Using Technological Politics to Examine Racial Healthcare Disparities in Neonatal Jaundice Assessment

STS Research Paper
Presented to the Faculty of the
School of Engineering and Applied Science
University of Virginia

By

William Adu-Jamfi

April 12th, 2024

On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

ADVISOR

Benjamin J. Laugelli, Assistant Professor, Department of Engineering and Society

Introduction

Neonatal jaundice, or neonatal hyperbilirubinemia, results from elevated total serum bilirubin (TSB) levels, posing significant health risks such as brain disease, hearing loss, and kernicterus to approximately 50% of term and 80% of preterm infants in their first week of life (Kemper et al., 2022; Woodgate & Jardine, 2011). To manage this condition, up to 10% of term and 25% of preterm neonates require phototherapy, which employs blue light to reduce bilirubin levels in the blood by converting it into the easily-excretable lumirubin (Queensland Clinical Guidelines, 2022). Hyperbilirubinemia is currently monitored and diagnosed through two methods: the invasive measurement of TSB via blood samples and non-invasive transcutaneous bilirubinometry (TcB) using a handheld bilirubinometer. While measuring TSB is the gold standard for neonatal bilirubin testing, it poses health risks and discomfort for neonates, whereas TcB provides a non-invasive and efficient alternative (Onesimo et al., 2011; Onks et al., 1993).

The effectiveness of TcB on Caucasian infants is widely accepted by professionals and scholars (Mahmoud et al., 2008). However, some scholars in recent years have begun to consider how skin tone influences the diagnostic accuracy of TcB devices. Specifically, researchers have explored the tendency of TcB devices to frequently overestimate TSB levels in neonates with darker skin tones, characterized by higher cutaneous melanin concentrations. Despite this insight, the current understanding is limited, as it overlooks the role of design choices that inadvertently contribute to this overestimation. Furthermore, the current understanding fails to address how this overestimation increases the likelihood of prescribing phototherapy, thereby posing potential adverse effects. If we do not properly consider all three of these elements in conjunction, we will not get a comprehensive outlook on the racial bias inherent in the current approach for obtaining accurate TcB readings, which disproportionately marginalizes these

individuals, restricts their access to equitable healthcare, and contributes to larger issues of racial health disparities on a global scale.

I argue that TcB devices unintentionally privilege neonates with lighter skin tones while marginalizing those with darker skin tones due to design choices expressing implicit bias, leading to an overestimation of TSB levels. This overestimation increases the probability of unnecessary phototherapeutic treatment, resulting in harmful short and long-term effects on darker skinned neonates. To support my argument, I will use the framework of Technological Politics, which claims that technological artifacts have "politics" through intentional or unintentional design choices which lead to the arrangements of power and authority in human associations. To support my analysis, I will analyze peer-reviewed academic publications from researchers and scholars within the field.

Background

TcB measurement is a non-invasive technique used to assess serum bilirubin levels. This method involves directing light into the skin and measuring the intensity of the wavelength of light that is reflected. The process relies on optical spectroscopy, which correlates the absorption of light by bilirubin to the concentration of bilirubin present in the skin. First introduced in 1980, the measurement is typically conducted by gently pressing the device against the sternum or forehead. This approach offers a rapid (within a minute) assessment of bilirubin levels, saving time compared to traditional serum bilirubin measurements and potentially reducing associated costs in newborns. Various TcB devices are accessible, such as the Bilicheck device, JM 103, and JM 105 devices.

The TcB assay provides a non-invasive means of measuring bilirubin levels, potentially diminishing the risks of anemia and trauma associated with blood sampling for TsB

measurement. Its effectiveness has been demonstrated in both hospital and outpatient settings, surpassing visual inspection in estimating hyperbilirubinemia. Moreover, TcB measurements yield immediate results for clinical decision-making, reducing the likelihood of infections linked to invasive procedures. The TcB meter serves as a screening tool to estimate serum bilirubin levels in non-clinically jaundiced newborns and as a diagnostic tool in jaundiced newborns to evaluate the necessity for treatment (Okwundu et al., 2017).

