A Comparison of Fluorescent and Nonfluorescent Light Sources for Phototherapy

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ABSTRACT. We have compared fluorescent and nonfluorescent light sources for phototherapy for newborn infants with hyperbilirubinemia. Phototherapy was provided by a tungsten halogen lamp and conventional fluorescent lights with identical radiant flux of 6 μW/sq cm. For 22 infants treated with the nonfluorescent lamp the mean duration of phototherapy was 33.77 hours and the mean reduction of bilirubin was 3.84 mg/100 ml/day. This did not differ significantly from infants treated with conventional fluorescent lights. The nonfluorescent light can be utilized for infants in incubators or on radiant warmers. These results provide additional support for the relationship between radiant flux as a practical measure of phototherapy dose and the clinical response of a reduction in serum bilirubin. *Pediatrics* 65:795–798, 1980; *hyperbilirubinemia, phototherapy, nonfluorescent light source.*

The use of phototherapy for neonatal hyperbilirubinemia is based upon a photochemical process with an action spectrum between the 400 and 500 nm range with a peak in the blue region at 450 nm. Light sources with different emission spectra in the 400 to 800 nm range have been used for treatment of neonatal hyperbilirubinemia. The photometric unit, foot-candle, assesses the illumination by a light source by a luminous efficiency curve or action spectrum for vision which is between the 400 and 700 nm range with a peak in the green region. Lucey[1] in 1972 suggested that the effectiveness of phototherapy be based on measurement of radiant flux in the 400 to 500 nm range rather than measurement of light illumination in foot-candles since efficacy may be totally independent of foot-candle measurement.

In a recently published study[2] conducted at Yale New Haven Hospital, we found that commercially available phototherapy units on intensive care radiant warmers (Air-Shields Infant Care System, model PT 53-1 (two, four-lamp units, one on either side of a central heating element) and Ohio Neonatal Intensive Care Center, model 305-0405-910, with accessory central NICC Phototherapy Light, model 217-5120-800) were ineffective in delivering therapeutic levels of radiant flux. Radiant warmers equipped with white fluorescent lights at a height of 100 cm from the infants provided a radiant flux of only 1.2 to 1.5 μW/sq cm/nm in the 400 to 500 nm wavelength range. It was shown that at least 4 μW/sq cm/nm of radiant flux was required for effective phototherapy and could be provided only by the conventional bank of white fluorescent lights placed 42 cm from the infant. Blue or special blue fluorescent lights rather than white fluorescent lights may be effective overhead phototherapy sources. However, their use has generally not been acceptable since infants' skin color changes are difficult to detect, and overhead narrow band blue lights may cause uncomfortable and sometimes nauseating sensations in the attending personnel. Also other possible side effects of narrow band blue sources are unknown since most of the experience in phototherapy over the last 20 years has been with broad spectrum white light. We have, therefore, evaluated a compact and convenient nonfluorescent overhead phototherapy lamp with white light with sufficient radiant flux to lower bilirubin levels in neonates with jaundice.

MATERIALS AND METHODS

The nonfluorescent lamp (Cavitron/KDC Medi-

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cal Sales, model PT-1400 phototherapy lamp mounted on model IW-10 radiant warmer) utilized in this study could be variably positioned about 75 cm away from the mattress. The lamp contains a tungsten halogen bulb with an infrared dichroic reflector. Its optical projection system consists of two lenses which collect and project the light and an infrared heat absorbing filter. Infrared irradiance on the infants from the lamp was 1 mW/sq cm or less. Ultraviolet emission from the lamp is negligible. The relative spectral irradiance for the lamp is shown in Fig 1. The color of the light output from the lamp is white.

In this study we have compared the effectiveness of this nonfluorescent light source with conventional fluorescent phototherapy. Twenty-two infants were treated with the nonfluorescent source and 21 with conventional fluorescent lights. For infants of both groups a measured average dose of 6.0 μW/sq cm/nm of radiant flux was selected.

Only infants with nonhemolytic (physiologic) jaundice or mild ABO or Rh incompatibility were included in the study. Phototherapy was begun between 24 and 120 hours of age. Indications for phototherapy were an indirect bilirubin of 10 mg/100 ml for infants weighing between 1,500 and 2,000 gm, 12 mg/100 ml for infants weighing between 2,000 and 2,500 gm, and 15 mg/100 ml for infants weighing more than 2,500 gm. Indirect bilirubin levels were determined from capillary blood samples. Determinations were made just before the initiation of phototherapy and at intervals during the course of therapy. The capillary blood sample was shielded from light from the time of sampling until the time of bilirubin measurements. The total and direct bilirubin level determinations were made by the method of White et al.[3] The indirect bilirubin was obtained by subtraction of the direct level from the total.

Each infant was completely naked with appropriate eye patches during the phototherapy. Phototherapy varied between 7 and 83 hours with nonfluorescent lights and between 7½ to 78 hours with the fluorescent source. Phototherapy was terminated when the bilirubin level had fallen below the criteria for treatment. Four infants with rebound of the bilirubin level required additional phototherapy. The results express the total duration of phototherapy.

