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Comparison of incandescent and fluorescent light sources for phototherapy

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Comparison of Incandescent and Fluorescent Light Sources for Phototherapy

by

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COMPARISON OF INCANDESCENT AND FLUORESCENT LIGHT SOURCES FOR PHOTOTHERAPY

ABSTRACT

Phototherapy is the preferred treatment for managing infants with rising or high levels of bilirubin. Each year infants with hyperbilirubinemia and the resulting jaundice are treated with phototherapy across the United States. The purpose of this study was to investigate the effects of incandescent and fluorescent light on the rate of decrease in serum levels of total bilirubin in neonates, the effects the neonates experienced when exposed to the lights, and what factors might influence the rate of decline in bilirubin levels. In this study, 42 jaundiced neonates were conveniently selected and randomly assigned to receive either incandescent or fluorescent phototherapy placed 42 to 45 cm above the infant in an isolette. There was a statistically significant difference in the amount of irradiance between the fluorescent and incandescent light and the total number of hours the infants were under the lights. There was also a slight difference in the amount of weight lost by the two treatment groups. Moreover, there was an actual increase in serum bilirubin levels in the first 24 hours of treatment when the average fluorescent radiant flux was 1.4 $uW/cm^2/nm$ compared to a decrease in serum bilirubin levels when the average irradiance was 7 $uW/cm^2/nm$. These differences may be due to the irradiance emitted from the lights and not the type of light itself and may also be partially attributed to the different ages and levels of

serum bilirubin at the onset of phototherapy treatment. None of the infants experienced deleterious effects from either type of light. The only factor that influenced the rate of decline of serum bilirubin levels was the pretreatment level of bilirubin. The higher the level, the faster it fell. Recommendations for practice are made based on results of this study comparing the incandescent and fluorescent phototherapy units in the treatment of neonatal hyperbilirubinemia.

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CHAPTER I

INTRODUCTION

Problem Area

Many normal newborn infants have hyperbilirubinemia and the resulting jaundice between the second and fifth day of life, usually because the hepatic system for conjugating and excreting bilirubin is functionally immature at birth and for a short time after. Various environmental influences and diseases such as acidosis, asphyxia, sepsis, certain drugs, ABO diseases, glucose-6-phosphatase deficiency, and prematurity can also result in an earlier or more severe form of hyperbilirubinemia. These factors can abnormally affect bilirubin metabolism in both the fetus and newborn which disrupts the normal balance between the production and excretion of bilirubin (Odell, 1980). Bilirubin accumulates in the circulation and extravascular tissues until the system becomes fully functional and the causal factor is eliminated. As the serum bilirubin concentration rises and the time it remains elevated increases, so does the risk of kernicterus which can result in central nervous system damage or even death of the neonate.

The prevention of kernicterus resulting from elevated levels of unconjugated bilirubin is the goal in managing neonates with hyperbilirubinemia. The exchange transfusion has been the accepted treatment for lowering bilirubin levels for the past thirty years. This

procedure is hazardous and can result in vascular embolism, thrombosis, cardiac arrhythmias or arrest, electrolyte imbalance, and infections. Therefore, new ways of preventing the serum bilirubin levels from increasing to dangerous levels were sought. Phototherapy (prolonged irradiation with light) is now the preferred treatment for hyperbilirubinemia in the newborn infant (Cohen & Ostrow, 1980; Lucey, Ferreira, & Hewitt, 1968).

The Committee on Phototherapy in the Newborn Infant (Albrecht & Roney, 1981) estimates that in 1974, 2.5 percent of live births in the United States were exposed to phototherapy. In a questionnaire distributed by this Committee, 57 percent of the hospitals used phototherapy in 1974 to treat neonates with transient hyperbilirubinemia.

It is a common observation that when a jaundiced neonate is exposed to efficient phototherapy, bleaching of the skin occurs, a decrease in plasma levels of unconjugated bilirubin results, and products of bilirubin breakdown are excreted into the bile. The exact action of phototherapy remains unclear. At the present time, the accepted theory is that phototherapy causes photo-oxidation or photodegradation of unconjugated bilirubin to other compounds that are easily excreted (Cohen & Ostrow, 1980; McDonagh, 1971, 1974).

Fluorescent phototherapy has been used since 1958 without a major toxic effect being noted. Several short- and long-term complications of fluorescent phototherapy have, however, been documented in the literature. These adverse effects are retinal damage to unshielded eyes, cutaneous erythema, hyperpigmentation, bronzing of the skin, impaired clinical assessment due to glare, increased insensible water

loss, thermal problems due to overheating, or chilling from exposure. Other complications of phototherapy which may occur are decreased serum nonesterified fatty acids, a decrease in riboflavin due to being a generator of singlet oxygen, loose stools because of the increase in transit time excreting the products of bilirubin breakdown, impairment to biologic rhythms, effect on the age of sexual maturation, increased hemolysis of erythrocytes (not yet demonstrated in vivo), an alteration in the normal parent-infant bonding pattern, and a decrease in serum calcium levels (Bergstrom & Hakanson, 1980; Dobson, 1976; Drew, 1976; Gromisch, Lopez, Cole, & Cooperman, 1977; Hadjigeorjiou, Triliouri, & Trichopoulou, 1978; Ham, Mueller, & Ruffolo, 1979; Hastings, 1974; Kitay, 1954; Kopelman, Brown, & Odell, 1972; Kopelman, Ey, & Lee, 1978; Lathe, 1976; Odell, 1980; Oh & Karecki, 1972; Sisson, Slavin, & Hamilton, 1976; Speck & Rosenkranz, 1976; Wu & Moosa, 1978; Wurtman, 1974).

Incandescent phototherapy units recently have been introduced into many nurseries across the United States to treat neonatal hyperbilirubinemia. Incandescent phototherapy differs from fluorescent phototherapy in that the light is produced by a filament of conducting material which is heated by electrical current instead of being produced by the illumination of fluorescent substance in a tube when mercury vapor is charged by electrons.

It is suspected that the clinical course of neonates with unconjugated bilirubin exposed to incandescent light may improve faster due to a decline in the unconjugated bilirubin level because of appropriate radiant flux levels. This would result in less exposure time for the neonate, fewer complications, and an earlier discharge, which decreases patient cost.

Nursing Goal

The nursing goal of phototherapy is to achieve the maximum benefit with the least harm. After the need for phototherapy has been determined, the nurse is responsible for the implementation, maintenance, and accurate evaluation of the efficacy of the therapy. The role of the nurse is one of a clinician, resource, and support person for the family.

Primary Purpose

The primary purpose of this study was to determine whether incandescent or fluorescent light is more effective in reducing elevated serum levels of unconjugated bilirubin in jaundiced neonates.

Secondary Purposes

Secondary purposes of this study were to study the relationship between the incandescent or fluorescent light and a neonate's weight loss, tanning, cutaneous erythema, temperature regulation, stool consistency, and duration of phototherapy treatment, and to determine if the rate of decline of serum levels of unconjugated bilirubin in the neonate was influenced by the administration of betamethasone, phenobarbitol, Apgar scores, birth weight, gestational age, and the level of unconjugated bilirubin prior to the start of phototherapy.

CHAPTER II

THEORY

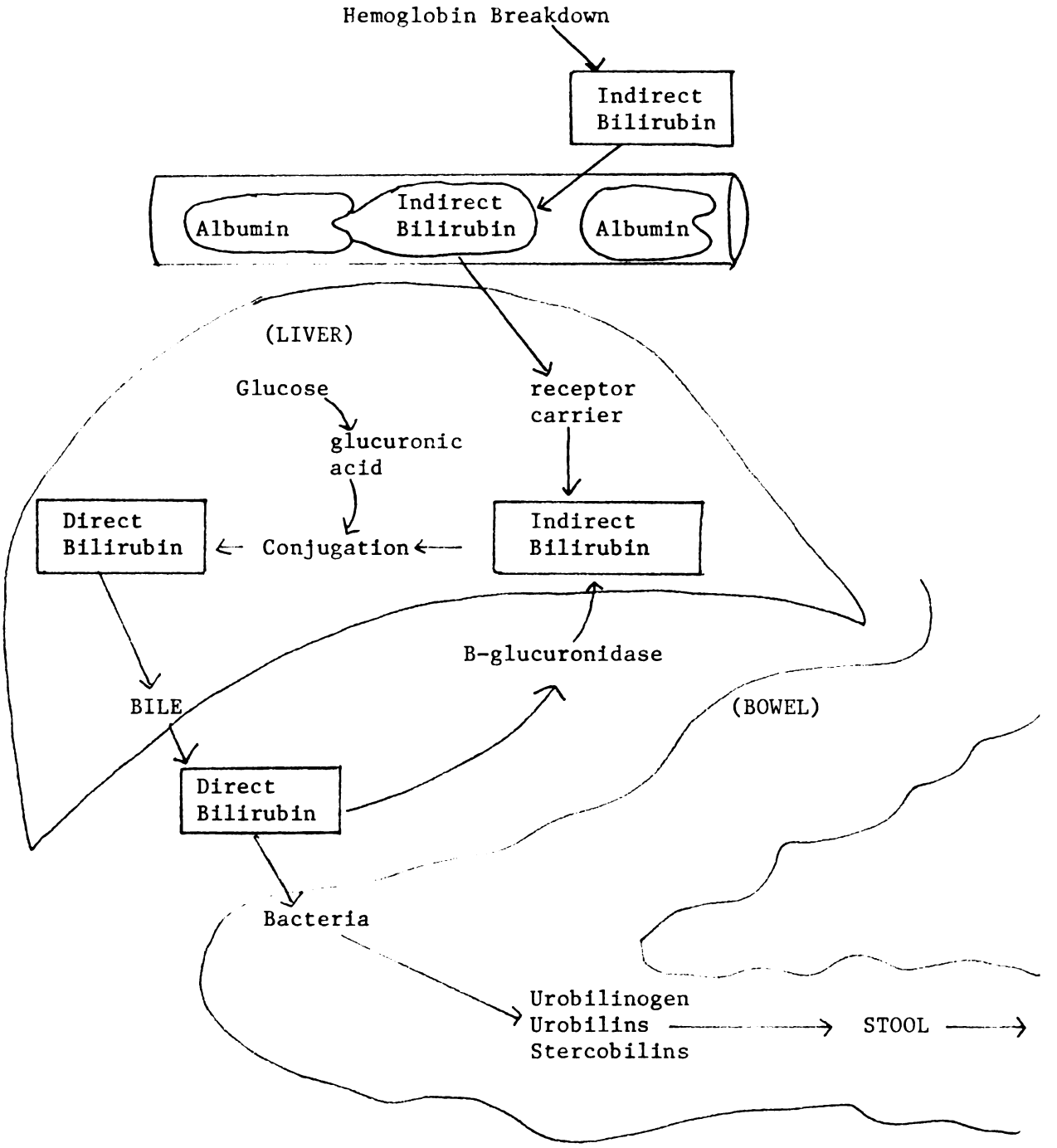
Bilirubin Formation and Excretion

The formation of bilirubin results from the catabolism of hemeproteins, especially hemoglobin. Each mole of albumin has one high affinity site for binding a single mole of bilirubin. As these protein-bound molecules of bilirubin flow near the liver's sinusoidal epithelium, they enter into the space of Disse. The sinusoidal epithelium is very porous and is situated parallel to the hepatocytes. The membrances of the hepatocytes facing the space of Disse contain two receptor-carrier molecules that bind bilirubin. The Y receptor-carrier protein, ligandin, is the most abundant. The biotransformation of bilirubin to a water soluble substance occurs in the endoplasmic reticulum of the microsomes of the hepatocyte. Uridine diphosphate glucuronic acid in the presence of the microsomal enzyme uridine diphosphoglucose (UDPG) glucuronly transferase converts bilirubin to a monoglucuronide. These enzymes unfold the bilirubin molecule, which encourages its excretion. In man, the mono- and diglucuronides of bilirubin are the excretory forms of bilirubin. The excretion of bilirubin is a secretory transport process that occurs in the canaliculus of the hepatocytes. After passing with bile into the duodenum, bacterial flora hydrogenate the direct bilirubin to a more

water soluble urobilinogen, urobilins, and stercobilins. These are then passed in the stool (Odell, 1980). (See Figure 1.)

