

Streamlining Neonatal Phototherapy: A New Design for Improved Quality of Care

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Importance of Accessible NICU Facilities

The neonatal intensive care unit (NICU) can be a stressful and challenging environment for clinicians and families of critically ill children. For optimal working conditions and outcomes, equipment must not interfere with access to the patient. Particularly when the census and acuity are high, space may be at a premium and bulky equipment may impede access to the patient. It is imperative that NICU space is utilized optimally to make it feasible for clinicians to have constant visual and hands-on access. An accessible NICU makes possible the ease of administering routine and emergency treatment while ensuring patient comfort and reducing caregiver stress, and it is crucial for patient safety and maintaining quality metrics within a healthcare institution.

A reasonable argument can be made that medical device design has focused on the patient's needs but has lacked understanding about how the device will operate in conjunction with all of the other equipment in the NICU. A prime example is the decades-old, traditional overhead phototherapy device used to treat neonatal jaundice. These devices are bulky and may limit access to the patient, especially in incubators and on radiant warmers. This article explores the factors that impact accessibility in the NICU and using the phototherapy device as an example, explores how phototherapy design strategies can help to alleviate the problem.

Current Challenges to Accessibility in the NICU

Compromised accessibility is a direct result of higher occupancy rates within NICUs. (2) In Great Britain, for example, the recommended occupancy of a NICU is 80% of the maximum bed capacity; however, a survey published in 2015 showed that two-thirds of hospitals are over this limit. (3) One result of high occupancy is the need for additional staff, causing further overcrowding. Overcrowding is exacerbated when borrowed or rented medical devices are brought into the nursery for excess occupancy. For example, incubators and mechanical ventilators are extremely bulky and may limit the space around the patient. Furthermore, there is substantial evidence that overcrowding is associated with a significant rise in healthcare associated infections (HAI). (4, 5)



Figure 1 NICU showing typical equipment overcrowding (7)
Image Credit: University of Michigan C.S. Mott Children's Hospital Branson

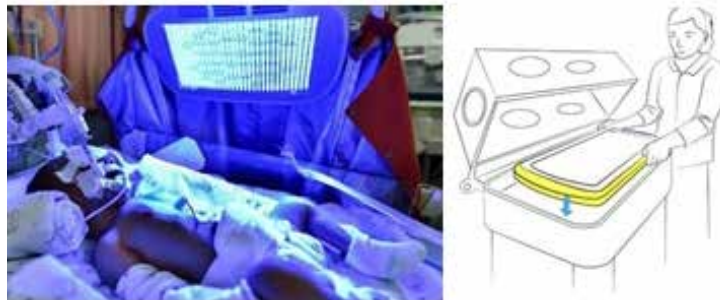


Figure 2: Traditional overhead phototherapy system (left) vs. accessible under-baby NeoLight Phototherapy device (right)

The fragile, immature population in the NICU is already at risk for infection, so the problem is compounded. Infection also leads to prolonged hospital stays and increases costs significantly, bearing in mind that a day in the NICU in the USA can exceed \$3500 USD. (7)

Factors in Improving Accessibility

The ergonomic challenges of a crowded NICU can be overcome partially by use of modular, compact, and efficient medical devices. Phototherapy devices are ideal candidates for redesign, lending themselves to the key principles of versatility, ease of use, and simplicity.

Phototherapy is the most common treatment for neonatal hyperbilirubinemia. It works by photo-isomerization of bilirubin in the skin facilitating its excretion in urine and stool. Blue light sources have replaced white light and may be delivered by lights or pads powered by fiberoptic cables. The light source may be placed over an infant, under an infant, or in a combination of both. We believe that a phototherapy device should have specific characteristics to enhance its usability in the NICU and improve accessibility. These are noted as follows:

Universality of Device:

Ideally, a single device should be able to treat both pre-term and term babies. The size of the baby should not dictate the practicality of the device. A major drawback when using fiberoptic phototherapy blankets is that the same size blanket will cover a different body surface area based on the size of the baby. For larger babies, multiple phototherapy devices may be needed. For term infants, particularly with near critical levels of hyperbilirubinemia, a combination of overhead and fiberoptic devices may be recommended. (8) The decision to use more than one type of phototherapy device increases the facility's burden of maintaining and monitoring the readiness of inventory.