Literature Review

A few scholars in recent years have conducted research to assess the influence of skin color on the diagnostic accuracy of TcB devices. While these analyses highlight how TcB devices often overestimate TSB levels in darker skinned neonates, they do not consider the underlying design choices leading to this overestimation. Additionally, no scholars have properly addressed the potential consequences of this overestimation, such as unnecessary phototherapy treatments that result in short and long-term adverse effects. Therefore, no scholars have considered all three of these elements in conjunction to comprehensively examine how current TcB devices marginalize those with darker skin tones and create racial healthcare disparities.

Two diagnostic cohort studies conducted in Canada provided evidence that TcB testing tends to overestimate total serum bilirubin levels in infants with darker skin tones. In the initial study, which involved 451 neonates with a gestational age of ≥ 35 weeks at a hospital in Ottawa, TcB was evaluated using the JM-103 meter. Neonates were categorized into light (n = 51), medium (n = 326), and dark (n = 74) skin tones using cosmetic reference color swatches. All participants underwent TcB and TSB assessments within 30 minutes of each other. TcB testing underestimated TSB in infants with light and medium skin tones and overestimated TSB in those

with darker skin tones (mean difference: –0.88 mg/dL for light, –1.1 mg/dL for medium, and 0.68 mg/dL for dark; P information not provided) (Samiee-Zafarghandy et al., 2014).

The second Canadian study, conducted in Calgary, involved 774 infants born at ≥ 37 weeks gestational age and assessed TcB using the JM-103 meter. Infants were classified as having light (n = 347), medium (n = 412), or dark (n = 15) skin tones by study nurses based on reference cosmetic colors. All infants underwent paired TcB and TSB measurements within 60 minutes of each other and before 120 hours of life. Multivariate linear regression analysis, using medium skin tone as the reference group, revealed a tendency toward lower TcB levels in infants with light skin tone and a tendency toward higher TcB levels in infants with dark skin tone (adjusted R2 = 0.86) (Wainer et al., 2009).

While these sources highlight the tendency of TcB devices to overestimate TSB levels in infants with darker skin tones, there is still a need for a thorough investigation into how design choices inadvertently contribute to this overestimation. Additionally, it is necessary to explore the potential repercussions of this overestimation, including the administration of unnecessary phototherapy treatments that may lead to both short-term and long-term adverse effects. In my analysis, I will advance current understanding in the scholarly discourse by examining all three of these elements in conjunction to answer how TcB devices favor neonates with lighter skin tones while marginalizing and excluding those with darker skin tones.

Conceptual Framework

My analysis of TcB devices draws on a Technological Politics (TP) framework, which allows me to systemically examine how this technology advantages neonates with lighter skin tones while harming those with darker skin tones, thereby creating racial healthcare disparities in neonatal jaundice assessment. This framework addresses concerns related to power, justice, and

care in the design and implementation of technology. Developed by Langdon Winner in 1980, Technological Politics claims that technological artifacts possess "politics," denoting "arrangements of power and authority in human associations." Winner argues against the notion of technological neutrality, asserting that design choices made during the development of technology can have profound social and political consequences.

In a similar vein, Winner introduces the concept of intentionality in technological design, which raises the question of whether bias is a deliberate or unintended outcome. In some cases, a technology's "politics" are intentionally shaped by design choices that reflect explicit bias, while in other instances, the technology's "politics" may unintentionally result from design choices expressing implicit bias. The primary argument of this framework is the notion that technological designs can influence relations of power and privilege among groups of people by empowering and advantaging some while marginalizing, excluding, or harming others (Winner, 1980).

