Similar Dose–Response and Persistence of Erythema with Broad-Band and Narrow-Band Ultraviolet B Lamps

Sharmila Das, James J. Lloyd,* and Peter M. Farr
Department of Dermatology and *Regional Medical Physics Department, Royal Victoria Infirmary, Newcastle upon Tyne, U.K.

Psoriasis may be treated with ultraviolet B from lamps that have a broad emission spectrum or, more effectively, with lamps that have a narrow emission spectrum at 311 ± 2 nm. There are conflicting reports of either greater or lesser burning episodes with narrow-band compared to broad-band ultraviolet B, even when treatments are based on predetermined minimal erythema dose measurements. This suggests that either the characteristics of the dose–response curve for erythema or the time course for erythema may be different for the two lamps. We examined the erythematic response to narrow-band and broad-band ultraviolet B in 12 patients with psoriasis. A geometric series of 10 doses from each lamp type were used on nonlesional skin on the back. Dose–response curves were constructed from reflectance measurements of erythema at 24 h and 72 h after irradiation. No significant difference was found in steepness of the erythema dose–response curve for the two lamps at 24 or 72 h. Persistence of erythema was assessed as the percentage of erythema remaining at 72 h. The mean persistence was 63% for narrow-band and 64% for broad-band lamps (p = 0.94). Therefore, in terms of erythematic response, no evidence has been found for a difference in burning potential for the two lamps.

Key words: dose–response curve/erythema/psoriasis/UVB phototherapy.


Ultraviolet B (UVB, 290–320 nm) phototherapy is an established treatment for psoriasis. Traditionally, fluorescent sources emitting a wide range of UV wavelengths (broad-band lamps) have been used, e.g., Westinghouse FS-40, or Philips TL-12. Following the observation that wavelengths of 290 nm or less (which are present in broad-band sources) do not contribute to clearance of psoriasis (Parrish and Jemec, 1981), a new lamp was developed in which 85% of the UVB emission is at 311 ± 2 nm (TL-01, Philips), a spectral region known to be effective at clearing psoriasis (Fischer, 1976; Parrish and Jemec, 1981). These “narrow-band” lamps have been shown to be significantly more effective in the treatment of psoriasis than broad-band lamps (van Weelden et al., 1988; Storbeck et al., 1993; Coven et al., 1997), although the magnitude of the difference in response appears to be small. Narrow-band UVB lamps are now increasingly used for treatment of psoriasis (British Photodermatology Group, 1997; Stern, 1997), although concerns remain about their long-term safety (Flindt-Hansen et al., 1991; Gibbs et al., 1995).

When treating psoriasis with UVB, the dose of radiation that can be given is limited by the potential for developing erythema or burning on nonlesional skin (Speight and Farr, 1994). It is routine clinical practice to measure each patient’s minimal erythema dose (MED) before commencing phototherapy, and then to give around 0.7 MED for the first exposure. Even when treatments are based upon predetermined MED measurements there are conflicting reports of either greater (Hansen et al., 1994; Alora and Taylor, 1997) or lesser (Green et al., 1988, 1992; Picot et al., 1992) burning episodes with narrow-band compared with broad-band UVB. It has also been suggested that narrow-band induced erythema is more intense and long lasting (Coven et al., 1997).

If a genuine difference in burning exists for the two lamp types then it might be expected that either (i) the characteristics of the dose–response curves for UV erythema would be different (a steeper curve for a particular lamp would increase the risk of burning as a small increase in dose would cause a large increase in erythema), or (ii) erythema persistence may be different (erythema lasting longer would increase the potential for burning).

It is known that the dose–response curve for erythema induced by UVC radiation (250–290 nm) is shallower than that for UVB wavelengths (Farr and Diffey, 1985). On this basis it might be predicted that broad-band lamps, which have significant emission within the UVC waveband, would induce a shallower erythematic response than narrow-band lamps, which have negligible UVC emission. For example, the UVC component from the broad-band lamp used in this study (Philips TL-12) is 9.2% of the total unweighted UV irradiance (250–400 nm), which represents 28.1% of the erythemally effective irradiance.

