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Brief Report

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BRIEF REPORT

Irradiance Decay in Fluorescent and Light-emitting Diode-based Phototherapy Devices: A Pilot Study

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ABSTRACT

We set out to determine the rate of decline of irradiance for fluorescent tube (FT) and light-emitting diode (LED) phototherapy devices in resource-limited settings where routine irradiance monitoring is uncommon. Irradiance levels (μW/cm^2/nm) were measured weekly using BiliBlanket® II Meter on three FT-based and two LED-based phototherapy devices over a 19 week period. The two LED devices showed stable irradiance levels and did not require any lamp changes. The three FT-based devices showed rapid decline in irradiance, and all required three complete lamp exchanges approximately every 5–6 weeks. FT-based devices are associated with more rapid decline in irradiance to sub-therapeutic levels and require more frequent lamp changes than LED devices. Clinicians should be alert to the maintenance requirements of the phototherapy devices available in their settings to ensure efficacy of treatment.

KEYWORDS: phototherapy, neonatal hyperbilirubinemia, irradiance, developing country

INTRODUCTION

Neonatal jaundice is a benign, transitional phenomenon affecting 60–80% of newborns worldwide [1]. The potential progression to severe hyperbilirubinemia or more devastating bilirubin-induced neurologic dysfunctions can be arrested by effective phototherapy [2, 3]. The light sources of phototherapy devices commonly used in clinical settings in low- and middle-income countries include fluorescent tubes (FTs), halogen and light-emitting diodes (LEDs) [3]. Whereas the merits and demerits of the irradiance output from different devices in reducing bilirubin levels have been widely reported [4], limited evidence exists on the rate of spectral irradiance decay among available light sources [3]. These data are needed to establish the maintenance requirements of these devices, especially in resource-constrained settings where routine irradiance monitoring is impracticable [5, 6]. This pilot

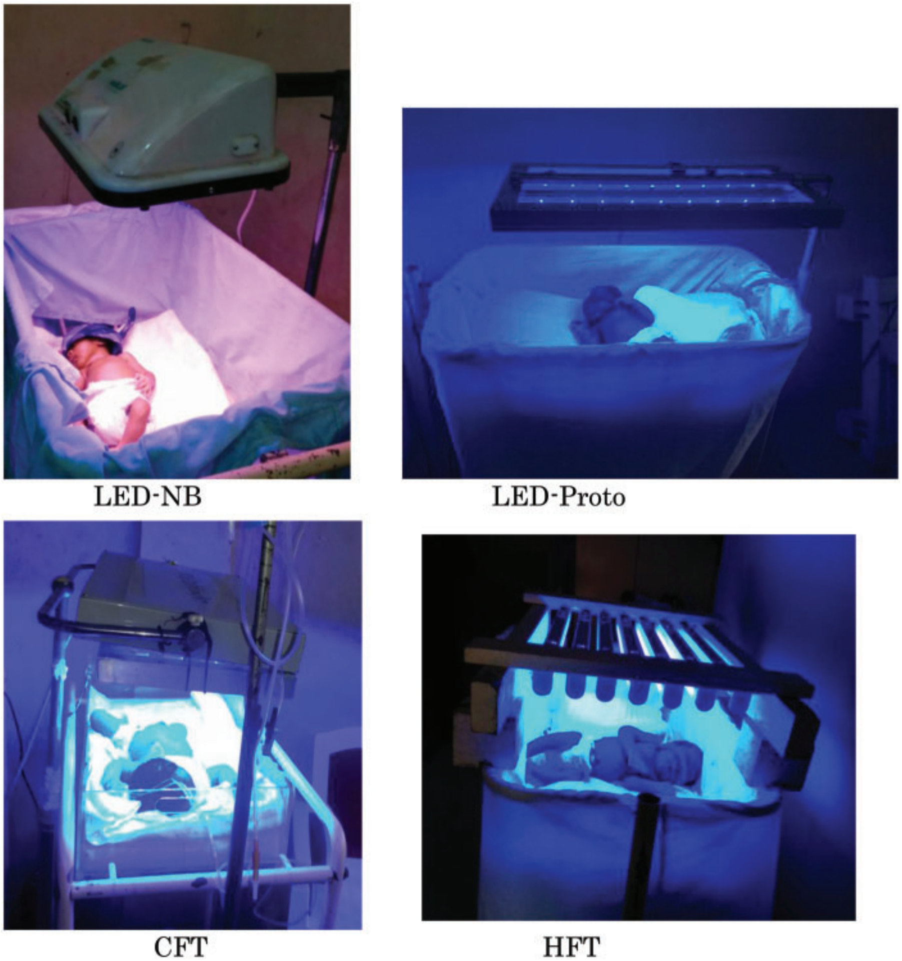

Fig. 1. Phototherapy devices used in this study. *Note*. LED-NB = NeoBlue with LED lamps; LED-Proto = Prototype by Hendrik Vreman; CFT = Hospital-owned. commercially available unit with fluorescent lamps; HFT = Locally made unit with fluorescent lamps.