In the analysis that follows, drawing on Technological Politics, I first examine how design choices in TcB devices express implicit bias. Subsequently, I delve into the implications of these design choices, providing further evidence that TcB devices tend to overestimate serum bilirubin levels in neonates with darker skin tones. Finally, I discuss the potential outcomes of this overestimation, including the overprescription of phototherapy and the resulting short and long-term adverse effects in neonates with darker skin tones.

Analysis

Design Choices in TcB Devices Express Implicit Bias

TcB's overestimation of TSB levels in darker skinned neonates, and the subsequent short- and long-term effects from unnecessary phototherapeutic treatment, are an unintentional result of

design choices that express implicit bias. Noninvasive TcB devices typically rely on the principle of optical spectroscopy. The procedure involves directing white light from a xenon tube into the patient's skin, allowing it to penetrate through the skin into subcutaneous tissues. Subsequently, the reflected light from the skin is captured by an integrated spectrophotometer. Depending on the device's design, various wavelengths are employed in different transcutaneous bilirubinometers, with modern devices, such as the Bilicheck, JM 103, and JM 105, conducting spectral analysis at over 100 wavelengths. A photodetector converts the optical spectrum signal reflected from the patient's subcutaneous tissues into an electrical signal. A microprocessor then processes these electrical signals to generate an accurate serum bilirubin value.

Given the instrument's emission of intense light, measurements are typically conducted on the patient's forehead or sternum. Figure 1 illustrates a typical example of such an instrument. Reflected light intensity is converted into absorbance units, specifically optical density (OD), for analysis. The resulting OD value corresponds to the concentration of bilirubin present in the skin, calculated using a proprietary algorithm. Modern instruments present results in clinically relevant units, such as mg/dl or µmol/l (Khandpur, 2020).

Figure 1: Portable Jaundice Meter-Bilirubinometer. *Source*: Courtesy of M/s Dragerwerk AG & Co. KGaA.

However, these design choices lead to an overestimation of bilirubin levels in neonates of darker skin tones, making the predictive utility of TcB screening lower in this racial population. This can be explained by the substantial overlap in the absorption spectra of bilirubin and melanin, as illustrated in Figure 2. The relative absorption due to melanin is noticeably high near the peak absorbance of bilirubin at 460 nm—which is near the ideal wavelength at which

bilirubin concentration would be most easily detected or monitored. Even considering other locations along the spectra, the relative absorption due to melanin is higher at all locations. As a result, higher cutaneous melanin concentrations can effectively mask fluctuations in bilirubin absorption and make it more difficult to accurately determine bilirubin concentrations in the skin (Mahmoud et al., 2008; Lamola & Russo, 2014).

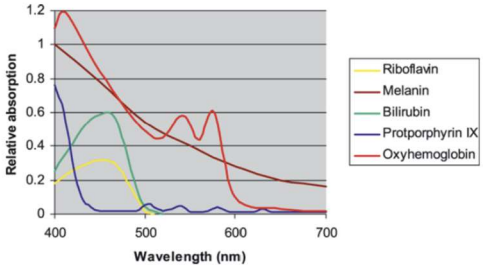

Figure 2: Comparative absorption profiles of typical skin pigments in the spectral range of 400 to 700 nm (Mahmoud et al., 2008).

To further examine the impact of these design choices, Onks et al. conducted a study measuring the effect of melanin on transcutaneous bilirubinometer readings *in vitro*. In this study, they analyzed changes in TcB readings with increasing melanin concentration. Their findings revealed that melanin increased the TcB reading, although the increase was not linear. Additionally, they discovered significant absorption of melanin at 460 nm and 550 nm—the peak absorbance of bilirubin. According to the results, the lesser correlation between TcB readings and serum bilirubin concentration in individuals with darker skin is likely due to the absence of a correction factor for melanin in the jaundice meter, which does not respond linearly to melanin concentration. Onks et al.'s study suggests that the overlap in absorbance between melanin and bilirubin often leads to the overestimation of TcB, as the increased absorption is generally interpreted as a higher bilirubin concentration by most bilirubinometers (Onks et al., 1993). TcB devices reliance on optical spectroscopy and the high degree of overlap between the absorption spectra of bilirubin and melanin showcases how design choices in TcB devices express implicit bias against darker skinned neonates by unintentionally leading to an overestimation of bilirubin levels.