Figure 1

Bilirubin Synthesis



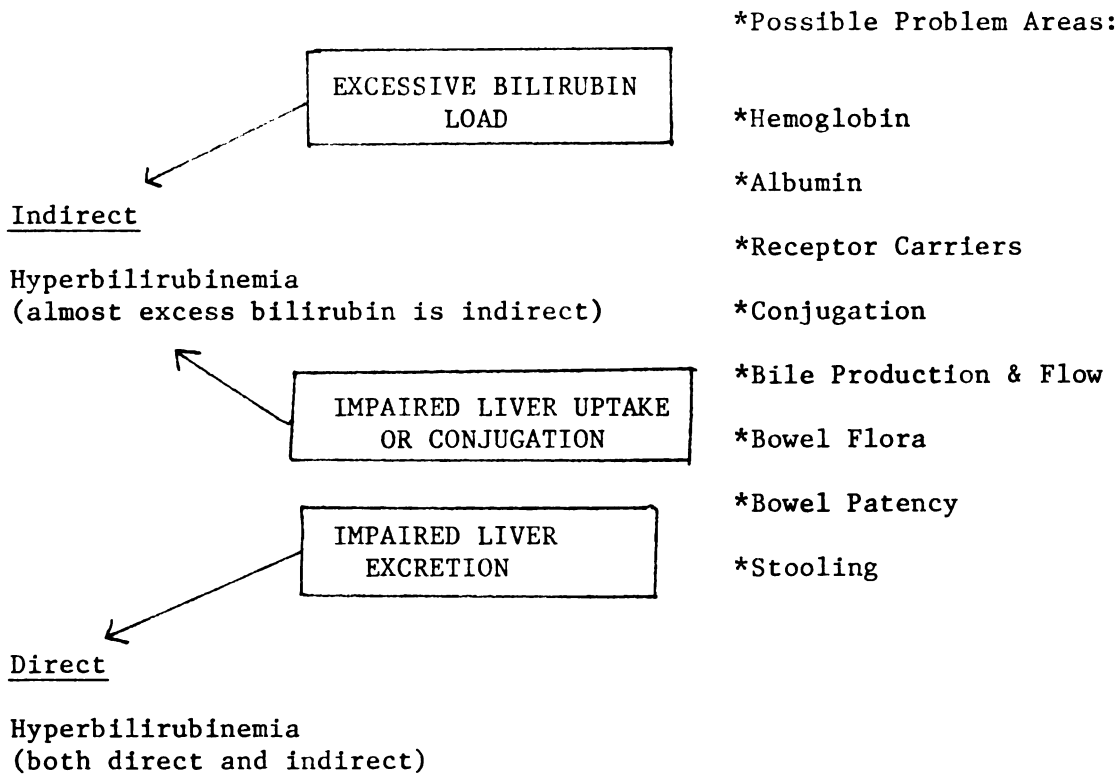
Fetal and Newborn Bilirubin Metabolism

The hepatobiliary system develops in the first ten weeks of gestation, and hemopoeisis begins during the sixth week of gestation (Moore, 1977). With hemoglobin synthesis beginning early in fetal life, the catabolism of hemeproteins must also co-exist because few, if any, fetal erythrocytes cross the placental barrier into the maternal circulation. Since the albumin concentration is lower in the fetal plasma than in the maternal circulation, bilirubin crosses the placenta easily and is usually cleared by the maternal conjugating and excreting system.

The conjugating and excreting system is less efficient in the fetus and newborn because: a) the rate of bilirubin production is twice that of older children due to a short life span of the fetal erythrocytes; b) blood is shunted from the sinusoidal circulation to the liver through the ductus venosus, hence not all the hepatocytes are used to clear the bilirubin; c) a large amount of extra medullary hematopoietic tissue exists in the sinusoids, which impedes the perfusion in the space of Disse; d) ligandin is decreased, which decreases the amount of bilirubin transported from the plasma into the hepatocyte; e) the multiple glucuronyl transferases may be suppressed; and f) the bowel is relatively sterile and the increased activity of the deconjugating enzyme B-glucuronidase may result in the majority of the direct bilirubin being converted back to indirect bilirubin and reabsorbed through the enterhepatic circulation (Odell, 1980). (See Figure 2.)

Figure 2

Altered Bilirubin Synthesis

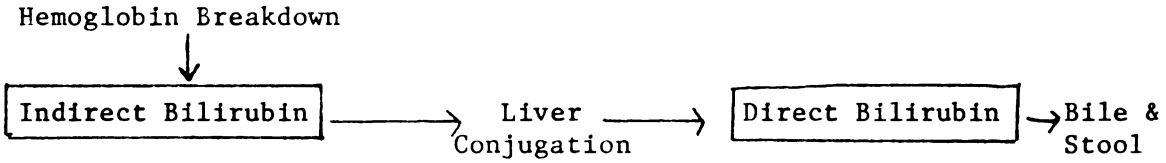


Kernicterus

If excess extra cellular unconjugated bilirubin is free or not bound to protein, it can diffuse into the central nervous system and result in decreased cellular respiration, impaired protein synthesis, and uncoupling of oxidative phosphorylation. This bilirubin encephalopathy (kernicterus) is not an all-or-none phenomenon. Children who survive may experience a sensorineural hearing loss, chorathertosis, or asymmetrical spacticity (Giunta, 1972; Johnson & Boggs, 1974; Seligman, 1977). (See Figure 3.)

Figure 3

Comparison of Indirect and Direct Bilirubin



1. Unconjugated Bilirubin	1. Conjugated Bilirubin
2. Insoluble in water and is not excreted in the bile or urine	2. Soluble in water, usually excreted in bile. If accumulates due to liver obstruction it will be secreted in urine
3. Transported in the plasma by binding to albumin	3. Transported in the plasma either by itself (free) or bound to albumin
4. Fat soluble. Accumulation results in adherence to lipid rich tissues such as skin and brain (Kernicterus)	4 Water soluble, does not accumulate in the tissues and is not toxic
5. Can be reabsorbed in the bowel and returned to the liver	5. Is reduced by bacteris in bowel and excreted in the stool

The Action of Phototherapy

Recent research has focused on the mechanisms by which phototherapy alters bilirubin molecules and results in its excretion. Ostrow and Branham (1970) conclude that oxygen is important in the photodecomposition of bilirubin. One possible explanation is that a stable form of activated (excited) oxygen (singlet oxygen) is generated by the transfer of energy to the oxygen molecule from a bilirubin molecule excited by the absorption of light photons occurring in the outer 2 mm of the skin. This singlet oxygen is added to one of the double bonds or unsaturated bridges of bilirubin. Degradation of this product then

occurs and probably is cleared rapidly by the liver and kidney (Ostrow, 1971). Bilirubin can also be transformed into photobilirubin or bilirubin E, which are water soluble. Photobilirubin or bilirubin E do not bind to tissues nor probably to albumin. This transformation is an actual change in the molecular structure and does not involve oxidation, nor does it require as much radiant flux. However, these molecules, photobilirubin or bilirubin E, revert back to unconjugated bilirubin after they are excreted into the bile and exposed to darkness. It has not been established how much bilirubin is converted by oxydation or changed to photobilirubin by the use of phototherapy in the newborn (Broderson, 1980). However, a direct increase in the photodegradation occurs with an increase in irradiance of the phototherapy lights (Mims, Estrada, Gooden, Caldwell, & Kotas, 1973; Wu, 1981). (See Figure 4).

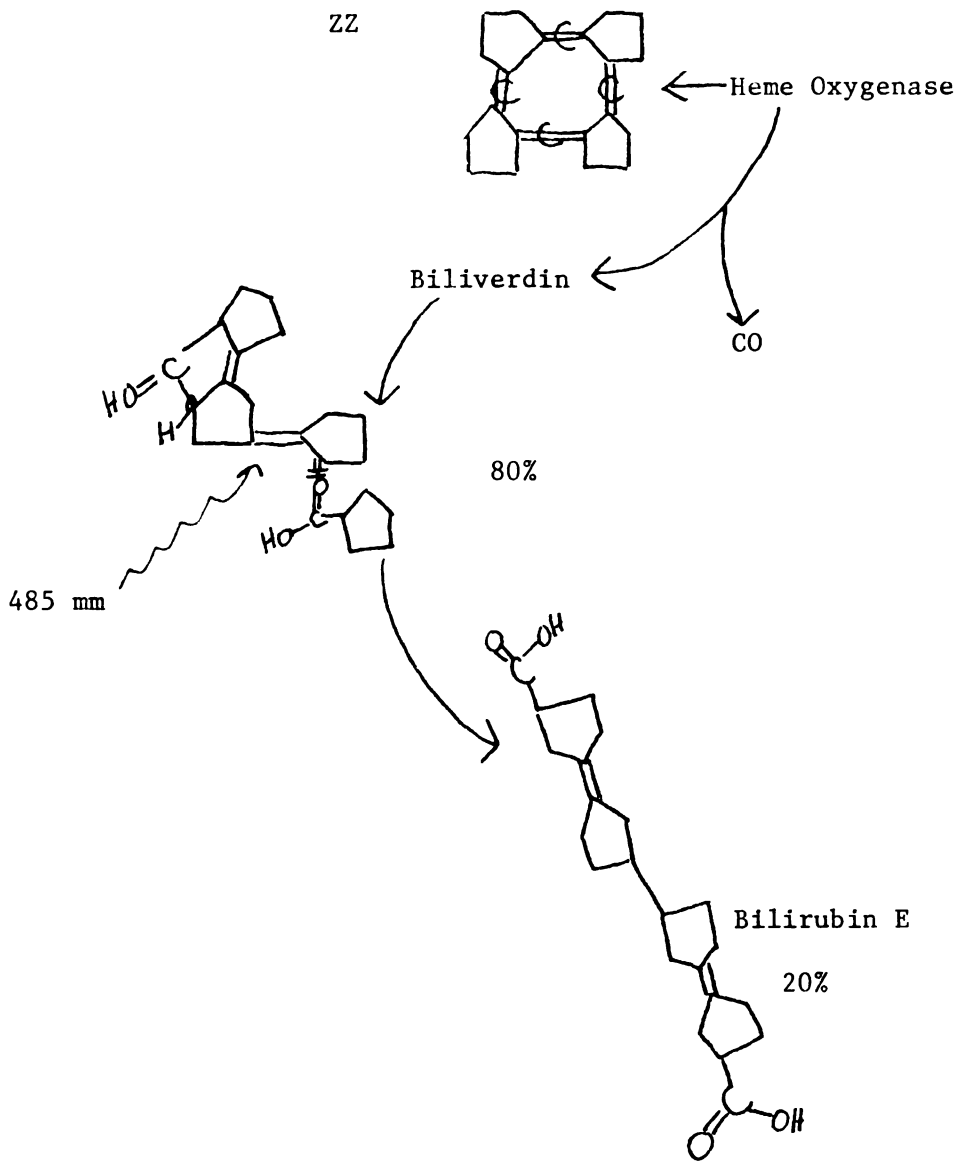
Review of the Literature

Artificial Lighting

The use of phototherapy as a treatment alternative for neonatal hyperbilirubinemia was first published by Cremer, Perryman, and Richards (1958) based on the observations of a Sister in a newborn nursery who noticed that the infants on the sunny side of the nursery were less jaundiced. Even though sun light and artificial light placed above an infant did decrease the amount of jaundice, the use of artificial light in the management of neonatal hyperbilirubinemia was delayed by concerns about the possible toxic effects resulting from the products of the photochemical decomposition of bilirubin and doubts as to its effectiveness to sufficiently and permanently reduce the neonate's serum bilirubin levels (British Medical Journal, 1970; Franklin, 1958).

Figure 4

Photodegration of Bilirubin



Research continued to confirm the effectiveness of fluorescent phototherapy lights. Lucey, Ferreiro, and Hewitt (1968) experimentally examined the effects of phototherapy in 111 premature infants weighing less than 2500 grams. They alternately assigned the infants to two groups before 12 hours of age. One group did not receive phototherapy while the other group underwent continuous irradiation with a canopy of ten 20-watt daylight fluorescent bulbs for 22 hours a day. This time was not controlled, only estimated. The infants were undressed except for eye-patches, and any infant with a positive Coombs was excluded from the study. The groups were comparable in birth weight, gestational age, time and amount of early fluid intake, weight loss, infection, sex, asphyxia (Apgar), and major blood group incompatibility. The lights were turned off when venous or capillary blood samples were drawn on the 1st, 2nd, 4th, and 6th day of treatment.

