Brief Report

Phototherapy Device Effectiveness in Nigeria: Irradiance Assessment and Potential for Improvement

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Summary

This study investigated the effectiveness of simple-to-implement adjustments of phototherapy devices on irradiance levels in a cross-section of Nigerian hospitals. A total of 76 phototherapy devices were evaluated in 16 hospitals while adjustments were implemented for a subset of 25 devices for which consent was obtained. The mean irradiance level was 7.6 ± 5.9 mW/cm²/nm for all devices prior to adjustments. The average irradiance level improved from 9.0 ± 5.9 mW/cm²/nm to 27.3 ± 5.4 mW/cm²/nm for the adjusted group (n = 25) compared with 6.8 ± 5.4 mW/cm²/nm for the unadjusted group (n = 51). Simple, inexpensive adjustments to phototherapy devices with sub-optimal irradiance levels can significantly improve their effectiveness to acceptable international standards and should be widely promoted in resource-constrained settings.

Key words: newborn jaundice, hyperbilirubinemia, phototherapy, irradiance, developing countries.

Introduction

Neonatal hyperbilirubinemia (NHB) is ubiquitous in newborns and remains a major cause of post-partum hospital (re)admission globally [1, 2]. Although timely use of high performance phototherapy devices has been established in the effective management of NHB [3], the condition still remains a leading cause of morbidity and mortality in resource-constrained settings [4–7]. Exchange blood transfusions (EBT) are frequent and inevitable in these settings due to late or ineffective treatment with phototherapy [8–10] thus placing the survivors at risk of adverse life-long neurological outcomes including kernicterus, deafness and cerebral palsy [11–14].

Whereas over 99.5% of term newborns with severe NHB in the USA are treated solely and successfully with phototherapy [1], widespread use of sub-optimal phototherapy devices have been implicated for...
unusually high rates of EBT in countries such as Nigeria [8]. A similar study which may not be unrelated to the effectiveness of treatment, found an uncommon risk of sensorineural hearing loss among newborns who received phototherapy prior to hospital discharge [15].

Irradiance is a key and easy-to-measure parameter for the effectiveness of phototherapy devices in resource-constrained settings [16]. Irradiance levels are not only determined by the quality of the light source but also based on the distance between the device and the patient [17]. We therefore set out to evaluate irradiance levels of phototherapy units in use in a sample of hospitals in Nigeria to identify practical and inexpensive measures to improve performance of sub-optimally operating devices.

Materials and Methods

Seventy-six functional phototherapy devices in 16 Nigerian hospitals were assessed and irradiance levels measured during March–April 2010. Facilities included private and government hospitals with large catchment areas of rural and urban populations to ensure representative sampling of nurseries covering all socio-economic groups in Nigeria. Sites were selected using convenience sampling and included nine public, three private and four religiously affiliated hospitals. As an observational study with nested sub-cohort for remedial intervention, no patient data were evaluated or recorded, and IRB approval was not required.

Only phototherapy devices currently in use and functional reserves were included in the study. Devices modified by hospital staff after our arrival and prior to evaluation (n = 2) were excluded. Parameters of interest for each device are listed in Table 1. Initial measurements were taken for each device as they were normally used. Irradiance was measured using a GE Healthcare BiliBlanket Light Meter I or II, or Minolta Fluoro-Lite 451 meter, which yield similar irradiance values [Vreman—unpublished data], with the meter positioned at the newborn’s abdomen height (10 cm above the mattress). Phototherapy devices not in use for patient care were turned on and allowed a minimum of 5 min to fully warm lamps.

Half of the facilities (n = 8), gave consent to implement series of adjustments (Table 2) for a total of 25 devices. After implementing adjustments that could demonstratively improve device performance, irradiance and distance of lamp from baby were re-measured. Data using Student’s t-test are presented as mean ± SD. Based on the guidelines from the American Academy of Pediatrics (AAP), irradiance levels of 8–10 μW/cm²/nm were considered as minimal or adequate while levels of up to 30 μW/cm²/nm were considered as intensive phototherapy [18].

Results

Mean irradiance of all PT devices was 7.6 ± 5.9 μW/cm²/nm. The distribution of device irradiance is presented in Figure 1. Only one device (1.3%) exceeded the AAP standards. Twenty-nine devices (38.2%) were below 5 μW/cm²/nm. Commercially manufactured devices (n = 68) had higher, statistically significant (p < 0.01) spectral irradiance (8.1 ± 5.9 μW/cm²/nm) than home-made devices (2.3 ± 2.8 μW/cm²/nm).

Mean spectral irradiance of the adjusted devices (n = 25) was significantly improved (p < 0.001) from 9.0 ± 6.6 μW/cm²/nm to 27.3 ± 15.2 μW/cm²/nm after the adjustments (Fig. 2). However, the observed trend toward higher mean irradiance among these...
Many devices were found to be at an excessive distance from the baby (Fig. 3). The mean distance was 40 ± 13 cm (range 20–79 cm). This included both structurally fixed and adjustable height devices. For adjustable height devices in the nested sub-cohort, adjusting distance improved irradiance. Similarly, replacing widely used white bulbs with
spectrally superior blue illumination sources, available at comparable cost, also improved device effectiveness.

**Discussion**

This study demonstrated the efficacy of simple-to-implement adjustments in providing higher therapeutic irradiance levels from 9.0 \( \mu \text{W/cm}^2/\text{nm} \) to 27.3 \( \mu \text{W/cm}^2/\text{nm} \). After adjustments, 10 devices (40%) exceeded the AAP intensive phototherapy standard, compared with 0 device beforehand. This underscores the importance of education regarding delivery of phototherapy, as well as monitoring and maintenance of devices. The findings of sub-optimal irradiance levels in our sample which were partially due to the sub-optimal positioning and inadequate maintenance of devices are consistent with previous surveys in Nigeria [16] and other resource-constrained settings [19].

Phototherapy units typically costing US$3000 or more are prohibitively expensive for many developing countries. Even hospitals that provide phototherapy treatment lack the ability to measure device irradiance as only one hospital in this study had access to an irradiance meter, obtained through a research study. Further hindrances such as unreliable electrical power supply and surges often caused voltage spikes that exceed device design limits. Voltage stabilizers may be cost-prohibitive and may not function as rated to protect against device damage. Additionally, availability of replacement parts such as spectrally optimized special blue (BB) fluorescent tubes is a perennial challenge.

Knowledge of technical requirements for effective phototherapy varied widely among medical staff. Many claimed that they had been taught to use 45 cm as the distance between device and newborn. Evidence from this study thus demonstrates the need for improved education on the correct positioning and maintenance of phototherapy devices wherever provided.

In conclusion, a uniform maintenance checklist to assure effective phototherapy treatment in resource-constrained settings is needed and should include elements of proper irradiance monitoring, availability of replacement parts and continuous education for relevant hospital staff. Such practical and inexpensive interventions would be pivotal to curtailing EBT as well as NHB-related morbidity and mortality in settings with access to phototherapy devices.

**References**