TcB Overestimates Serum Bilirubin Levels in Neonates with Darker Skin Tones

TcB tends to overestimate serum bilirubin levels in neonates with darker skin tones, increasing the likelihood of unnecessary phototherapeutic treatment and leading to adverse short and long-term effects that marginalize and exclude them. Dr. Bolajoko O. Olusanya and her team at the Center for Healthy Start Initiative in Lagos, Nigeria discovered that transcutaneous bilirubinometers tend to overestimate serum bilirubin levels in black neonates. Specifically, TcB is likely to overestimate serum bilirubin by at least 3 mg/dL in one out of every three cases, reaching up to 8 mg/dL in some instances. Their prospective cohort study, which involved 1553 infants in Nigeria from December 2011 to June 2015, assessed the accuracy of TcB measurements using two transcutaneous bilirubinometers—Konica Minolta/Air Shields JM-103 and Respironics BiliChek. The study focused on neonates delivered in a single maternity hospital in Lagos with a gestational age of ≥ 35 weeks or a weight of ≥ 2.2 kg. Neonates were categorized into three skin tone groups: light brown, medium brown, or dark brown. TcB and total serum bilirubin (TSB) paired samples were collected within the first 120 hours of life for all patients, with JM-103 recordings constituting 71.9% of TcB readings. Overall, TcB testing tended to overestimate TSB, with 64.5% of infants showing an overestimation of ≥ 2 mg/dL, 42.7% of ≥ 3 mg/dL, and 25.7% of > 4 mg/dL. In contrast, TcB testing underestimated TSB in 1.1% of infants by ≥ 2 mg/dL, 0.5% by ≥ 3 mg/dL, and 0.3% by > 4 mg/dL (Olusanya et al., 2016).

Another prospective diagnostic cohort study conducted in the United States included 849 newborns with a gestational age of ≥35 weeks who underwent TSB level assessments based on clinical indications between February 1, 2001, and December 31, 2002. This study included infants from the normal newborn nursery populations of William Beaumont Hospital (Royal Oak, MI; n = 670), Hutzel Hospital (Detroit, MI; n = 86), and Thomas Jefferson University

Hospital (Philadelphia, PA; n = 93). TSB levels were measured as per clinical indication, and TcB levels were obtained within 1 hour using the Minolta/Hill-Rom Air-Shields Transcutaneous Jaundice Meter model JM-103. The demographic distribution included 59.2% white, 29.8% black, 4.5% East Asian, 3.8% Middle Eastern, 1.6% Indian/Pakistani, and 1.1% Hispanic. Maisels et al. discovered a strong correlation between TSB and TcB values across all population groups: white (n = 503, r = .949), black (n = 253, r = .822), and East Asian, Indian/Pakistani, and Hispanic (n = 93, r = .926). However, in the black population, the correlation was less close compared to other groups, and consistently, the JM-103 value exceeded the TSB value. Specifically, TSB was overestimated by ≥ 2 mg/dL in 37.9% of black infants, in contrast to 1.8% in whites or 5.4% in other races. Among black infants, overestimations of ≥ 3 mg/dL occurred in 17.4%, and ≥ 4 mg/dL in 6.7%. Furthermore, TcB consistently registered higher values than TSB in the black population whenever the discrepancy between TcB and TSB was ≥ 3 mg/dL (Maisels et al., 2004).

In both studies conducted in Lagos and the United States, a consistent pattern emerged: TcB consistently overestimated TSB levels across different devices and locations. This highlights the tendency of TcB to inaccurately estimate bilirubin levels, particularly in infants with darker skin tones. The collective findings emphasize the importance of exercising caution and considering variations in skin tone when interpreting TcB measurements.

