Light transmission measurements and phototherapy eyepatches

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Abstract

The transmission characteristics of phototherapy eyeshields have been measured under conditions that mimic the clinical situation. Peak transmission (<10%) was detected at 700 nm for the poorest patch tested and <2% for either of the other patches examined. The optics of measurement systems are considered with reference both to this and previous studies of light transmission through eyepatches. The simplicity and effectiveness with which eyepatches can be secured may be as important as their transmission characteristics.

It is routine clinical practice to protect the eyes by covering them with patches while neonates are being treated by phototherapy. As the intensity of light produced by such phototherapy units is in the region known to cause retinal damage in animals the light attenuating properties of eyeshields are of clinical interest.¹

There are several studies that have measured the transmission of light through commercial phototherapy eyeshields and/or 'home made' patches used in some neonatal units.^{2–4} These may be criticised on two main grounds: firstly the instruments used could not obtain spectral plots,^{2,4} and secondly the relative positions of the light source, eyepatch, and detector did not mimic the clinical situation.³

Porat *et al* used a standard photographic light meter to obtain their penetrance measurements (converted here to transmission values) which ranged from 0.3% for the commercially produced 'Bilimask' up to 48% for a single layer of stockinette material.⁴ However, this data may be misleading as the instruments and the units of measurement chosen were inappropriate.⁵ Photographic light meters are not specifically designed for performing transmission measurements and undoubtedly lack sufficient accuracy. In addition, when considering the potential hazards of phototherapy light to the cornea and/or retina, both the intensity and wavelength of light must be considered. Illuminance, as measured by Porat and associates, is a photometric unit and describes the intensity of light falling upon a surface weighted by the spectral sensitivity of the human observer (V_λ) as defined by the Commission Internationale d'Eclairage. The V_λ curve peaks in the yellow-green (555 nm) region of the visible spectrum whereas most phototherapy sources emit blue light (425–470 nm), and a small amount of ultraviolet radiation between 330 and 400 nm.

Chin *et al* measured the transmission of light

through a variety of phototherapy eyeshields currently used in neonatal units in England.³ These authors measured the transmission of light at wavelengths between 250 and 800 nm using a Perkin-Elmer 330 spectrophotometer (sensitivity 0.002%), a range which contained the spectral region in which energy from a phototherapy source is maximal. The commercial patches examined, which included the Bilimask manufactured by Olympic Medical, demonstrated a peak transmission of less than 0.02%, a figure matched or improved on by some of the home made eyeshields. But the optics of the system used permit the measurement of only directly transmitted light and thus this data may underestimate the total amount of light (direct and scattered) which penetrates the eyeshield.

Here we report a small study in which the transmission characteristics of eyepatches has been measured under conditions that attempt to mimic their use in a neonatal unit as closely as possible.

Materials and methods

A Macam SR300 spectral radiometer was used to perform the transmittance measurements. This consists of a Macam MCG201 monochromator, electrometer, silicon diode photodetector, liquid light guide 1000 mm long with a 5 mm active diameter and/or a sideview attachment with diameter 1.0 cm. The system has a bandwidth of 15 nm and has been calibrated in watts (W) (per steradian for radiance)/cm²/nm correct at 510 nm against lights traceable to the National Bureau of Standards (NBS). Measurements at other wavelengths require the display reading to be modified by the multiplication factors given in the table. The Macam radiometer used has a calibrated spectral range of 380–740 nm and an uncalibrated range of 350–800 nm. Sensitivity for irradiance is 1×10^{-8} W/cm²/nm.

Background light was nulled and the eyepatch placed over the detector head, the separation of detector and eyepatch being about 2 mm. A series of measurements of the irradiance (taken at 10 nm intervals between 400–700 nm) were then taken with the detector placed 35 cm from the phototherapy source (Vickers Medical 80/885). The eyepatch was removed from the detector head and the series of readings repeated to obtain baseline measurements. The percentage transmission at each wavelength was made by dividing each eyepatch reading by the corresponding baseline measurement and multiplying by 100.