The phototherapy group was reported to have a clinical and statistically significant decrease in their serum levels of unconjugated bilirubin on the fourth and sixth day of life ($p < .001$). No instances of rebound occurred, and there were no differences found in the sleeping, feeding, percent of weight loss, and fluid intake in the two groups. Stool color of some of the irradiated infants was noted to change. The authors did not report the measures used in noting the differences in these variables.

Six months later, 102 infants from this sample were reexamined for motor development. Two infants in the light group and one in the control group were thought to demonstrate "delayed motor development". The criteria used to measure development were not reported. Since this

delayed motor development could result from many factors, follow-up would have been helpful in differentiating its cause.

Several controlled experimental studies following Lucey and colleagues' (1968) work concluded that continuous fluorescent phototherapy starting soon after birth resulted in a significant decrease in the frequency of hyperbilirubinemia due to various causes in neonates of any weight and race (Elliott, Moncrieff, & George, 1974; Giunta, 1971; Swartz & Hodgman, 1970; Porto, Pildes, & Goodman, 1969; Seligman, Andrews, & Elias, 1969; Sisson, Kendall, Glauser, Knutson, & Bunyaviroch, 1971; Tan, 1976).

Giunta (1972) observed 420 infants in a specially lighted intensive care nursery. The nursery was lighted by fluorescent daylight canopies with one corner designed with lower canopies. Any infant who experienced hyperbilirubinemia greater than 10 mg/100 ml was placed beneath the lower light canopy. Twenty-seven percent of the infants needed to be placed below the lower canopy. Only 3.1 percent of the infants below the lower canopy needed additional light to sufficiently lower bilirubin levels. It was concluded that continuous phototherapy starting soon after birth resulted in significant decrease in the number of babies developing hyperbilirubinemia. No statistical analysis was computed for these observations.

Elliot and colleagues (1974) examined the responses to phototherapy in 88 infants with a birth weight between 1500 and 2500 grams. Each infant was alternately assigned to either the light-treated group or the untreated group. The phototherapy group was treated with four to five thousand lux. Control cases were not treated unless the serum bilirubin

exceeded 15 mg/100 ml. The infants were comparable as to cause of jaundice, age, sex, birth weight, neonatal illness, and bruising.

No infant in the light-treated group developed a bilirubin greater than 15 percent. Forty-four percent of the infants in the untreated group did. The analysis of the data is not clear. The number of hours the infants were placed beneath the lights was not reported nor were the infants randomly selected or assigned.

Race and Phototherapy

Porto and colleagues (1969) randomly assigned 23 infants into two groups based upon skin color. Both groups were comparable as to gestational age, Apgars, birth weight, and respiratory distress. Similar responses to continuous phototherapy were demonstrated by both groups of infants ($p < .01$), dispelling the concern that dark-skinned babies did not respond as well to light therapy as did light-skinned babies. The authors did not fully report their criteria used to determine shades of skin color.

Weight and Phototherapy

Sisson and colleagues (1971) found that the response to fluorescent phototherapy did not vary according to the infant's weight. Thirty-five infants with hyperbilirubinemia due to ABO incompatibilities were randomly selected and assigned according to birth weight. One group weighed less than 2500 grams at birth, the other more than 2500 grams. These two groups were then divided and either received continuous blue fluorescent phototherapy or no phototherapy. The groups of infants were comparable as to gestational age, Apgar, and fluid intake. An analysis

of covariance was performed. There was no significant difference in bilirubin decrease between those infants who were greater than or less than 2500 grams receiving blue fluorescent phototherapy. Those infants weighing less than or more than 2500 grams not receiving phototherapy did not differ in their inabilities to lower bilirubin levels. The authors concluded that phototherapy was an effective means of treating neonates of any weight with hyperbilirubinemia due to ABO incompatibilities.

Etiology of Jaundice and Phototherapy

These studies were followed by controlled experimental research showing that fluorescent light is effective in decreasing the serum levels of unconjugated bilirubin in infants who experience jaundice due to multiple causes. Seligman and associates (1969) studied 95 infants suffering hyperbilirubinemia due to RH and ABO incompatibilities, contained hemorrhage, maternal diabetes, sepsis, and other rarer causes of jaundice. These infants were divided into four groups based on the cause of their hyperbilirubinemia. Each group was continuously irradiated with fluorescent daylight tubes delivering 420 to 490 nanometers (nm). There was no statistical difference between the four groups and the fall in plasma bilirubin levels. The comparability of each group as to gestational age, weight, race, sex, fluid intake, type of equipment used, or the selection of the infants was not reported by the authors.

In 1970, Swartz and Hodgman studied 98 infants weighing less than 1500 grams and randomly assigned them into two treatment groups. All the infants experienced hyperbilirubinemia due to a variety of causes,

but were comparable in birth weight, gestational age, races, and Apgar scores. The authors noted a significant difference in the decline of serum bilirubin in the treated infants versus the nontreated ones ($p < .01$). The dosage of light delivered and the amount of time each infant experienced phototherapy were not reported by the authors.

Tan (1976) compared 19 "healthy" Chinese infants to 19 "ill" Chinese infants. The infants were matched in regard to age at onset of phototherapy, sex, birth weight, gestational age, hemoglobin count, and bilirubin level. Both groups were irradiated with white fluorescent lamps. This is the first time the exact type of light was reported. Earlier studies did not indicate the exact type of light used, although white fluorescent light presumably was used. Phototherapy was effective in reducing unconjugated bilirubin levels in both groups. The "healthy" infants did not reduce their bilirubin levels significantly more than the "ill" infants, and rebound bilirubin levels were similar in both groups.

Adverse Effects of Phototherapy

As the use of phototherapy to treat neonatal hyperbilirubinemia became widespread, concern grew that this practice had adverse consequences to the infant. Investigators observed an increased respiratory rate, diarrhea, a generalized "stork bite" rash, and a bronzing of the skin of some infants beneath the phototherapy lights (Cohen & Ostrow, 1980). Oh and Karecki (1972) noted an increase in body water loss associated with the heat from the phototherapy lamp and the increased excretion of the by-products of bilirubin photo-oxidation in 12 full-term infants. Water is the major component of an infant's body,

and excessive loss could result in hypernatremia. In this controlled study he compared 12 jaundiced infants who received phototherapy to 14 control and 10 jaundiced infants who did not receive phototherapy. He examined their food and fluid intake, stool and urine output, and changes in their body weight over a specified period of time.

At the same time, concerns grew over seemingly delayed physical and motor growth in infants undergoing phototherapy. Drew (1976) observed a delay in motor development in four out of 300 infants with hyperbilirubinemia who underwent phototherapy. The motor development delay was found in only two out of 300 randomly selected control infants who did not have phototherapy or jaundice. The four infants who experienced a delay were normal in height and weight but had experienced a difficult delivery with resultant low Apgars or repeated episodes of severe apnea and bradycardia. Drew concluded these delays could not be attributed solely to phototherapy.

Telzrow, Snyder, Tronick, Als, and Brazelton (1980) compared ten infants with hyperbilirubinemia who underwent phototherapy to ten newborns without hyperbilirubinemia and phototherapy for ten days. They noted a decrease in animate and inanimate visual response on the Brazelton assessment scale equally in both groups. Their findings of low infant responsiveness could not be attributed to hyperbilirubinemia or phototherapy. The implications of these findings to the role the infant plays in the maternal-infant attachment process is very important (Barnard, 1979). These studies demonstrated that phototherapy may not be a panacea, and its use demands thoughtful application and observation.

Continuous or Intermittent Phototherapy

As concern grew over the use of continuous phototherapy, the effectiveness of applying phototherapy intermittently was studied and reported by Zachman (1974) to be as effective as continuous phototherapy. Treatment for as little as 12 hours was shown by Tabb, Inglis, Savage, and Walker (1972) to be sufficient to prevent the serum bilirubin levels from exceeding 13 mg/100 ml in 80 percent of 44 irradiated infants.

Wu, Lim, Hodgman, Kokosky, and Teberg (1974) conducted a study to compare the effectiveness of continuous to intermittent phototherapy of preterm infants and to determine any differences in the growth on infants during phototherapy. One hundred twenty infants were randomly assigned into three groups. The infants in the first group did not receive phototherapy while the infants in the second group were treated continuously for five days starting at 24 to 48 hours of age. The last group of neonates received intermittent phototherapy, 12 hours on and 12 hours off, for five days. The birth weight, gestational age, fluid and caloric intake, and initial serum bilirubin levels were comparable in each group. The source of phototherapy was from ten 20-watt cool white fluorescent lamps suspended 45 cm above the infant with the average irradiance in the 400 to 500 nm range as measured by a radiometer. The infants under the lights were undressed except for eye-patches. The blood sample were drawn with the lights off. Thirty-five percent of the infants in the control group had serum bilirubin levels above 12 mg/100 ml as opposed to 7.5 percent and 5 percent in the intermittent and continuous phototherapy groups respectively.

The authors concluded that both continuous and intermittent fluorescent phototherapy are effective in preventing neonatal hyperbilirubinemia. This study suggested a dose-response theory of phototherapy; that is, a specific amount of irradiance or dose of light is needed to bring about a decrease in serum levels of bilirubin in a neonate.

Irradiance and Phototherapy

As controlled observation of phototherapy continued, realization grew that the irradiance of the light sources played an important part in the photodecomposition of indirect bilirubin in the neonate. Lucey (1972), in an editorial, called upon all the investigators of phototherapy to measure the effectiveness of phototherapy units by using radiant flux. As the more sophisticated measurement of radiant flux replaced foot-candle measurements, a dose-response theory became clear. While earlier studies contributed to the study of the effectiveness of phototherapy, the comparison of light source has not been fully investigated.

Sisson, Kendall, Shaw, and Kechavarz-Oliai (1972) studied the effectiveness of different fluorescent phototherapy lights. Seventy-two infants were placed into three groups. One group was placed beneath daylight (white) fluorescent lights, the second beneath blue fluorescent lights, and the third below special blue narrow spectrum (420-490 nm) fluorescent lights. The lights were on continuously, and each bank of lights was covered by a plexiglas-G plate, which protected the neonate from broken glass and ultraviolet light (390 nm or less). Each group exhibited a decline in mean serum bilirubin. However, those infants

placed below the special blue narrow spectrum light lowered their mean 24-hour serum bilirubin levels significantly more than the infants placed below the standard blue fluorescent or daylight lamps. These findings further supported the dose-response theory. The distance of light placement and the comparability of the three groups were not discussed by the authors.

Replicating Sisson and colleagues' work, Mims and colleagues (1973) observed 44 infants placed into four groups arbitrarily by their physicians' orders. Each group received a varying amount of radiant flux from different combinations of fluorescent lights ranging from daylight to special narrow spectrum blue. Mims found a positive correlation ($r = .72$) in the decline of the 24-hour serum bilirubin values and the amount of blue light received. An almost linear relationship existed between the light intensity, measured by a radiometer in microwatts per centimeter squared (uW/cm^2), and a fall in the serum levels of indirect bilirubin. This further supports the dose-response theory. The comparability of the groups as to age, weight, age at onset of treatment, etiology of jaundice, fluid intake, or the distances the lights were placed from the infants were not reported.

In 1975, Tan closely matched 40 "well" Chinese infants and placed them into two experimental groups. There was no significant difference between groups as to age, birth weight, and age at the onset of treatment. One group was continuously exposed to single direction daylight fluorescent phototherapy, the others to double direction daylight fluorescent phototherapy. The 24-hour fall in bilirubin levels was almost equal. It was concluded that whether the amount of light was

concentrated on a small area of skin or spread over a much larger are, an almost identical effect on the fall of plasma bilirubin levels existed as long as the amount of light energy was in the effective range. This suggests that when a maximum dose of radiant energy (9 $uW/cm^2/nm$) is achieved, further enhancement of the rate of bilirubin degredation is held constant. Thus, a therapeutic range of radiant flux or dosage of phototherapy was confirmed.