Phototherapy Presents Both Short and Long-Term Adverse Effects

Phototherapy, a widely used treatment for neonatal hyperbilirubinemia, induces various adverse reactions, which marginalizes and excludes neonates with darker skin tones who have a higher likelihood of being prescribed it. Notably, this treatment can impact crucial aspects of the

mother-infant relationship, as newborns are often separated from their mothers during phototherapy sessions, potentially disrupting the fundamental process of mother-infant interaction crucial for psychological development. While treatment interruptions are sometimes permitted to facilitate breastfeeding or parent visitations, concerns linger about the potential long-term psychological impact on both infants and parents. Furthermore, reports suggest that phototherapy may temporarily affect the vision, hearing, and alertness of the newborn, with these transient impairments, although generally reversible, adding complexity to the short-term considerations (Wang et al., 2021).

Additionally, short-term side effects include an imbalance in the thermal environment and water loss. Conventional phototherapy alters the thermal environment, leading to insensible water loss, hypothermia/hyperthermia, and dehydration, particularly impactful in premature infants. Electrolyte disturbance, notably hypocalcemia, emerges as a concern during phototherapy, especially in preterm neonates. The light used in phototherapy can disturb circadian rhythms, influencing the expression of circadian genes and potentially resulting in abnormal behaviors like frequent crying and jitteriness. The rare complication of Bronze Baby Syndrome (BBS) may occur in neonates undergoing phototherapy, with the pathogenesis remaining unclear (Xiong et al., 2011).

The long-term effects of phototherapy for neonatal hyperbilirubinemia unveil several potential health implications, moving beyond the immediate acute reactions. Notably, concerns extend to the potential long-term impact on asthma, allergic rhinitis, and conjunctivitis, with studies reporting associations between neonatal phototherapy and an increased risk of asthma. The Th-2/Th-1 immune system switch disorder caused by phototherapy, affecting cytokine levels

and inducing DNA damage, is proposed as a mechanism contributing to allergic diseases (Xiong et al., 2011).

Another area of concern is the possible connection between phototherapy and tumors in children. Epidemiological studies hint at an increased risk of cancer later in life for newborns treated with phototherapy. The mechanisms behind this potential association remain unclear, raising questions about the long-term safety of this commonly employed treatment (Wang et al., 2021). Additionally, there has been increased focus on the potential association between phototherapy and melanocytic nevi, melanoma, and skin cancer. While some studies suggest a correlation between phototherapy and an increased melanocytic nevus count, the evidence regarding a direct link to skin cancer remains inconclusive (Xiong et al., 2011). DNA damage represents another layer of complexity in the long-term considerations. Some studies argue that phototherapy does not trigger DNA damage, while others propose that neonatal peripheral blood lymphocytes may indeed experience DNA damage during the process. The potential implications of such damage, including alterations in cell replication and apoptosis, further complicate the risk-benefit assessment of phototherapy (Wang et al., 2021).

Furthermore, concerns about infant mortality have been raised in connection with phototherapy. Prolonged duration of phototherapy and increased oxidative stress have been identified as potential factors associated with increased mortality rates, particularly in infants with lower birth weights. Additionally, concerns have been raised about the potential long-term impact on allergic diseases. Research suggests that neonates treated with phototherapy exhibit elevated levels of eosinophilic cationic protein (ECP), indicating a potential link to allergic conditions later in life (Wang et al., 2021). This emphasizes the importance of considering not

just the immediate bilirubin-lowering benefits but also the potential immunological consequences.

Lastly, concerns about patent ductus arteriosus (PDA) and retinal damage have been raised, with phototherapy potentially affecting the closure of PDA in preterm infants and contributing to retinopathy of prematurity (ROP) (Wang et al., 2021). These complexities raise critical questions about the overall safety and potential risks associated with a treatment that is routinely employed to address neonatal hyperbilirubinemia. When considering how the overestimation of TSB leads to an increased propensity to be prescribed phototherapy in darker skinned neonates, these studies suggest that phototherapy can have serious short and long-term effects in these individuals.

