EDITORIAL

Phototherapy: The Challenge to Accurately Measure Irradiance

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In a seminal report, about fifty years ago, Cremer, *et al.*(1) defined the basic principles of phototherapy as the spectral distribution for the photo-destruction of bilirubin (action spectrum ~ 400-520 nm), the effect of light intensity on the rate of bilirubin photo-degradation *in vitro* ($t_{1/2}$=23 minutes, for sunlight) and the *in vivo* rate of bilirubin decline (–1.0 to 3.5 mg/dL/h or –17 to 60 µmol/L/h) under sunlight. Realizing that the use of sunlight phototherapy entailed various strategic and clinical disadvantages, they proceeded to investigate the more easily controlled light from artificial light sources. Thereupon, the first artificial light device, with strategically placed reflectors, was thoughtfully developed. Using eight closely spaced blue (B) fluorescent tubes, they studied the first overhead treatment of newborns in a cradle. This device demonstrated a very significant and satisfactory fall in bilirubin (0.08 to 0.50 mg/dL/h or 1.4 to 8.5 µmol/L/h). Although it took some time for the world to realize the significance of this novel therapy, it is now the global standard of care(2-4).

It is now well established that an effective phototherapy device needs to deliver light with (*a*) a light emission spectrum within the bilirubin absorption spectrum (400-520nm); (*b*) a peak emission of 450±20nm; (*c*) an irradiance foot print which exposes at least one horizontal body surface plane or optimally the entire circumferential (360º) body surface area; (*d*) an irradiance level ≥30 µW/cm^2/nm, as measured with an appropriate irradiance meter; and, (*e*) optimized duration of exposure (3-5). Many phototherapy devices with light sources such as blue and special blue fluorescent tubes, halogen, and halogen/fiberoptic, and most recently, light emitting diode-based (LED) lamps have been developed and marketed. However, for use in communities with constrained resources, these devices are often not affordable to purchase or to maintain. Hence, a cottage industry of phototherapy devices has evolved using locally available or adapted light sources such as daylight- and blue-painted fluorescent tubes and incandescent lamps. Most of these devices have never been adequately tested for performance or irradiance delivery. Their safety, efficacy and performance remain a public health concern.

An earlier *in vivo* study(5) and our recent bench data(6) illustrate the dose-response relationships of phototherapy as a direct relationship between the irradiance used and the rate at which the serum/plasma bilirubin declines under blue light phototherapy. Each blue light source typically emits a specific spectral range of photons with a characteristic peak emission. Similarly, each irradiance meter typically displays its own, specific and characteristic spectral sensitivity distribution and peak. Consequently, light source and irradiance meter need to be matched carefully by the manufacturer. Thus, meters for specific light source irradiance measurements are not interchangeable(7). In fact, it has not yet been demonstrated that even the matched sets of light source and meter accurately measure irradiance. This situation has given rise to much confusion regarding levels of irradiance, not only at the bedside, but also with many research studies, particularly those that compare the efficacy of different lamps for phototherapy. In many published studies, if an irradiance value is reported, the light meter is often not described or identified.

Two major issues impact the use of any light meter; its ability to measure a phototherapy device's decay of irradiance over time and its ability to quantitate the delivered irradiance over the entire therapeutic spectral range. Though these issues are of technical concern in a clinical situation, there is an urgent need to standardize their application in research studies. It is important to be able to obtain accurate absolute measures of irradiance, especially when irradiance levels are used as a criterion for comparison of lamps with differing spectral emission. The best method for this situation appears to be the use of a calibrated flat response spectrometer for measuring the energy distribution ($\mu W/cm^2$) across an accurately determined *in vivo* action spectrum of bilirubin photo-degradation (~400-520nm). From the integration of spectral range and energy level, the spectral irradiance can then be calculated in terms of $\mu W/cm^2/nm$. However, this type of spectrometer system needs to be assembled by experts for this specific purpose and is not available for bedside use.

Kumar, *et al*.(8) also faced an irradiance-related dilemma when they set out to compare the efficacy of phototherapy with compact fluorescent tube-based device *vs* a light emitting diode device. Instead of normalizing the two devices on the basis of irradiance, the most common method, they elected to normalize devices on the basis of equal distance of light source to patient (25cm). In doing so, they found that both devices were equally effective, even though the irradiance footprints and irradiance levels, measured with the Fluoro-Lite 451 meter (Minolta/Air-Shields, USA) (a functional equivalent to the Ohmeda Medical Bili Blanket meter) at one of the three study centers, varied dramatically. The title of their study implies that the study goal was to compare two different light sources. In retrospect, it would have been more appropriate, to normalize both devices with respect to irradiance and its footprint. However, dedicated light meters for the light sources used for the study were unlikely to have been available**.** Instead, the authors have done the best they could under the circumstances, by measuring the irradiance of both light sources with a well-identified irradiance meter, so that their experiments can be reproduced, should that be desirable.

Clearly, towards improving the application of effective phototherapy, there is an urgent need to develop an affordable, user-friendly, handheld, universal irradiance meter which accurately measures irradiance delivered by all types of phototherapy light sources.

Funding: None.

Competing interests: None stated.

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