study set out to determine the frequency of lamp replacement for LED and fluorescent-based phototherapy devices to guide routine lamp replacements before they become therapeutically ineffective.

METHODOLOGY

This descriptive study was conducted at Massey Street Children's Hospital, in Lagos, Nigeria under an institutional ethical approval from the Lagos State Health Service Commission. Five phototherapy devices with two different light sources were evaluated: one LED-lamp prototype (LED-Proto); one LED-based NeoBLUE™ by Natus Medical, San Carlos, CA (LED-NB); two commercial FT-based devices (CFT1 and CFT2); and one locally built/homemade FT-based device (HFT) as shown in Fig. 1. The LED-Proto was built and supplied by Hendrik Vreman, Stanford University, USA. The CFT1 and CFT2 were owned and maintained by the hospital before start of the study. The HFT was fabricated locally and installed with standard blue-light fluorescent lamps purchased from the open market.

Weekly irradiance measurements (μW/cm^2/nm) were recorded using a duly calibrated BiliBlanket® II Meter (General Electric, Fairfield, CT) at distances currently used clinically, and varied from 27 to 40 cm. The distance for each device was fixed

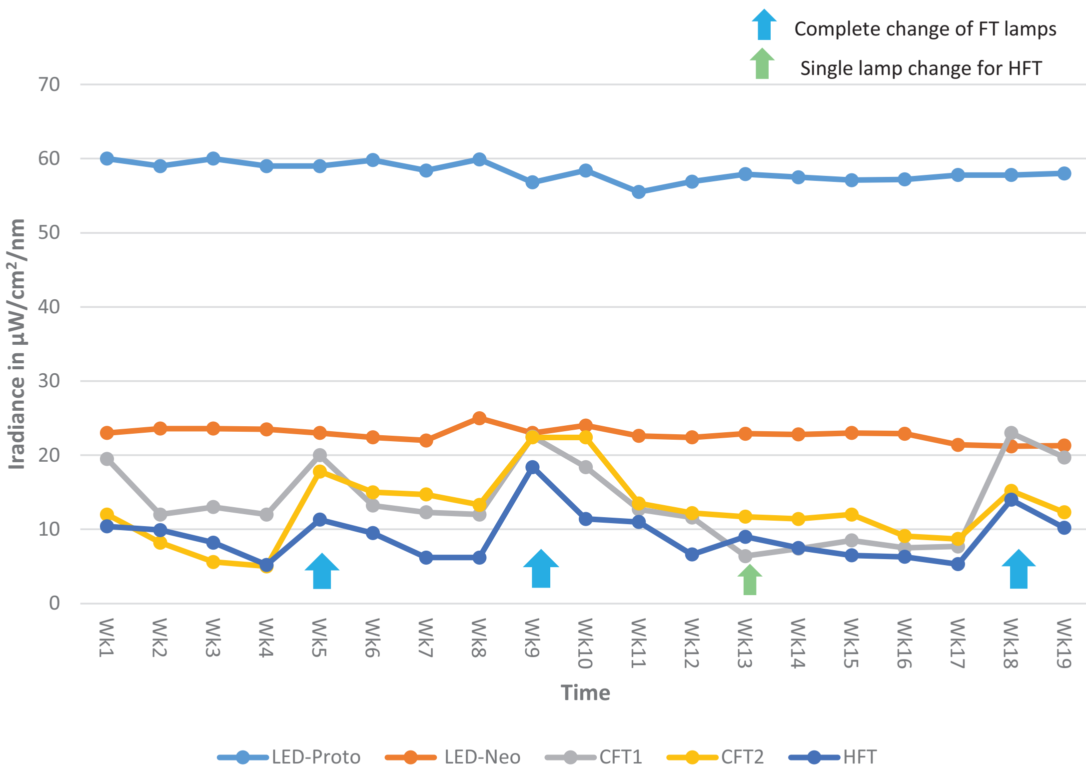

Fig. 2. Pattern of irradiance decay of PT devices over a period of 19 weeks.

throughout the study duration. All FT devices were equipped with new lamps at the start of the study, with planned lamp changes when irradiance levels fell below ~8 μW/cm^2/nm or earlier. The study was conducted over a consecutive period of 19 weeks between January and June 2014. The devices were in continuous use throughout this study period.