In 1976, Bonta and Warshaw studied 42 infants who were exposed to different radiant flux levels due to the design of the phototherapy units (portable, wall mounted, and bed mounted). All the infants included in the study experienced hyperbilirubinemia due to a mild ABO incompatibility or prematurity. The infants were comparable as to average birth weight, gestational age, age at onset of therapy, bilirubin level at the start of therapy, the peak bilirubin level, and the average total hours of therapy. The radiant flux levels were all within the 400 to 500 nm range. Cool white fluorescent light was used, and each phototherapy unit was covered by a plexiglas plate to guard against ultraviolet light 100 cm away with a radiant flux between 1.2 to 1.5 $uW/cm^2/nm$. Fifteen infants in group two received phototherapy from a "conventional" fluorescent canopy 42 cm above the infants with a radiant output of 2.5 to 3.8 $uW/cm^2/nm$. Group three consisted of 21 infants who experienced 4 to 6 $uW/cm^2/nm$ of radiant energy. Bilirubin levels were drawn every 12 hours. When group three was compared to groups one and two, significant changes in bilirubin was noted with 48 hours of treatment. The authors stressed the importance of measuring the radiant flux with a narrowly defined wavelength, 400 to 500 nm, where the peak absorption of radiant energy by bilirubin

molecules is found and cautioned the use of overhead phototherapy units as presently mounted on intensive care beds since these models appeared to be ineffective in delivering therapeutic levels of radiant flux of at least 4 $uW/cm^2/nm$. Selection and assignment of the infants, the length of exposure time, method of exposure (continuous or intermittent), or definition of "conventional" canopy were not reported.

Incandescent and Fluorescent Light

Two studies were found in the literature which compare incandescent and fluorescent light sources used for phototherapy in the newborn, the topic of this research investigation. One study concluded that the incandescent light source was more effective in decreasing serum levels of unconjugated bilirubin in neonates (Sisson, Ruiz, Wu, & Afuape, 1978). The second study found that when both the incandescent and fluorescent lights were positioned to yield the same irradiance, no statistical difference existed between the light sources and the rate of decline of unconjugated bilirubin levels (Warshaw, Gagliardi, & Patel, 1980).

Sisson and colleagues (1978) randomly assigned 40 "well" neonates with physiologic jaundice into two groups. One group was treated with fluorescent light and the other with incandescent light. The group placed 45 cm below a canopy of eight standard blue fluorescent lights decreased their mean serum levels of unconjugated bilirubin by 0.48 mg/dl/24 hr in an average treatment time of 46.7 hours. The other group was treated in a radiant warmer by placing a quartz-halide tungsten filament incandescent lamp 60 cm above them. This group of infants decreased their levels of serum bilirubin by 1.92 mg/dl/24 hr in

an average treatment time of 41.5 hours. The average irradiance of the fluorescent lamp was 4.1 uW/cm^2/nm while the incandescent lamp measured an average flux of 6.5 uW/cm^2/nm. Phototherapy was initiated when the serum levels of unconjugated bilirubin exceeded 10 mg/dl in the first 72 hours of life. All infants irradiated with the incandescent light decreased their serum levels of bilirubin and phototherapy was discontinued. Only two-thirds of the infants receiving fluorescent phototherapy effectively lowered their serum levels of unconjugated bilirubin enough to discontinue phototherapy. The other third was removed from the light and the study after 36 hours due to the "failure of phototherapy". It was concluded that the incandescent lamp was more effective in treating infants with normal physiologic jaundice than the standard blue fluorescent light sources. The term "failure" was not clarified. It was not indicated if the blue fluorescent lamps were timed or properly ventilated since a lamp's therapeutic effectiveness may be greatly diminished after 200 hours of use or sooner if not properly ventilated. The comparability of the two groups of infants as to gestational age, weight, feedings, Apgar, light regimen (continuous or intermittent), and laboratory determination of bilirubin and flux levels was not reported by the authors.

Warshaw and colleagues (1980) studied 43 infants with physiologic jaundice, mild ABO, or RH incompatibility, who received either incandescent or fluorescent phototherapy. The distance of the light sources from the neonates were adjusted according to the radiant flux measurement of 6 uW/cm^2/nm. The two groups of neonates showed no statistically significant difference with regard to birth weights, gestational ages, age of onset of therapy, and serum levels of

unconjugated bilirubin. The bilirubin concentration also was similar at the beginning and end of phototherapy. The rate of the daily drop in the serum levels of unconjugated bilirubin was almost equal in both groups. The neonates exposed to the incandescent light showed a 3.84 mg/100 ml/day drop in their serum levels of bilirubin and experienced an average of 33.77 hours of treatment. Those neonates placed below the conventional fluorescent phototherapy unit decreased their serum levels of unconjugated bilirubin 3.38 mg/100 ml/day and experienced 27.48 hours of therapy on the average. These findings must be viewed with caution since the subject selection, assignment, type of fluorescent light and unit used, the light regimen (continuous or intermittent), or the average distance of light placement were not discussed.

Summary

These studies confirm the use of artificial light sources for phototherapy is effective in reducing elevated levels of unconjugated bilirubin in neonates with hyperbilirubinemia due to any cause. The literature also introduced the concept that a specific amount of irradiance (4 to 9 uW/cm^2 at the 400 to 500 nm range) is required to bring about the neonatal response of lowering serum bilirubin levels (Wu, 1981).

Sisson and colleagues (1978) concluded that the incandescent light was superior to the fluorescent light in decreasing serum bilirubin levels. He does not consider that the differences noted may have resulted from differing irradiance output rather than the different properties of the lights themselves.

Warshaw and colleagues (1980) sought to determine whether it was the irradiance emitted from a light or the property of the light that effected the neonates' bilirubin levels. Indeed, they discovered there was no difference between the two lights when radiant flux was held constant.

These studies confirm that a dose of 4.1 $uW/cm^2/nm$ is not as effective as 6.5 $uW/cm^2/nm$ in lowering serum bilirubin levels in newborns. These findings suggest that if the dose or radiant flux is adequate, the type of light source used is not significant.

CHAPTER III

METHODOLOGY

Purpose

The primary purpose of this study was to determine whether incandescent or fluorescent light is more effective in reducing elevated serum levels of unconjugated bilirubin in jaundiced neonates.

Secondary purposes of this study were to study the relationship between the incandescent or fluorescent light and a neonate's weight loss, tanning, cutaneous erythema, temperature regulation, stool consistency, and duration of phototherapy treatment; and to determine if the rate of decline of serum levels of unconjugated bilirubin in the neonate was influenced by the administration of betamethasone, phenobarbitol, Apgar scores, birth weight, gestational age, and the level of unconjugated bilirubin prior to the start of phototherapy.

Definition of Terms

Apgar

An Apgar score was the total points assigned to a neonate's heart rate, respiratory effort, muscle tone, reflex irritability, and color. These five criteria were evaluated and given a score of 0, 1, or 2 at one and five minutes after birth by a physician attending the birth. A score of 10 indicated an infant in perfect condition.

Betamethasone

Betamethasone was a semisynthetic glucocorticoid administered in two doses over a 48-hour period to a woman in premature labor to prevent respiratory distress in the preterm infant who was less than 34 weeks gestation. Since this medication has been found to mature the lungs at a greater rate, it was questioned if it may have an effect on the fetus' liver's conjugating abilities (Thaler, 1981).

Bilirubin

This is a substance which results from the catabolism of hemeproteins in the body, especially hemoglobins. It is transported in the blood to the liver where it is conjugated, secreted into the bile, and then excreted in stool. A direct two-wavelength spectrophotometric procedure was used to quantitatively measure bilirubin in plasma and serum from patients less than ten days old. A modified direct van den Bergh diazo reaction was used to quantitatively measure conjugated bilirubin in serum of neonates greater than ten days old. These determinations were carried out in the same laboratory, and the results were presented as direct bilirubin levels in mg/100 ml.

Birth Weight

The birth weight in grams of a neonate was that weight obtained within the first 60 minutes after birth.

Cutaneous Erythema

Cutnaeous erythema was a red "stork bite" rash which covered the skin of a neonate resulting from phototherapy as noted by the bedside nurses and the researcher.

Fluorescent

The source of fluorescent light was emitted from the portable Air Shields canopy of eight white (Sylvania cool white F20t12-cW) 20-watt fluorescent lights. This light source was covered by a plexiglas plate (plexiglas-G) one inch away from the ballast which shielded the infants from broken glass and ultraviolet light. This canopy was positioned 42 to 45 cm away from the infants.

Gestational Age

Gestational age was determined by a modified Dubowitz exam as recorded by the pediatrician or nurse practitioner.

Hyperbilirubinemia

This was an accumulation of unconjugated bilirubin in the body of a neonate as measured by a direct two-wavelength spectrophotometric procedure or a modified direct van den Bergh diazo reaction and recorded in mg/100 ml. In this study only, the physiologic form of neonatal jaundice occurring between the second and fifth day of life as diagnosed by the pediatrician was studied. Treatment with phototherapy was begun when the pediatrician determined that the amount of unconjugated bilirubin was climbing to unacceptable levels for the infant's age, weight, and history.

Incandescent

The incandescent light was emitted from the portable quartz-halogen lamp (Cavitron PT-1400). This lamp is covered by a lens system which protects the neonate from broken glass and ultraviolet radiation. The

lamp was set on the brightest setting and the largest aperture and was positioned 42 to 45 cm away from the infant.

Neonate

A neonate was an infant during its first month of extra-uterine life regardless of its weight and gestational age.

Radiant Flux

This was the amount of radiant energy impinging on the skin of a neonate as measured by a radiometer (IL 770 RR with an SC 144 probe) in microwatts per square centimeter within the 400 to 500 nanometer range ($uW/cm^2/nm$). This may also be known as flux or irradiance. The radiometer was compared to lights of known irradiance at the beginning of the study and with the standards of the National Bureau of Standards. No calibration factor was necessary (Appendix A).

Tanning

This was the browning of a neonate's skin when observed by the bedside nurses and the researcher after the infant was exposed to phototherapy.

Temperature Regulation

This was the stability of a neonate's heat intensity as measured in the axilla with a centigrade thermometer by the nursing staff and recorded every four hours.

Weight

This was the weight in grams as recorded by the nursing staff from the same Toledo scale at the same time each day. The scale was calibrated every day by the nurse by placing a known weight on the scale and adjusting the numerical readout.

Assumptions

This study has the following four assumptions:

1. Phototherapy was a preferred and widely accepted method of treatment for reducing elevated serum levels of unconjugated bilirubin in neonates experiencing transient hyperbilirubinemia.

2. Elevated serum levels of unconjugated bilirubin in a neonate would decrease when phototherapy was used.

3. Both the incandescent light and the fluorescent light were accepted as standard practice in the treatment of transient unconjugated hyperbilirubinemia in the neonate.

4. Phototherapy could cause adverse side effects.

Research Questions

The specific research question investigated in this study was: What was the effect of incandescent and fluorescent sources of light on serum levels of unconjugated bilirubin in the neonate?

Secondary questions of this study were:

A. Was the type of light associated with the following neonatal complications:

   1) weight loss

   2) tanning

3) cutaneous erythema

4) temperature regulation

5) stool consistency

6) duration of treatment?

B. Was the rate of decline of serum levels of unconjugated bilirubin in the neonate influenced by:

1) radiant flux

2) the administration of betamethasone

3) the administration of phenobarbitol

4) Apgar scores

5) birth weight

6) gestational age

7) the level of unconjugated bilirubin prior to the start of phototherapy?

Hypotheses

Null Hypothesis I

The effects of incandescent or fluorescent light on the decrease of serum levels of unconjugated bilirubin in the neonate will not be significantly different as measured by 24-hour serum bilirubin levels.

Null Hypothesis II

Weight loss associated with phototherapy will not differ significantly when either the incandescent or fluorescent phototherapy unit is used.

Null Hypothesis III

Tanning associated with phototherapy will not differ significantly when either the incandescent or fluorescent phototherapy unit is used.

Null Hypothesis IV

Cutaneous erythema associated with phototherapy will not differ significantly when either the incandescent or fluorescent unit is used.

Null Hypothesis V

Temperature regulation of the neonate receiving phototherapy will not differ significantly when either the incandescent or fluorescent unit is used.

Null Hypothesis VI

Loose stools associated with phototherapy treatment will not differ significantly when either the incandescent or fluorescent phototherapy unit is used.

Null Hypothesis VII

The duration of phototherapy treatment will not significantly differ when either the incandescent or fluorescent phototherapy unit is used.

Null Hypothesis VIII

The radiant flux will not significantly differ between the incandescent or fluorescent phototherapy unit.