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Overhead phototherapy devices have been widely used to manage neonatal jaundice for decades and occupy significant space around and over an infant bed. A phototherapy light on a roll stand

can have typical dimensions around 19.7 x 7.9 in., and a height of well over 39.3 in., which can obstruct staff access to at least one side of the bed. (9) These devices must be correctly positioned, and the position maintained at a specified, measured distance from the baby to ensure administration of the correct dosage of light intensity. Fiberoptic pads that fit inside bassinets or incubators usually require additional hardware configurations, such as a nearby table with a means of securing the light source, creating further inconvenience and safety concerns.

These limitations support an improved approach to the design of phototherapy devices that are compatible with all neonatal beds. An additional benefit of these devices would be seamless usability

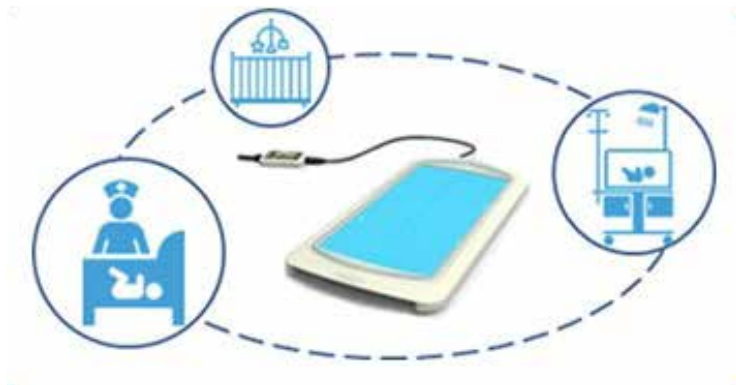


Figure 3: Optimal universality of NeoLight Phototherapy device that facilitates usage in the NICU, well-baby nursery, and home.

at home. The versatility of low-profile, easy to use phototherapy systems is a key factor in expanding the care models in which these devices can be employed.

Tandem Treatment:

Critically ill NICU babies require multiple life-supporting pieces of equipment such as a radiant warmer, high-frequency ventilator, NIPPV or CPAP machines, and infusion pumps. These devices are in operation simultaneously and are monitored primarily by the patient's nurse. Phototherapy treatment can compound the complexity in managing the organization and functionality of the collective devices needed to treat the patient. It is therefore essential for phototherapy devices to be simple to use and effective without compromising functionality of any life-supporting equipment. In these situations, a low profile, under-baby phototherapy system is optimal.

Ease of Storage:

Ensuring a device can be easily stored in a small space is critical. Most importantly, a device should be lightweight and ergonomically designed to help prevent back injuries to clinicians, which is one of the most common and costly injuries to health care staff. As patients are discharged, or soiled equipment needs to be cleaned, dirty equipment often is placed into a hallway or other central area awaiting cleaning. Once cleaning has been completed, it is common to place a sheet over the device to maintain cleanliness and denote that it is ready for use. Overhead phototherapy devices, ventilators, IV poles and other similar types of equipment take up a large volume of storage space due to their height and overall footprint. With many devices stored in the same area, equipment damage and staff injury are valid concerns as employees attempt to reach items at the back of the storage room through the plethora of devices sharing floor and air space. (10) Many phototherapy devices that are placed beneath the baby, although relatively small, are irregular in shape, making them difficult to



Figure 4: Phototherapy Body Surface Area Coverage Comparison*

stack compactly. This situation overburdens inventory management and hinders the redeployment of clean devices available for treatment. Ideally, devices should employ a sleek, compact form that is easy to store, clean and mobilize to NICU patients when needs arise, which is why the NeoLight phototherapy system has been designed to be lightweight, stackable and easy to carry.

Treatment Efficacy:

The efficacy of a phototherapy device depends on several factors: the intensity, the capacity to cover a larger body surface area (BSA), the wavelength range of treatment light, and the average uniformity in light distribution. High BSA coverage enables light to reach larger areas of the infant's body. Higher light intensity per unit in conjunction with high BSA can reduce the need for using multiple phototherapy devices on a single baby, creating greater efficiency in patient care.