RESULTS

Both LED-Proto and LED-NB had minimal declines (3.3% and 7.4%) and remained quite stable throughout the entire period (Fig. 2). Irradiance level of the LED-Proto at the onset was 60 μW/cm^2/nm and recorded the lowest level of 55.5 μW/cm^2/nm, indicating a 7.5% decay. The mean irradiance was 58.2 ± 1.2 μW/cm^2/nm for the entire period. The LED-NB recorded a maximum decline of 15.2% from its peak of 25 μW/cm^2/nm and a mean of 22.8 ± 0.9 μW/cm^2/nm. Neither LED-based device required any lamp replacements throughout the duration of the study.

In contrast, the FT-based devices displayed significant declines in irradiance over the study period and had three complete lamp changes each with an additional, single lamp change for HFT. The two hospital-owned devices (CFT1 and CFT2) had maximum irradiance of 23.0 μW/cm^2/nm and 22.4 μW/cm^2/nm and lowest irradiance of 6.4 μW/cm^2/nm and 5.0 μW/cm^2/nm, respectively. CFT1 recorded an irradiance decay of 38.5% in the first 4 weeks, 40% within the next 4 weeks and 65.8% within the following 9 week period. The irradiance for CFT2 declined by 58% in the first 4 weeks, 25.3% within the next 4 weeks and 61.2% within the following 9 weeks. The mean irradiances for CFT1 and CFT2 were 13.7 ± 5.3 and 12.8 ± 4.7 μW/cm^2/nm, respectively. The HFT device had a maximum irradiance of 18.4 μW/cm^2/nm and the lowest irradiance of 5.2 μW/cm^2/nm with a mean of 9.1 ± 3.3 μW/cm^2/nm. The irradiance declined by 50% in the first 4 weeks, 45.1% in the next 4 weeks and 64.1% in the following 4 weeks after which a single lamp was replaced. The irradiance declined in the following 5 weeks by 41.1%.

DISCUSSION

This study was conducted against the backdrop of the lack of routine monitoring of irradiance levels of phototherapy devices in most clinical settings as well as several reports from both developing and developed countries that found the use of phototherapy devices with sub-optimal irradiance to be widespread [6–8]. The overarching finding is that the light sources in LED-based phototherapy devices have longer lifespan and significantly lower irradiance decay compared with FT-based devices within the same physical environment. Although the FT-based devices were all fitted with new lamps at the beginning of the study, they delivered lower initial irradiance levels compared with LED-based devices. They also showed more rapid declines in irradiance levels (to sub-therapeutic levels), necessitating complete or partial replacement of lamps. To maintain PT irradiance at the therapeutic range, FT devices required lamp changes every 5–6 weeks. In fact, our data would suggest that lamps in homemade units (HFT) should be changed more frequently.

Some reports have suggested that LED-based devices may last up to 20 000 h while FT-based devices may require lamp replacement every 3000 hours [3, 9]. However, it is difficult to formulate lamp replacement schedule for phototherapy devices based entirely on the current findings, although our study supports the growing preference for LED-based phototherapy devices worldwide. Where the only available phototherapy devices are FT-based, especially locally made units fitted with cheap commercially available lamps, as in many developing countries [3], our study underscores the need to ensure that maintenance records for such devices are kept and accessible to the clinicians. Where the record for a particular FT-based device, for example, indicates a lamp in use for an unusually long duration ($\geq$6 weeks), and the irradiance level cannot be ascertained, the likelihood of unduly prolonged or even worsening treatment under such device(s) must be recognized.

A limitation in this study was the lack of a strict bulb replacement criterion, thus resulting in variable and inconsistent replacement of fluorescent bulbs. The models of lamps used in the study may also have influenced the observed outcomes. Nonetheless, this pilot study suggests that LED-based devices emit stable irradiances without the need for frequent lamp replacements and should be preferred in resource-limited settings where regular irradiance monitoring cannot be assured. More frequent lamp replacement should be considered routinely, where FT-based devices are inevitable.

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