One previous study (Hansen et al., 1994) has shown a steeper 24 h dose–response curve for narrow-band compared with broad-band erythema. Another (Leenutaphong and Sudtim, 1998), however, found no difference. The time course of erythema from these two lamps has not been compared. The purpose of our study was to compare the erythema induced by broad-band and narrow-band UVB lamps, looking particularly at the dose–response and time course.

MATERIALS AND METHODS

Patients We studied 12 adult patients with psoriasis (nine female; median age 41 y; range 21–57) who were about to commence a course of narrow-band UVB phototherapy. None of the patients had a history of
of abnormal sunlight sensitivity, and none was receiving potentially photosensitizing medication. No patient had received UV phototherapy or significant sun exposure to the skin of the back for a period of 4 mo prior to the study. They were of skin types I ($n = 2$), II ($n = 8$), and IV ($n = 2$).

**Photoirradiation apparatus** The irradiation sources (Fig 1) were a narrow-band UVB fluorescent lamp (TL-20 W/01; Philips, The Netherlands) and a broad-band UVB fluorescent lamp (TL-20 W/12; Philips), each housed in a fully enclosed luminaire. Ten closely spaced apertures, each $8 \times 12$ mm, were milled into the lamp diffuser. One aperture was open; the rest were backed with metal foil attenuators, each perforated with a grid of holes of differing sizes (Fig 2). This allowed subjects to be exposed simultaneously to a geometric series of 10 UV doses, with a dose range of approximately 7:1. The principle of the attenuator design and its use for phototesting has been described in detail previously (Diffey et al., 1993; Gordon et al., 1998). Irradiance was measured using a radiometer (type IL1400a; International Light) and UVB detector that had been calibrated spectroradiometrically (Diffey, 1995). The unweighted open aperture UV (250–400 nm) irradiance at the skin surface was 2.86 mW per cm$^2$ (TL-01) and 3.41 mW per cm$^2$ (TL-12). The UVB 290–320 nm component of the total UV (250–400 nm) irradiance was 80% for the TL-01 lamp and 62% for the TL-12 lamp. Doses given in this paper are expressed as unweighted total UV doses.

**Phototesting protocol** The patients were phototested on clinically normal skin of the mid-back. For patients of skin types I to III, a dose range of 35–238 mJ per cm$^2$ was used for broad-band (TL-12) irradiation and 180–1360 mJ per cm$^2$ for narrow-band (TL-01) irradiation. These dose ranges were chosen with the aim of achieving an approximately equal range of erythematous responses with the two lamps, and were based on the erythema action spectrum of human skin (McKinlay and Diffey, 1987). The doses from both of the lamps were increased by 10% for patients of skin type IV.

**Measurement of erythema** The MED, defined as the smallest dose of radiation to result in just detectable erythema, was assessed visually at 24 and 72 h after irradiation. Objective measurements of erythema were made using a commercially available reflectance instrument (Diastron,
RESULTS

Out of the 12 patients studied, in nine cases complete data sets were obtained sufficient to construct four dose–response curves for each patient (both lamps at both times of measurement). In the remaining three patients, the range of erythema values was insufficient to calculate the $D_{0.025}$ and $D_{0.1}$ values for one or more of their curves. The data points were well-fitted by the sigmoid dose–response curves ($R^2$ values ranged from 0.95 to 0.99).

The median MED for broad-band (TL-12) UVB was 67.9 mJ per cm$^2$ (range 38.1–130.7) at 24 h and 85.8 mJ per cm$^2$ (67.9–130.7) at 72 h. The median MED for narrow-band (TL-01) UVB was 360 mJ per cm$^2$ (range 290–560) at 24 h and 470 mJ per cm$^2$ (range 350–860) at 72 h.