The optimum recommended light intensity, also referred to as irradiance, is 30 $\mu\text{W}/\text{cm}^2/\text{nm}$. (11,12) International standards governing phototherapy systems state that peripheral intensity must be equal to or exceed 40% of the peak intensity (also known as distribution ratio). (13) A more uniformly irradiated patient surface offers optimal levels of light intensities over a larger peripheral surface area of the patient. The NeoLight Phototherapy device offers 79% average distribution across the treatment surface*, a key achievement for phototherapy devices owing to the innovative optical engineering. Measuring irradiance requires that care-

Intensity: 30 $\mu\text{W}/\text{cm}^2/\text{nm}$

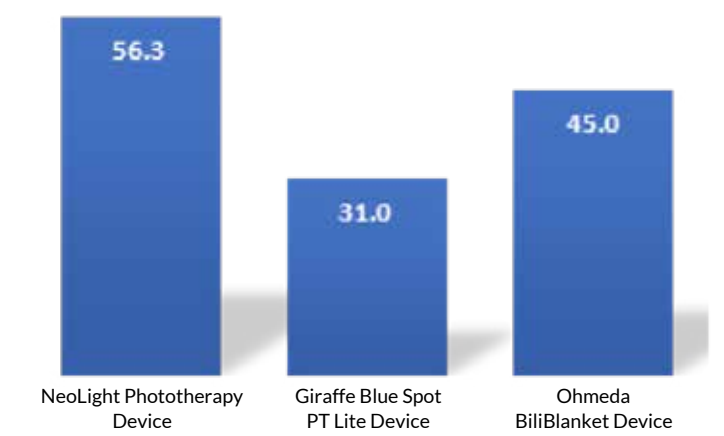


Figure 5: Average intensity of 3 phototherapy devices across treatment surface*

givers take measurements at multiple points along the treatment area to verify that their device meets these treatment standards. If these measurements are suboptimal, additional phototherapy lights may need to be added, creating a larger equipment burden.

Comfort for all persons in the NICU must be considered when designing neonatal phototherapy devices. Glare is an optical phenomenon described as the inhibition in one's ability to view a scene which is normally associated with discomfort. (14) Studies have shown that visual exposure to blue phototherapy treatment lights can cause effects such as the alteration of one's circadian rhythm, headache, nausea, and suppression of melatonin. (15, 16) Therefore, it is important to mitigate the visual light exposure for nurses and physicians to mitigate the discomfort. The NeoLight phototherapy system has been designed to focus the light on the newborn and as much as possible, out of the direct visual path of the caregivers.

Variable Intensity:

A device that can provide flexibility to caregivers by allowing ad-

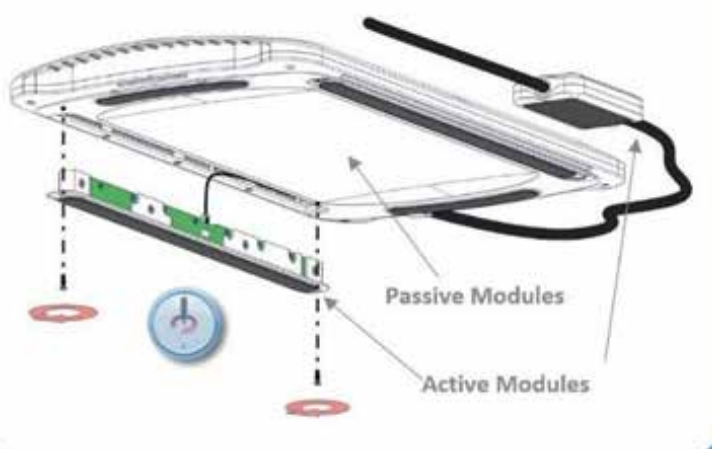


Figure 6: NeoLight phototherapy device modules

justment of administered light can facilitate the appropriate level of treatment from low to high severity infants, negating or greatly reducing the need for the use of multiple devices. Adjusting the intensity on a single device minimizes disturbance to the baby and others in close proximity and takes a few seconds instead of the longer time, noise, and possible jostling required to arrange multiple pieces of equipment. A single, flexible device effectively combats the limitations of conventional phototherapy devices.