Null Hypothesis IX

The administration of betamethasone to the mother prior to the neonate's delivery will have no statistically significant effect on the rate of decline in serum levels of unconjugated bilirubin in the neonate when either the incandescent or fluorescent phototherapy unit is used.

Null Hypothesis X

The administration of phenobarbitol to the neonate will not have a statistically different effect on the rate of decline in serum levels of unconjugated bilirubin in the neonate when either the incandescent or fluorescent phototherapy unit is used.

Null Hypothesis XI

The Apgar scores as noted on the patient's chart will not have a statistically significant effect on the rate of decline in serum levels of unconjugated bilirubin in the neonate when either the incandescent or fluorescent light is used.

Null Hypothesis XII

The birth weight will not significantly affect the rate of decline in the serum levels of unconjugated bilirubin in the neonate when either the incandescent or fluorescent phototherapy unit is used.

Null Hypothesis XIII

The gestational age will not have a significant effect on the rate of decline in serum levels of unconjugated bilirubin in the neonate when either the incandescent or fluorescent phototherapy unit is used.

Null Hypothesis XIV

The level of unconjugated bilirubin prior to the institution of phototherapy will not significantly effect the rate of decline in serum levels of unconjugated bilirubin in the neonate when either the incandescent or fluorescent phototherapy unit is used.

Hospital Characteristics

Data for this study was obtained in a large northern California teaching hospital with a level I, II, and III nursery and a level III labor and delivery unit. The average number of deliveries was 140 per month including an average of 11 maternal transports from outlying hospitals. Neonatal transports average 35 per month.

Since this hospital is a large regional center, the clientele come from all social, economic, and ethnic origins.

Design

A pretest-posttest experimental design was used.

Sample

All neonates admitted to a level I, II, or III nursery over a six-month period and presented with transient unconjugated hyperbilirubinemia requiring phototherapy per a doctor's order were eligible for this study. Forty-four jaundiced neonates were conveniently selected and randomly assigned by a set of randomized cards into two accepted treatment groups. Eighteen neonates were exposed to

incandescent light, 24 neonates to fluorescent light. Two infants were dismissed from the study for failing to follow the protocol.

Exclusion Criteria

Those infants who (a) received an exchange transfusion or continued albumin administrations, (b) had continuous blood gases with a pH less than 7.30, (c) had profound hypoglycemia (less than 45 percent), (d) were septic, (e) had profound hemolytic disease, (f) were in a radiant warmer, (g) had genetic abnormalities, (h) had a direct bilirubin greater than 2 mg percent, and (i) had a direct Coombs greater than 1+ were excluded from this study.

Procedure

Permission to carry out this research project comparing the incandescent and fluorescent light sources used for phototherapy was given by the hospital's Committee on Human Research, the nurse clinical specialist, nursing directors for the nurseries, and the physicians in charge of the nurseries. Two informal staff inservices covering hyperbilirubinemia in the neonate and the use of phototherapy were presented to the nursery staff. Formal instruction covering the purpose, protocol, and procedures for the study was given three times the following week. A reference sheet was posted in the nurseries with the researcher's phone number and an outline of the study's purpose, protocol, and procedures to encourage compliance and reliability of measures taken by the nursing staff.

Standard laboratory studies (direct Coombs, CBC, hematocrit, urine glucose, and a direct bilirubin) to determine the etiology of the

neonate's hyperbilirubinemia were performed prior to inclusion in the study. After the physician had informed the parents of the instigation of phototherapy, the parents of the 44 neonates who met the criteria of this study were approached by the researcher and asked to sign a form giving permission to examine and compare data from their infant's routine blood samples for the duration of light treatment (Appendix B). All the parents gave permission to include their infant in the study. Confidentiality was ensured since the names and hospital numbers were not recorded. The subjects were not compensated for their participation in this study.

Independent Variables

Standard procedures (outlined in the hospital's Neonatal Intensive Care Unit nursing procedure manual) were followed in this study. The first group was placed 42 to 45 cm below the incandescent phototherapy unit (Cavitron PT-1400). The second group was placed 42 to 45 cm below the daylight fluorescent canopy (Air-Shields). New bulbs were placed in each phototherapy unit at the beginning of this study. The fluorescent lights were manually timed by the bedside nursing staff. The fluorescent lights were then changed by the unit manager after 200 hours of marked-off use. The incandescent bulbs were changed after they burned out at approximately 200 hours of age.

The neonates were placed in the same area of the nursery away from windows. Each neonate was in an isolette and received continuous phototherapy for 22 hours a day. The lights were turned off for four to six feedings a day, eye care, and blood sampling. The infants were clothed in eye-patches and a small loin cloth made from a paper surgical

mask. A stockinette cap was worn by neonates less than or equal to 37 weeks gestation except when interference with intravenous therapy would occur. All the neonates were repositioned periodically as nursing care required.

Dependent Variables

The neonate's gestational age, birth weight, Apgar at one and five minutes, race, history of betamethasone or phenobarbitol treatment, total bilirubin level, age at the onset of treatment, and the existence of a rash, tanning, temperature instability, and loose stools were noted by the researcher after the parents gave permission to include their infant in this study. Daily between 10 and 11 am, the neonate's total bilirubin, weight, and the phototherapy unit's radiant flux were recorded by the researcher. These daily recordings between 10 and 11 am continued until the end of treatment. The serum levels of total bilirubin used in this study were drawn by hellstick of venous puncture daily at 7 am by trained hospital personnel and reported between 10 and 11 am daily. More frequent blood sampling may have occurred but was not recorded by the researcher. Immediately after phototherapy was discontinued, the existence of tanning, cutaneous erythema, temperature regulation, and loose stools were recorded by the bedside nurse and the researcher. Twenty-four hours later it was recorded if the total bilirubin had increased or "rebounded" to a level requiring reinstitution of phototherapy. The neonate's total treatment hours were then calculated by the researcher.

The neonate's temperature was monitored by an axillary centigrade thermometer every four hours, an intake and output record kept, and a

daily weight done at approximately the same time of day by the nursing staff.

Limitations

Since the investigator collected all the data on the radiant flux levels, serum bilirubin levels, and the occurrences of tanning and cutaneous erythema, investigator bias may be considered a threat to internal validity of this study. Standardized equipment, short time intervals, and a standard protocol throughout the study, on the other hand, were used to decrease the possibility of this threat.

The use of the nursing staff to obtain the objective measurements of temperature, weight, intake, output, and fluorescent lamp usage could be considered a threat to validity. In an attempt to obtain valid measurements prior to the data collection, the nursery staff of approximately 70 registered nurses received formal instruction covering the purpose, protocol, and procedures for the study. A reference sheet was posted in the nurseries. The nursery's procedure manual was used as a base for the study's protocol.

The lack of available incandescent lamps required eight neonates to be placed in the fluorescent group. The use of a convenient sample and the lack of random assignment of these eight neonates could produce a bias and threaten the validity of this study since it is not certain if the two groups experienced equal maturational processes, which may have affected the observed changes and differences between the two groups.

As the nursing staff, physicians, and parents of infants in the nurseries became aware of the differences between the two treatment groups, the study's protocol was followed more closely. The researcher

received an increased number of phone calls from the nursing staff notifying her of a new infant beginning phototherapy, a neonate being removed from therapy, or a change in therapy of a neonate in the study. The researcher also received phone calls from parents and physicians seeking information regarding preliminary results. Occasional bargaining for placement of a jaundiced neonate into a different treatment than the one randomly assigned also began to occur; however, the deliberate placement of a neonate into a treatment group did not occur.

CHAPTER IV

RESULTS

Nature of the Sample

All neonates admitted to a level I, II, or III nursery over a six-month period and presenting with transient unconjugated hyperbilirubinemia requiring phototherapy per a doctor's order were eligible for this study. Forty-two jaundiced neonates were conveniently selected and randomly assigned by a set of randomized cards into two accepted treatment groups. Eighteen neonates were exposed to incandescent light, 24 neonates to fluorescent light.

The demographic data on the 42 neonates studied is summarized in Tables 1 and 2. The gestational ages of the sample ranged from 27 to 42 weeks with a mean gestational age of 37.4 weeks in the incandescent group and 36.75 weeks in the fluorescent group. Birth weights ranged from 580 grams to 4360 grams, with the mean weight in the incandescent group of 2933 grams and 2767 grams in the fluorescent group. Apgar scores ranged from 1 to 9 in the first minute and 4 to 10 at five minutes. The mean one-minute Apgar was 6.8 in the incandescent group and 6.1 in the fluorescent group. The mean five-minute Apgar was 8.3 in the incandescent group and 8.0 in the fluorescent group. The pretreatment level of bilirubin ranged between 5.5 mg/100 ml to 17.4 mg/100 ml, with the mean level of 12.3 mg/100 ml in the incandescent group

TABLE 1

Sample Characteristics

Characteristic	Incandescent Light Treatment Group	Fluorescent Light Treatment Group	t
Number of Neonates	18	24	
Gestational Age (weeks)			
mean	37.4	36.7	.50
range	27 - 42	27 - 42	
SD	4.48	4.15	
Birth Weight (grams)			
mean	2767	2933	.56
range	900 - 4360	580 - 4170	
SD	873.7	988.8	
Apgar (1 minute)			
mean	6.8	6.1	.81
range	1 - 9	1 - 9	
SD	2.4	2.9	
Apgar (5 minutes)			
mean	8.3	8.0	.81
range	4 - 10	4 - 10	
SD	1.33	1.60	
Pretreatment Total Bilirubin (mg/100 ml)			
mean	12.3	10.8	1.38
range	5.6 - 17.4	5.5 - 17.4	
SD	3.57	3.44	
Posttreatment Total Bilirubin (mg/100 ml)			
mean	10.1	10.1	
range	3.1 - 13.2	5.3 - 13.8	
SD	3.06	2.55	
Age at Treatment (hours)			
mean	112.3	53.2	3.10*
range	40 - 342	16 - 106	
SD	86.0	25.3	

* $p < .05$, $t(.05) = 1.6$

and 10.8 mg/100 ml in the fluorescent group. The posttreatment levels of serum bilirubin ranged between 3.1 mg/100 ml and 13.2 mg/100 ml, with a mean of 10.1 mg/100 ml in the incandescent and fluorescent group. None of these differences between the groups were found to be significant when analyzed with a student's t-test and a one-way analysis of variance.

The age of the neonates at the onset of their phototherapy treatment ranged from 16 hours of age to 342 hours of age. The mean age at the beginning of incandescent phototherapy was 112.3 hours. The mean age at the start of fluorescent phototherapy was 53.2 hours of age. This difference was found to be significant according to a student's t-test ($t = 3.1$, $p < .05$, $t(0.5) = 1.6$).

TABLE 2

Sample Characteristics

Characteristic	Category	Incandescent Light Treatment Group	Fluorescent Light Treatment Group
Race	Caucasian	55.0%	62.5%
	Latina	11.0%	25.0%
	Black	0%	0%
	Oriental/Asian	27.7%	12.5%
	American Indian	5.5%	0%
Betamethasone	Yes	5.5%	20.8%
	No	94.4%	79.1%
Phenobarbitol	Yes	0%	8.3%
	No	100.0%	91.6%

Twenty-five of the neonates in the sample were Caucasian, eight were Latina, eight were Oriental/Asian, and one was an American Indian (see Appendix C).

Six neonates in the sample received betamethasone prior to birth. Two received phenobarbitol during the study.

Findings Related to Hypotheses

The findings of this study will be discussed under each hypothesis.

Hypotheses

Null Hypothesis I

The effects of incandescent or fluorescent light on the decrease of serum levels of unconjugated bilirubin in the neonate will not be significantly different as measured by 24-hour serum bilirubin levels.

When the total serum bilirubin levels were compared at 24 hours of treatment, the incandescent group lost an average of 0.7 mg/100 ml and the fluorescent group gained 0.2 mg/100 ml. This difference was significant according to a student's t-test ($t = 1.8$, $p < .05$, $t(.05) = 1.6$). Therefore, the incandescent light resulted in a 24-hour decrease of serum levels of unconjugated bilirubin, significantly greater than the fluorescent lamp. Null hypothesis I was rejected (Appendix D).

Null Hypothesis II

Weight loss associated with phototherapy will not differ significantly when either the incandescent or fluorescent phototherapy unit is used.