**Steepness of dose–response**  The ratio $D_{0.1}:D_{0.025}$ calculated from each patient’s dose–response curve (Fig 3) was used as a measure of curve steepness. This value represents the UV dose increment ratio that would be required to move from just perceptible to moderate or symptomatic erythema. There was no significant difference between the mean $D_{0.1}:D_{0.025}$ ratio for broad-band and narrow-band UVB at 24 h or 72 h after irradiation (Fig 4).

**Persistence of erythema**  As an indication of persistence of erythema from 24 h to 72 h after irradiation, the $D_{0.1}$ calculated from the 24 h erythema measurements was inserted into the corresponding 72 h curve, and the intensity of erythema that would have remained by 72 h was calculated (Fig 5). There was no significant difference in the mean persistence of erythema for broad-band compared with narrow-band lamps (Fig 6).

**DISCUSSION**

We did not find a significant difference in the steepness of the dose–response curves for erythema induced by broad-band and narrow-band UVB lamps, nor in the degree of resolution of erythema from 24 to 72 h. Our results do not therefore support the clinical impression of a difference in burning potential or erythema persistence for the two lamp types.

As expected, the MED for broad-band UVB was considerably lower than that for narrow-band UVB. This difference [which can be predicted from the emission spectrum of the lamps and the erythema action spectrum of human skin (McKinlay and Diffey, 1987)], does not imply a difference in burning potential for the two lamps, provided, of course, that exposure times are based on a patient’s predetermined MED. Although the MED is a widely used and useful measure of an individual's erythematic sensitivity, it is a threshold response and gives no information concerning response of the skin to higher doses of radiation, potentially an important factor in burning potential. We therefore used an objective method to quantify erythema, allowing the construction of dose–response curves for individual patients. As a measure of curve steepness, we calculated the ratio $D_{0.1}:D_{0.025}$ in other words the dose increment factor that would cause an increase in erythema from just perceptible erythema ($D_{0.025}$) to “moderate” erythema ($D_{0.1}$) likely to be symptomatic if involving a large area of skin. We used this ratio as a measure of curve steepness rather than the maximum slope of the fitted sigmoid dose–response curve, as the latter parameter is quite dependent on analysis of a complete dose–response curve. In several of the patients that we studied, the plateau part of the dose–response curve, where maximum erythema is reached, was not achieved. In addition, the ratio $D_{0.1}:D_{0.025}$ refers to a clinically important region of the response, just above the MED, and gives an easily understandable measure of the likely effect of a given dose increment. The similar values of $D_{0.1}:D_{0.025}$ that we found for the two UVB sources (around 1.8) may be compared with a typical response for psoralen plus UVA erythema of around 3.5 (Ibbotson and Farr, 1999; P.M. Farr, unpublished data), where the higher ratio indicates a much shallower dose–response curve.

We used the individual patients’ dose–response curves to calculate the persistence of erythema from 24 to 72 h after irradiation. No significant difference in mean percentage persistence was found for the two lamps, although, interestingly, for both sources there was considerable interpatient variability (Fig 6).

Previous studies comparing erythema from broad-band and narrow-band UVB lamps have shown conflicting results (Hansen...
et al, 1994; Leenutaphong and Sudtim, 1998). Our results are in keeping with those of Leenutaphong and Sudtim (1998), finding no difference in steepness of the dose–response for broad-band and narrow-band lamps at 24 h after irradiation. In clinical practice, the time to resolution of erythema may be an important factor with regard to burning. Previous investigators limited their comparison to a single time-point of 24 h. We have now shown that there is no difference in slope or resolution of erythema up to 72 h after irradiation.

We have found no evidence, at least in terms of erythema production, to support the clinical impression (Green et al, 1988; 1992; Picot et al, 1992; Hansen et al, 1994; Alora et al, 1997) of a difference in burning potential between broad-band and narrow-band lamps. Neither is there evidence of longer-lasting erythema with narrow-band lamps as suggested by Coven et al (1997). We have not examined the change in erythematic sensitivity during a course of UVB phototherapy; a difference in the rate or degree of photoadaptation might account for a difference in burning potential for narrow-band and broad-band lamps.

REFERENCES