Efficient Maintenance through Modularity:

Ongoing maintenance of medical devices must be continually monitored and can be inconvenient. The light source and mechanical components of the equipment must be regularly inspected to ensure that they are treatment ready. Devices with a modular design, e.g., consisting of separate replaceable modules, can effectively alleviate the cost and labor time to maintain equipment standards. For example, the light source represents one module, and in case of a failure, it is much more efficient to replace the module than the entire device. A modular design, as in the case of the NeoLight phototherapy device, supports the shipping and storage of modules that need regular maintenance and/or replacement rather than an entire device, reducing overall costs and streamlining inventory management for hospitals.

Ease of Cleaning:

As noted earlier, it is essential that a phototherapy device is easy to clean to ensure minimal downtime. A device administering phototherapy treatment from beneath a baby should be covered in a soft fabric that can be easily disposed of and replaced when soiled. An optimal device should not have irregular surfaces which would require complex cleaning procedures. Smooth, nonporous surfaces are key in making it easier to clean such a device.

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Final Recommendation

The prime reason for improving accessibility in the NICU is to promote patient and staff safety, quality of care, and to reduce stress on clinical staff and families.

The use of bulky, inefficient technologies must be addressed to achieve increased patient accessibility. The use of smaller, compact, versatile phototherapy devices will significantly contribute to reducing equipment overcrowding within the NICU environment. Smart design of these devices will also broaden the use cases for phototherapy in the hospital as well as in the home environment.

References:

- 1 <https://www.theguardian.com/society/2015/oct/19/bliss-neonatal-intensive-care-units-stretched>.
- 2 <https://www.hopkinsmedicine.org/news/articles/NICU-Design-with-Less-Movement-in-Mind>.
- 3 Clements, Archie, et al. “Overcrowding and understaffing in modern health-care systems: key determinants in methicillin-resistant *Staphylococcus aureus* transmission.” *The Lancet infectious dis-*



- eases 8.7 (2008): 427-434.
- 4 Haley, Robert W., and Dennis A. Bregman. "The role of understaffing and overcrowding in recurrent outbreaks of staphylococcal infection in a neonatal special-care unit." *Journal of Infectious Diseases* 145.6 (1982): 875-885.
 - 5 Wubben, Stephanie M., et al. "The sound of operation and the acoustic attenuation of the Ohmeda Medical Giraffe OmniBed™." *Noise and Health* 13.50 (2011): 37.
 - 6 Whitfield, Michael, and Philippe Chessex. "The need for public involvement when operating a regionalized neonatal care system at maximum capacity." *Paediatrics & child health* 15.9 (2010): 573-575.
 - 7 <https://johnsontwinsjourney.wordpress.com/2014/10/27/more-bed-rest/>.
 - 8 Muchowski, Karen E. "Evaluation and treatment of neonatal hyperbilirubinemia." *Am Fam Physician* 89.11 (2014): 873-8.
 - 9 <https://www.slhd.nsw.gov.au/rpa/neonatal/content/pdf/guidelines/phototherapy.pdf>.
 - 10 Vreman, Hendrik J., Ronald J. Wong, and David K. Stevenson. "Phototherapy: current methods and future directions." *Seminars in perinatology*. Vol. 28. No. 5. Elsevier, 2004.
 - 11 Maisels, M. Jeffrey, and Antony F. McDonagh. "Phototherapy for neonatal jaundice." *New England Journal of Medicine* 358.9 (2008): 920-928.
 - 12 Harrison, Wade, and David Goodman. "Epidemiologic trends in neonatal intensive care, 2007-2012." *JAMA pediatrics* 169.9 (2015): 855-862.
 - 13 <http://www.usmed-equip.com/content/datasheet/GE%20lullaby-led-phototherapy-system%20%281%29.pdf>.
 - 14 https://www.jointcommission.org/assets/1/6/JCPEP_LS_0201_20_LD_Module_FINAL.pdf.
 - 15 <http://ephesuslighting.com/wp-content/uploads/2014/01/Addressing-Glare.pdf>
 - 16 Margrain, Tom H., et al. "Do blue light filters confer protection against age-related macular degeneration?." *Progress in retinal and eye research* 23.5 (2004): 523-531.
 - 17 <https://www.health.harvard.edu/staying-healthy/blue-light-has-a-dark-side>.

*NOTE: Phototherapy device comparison data and light intensity comparison data referenced in this document is based on internal, anecdotal information gathered by NeoLight, LLC.

Disclosure: The authors are co-founders of NeoLight LLC and have a financial relationship with NeoLight LLC.

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