The weights of the neonates ranged from 750 grams to 4000 grams, with the average weight of 2775 grams in the incandescent group and 2532 grams in the fluorescent group at the beginning of therapy. After treatment, the weights ranged between 780 grams and 4080 grams. The average weight after 24 hours of treatment was 2773 grams in the incandescent group and 2508 grams in the fluorescent group. The incandescent group lost a mean of 0.83 grams in the first 24 hours of treatment. The fluorescent group lost a mean of 24.6 grams in the first 24 hours of treatment. The differences in weight loss were not statistically significant according to a student's t-test; therefore Null hypothesis II was accepted. This finding is reported in Table 3.

TABLE 3

Weight Loss

Characteristic	Incandescent Light Treatment Group	Fluorescent Light Treatment Group	t
Number of Neonates	18	24	
Weight at Beginning of Phototherapy (grams)			
mean	2775	2532	14.8*
range	750 - 4000	840 - 3800	
Weight After 24 Hours of Phototherapy (grams)			
mean	2773	2508	16.15*
range	750 - 4080	880 - 3880	
Weight Loss After 24 Hours of Phototherapy (grams)			
mean	0.83	24.6	1.4
range	+70 to -150	+40 to -160	
SD	220	200	

* $p < .05$, $t(.05) = 1.6$

Null Hypothesis III

Tanning associated with phototherapy will not differ significantly when either the incandescent or fluorescent phototherapy unit is used.

Tanning occurred in two neonates undergoing incandescent phototherapy and five undergoing fluorescent phototherapy. Null hypothesis III was accepted. The difference in the number of infants experiencing tanning in both groups was not significant according to a chi-square analysis. This finding is reported in Table 4.

TABLE 4

Neonates Response to Phototherapy

Characteristic	Incandescent Light Treatment Group		Fluorescent Light Treatment Group	
	N	%	N	%
Number of Neonates	18		24	
Tanning	2	11	5	20
Cutaneous Erythema	4	22	7	29
Temperature Instability	5	27	3	12.5
Loose Stools	12	66	14	58

Null Hypothesis IV

Cutaneous erythema associated with phototherapy will not differ significantly when either the incandescent or fluorescent unit is used.

Cutaneous erythema occurred in four neonates experiencing incandescent phototherapy and in seven undergoing fluorescent phototherapy. Null hypothesis IV was accepted. As shown in Table 4, the number of infants with cutaneous erythema associated with phototherapy did not differ significantly in either group according to a chi-square analysis.

Null Hypothesis V

Temperature regulation of the neonate receiving phototherapy will not differ significantly when either the incandescent or fluorescent unit is used.

Temperature instability occurred in five infants undergoing incandescent phototherapy and in three infants under fluorescent lighting. Null hypothesis V was accepted. Temperature instability did not differ significantly in either group according to a chi-square analysis, as shown in Table 4.

Null Hypothesis VI

Loose stools associated with phototherapy treatment will not differ significantly when either the incandescent or fluorescent phototherapy unit is used.

Twelve infants in the incandescent treatment group experienced loose stools. In the fluorescent group 14 neonates experienced loose stools. Null hypothesis VI was accepted. Stool patterns between treatment groups did not differ significantly according to a chi-square analysis. This finding is reported in Table 4.

Null Hypothesis VII

The duration of phototherapy treatment will not significantly differ when either the incandescent or fluorescent phototherapy unit is used.

The total number of hours the infants remained under the lights ranged from 8 to 155 hours. The mean total hours the infants remained under the incandescent lights was 26.6. The fluorescent group remained under the lights a mean of 57.5 hours. Null hypothesis VII was rejected. The infants undergoing fluorescent phototherapy remained beneath the lamps approximately twice as long as those infants under the incandescent light. This difference was significant according to a student's t-test and a one-way analysis of variance ($t = 3.3$, $F = 11$, $p < .05$). This finding is reported in Table 5.

TABLE 5

Response Data

Characteristic	Incandescent Light Treatment Group	Fluorescent Light Treatment Group	t	F
Number of Neonates	18	24		
Duration of Treatment (hours)				
mean	26.6	57.5	3.3*	11.4*
range	8 - 62	12 - 155		
SD	14.6	36.1		
Radiant Flux During 24 Hours of Treatment ($uW/cm^2/nm$)				
mean	7.0	1.4	11.6*	137.0*
range	3.95 - 10.95	0.95 - 1.95		
SD	2.29	0.28		

* $p < .05$, $t(.05) = 1.6$, $F(.05) = 4.08$

Null Hypothesis VIII

The radiant flux will not significantly differ between the incandescent or fluorescent phototherapy unit.

The radiant flux during the first 24 hours of treatment ranged from 0.95 to 1.95 uW/cm^2/nm in the fluorescent group, with a mean of 1.4 uW/cm^2/nm. In the incandescent group the radiant flux ranged between 3.95 and 10.95 uW/cm^2/nm, with a mean of 7 uW/cm^2/nm. Null hypothesis VIII was rejected. Table 5 reports that the radiant flux differed significantly between the two light groups according to a student's t-test and a one-way analysis of variance ($t = 11$, $F = 137$, $p < .05$). There was a slight correlation between the flux levels and the reduction of serum total bilirubin in the first 24 hours of treatment according to a Pearson product-moment correlation analysis with an actual rho of +.23. This correlation was not significant.

Null Hypothesis IX

The administration of betamethasone to the mother prior to the neonate's delivery will have no statistically significant effect on the rate of decline in serum levels of unconjugated bilirubin in the neonate when either the incandescent or fluorescent phototherapy unit is used.

The total bilirubin levels ranged from 5.5 to 10.9 mg/100 ml before phototherapy and 5.4 to 10.3 mg/100 ml after 24 hours of phototherapy in the group of six infants receiving only betamethasone. The mean loss of total serum bilirubin in the first 24 hours of the infants receiving betamethasone undergoing either incandescent of fluorescent phototherapy was 0.2 mg/100 ml. Null hypothesis IX was accepted. The administration

of betamethasone did not affect the rate of total bilirubin loss in neonates undergoing either incandescent or fluorescent phototherapy according to a student's t-test.

Null Hypothesis X

The administration of phenobarbitol to the neonate will not have a statistically different effect on the rate of decline in serum levels of unconjugated bilirubin in the neonate when either the incandescent or fluorescent phototherapy unit is used.

The total bilirubin levels ranged from 8.4 to 13.6 mg/100 ml prior to phototherapy and from 7.2 to 15.6 mg/100 ml after 24 hours of phototherapy in the two infants receiving phenobarbitol. Statistical analysis of the total serum bilirubin loss when either the incandescent or fluorescent light was used was not possible due to the small sample size. Therefore null hypothesis X was not tested. The two infants who received phenobarbitol underwent fluorescent phototherapy. One infant experienced a drop in total serum bilirubin in the first 24 hours of treatment. The other infant increased the total serum bilirubin level in the first 24 hours of treatment.

Null Hypothesis XI

The Apgar scores as noted on the patient's chart will not have a statistically significant effect on the rate of decline in serum levels of unconjugated bilirubin in the neonate when either the incandescent or fluorescent light is used.

There was a minimal correlation between the Apgar score at one and five minutes and the amount of bilirubin loss in the neonate undergoing either incandescent or fluorescent phototherapy according to a Pearson product-moment correlation analysis, with an actual rho of +.13. This was not significant; therefore null hypothesis XI was accepted.

Null Hypothesis XII

The birth weight will not significantly affect the rate of decline in the serum levels of unconjugated bilirubin in the neonate when either the incandescent or fluorescent phototherapy unit is used.

There was a minimal correlation between the birth weight and the amount of bilirubin loss in the neonates in either group treatment according to a Pearson product-moment correlation analysis ($r = +.15$). This was not significant. Null hypothesis XII was accepted.

Null Hypothesis XIII

The gestational age will not have a significant effect on the rate of decline in serum levels of unconjugated bilirubin in the neonate when either the incandescent or fluorescent phototherapy unit is used.

There was a slight correlation between the gestational age of the neonate undergoing either incandescent or fluorescent phototherapy and the rate of total serum bilirubin loss according to a Pearson produce-moment correlation analysis ($r = +.05$). This was not significant. Null hypothesis XIII was accepted.

Null Hypothesis XIV

The level of unconjugated bilirubin prior to the institution of phototherapy will not significantly effect the rate of decline in serum levels of unconjugated bilirubin in the neonate when either the incandescent or fluorescent phototherapy unit is used.

A positive correlation existed between the amount of bilirubin loss and the pretreatment level of bilirubin according to the Pearson product-moment correlation analysis, with an actual rho of +.38. This was significant ($p < .05$, $r(.05) = +.3$). Null hypothesis XIV was rejected. The higher the prephototherapy level of unconjugated bilirubin the faster the decline in total bilirubin levels.

Miscellaneous Findings

There was a slight correlation between the age of the neonate at the onset of phototherapy and the rate of decline in the total bilirubin levels according to a Pearson product-moment correlation analysis, with an actual rho of +.17. This was not significant. The age of the neonate in hours at the onset of phototherapy did not significantly affect the rate of decline in serum levels of unconjugated bilirubin in the neonate when either the incandescent or fluorescent phototherapy unit was used.

Rebound occurred in three infants experiencing incandescent phototherapy and in five infants undergoing fluorescent phototherapy. The number of infants experiencing rebound of their serum levels of unconjugated bilirubin in either treatment was not significant.

It is important to note that the fluorescent lamp usage record in 20 out of 24 fluorescent canopies was mismarked by the nursing staff. The record lagged the timing record kept by the researcher by approximately 8 to 36 hours of use.

Effects of Saran Wrap

Three infants beneath plastic wrap (Saran) were inadvertently included in this sample. The two neonates in the incandescent group were exposed to a decrease of 1.4 to 2.12 uW/cm^2/nm from the light. Both infants lowered their serum concentration in the first 24 hours of treatment. The infant beneath Saran wrap in the fluorescent group was also exposed to a decrease of 0.5 uW/cm^2/nm from the fluorescent canopy. This infant also lowered its serum bilirubin concentration within the first 24 hours of treatment.

Nine other neonates beneath Saran wrap and/or heat shields were examined by the researcher. Five neonates were placed in radiant warmers with both a heat shield made of thermoplastic and Saran wrap. All the infants were placed beneath the incandescent light at a distance of approximately 52 cm. The lamp was set at the widest aperture and brightest setting. The infants were exposed to irradiance levels of 4.32 to 5.67 uW/cm^2/nm. When the plastic heat shield was removed (leaving the Saran wrap covering the neonate), the irradiance level climbed 0.5 to 0.76 uW/cm^2/nm. When the plastic and the heat shield were removed, the radiant flux increased 1 to 2 uW/cm^2/nm. The other four infants were placed in isolettes and were undergoing fluorescent phototherapy. When the heat shield was removed, leaving the infant covered by Saran wrap, the irradiance increased 0.3 to 0.5 uW/cm^2/nm.

When the plastic heat shield and the Saran wrap were removed, the neonates were exposed to an increase of 0.42 to 1.1 uW/cm^2/nm from the fluorescent canopy.

Three infants not included in this study were placed in an older discolored isolette undergoing fluorescent phototherapy. When they were moved into newer isolettes, the irradiance from the fluorescent canopy increased 0.3, 0.42, and 0.24 uW/cm^2/nm.

Eight infants undergoing both fluorescent and incandescent phototherapy "double" were also examined by the researcher. All eight neonates were initially started on fluorescent phototherapy and exposed to a radiant flux between 1.89 and 2.10 uW/cm^2/nm in an isolette. Each infant's serum concentration of total bilirubin continued to rise after 24 hours of treatment. The incandescent lamp was then added to the fluorescent canopy, which raised the irradiance to 4.76 to 5.72 uW/cm^2/nm. Because of the size of the fluorescent canopy the incandescent lamp was positioned 48 to 54 cm above the infant in the isolette. It was noted by the researcher that when the fluorescent canopy was removed and the incandescent lamp was positioned 42 cm above the infant, it was possible to achieve irradiance levels ranging from 6.58 to 10.32 uW/cm^2/nm.

Three neonates returning from home with hyperbilirubinemia were observed in isolettes receiving incandescent phototherapy from two incandescent lamps. All the lamps were positioned 42 cm above the neonates and set at the widest aperture and brightest setting. The neonates were exposed to an irradiance level of 9.82, 10.65, and 10.12 uW/cm^2/nm.