While I have argued that phototherapy presents various adverse effects, some might think that phototherapy is safe for neonates, as it has been generally acknowledged that phototherapy is a simple, effective, and safe treatment for neonatal hyperbilirubinemia. For instance, in an article published by Adel Zauk, Chief of Neonatology at St. Joseph's Children's Hospital, it is argued that phototherapy is a safe, efficient, inexpensive, and easy treatment option for neonatal jaundice (Zauk, 2015). However, this view fails to consider the evidence that has emerged in recent years, where several studies have suggested that phototherapy may elicit a series of short- and long-term adverse reactions.

In a review article published in the European Society of Medicine, Sherri Mendelson sought to determine what adverse effects of neonatal phototherapy have been identified and the general breadth of the research. To accomplish this, she conducted a search for relevant sources using PubMed, The Cochrane Database, Ovid, and Clinical Key via EBSCO Discovery Search

from January 2013-January 2023. Overall, 25 studies ended up being included in the scoping review, where the inclusion criteria was that participants had undergone phototherapy for hyperbilirubinemia during their first weeks of life, including term and preterm infants. It was found that adverse reactions such as allergic reactions, patent ductus arteriosus (PDA), childhood cancers, neurological disorders, hearing loss, and electrolyte disturbance appear to be increased in infants exposed to phototherapy for treatment of hyperbilirubinemia (Mendelson, 2023). Despite the widespread belief in the safety of neonatal phototherapy, recent research, as highlighted by Mendelson's comprehensive scoping review, suggests a concerning association with various adverse reactions. The identified risks emphasize the importance of reevaluating the perceived safety of phototherapy in neonatal care.

Conclusion

This paper has examined a critical oversight in the current understanding and application of TcB devices in neonatal jaundice assessment. While widely endorsed as a safe and efficient alternative, the existing literature and clinical guidelines fail to comprehensively consider the inherent racial bias present in the current method of acquiring accurate TcB measurements. The empirical evidence presented in this paper highlights a consistent trend of TcB devices overestimating TSB levels in infants with darker skin tones, leading to an increased likelihood of prescribed phototherapeutic treatment and subsequent short and long-term side effects. Through the lens of Technological Politics, this analysis exposes the implicit bias embedded in the design choices of TcB devices, inadvertently privileging neonates with lighter skin tones and disadvantaging those with darker skin tones.

By revealing the unintended racial healthcare disparities introduced by TcB devices, this study prompts a reevaluation of their design and application. Recognizing and rectifying these biases is imperative to ensure equitable healthcare access for all neonates, transcending the current limitations in neonatal jaundice assessment. As technological advancements shape medical practices, addressing implicit biases becomes paramount to fostering inclusive and just healthcare systems globally. Moving forward, engineers developing neonatal care devices, especially TcB devices, must now consider the racial dimensions of their designs. Applied research in medical technology must pivot toward inclusivity, emphasizing diversity in clinical studies and a commitment to developing technologies that address the needs of all racial and ethnic groups.

References

Kemper, A. R., et al. (2022). Clinical practice guideline revision: Management of hyperbilirubinemia in the newborn infant 35 or more weeks of gestation. *Pediatrics*, *150*, e2022058859. https://doi.org/10.1542/peds.2022-058859

Khandpur, R. S. (2020). Bilirubinometer. In R. S. Khandpur (Ed.), *Compendium of Biomedical Instrumentation* (Chapter 31). Wiley. https://doi.org/10.1002/9781119288190.ch31

Lamola, A. A., & Russo, M. (2014). Fluorescence excitation spectrum of bilirubin in blood: A model for the action spectrum for phototherapy of neonatal jaundice. *Photochemistry and Photobiology, 90*(2), 294–296. https://doi.org/10.1111/php.12167

