Short reports

Uneven distribution of light in standard phototherapy

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SUMMARY Maldistribution of light is a potential cause of phototherapy failure in the neonate. Differences in light intensity over the surface can be measured with a radiometer as this detects the radiant energy impinging on the incubator mattress. An infant nursed on the front third of the mattress receives less than 40% of the maximal light incident on the centre of the mattress, and consequently degradation of unconjugated bilirubin will be less effective.

The outcome of the serendipitous observations at Rochford General Hospital in the early 1950s¹ led to the first description of the clinical use of light in the management of the jaundiced infant.² Since then phototherapy has become a widespread and effective method of treating unconjugated hyperbilirubinaemia of infancy.

Failure of phototherapy to degrade bilirubin effectively may be due to the use of a light source emitting spectral energy of low radiant intensity,³ ageing of the fluorescent tubes,⁴ or exposing insufficient skin surface to the light source. This paper explores the possibility of phototherapy failure due to uneven distribution of light within the incubator.

Methods and results

The light intensity of phototherapy units was recorded in various positions over a standard Air-Shields Isolette incubator mattress. The mattress was divided into 9 equal rectangles (A-I) each measuring 21 × 12 cm (Figure). Two different phototherapy units were used to provide the light source: the Vickers Medical phototherapy unit (four element), and the Air-Shields S400 (four element). Various permutations of blue and white fluorescent tubes were used in both. The phototherapy units were tested in a lightproof room and measurements of light intensity were made after the tubes had warmed up.

Back

Figure Relative light incident on the 9 equal areas of the incubator mattress expressed as a percentage of the maximal area (phototherapy unit is at back).

Measurement of light irradiance was made at the mattress in the incubator, 45 cm from the light source by a newly calibrated Air-Shields radiometer S450 (Narco Air-Shields, Europe), and the intensity was recorded in $\mu\text{W}/\text{cm}^2$. The peak sensitivity of the radiometer was at wavelength 450 nm.

Four recordings were made in each of the 9 rectangles for each combination of fluorescent tube. Altogether 32 readings were made in each area. The results are expressed as a percentage of the highest reading made in any rectangle (Figure). There was no significant difference in the distribution of light irradiance between different phototherapy units or between different combinations of tubes.

The areas receiving most light are the centre back and middle rectangles. There is a significant difference between the light intensity of these two areas, and areas A, C, D, and F ($P < 0.001$). Area H receives only half the light irradiance of areas B and E, and areas G and I receive less than a one-third of the irradiance of B or E. There is a highly significant difference between areas G and I, and area H ($P < 0.001$).

Discussion

The radiant flux of a light source in $\mu\text{W}/\text{cm}^2$, measures the total power of light radiation within a defined wavelength band. A dose-response curve has been constructed by Mims *et al.*⁵ demonstrating that increments of radiant flux increase photodegradation of bilirubin in a near linear manner. This curve assumes that the irradiance of incident light is uniform over the entire infant, and the results of this study indicate that the intensity of light on different areas of the incubator varies considerably.

The usual position for an infant to be nursed in an enclosed incubator is towards the front to give easy access through the ports or door. From this study it appears that an infant nursed on the front third of the mattress receives less than 40% of the maximal light impinging on the centre of the mattress.

Further studies on the optimal number and orientation of the fluorescent tubes should ensure that a more even distribution of light occurs. A

simple solution may be a plastic diffusing element under the tubes to distribute the light more evenly over the entire incubator surface.

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Comparison of efficiency of commercially available phototherapy units

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SUMMARY The efficiency of two phototherapy units was compared by exposing solutions of bilirubin *in vitro*. Both units are commercially available.

Phototherapy is a procedure that is no longer considered to be free of complications. The efficiency of photodegradation by two phototherapy units was compared in an effort to discover which unit exposed the infant to the least light energy for greatest bilirubin decay.

Methods A standard solution containing about 360 $\mu\text{mol}/\text{l}$ (21 mg/100 ml) bilirubin (Versatol Paediatric*) was prepared. 14 glass microcapillary tubes were filled with this and placed under the phototherapy unit. An estimate of total bilirubin was made at zero time on two tubes using a bilirubinometer (American Optical Instruments). The other 12 tubes were placed in the light source to be tested at the centre of the mattress of an Air-Shields Isolette incubator with the motor switched off.

The incubator had been placed in a lightproof room which was not affected by changes in external

*General Diagnostics, Morris Plains, New Jersey.

temperature. The two phototherapy units were the Air-Shields S400 (four tubes) and the Vickers Medical (four tubes); both were supplied by the manufacturers with standard new white and blue fluorescent tubes. The units were fitted consecutively with four white, four blue, and a combination of two blue and two white tubes. Each was assessed on its ability to degrade the bilirubin solution in the capillary tubes.

The light sources were placed 45 cm directly over the incubator and left on for 24 hours. Two capillary tubes were removed at intervals of 1, 2, 3, 6, 9, and 24 hours and the total bilirubin in each tube was estimated. The light intensity at the centre of the incubator mattress was recorded by means of a newly calibrated spectroradiometer (Air-Shields S450) for each of the three combinations of light in both phototherapy units. These results are expressed in $\mu\text{W}/\text{cm}^2$ of the measured wavelength between 350 and 550 nm, peaking in sensitivity at 450 nm which is at the blue end of the visible spectrum.

Results

The photodecomposition of the standard bilirubin