Summary of Results

There was no significant difference between the two treatment groups except for the age at the onset of phototherapy treatment. No correlation existed, however, between the age in hours at the onset of phototherapy and the loss of serum bilirubin in a 24-hour period. There was a slight difference between the two treatment groups and their pretreatment levels of bilirubin. The differences observed between the two treatment groups and the fall in total bilirubin concentration after 24 hours of treatment cannot be ascribed to nor predicted by the age at onset of treatment or the pretreatment level of total serum bilirubin (R^2 = .182, T^2 = ns for each variable).

Null hypotheses I, VII, VIII, and XIV were rejected. The incandescent and fluorescent phototherapy light had significantly different effects on the decline of a neonate's total serum bilirubin levels, the duration of phototherapy treatment, and the radiant flux. The higher the pretreatment level of unconjugated bilirubin the faster the level fell, regardless of the type of phototherapy light.

Null hypotheses IX and X were not tested due to the small sample size. The rest of the null hypotheses were accepted. The incandescent phototherapy light did have a slightly different effect on the amount of weight loss by the neonates undergoing phototherapy. However, the occurrence of tanning, cutaneous erythema, temperature instability, and loose stools did not differ significantly between treatment groups. The rate of decline in the neonate's total serum bilirubin levels was not affected by Apgar scores, birth weight, or gestational age.

An incidental finding was that infants beneath Saran wrap, plastic heat shields, and in older discolored isolettes received less irradiance from either type of phototherapy lamp.

In addition, it was noted that when an incandescent lamp was added to the ongoing fluorescent phototherapy, the irradiance level received by the infant was increased. However, the placement of two incandescent phototherapy lamps did not increase the amount of irradiance received by a neonate. Therefore exposure of infants to two sets of light is not needed if one light is capable of producing therapeutic levels of irradiance.

CHAPTER V

DISCUSSION AND RECOMMENDATIONS

Discussion

Neonates experience hyperbilirubinemia and the resulting jaundice between the second and fifth day of life because the hepatic system for conjugating and excreting bilirubin is functionally immature at birth and for a short time after. As the serum bilirubin concentration rises and the time it remains elevated increases, so does the risk of kernicterus, which can result in central nervous system damage or even death. The prevention of kernicterus is the goal in managing neonates with jaundice. Phototherapy is the preferred treatment.

Studies confirm that continuous use of artificial light for phototherapy effectively reduces elevated levels of bilirubin in infants of any weight, race, or etiology of the jaundice. The literature also introduced the concept of measuring the dosage of light irradiance in microwatts per square centimeter when the light is within the 400 to 500 nanometer wavelength. This wavelength is responsible for the photodegradation or photooxidation of bilirubin molecules in the first 2 mm of an infant's skin. Appropriate irradiance brings about a clinical response of decreasing bilirubin levels in a neonate.

Recently, incandescent light has been introduced into many nurseries as a form of phototherapy. This light source has not been completely studied.

The purpose of this study was to determine if there were differences between the incandescent and fluorescent light in lowering serum concentrations of bilirubin in jaundiced neonates without increasing the incidence of the side effects associated with phototherapy.

The incandescent light was a light produced by an electrically heated element. In this study, the incandescent lamps would briefly drop to an irradiance of approximately 4 $uW/cm^2/nm$ before burning out. The average life of the light was approximately 200 hours if the ventilation system was working properly.

The fluorescent light was a light which was produced by the illumination of a fluorescent substance in a glass tube. Its use in neonatal phototherapy has been demonstrated since the beginning of the use of artificial light for neonatal hyperbilirubinemia. As fluorescent light ages or becomes overheated, much of its irradiance is lost (Cohen & Ostrow, 1980). This study demonstrated that the fluorescent lamps lost 10 percent of their irradiance after ten hours of marked-off use. The line voltage to the lamps remained constant at 120 volts, so fluctuations in voltage could not be responsible for the noted decrease in flux after ten hours. However, with the crowded conditions in the nursery requiring the tops of the canopies to be used as shelf space, the fluorescent lamps may have overheated because of poor ventilation.

Two studies were found in the literature which compared the incandescent and fluorescent light sources used for phototherapy in the

newborn. One study concluded that the incandescent light was more effective in decreasing serum levels of unconjugated bilirubin in neonates (Sisson et al., 1978). The second study found that when both the incandescent and fluorescent lights were positioned to yield the same irradiance (6 uW/cm^2/nm), no statistical difference existed between the light sources and the rate of decline of unconjugated bilirubin levels (Warshaw et al., 1980).

This study demonstrated that when the incandescent and fluorescent phototherapy light sources were positioned at equal distances from physiologic jaundiced neonates in isolettes, statistically significant differences were noted in the rate of decline in serum bilirubin levels at 24 hours of treatment, the duration of the treatment, and radiant flux levels of the lights. There was also a slight difference between the two groups in the amount of weight loss experienced by the jaundiced neonates.

When the total serum bilirubin levels of both groups were compared after 24 hours of treatment, the incandescent group lost an average of 0.7 mg/100 ml of total bilirubin with an average flux of 7 uW/cm^2/nm. The fluorescent group experienced an increase in their total serum concentration of bilirubin of 0.2 mg/100 ml while undergoing an average irradiance of 1.4 uW/cm^2/nm. In addition, the neonates undergoing fluorescent phototherapy remained beneath the lamps approximately twice as long and lost approximately three times the amount of weight as those infants under the incandescent phototherapy lamp.

No significant differences were noted between the two treatment groups in the occurrence of tanning, cutaneous erythema, temperature instability, and loose stools. The rate of serum bilirubin loss was not

affected by the Apgar scores, birth weight, or gestational age, but it was affected by the pretreatment level of serum bilirubin. The higher the pretreatment level of serum bilirubin, the faster it fell over a 24-hour period of phototherapy treatment.

The dose-response theory related to phototherapy is a recent concept. Several researchers have concluded that the therapeutic level of radiant flux delivered by artificial light during phototherapy for neonatal hyperbilirubinemia is between 4 and 9 $uW/cm^2/nm$ in the 400 to 500 nm range (Mims et al., 1973; Sisson et al., 1972; Wu, 1981). When a phototherapy light emits between 4 and 9 $uW/cm^2/nm$, the jaundiced neonate should receive the maximum benefit from the light while experiencing the least harm associated with phototherapy. The findings that those infants experiencing a therapeutic dose of flux from the incandescent lamp (7 $uW/cm^2/nm$) lowered their serum bilirubin levels faster, had a shorter course of treatment, and experienced either the same or less weight loss, tanning, cutaneous erythema, temperature instability, or loose stool associated with phototherapy than those infants beneath the fluorescent lamps supports the dose-response theory of phototherapy. Therefore the incandescent lamp was more effective in reducing serum levels of unconjugated bilirubin without an increase in the number or severity of the side effects associated with phototherapy.

The differences observed between the two treatment groups may be due to the amount of radiant flux emitted from the lamps and not the type of light used. Warshaw and associates (1980) found no statistical difference between the incandescent and fluorescent phototherapy lamp when the irradiance was held constant at 6 $uW/cm^2/nm$. The differences in the 24-hour loss of bilirubin between the two treatment groups was

thought to be affected by the age of onset of treatment and the pretreatment level of bilirubin. However, it was found that these variables did not significantly contribute to nor could they predict the reported differences between the two groups in loss of serum bilirubin concentration.

The following conclusions are made based on the results of this study comparing the incandescent and fluorescent phototherapy lamps.

1. The incandescent phototherapy lamp was more effective in lowering unconjugated bilirubin levels in jaundiced neonates of any race and age.
2. The incandescent phototherapy lamp did not impose greater risks for weight loss, tanning, cutaneous erythema, temperature instability, or loose stools.
3. The Apgar score, birth weight, gestational age, or age at the onset of phototherapy treatment did not affect the rate of serum bilirubin loss in jaundiced neonates.
4. The higher the serum bilirubin level prior to the start of phototherapy the faster the serum bilirubin level fell after phototherapy was begun with any lamp.

Recommendations

The necessity for a phototherapy light to have adequate radiant flux (4-9 $uW/cm^2/nm$) is essential. Lamps that produce optimal levels of irradiance and minimize the potential physiological, psychological, and financial complications of phototherapy should be easily implemented by the staff, suitable for the budget, result in a timely discharge, and store easily and safely.

Policies and procedures for intervening in neonatal hyperbilirubinemia vary with individual institutions. However, the following principles should be considered.

1. Phototherapy lamps should received between 115 and 120 volts and be properly ventilated (Wu, 1981).
2. The lights should be covered by a plexiglas G plate or lenses to shield the infants from broken glass and ultraviolet light (Wu, 1981).
3. Phototherapy lamps should be positioned (usually 42 to 45 cm above the infant) to yield the optimum radiant flux (between 4 and 9 $uW/cm^2/nm$).
4. The radiant flux of the lights should be measured frequently and the light changed when the irradiance falls below 4 $uW/cm^2/nm$. If flux measurements are not routinely done, fluorescent lights should be accurately timed by a mechanical timer and changed at 200 hours of use.
5. Infants should receive extra fluid and be placed on servo temperature control (Oh & Karecki, 1972).
6. Infants should be undressed except for eye-patches and a loin cloth. Stockinette caps should be worn by premature infants 37 gestational weeks or younger to avoid excess calcium absorption from the skull bones (unless this interferes with intravenous therapy (Bergstrom & Hakanson, 1980).
7. The lights should be turned off with eye care, blood sample, or parent visit.
8. Infants beneath Saran wrap or heat shields and in older discolored isolettes will receive less radiant energy from the lights.

9. Exposure of infants to two sets of light is not needed if one light is capable of producing a therapeutic level of irradiance.
10. Weight loss, lethargy, changes in stool patterns, tanning, rashes, or temperature problems may develop. Parents should be aware these side effects can occur and be supported when they do.

After the need for phototherapy is determined, the nurse should implement, maintain, and evaluate the treatment regimen, mindful of the possible physical adverse effects associated with phototherapy (overheating or chilling with increased insensible water loss, diarrhea, weight loss, rash, or tanning) and the psychological and financial effects (maternal-infant separation and prolonged hospitalization). Approaches and equipment used in phototherapy must offer maximum therapeutic effects and minimize the physical, psychological, and financial complications that arise when a neonate undergoes phototherapy.

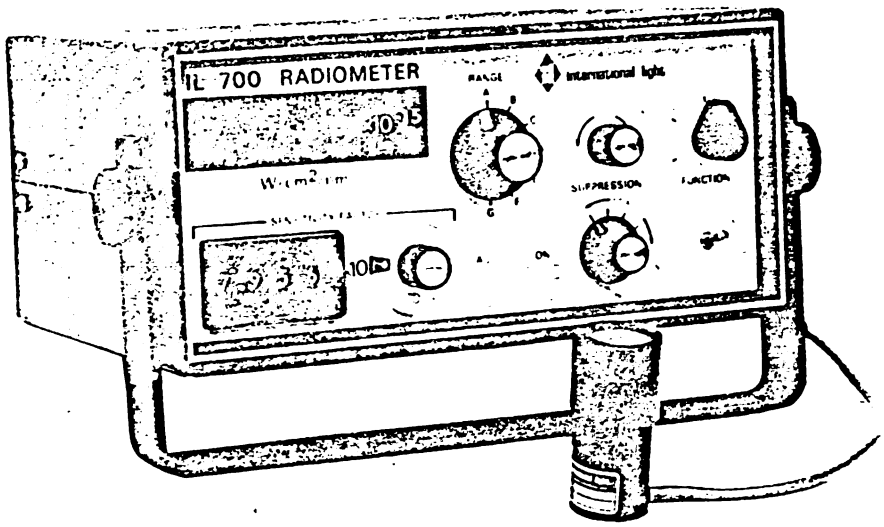
Recommendations for future study include: a) the investigation of combining different spectral fluorescent lamps to obtain therapeutic levels of irradiance without complications to the infant or staff, b) the study of the influence of betamethasone on an infant's serum concentration of bilirubin, c) the examination of the effect of different plastic covers over an infant on the amount of irradiance received by an infant from a phototherapy light, and d) the investigation of the effectiveness of double-direction phototherapy compared to single-direction phototherapy.