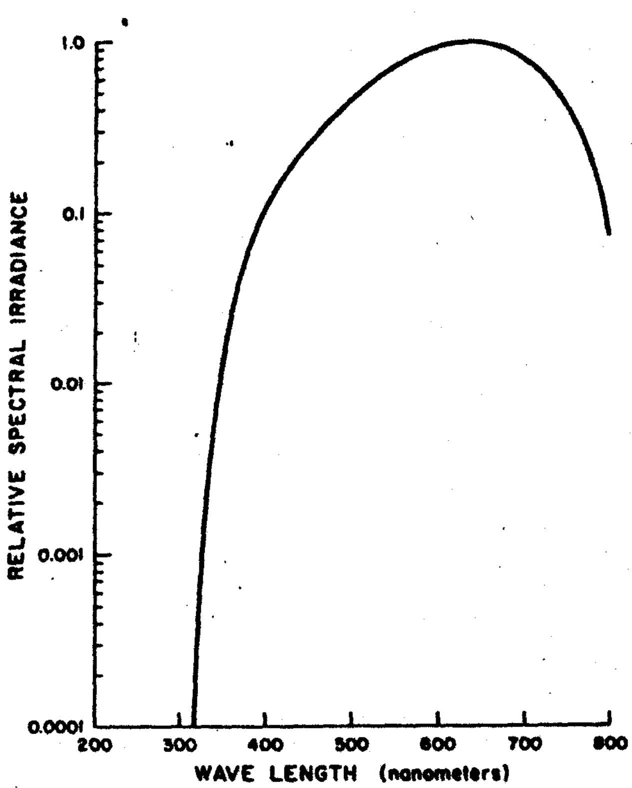

Fig 1. Relative spectral irradiance of the nonfluorescent lamp used in this study. The absolute value of irradiance is dependent on the distance of the lamp and was 9.6 μW/sq cm/nm at 450 nm at a distance of 61 cm.

RESULTS

Table 1 compares the patient population in the study. Group I consisted of 22 infants treated with the nonfluorescent light and group II, 21 infants treated with the conventional fluorescent light. No statistically significant differences were described between the two groups with respect to birth weight, gestational age, or age at onset of the phototherapy. The bilirubin levels at the start of, at the end of, as well as for the duration of phototherapy were similar in both groups.

The rate of reduction in indirect bilirubin level in response to the two modes of phototherapy is shown in Table 2. The rate of reduction in bilirubin was obtained by dividing the reduction in indirect bilirubin level by the required duration of phototherapy treatment. Data presented in Table 2 show the rate of reduction per day and the rate of reduction per hour. Reduction of bilirubin in the nonfluorescent and fluorescent groups was virtually identical.

Fig 2 compares changes in bilirubin in infants receiving 6.0 μW/sq cm/nm by other fluorescent or nonfluorescent light with a group of infants receiving an average flux of 4.66 μW/sq cm/nm.[2] The data show that a flux of 6 μW/sq cm/nm from either nonfluorescent or fluorescent is equally effective in reduction in bilirubin level and is more effective than fluorescent light of 4.4 μW/sq cm/nm.

DISCUSSION

Several investigations have shown the effectiveness of phototherapy for treatment of neonatal jaundice and suggest dose-response relationships.[2,4-7] It is difficult to compare the results of

TABLE 1. Comparative Data for the Two Groups of Infants*

Data	Group I Treated with 6 μW/sq cm/nm† from Nonfluorescent Light	Group II Treated with 6 μW/sq cm/nm from Fluorescent Light	t-Ratio	P Value
No. of Infants	22	21		
Weight (gm)				
Mean	3187.5	3,082.15	0.513	>.6
Range	2,100–4,400	1,750–4,020		
SD	710.96	630.87		
SE	151.58	137.67		
Gestational age (wk)				
Mean	38.84	38.50	0.741	>.42
Range	35–43	32–41		
SD	2.16	2.40		
SE	0.46	0.52		
Age at Treatment (hr)				
Mean	72.47	71.71	0.103	>.9
Range	24–120	30–120		
SD	24.59	23.86		
SE	5.24	5.21		
Pretreatment indirect bilirubin				
Mean	15.21	14.91	0.384	>.7
Range (mg/100 ml)	10.7–20.4	7.3–19.4		
SD	2.71	2.39		
SE	0.58	0.52		
Post-treatment indirect bilirubin				
Mean	10.84	11.43	1.058	>.27
Range (mg/100 ml)	7.7–13.7	6.1–14.4		
SD	1.55	2.08		
SE	0.33	0.45		
Duration of therapy (hr)				
Mean	33.77	27.48	1.126	>.23
Range	7–83	7.5–78		
SD	20.66	15.66		
SE	4.40	3.37		

* Mean, range, standard deviation, and standard error of the mean are indicated.
† IL-155 color radiometer—blue scale, International Light, Inc., Newburyport, MA.

