 The results of our study show that when humidification is set at ≥90%, irradiance delivered by LED and halogen phototherapy decreases 15% and 45% of initial values, respectively. Water condensation on incubators wall and the resulting foggy atmosphere inside it are probable causes for the observed decrease in irradiance. However, with phototherapy using daylight fluorescent lamps no change in irradiance was observed with increasing humidification. This finding. One can also speculate that the distance between the irradiance meter and the light source may have influenced our results. In the daylight fluorescent phototherapy this distance was smaller (35 cm) than the LED (40 cm) and halogen phototherapy device (50 cm), which means that light had to go through a smaller column of mist. In addition, the irradiance meter sensitive used in our study (1 μW/cm²/nm) may not have been enough to accurately measure the relatively small absolute changes in irradiance with the daylight fluorescent lamps phototherapy.

The efficacy of phototherapy is dependent on the wavelength, irradiance of the light and the exposed body surface area. There is a clear dose-response relation between irradiance and the effectiveness of phototherapy. Many factors alter the amount of light energy reaching the newborn’s skin and consequently the irradiance delivered by a phototherapy device.9 In this study, although the irradiance delivered by the daylight fluorescent lamps phototherapy was no affected by the increasing humidification levels, the low reading suggests that they are not an effective device. The low level of irradiance delivered by these units may be related to the quality of daylight fluorescent lamps used in Brazil. A previous study conducted in 21 nurseries located in the city of Rio de Janeiro showed that the mean irradiance level in 102 phototherapy devices tested was less than 4 μW/cm²/nm.10 Since then, the use of daylight fluorescent lamps has been gradually replaced to more effective devices.11

Very low birthweight preterm infants area more likely to develop hyperbilirubinaemia needing efficient phototherapy. These infants are usually nursed in double-wall incubators with high humidification to minimise water and heat loss. In addition, these infants are more likely to develop hyperbilirubinaemia needing efficient phototherapy. The influence of the incubator acrylic wall, the use of heat shields and plastic blanket have been studied.13,14,15 However, the effects of mist and water condensation produced by excessive humidification on irradiance level should also be considered. When treating jaundiced premature infants nursed in humidified incubators, health professionals should be aware that the efficacy of phototherapy may be decreased by the concentration of mist and water condensation.

Competing interests None.

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