Mahmoud, B. H., Hexsel, C. L., Hamzavi, I. H., & Lim, H. W. (2008). Effects of visible light on the skin. *Photochemistry and Photobiology, 84*(2), 450–462. https://doi.org/10.1111/j.1751-1097.2007.00286.x

Maisels, M. J., Ostrea, E. M., Jr, Touch, S., Clune, S. E., Cepeda, E., Kring, E., Gracey, K., Jackson, C., Talbot, D., & Huang, R. (2004). Evaluation of a new transcutaneous bilirubinometer. *Pediatrics*, *113*(6), 1628–1635. https://doi.org/10.1542/peds.113.6.1628

Mendelson, S. (2023). Neonatal phototherapy adverse effects in infants: A scoping review. *Medical Research Archives, 11*(7.1). doi:10.18103/mra.v11i7.1.4099

Okwundu, C. I., Uthman, O. A., Suresh, G., Smith, J., Wiysonge, C. S., & Bhutani, V. K. (2017). Transcutaneous bilirubinometry versus total serum bilirubin measurement for newborns. *The Cochrane Database of Systematic Reviews*, *2017*(5), CD012660. https://doi.org/10.1002/14651858.CD012660

Olusanya, B. O., Imosemi, D. O., & Emokpae, A. A. (2016). Differences between transcutaneous and serum bilirubin measurements in black african neonates. *Pediatrics*, *138*(3), e20160907. https://doi.org/10.1542/peds.2016-0907

Onesimo, R., et al. (2011). Is heel prick as safe as we think? *BMJ Case Reports*, *2011*, bcr0820114677. https://doi.org/10.1136/bcr.08.2011.4677

Onks, D., Silverman, L., & Robertson, A. (1993). Effect of melanin, oxyhemoglobin, and bilirubin on transcutaneous bilirubinometry. *Acta Paediatrica*, *82*, 19–21. https://doi.org/10.1111/j.1651-2227.1993.tb12507.x

Queensland Clinical Guidelines. (2022). *Neonatal Jaundice* (Guideline No. MN22.7-V9-R27). Retrieved from http://www.health.qld.gov.au/qcg

Samiee-Zafarghandy, S., Feberova, J., Williams, K., Yasseen, A. S., Perkins, S. L., & Lemyre, B. (2014). Influence of skin colour on diagnostic accuracy of the jaundice meter JM 103 in newborns. *Archives of Disease in Childhood. Fetal and Neonatal Edition*, *99*(6), F480–F484. https://doi.org/10.1136/archdischild-2013-305699

Wainer, S., Rabi, Y., Parmar, S. M., Allegro, D., & Lyon, M. (2009). Impact of skin tone on the performance of a transcutaneous jaundice meter. *Acta Paediatrica (Oslo, Norway : 1992)*, *98*(12), 1909–1915. https://doi.org/10.1111/j.1651-2227.2009.01497.x

Wang, J., Guo, G., Li, A., Cai, W. Q., & Wang, X. (2021). Challenges of phototherapy for neonatal hyperbilirubinemia (Review). *Experimental and Therapeutic Medicine*, *21*(3), 231. https://doi.org/10.3892/etm.2021.9662

Winner, L. (1980). Do artifacts have politics? *Daedalus, 109*(1), 121–136. http://www.jstor.org/stable/20024652

Woodgate, P., & Jardine, L. A. (2011). Neonatal jaundice. *BMJ Clinical Evidence*, *2011*, 0319.

Xiong, T., Qu, Y., Cambier, S., & Mu, D. (2011). The side effects of phototherapy for neonatal jaundice: What do we know? What should we do? *European Journal of Pediatrics*, *170*(10), 1247–1255. https://doi.org/10.1007/s00431-011-1454-1

Zauk, A. M. (2015). Phototherapy: A simple and safe treatment for neonatal jaundice. *Journal of Pediatric and Neonatal Care*, *2*(3), 00070. https://doi.org/10.15406/jpnc.2015.02.00070