TABLE 2. Comparative Response-Related Data for the Two Groups of Infants

Data	Group I Treated with 6 μW/sq cm/nm from Nonfluorescent Light	Group II Treated with 6 μW/sq cm/nm from Fluorescent Light	t-Ratio	P Value
Rate of reduction of bilirubin (mg/100 ml/hr)				
Mean	0.16	0.14	0.611	>.5
Range	0.036–0.57	0.048–0.318		
SD	0.126	0.0674		
SE	0.027	0.015		
Rate of reduction of bilirubin (mg/100 ml/day)				
Mean	3.84	3.38	0.614	>.5
Range	0.864–13.74	1.15–7.64		
SD	3.04	1.62		
SE	0.65	0.35		

these studies directly since there were differences in factors such as spectral irradiance, distribution curve of the light, distance from infant, area of exposure, directional relationship of the light, and responsivity curve of the radiometer used to measure the irradiance of the lights. For example, the area of exposure from the multidirectional light source in Tan's[5] study is uniquely different, and, thus, his results cannot be compared directly with this or other studies.

The integration of the curve obtained by multiplication of the spectral irradiance distribution curve for the lamp (75 cm) from the infant by the action spectrum at which bilirubin photoreacts de-

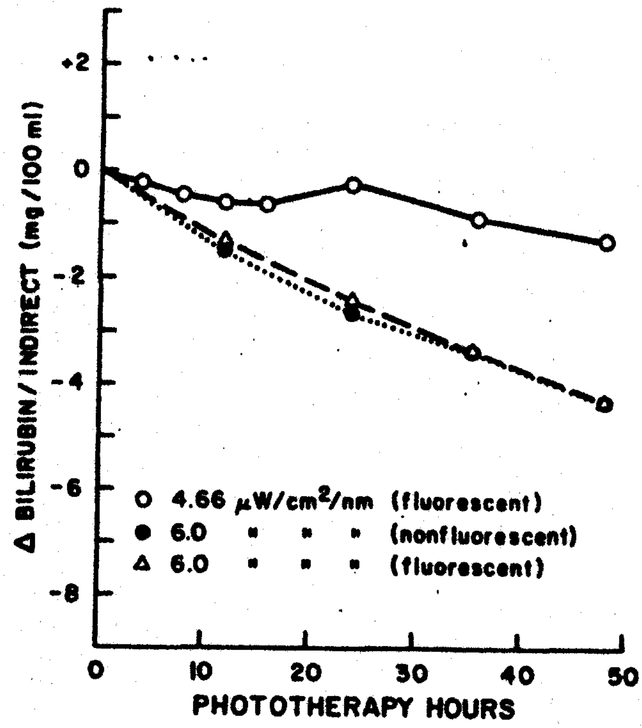

Fig 2. Effect of phototherapy with different average radiant flux levels vs time. The zero point indicates the level of indirect bilirubin prior to start of phototherapy. Changes (triangle) are based on this initial value. Open circles represent the average change for 21 infants treated with 4.66 μW/sq cm/nm of radiant flux from fluorescent white light in our previous study. Solid circles represent the average change for 22 infants treated with 6 μW/sq cm/nm of radiant flux from nonfluorescent white light.

termines the effective dose for phototherapy. In common practice in the United States, this applies to only the front or back of the infant. The "in vivo" action spectrum for bilirubin breakdown, while not precisely known in infants, is generally agreed to be a bell-shaped curve between 400 and 500 nm wavelength with a peak around 450 to 460 nm. Thus, radiant flux measured by radiometer with a similar responsivity curve is a practical measure for the dose of phototherapy. Therefore, as an extension of our previous study, where we showed with a radiometer that a minimum of 4 μW/sq cm/nm radiant flux was necessary for phototherapy treatment, we decided to ascertain the effectiveness of the 6 μW/sq cm/nm from the new nonfluorescent light. As a control, conventional fluorescent lights were also used at a closer distance to the infant to provide similar radiant flux.

We have shown that the two lights of differing spectral irradiance distribution and at different distances are equally effective and there is no statistically significant difference in the response to fluorescent or nonfluorescent light at 6 μW/sq cm/nm radiant flux.

Moreover, the decrease in bilirubin (Fig 2) appears to be more rapid with a radiant flux of 6 μW/sq cm/nm than with 4.66 μW/sq cm/nm provided in our previous study.[2] Our results showing a mean 24-hour reduction of bilirubin of 3.84 mg/100 ml for nonfluorescent light and 3.38 mg/100 ml for conventional fluorescent light while somewhat greater is within the range obtained with an irradiance of 6 μW/sq cm/nm reported elsewhere.[6,7] The mean 24-hour decrease of bilirubin when 4.66 μW/sq cm/nm was used was only 0.48 mg/100 ml as reported in our previous study. Thus, our data provide additional support for the importance of dose-response relationships and emphasize the importance of quantifying the phototherapy dose (irradiance) for [redacted]

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