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Correction factors for each wavelength for the Macam SR300 spectral radiometer

Wavelength (nm)	Multiplication factor to obtain (W/cm ² /nm)
380	4.00
390	2.47
400	1.87
410	1.54
420	1.42
430	1.32
440	1.24
450	1.20
460	1.14
470	1.13
480	1.12
490	1.10
500	1.08
510	1.00
520	1.08
530	1.21
540	1.23
550	1.24
560	1.23
570	1.33
580	1.29
590	1.34
600	1.45
610	1.52
620	1.60
630	1.62
640	1.64
650	1.68
660	1.69
670	1.75
680	1.75
690	1.77
700	1.88

Three sets of measurements were made for each of three eyepatches: Olympic Medical Bilimask, Opticlude orthoptic eyepatch, and two layers of dual thickness woven green cloth, all three of which were similar to patches used in a previous study of transmission characteristics of eyepatches.³

Results and discussion

The figure shows the transmission measurements obtained for the three eyepatches. In the critical spectral region of 460 nm neither the Bilimask nor the green cloth had a peak transmission of greater than 4% at 700 nm and even for the poorest patch tested (Opticlude orthoptic eyepatch) this did not exceed 10%.

Although our data may appear contrary to previously spectral transmittance characteristics of eyepatches used in England,³ this is not entirely so: both the sets of data confirm that there is very little difference between the home

Light transmission characteristics of three phototherapy eyepatches.

made patches and commercially produced eyeshields. The difference in magnitude can be explained by variations in the apparatus used to perform the measurements. The Perkin-Elmer spectrophotometer used in the former study is correct for normal incidence transmission, while the data reported here includes the contribution of both normal and diffuse scattered light.

It is possible to compare the two sets of data directly by considering the specifications of the detector system (see appendix) and differences in the systems explain the multiplication factor of ~100 between the two sets of measurements. Therefore although both sets of data are correct, the question remains—which set is most appropriate when considering the transmission characteristics of phototherapy eyeshields? We suggest that the data reported above are most appropriate for conditions under which eyepatches are used in clinical practice as they represent the amount of light reaching the eye or eyelid through the patch due to a combination of directly transmitted and scattered light. This does not invalidate the previous study, however,³ or experimental methods employed, as the apparatus used permitted very accurate curves of light transmission to be plotted.

It is also pertinent to note that eyepatches are difficult to keep in place and may slip,⁶ and indeed a recent report noted that they did not fully cover the eyes for 56% of observations.⁷ This slippage may be explained by the difficulty in securing the eyepatches and perhaps the reluctance of the nursing staff to disturb an immature and hence tiny baby frequently for a task of perceived secondary importance compared with more immediate and life saving interventions. The choice of eyepatches should therefore take into account the simplicity and effectiveness with which they can be secured.

Appendix

After light has passed through the eyepatch one of two detector systems is present.

(1) It is assumed that light spreads from a point source of intensity I_0 (W/cm²) as $I_0 \cos\theta/l^2$ (the cosine rule) where θ is the angle from normal and L is the distance of the detector from the source. Thus any ring will gather:

$$I_g = (I_0 \cos\theta \cdot (\text{area}))/L^2$$
$$I_g = I_0 \cos\theta (2\pi x dx)/L^2$$
$$I_g = \frac{I_0}{L} \int_0^R \frac{L}{(l^2 + x^2)^{3/2}} 2\pi x dx$$
$$= \frac{2\pi I_0}{L} \int_0^R \frac{x}{(x^2 + L^2)^{3/2}} dx$$
$$= \frac{2\pi I_0}{L} \left[\frac{-1}{\sqrt{x^2 + L^2}} \right]_0^R$$
$$= \frac{2\pi I_0}{L} \left(\frac{1}{L} - \frac{1}{\sqrt{R^2 + L^2}} \right)$$

For the Perkin-Elmer spectrophotometer: $L \sim 200$ mm and $R \sim 7$ mm hence

$$I_{gPE} = 0.385 \times 10^{-3} I_0$$

But, the phototherapy lamp must be considered as an extended rather than a point source so, for a radius of 4 mm

$$I_o \rightarrow I_o \pi (4)^2 \rightarrow I_{gPE} = 0.019 I_o$$

(2) For the Macam spectrophotometer: here the set up is for an extended source of which all the light incident on a given area is gathered.

$$I_{gM} = \frac{I_o \pi (5)^2}{2^2} \text{ for } r=5 \text{ mm and } L=2 \text{ mm}$$

$$= 19.6 I_o$$

Therefore the theoretical ratio between the measurements obtained by Chin *et al*³ and those reported in this study should be:

$$\frac{I_{gM}}{I_{gPE}} = \frac{19.6}{0.019} = 103$$

These calculations also demonstrate that the intensity of the light falling on a surface declines with increasing distance from the source—the $1/R^2$ rule.

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