APPENDIX A

RADIOMETER CHARACTERISTICS

data sheet **IL700 RR**

IL700 RESEARCH RADIOMETER



FEATURES:

- *Direct* digital readout in *any* optical units desired. Microwatts/cm^2, footcandles, lumens/ft^2, finsens, etc.
- High radiant sensitivity.
- 20 Decade range of readout, 3½ digit display with 400% overranging.
- Can integrate pulses as fast as five nanoseconds and as long as five minutes with ± 1% accuracy.
- Completely field portable, battery or ac operation.
- Modular design for use with spectroradiometers and other I.L. instrumentation.
- Programmable calibration factor eliminates time consuming conversion calculations.
- Can be used as a picoammeter.

DESCRIPTION

The IL700 Research Radiometer is the readout unit for the IL modular series of optical instrumentation. The model IL700 allows for precise measurement of power, energy and spectral distribution of direct and pulsed radiation sources.

The IL700 can read in two modes; the first mode is for direct reading of continuous radiation. The second mode can measure pulsed irradiance or energy. Either mode can be easily programmed with the front panel digital switch to readout in any desired optical units.

The IL700 features direct indication of the exponent when switching through the sensitivity values. In this way, no ambiguous readings are possible. An illuminated exponent indicator is provided to facilitate darkroom operation. Chart recorder jack is provided for continuous monitoring of irradiance level or use with scanning spectroradiometer accessories.

international light INC. DEXTER INDUSTRIAL GREEN, NEWBURYPORT, MASS. 01950 ■ TEL. 617 465-5923

IL700 SPECIFICATIONS

Sensitivity:

1×10^{-13} watts/cm^2 or 1×10^{-6} footcandles at 20°C
1×10^{-16} watts/cm^2 or 1×10^{-9} footcandles at -20°C

Spectral Range:

From 240 nanometers to 1100 nanometers. S-1, S-5 and S-20 responses available. Silicon response also standard.

Input Current:

Over 8 decades of overlapping current measurement from 10×10^{-12} amps to 4×10^{-3} amps.

Current Measurement Accuracy:

±0.2% full scale (1ua - 2ma) ±0.5% full scale (1na - 1ua) ±1% full scale (below 1na)

Input Impedance:

Virtual ground (summing node of operational amplifier)

Input Sensitivity Data:

Data entry range of 15 decades (1.000×10^{-9} to 9.999×10^{4}). A 4 digit thumbwheel switch plus exponent switch provides detector sensitivity input for direct radiometric or photometric readout.

Readout:

4 digit plus illuminated power of 10 exponent for more than 20 decades of direct readout. (1.00×10^{-15} to $40 \times 10^{+4}$)

Suppression:

6 range plus a 10 turn fine pot control for suppression of dark current and/or ambient illumination. (0 to 1ua)

Recorder Output:

Full scale output voltage of 10mv, 100mv and 1 volt. Current limited.

Output Impedance:

10mv = 24, 100mv = 231, 1 volt = 4. To maintain accuracy the load to be driven should have input impedance 100 times greater.

PULSE INTEGRATION OPERATION:

Flash Duration:

5×10^{-9} seconds to five minutes (can be used for longer exposures at reduced accuracy).

Charge Ranges:

Over 8 decades of overlapping ranges from 10×10^{-9} coulombs to 4×10^{-3} coulombs.

Charge Measurement Accuracy:

±0.3% full scale (μc - 2mc) ±0.6% full scale (1nc - 1μc) ±1% full scale (below 1nc)

Synchronizer:

Contact closure (to trigger flash lamp or pulsed source) rated at 2.75 amperes at 15 volts D.C., 230 milliamperes at 115AC.

Hold Drift:

Permanent digital memory.

Regulated Sensor Voltages:

-160V and -12V (excluding optional photomultiplier power supplies).

Power:

External 95-135 or 190-270 VAC, 50-60 HZ or auxilary D.C. Power 10-28 VDC; self contained rechargeable nickel cadmium battery: Four hours continuous operation. Regulation on all internal voltages.

Battery Charge Indicator:

Indicator light on front panel begins to blink when charge drops below operating level.

Size:

11" (27.9 cm) wide x 5" (12.7 cm) high x 7" (17.8 cm) deep.

Weight:

15 lbs. (6.8 kg).

Color:

Ebony with Oyster white panel.

1. INTRODUCTION: The IL700 series of Radiometers and Photometers can read out directly in any predetermined optical units applicable to energy or power measurement. The IL700 series also features both pulsed and continuous measurement capability. The pulsed measurements can be made accurately with pulse durations as fast as 5 nanoseconds. Continuous measurements of light power can be made in the spectral band from 220nm to 1100nm with the appropriate detector. Power levels as low as $1x10^{-16}$ watts/cm^2 or $1x10^{-9}$ foot-candles can be monitored with suitable accessory options. Optical Radiation Hazards can also be monitored with use of the Actinic input optics attachment. The IL700 is both AC and battery operable for full field portability. Fiber optics and spectroradiometric options are directly compatable with all IL700 instrumentation for a full range of measurement situations.

INTERNATIONAL LIGHT, INC.
DEXTER INDUSTRIAL GREEN
NEWBURYPORT, MASSACHUSETTS 01950

INTERNAL PHOTODETECTOR CALIBRATION

IL 700 Research Radiometer and Photometer

Rendered to: Univ. of California at San Francisco

Date: 3/19/81 Detector S/N: 1146 · SC 177 bilirubin

Instrument S/N:

Notes: from below $SF = (24.6) \div R + 1657$

$SF = 24.6 \div 12307$

$SF = 2.00 \times 10^{-3}$

Calibrated By: R. G. Checked By: DS.

The Detector described above has been compared with the standards of International Light, Inc., whose standards are traceable to the National Bureau of Standards. No calibration factor is necessary.

Measure resistance between pins F to N

$$\text{Resistance (ohms)} = \frac{24.6}{\text{Sensitivity Factor (no units)}} - 1657$$

$R_{fton} = 10650$ ohms

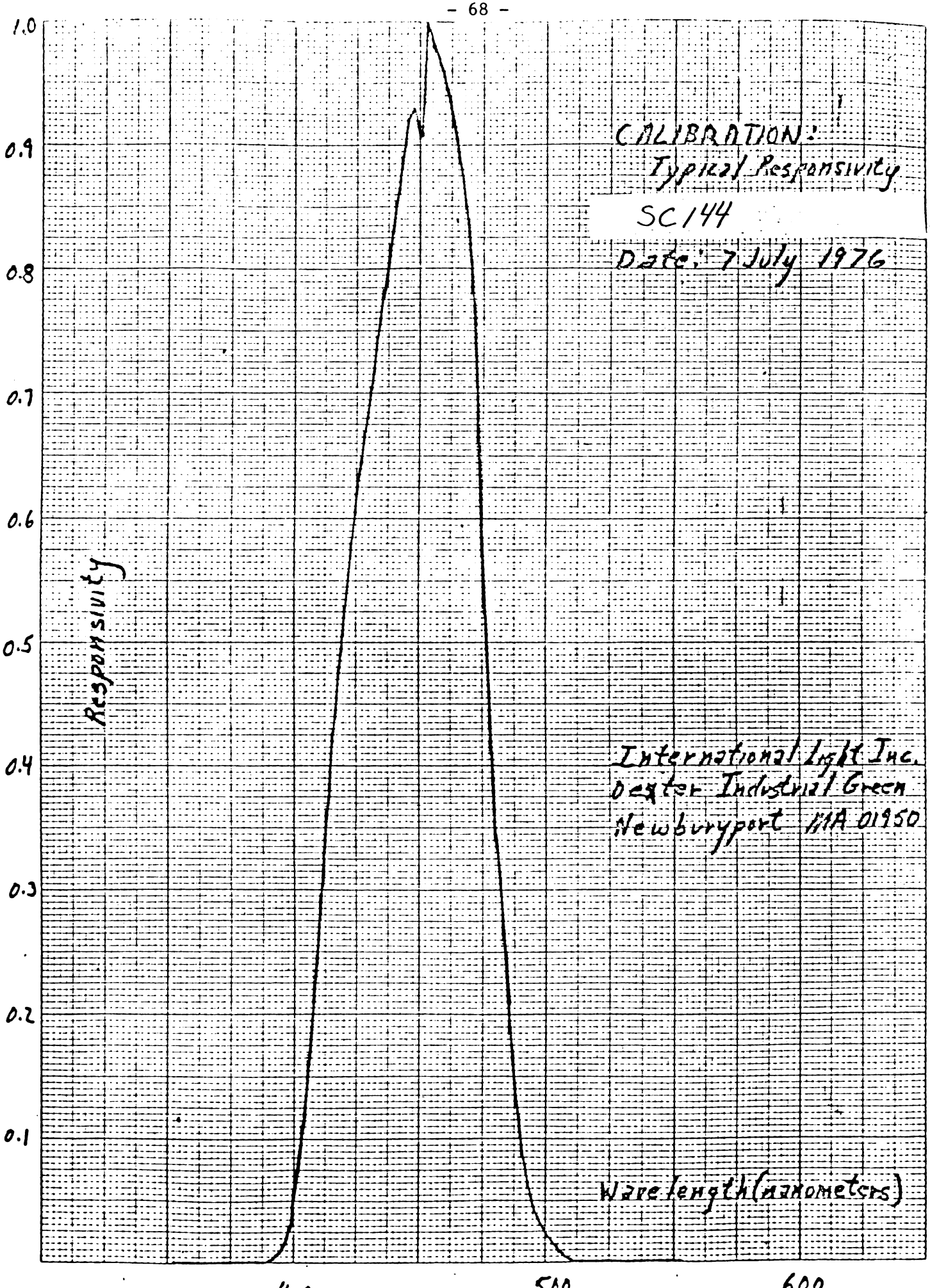
measured by Mary Shepard

$$R = \frac{24.6}{SF} - 1657$$

$$SF(R) = 24.6 - SF(1657)$$

$$SF(R + 1657) = 24.6$$

$$SF = 24.6 / (R + 1657)$$


1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Responsivity
CALIBRATION:
Typical Responsivity
SC144
Date: 7 July 1976
International Light Inc.
Dexter Industrial Green
Newburyport MA 01950
Wavelength (nanometers)
400
500
600

APPENDIX B

PERMISSION FORM

524-80-3580

University of California, San Francisco
Permission to Include my Baby as a Research Subject

Susie Blake R.N., a graduate student at the University of California at San Francisco School of Nursing, is conducting a study to learn more about the effectiveness of different phototherapy lights in decreasing jaundice in newborn infants. My infant has jaundice and will be placed below phototherapy lights as standard treatment. Because of this treatment, I have been invited to allow my infant to be a subject in this study of phototherapy.

If I agree to allow my infant to participate in the study, there will be one difference in the manner in which he or she is treated. That is, there are two types of lights currently used and both are believed to be acceptable. The choice of the light will be determined by the protocol of the study and there will be an equal chance of having either light selected. The results of my baby's routine blood tests will be used for the study.

My infant may be assigned to a group whose lights are later shown to be less effective in decreasing jaundice in newborn infants. This information will not be known until the study data is analyzed.

If one type of phtottherapy light is more effective, my infant may require less time beneath the light. This information will not be known until the study data is analyzed.

I have talked with Susie Blake R.N. about this study and she has answered my questions. If I have other questions I may call her at 564-9415.

I have been offered a copy of this consent form and the Experimental Subject's Bill of Rights to keep.

Participation in research is voluntary. I may refuse to participate or may withdraw at any time without jeapordy to the treatment my infant will receive at the medical center. I just have to say so.

_____ _____

Signature / Relationship Date

UNIVERSITY OF CALIFORNIA, SAN FRANCISCO

EXPERIMENTAL SUBJECT'S BILL OF RIGHTS

The rights below are the rights of every person who is asked to be in a research study. As an experimental subject I have the following rights:

1) To be told what the study is trying to find out,

2) To be told what will happen to me and whether any of the procedures, drugs, or devices is different from what would be used in standard practice,

3) To be told about the frequent and/or important risks, side effects or discomforts of the things that will happen to me for research purposes,

4) To be told if I can expect any benefit from participating and, if so, what the benefit might be,

5) To be told the other choices I have and how they may be better or worse than being in the study,

6) To be allowed to ask any questions concerning the study both before agreeing to be involved and during the course of the study,

7) To be told what sort of medical treatment is available if any complications arise,

8) To refuse to participate at all or to change my mind about participation after the study is started. This decision will not affect my right to receive the care I would receive if I were not in the study.

9) To receive a copy of the signed and dated consent form,

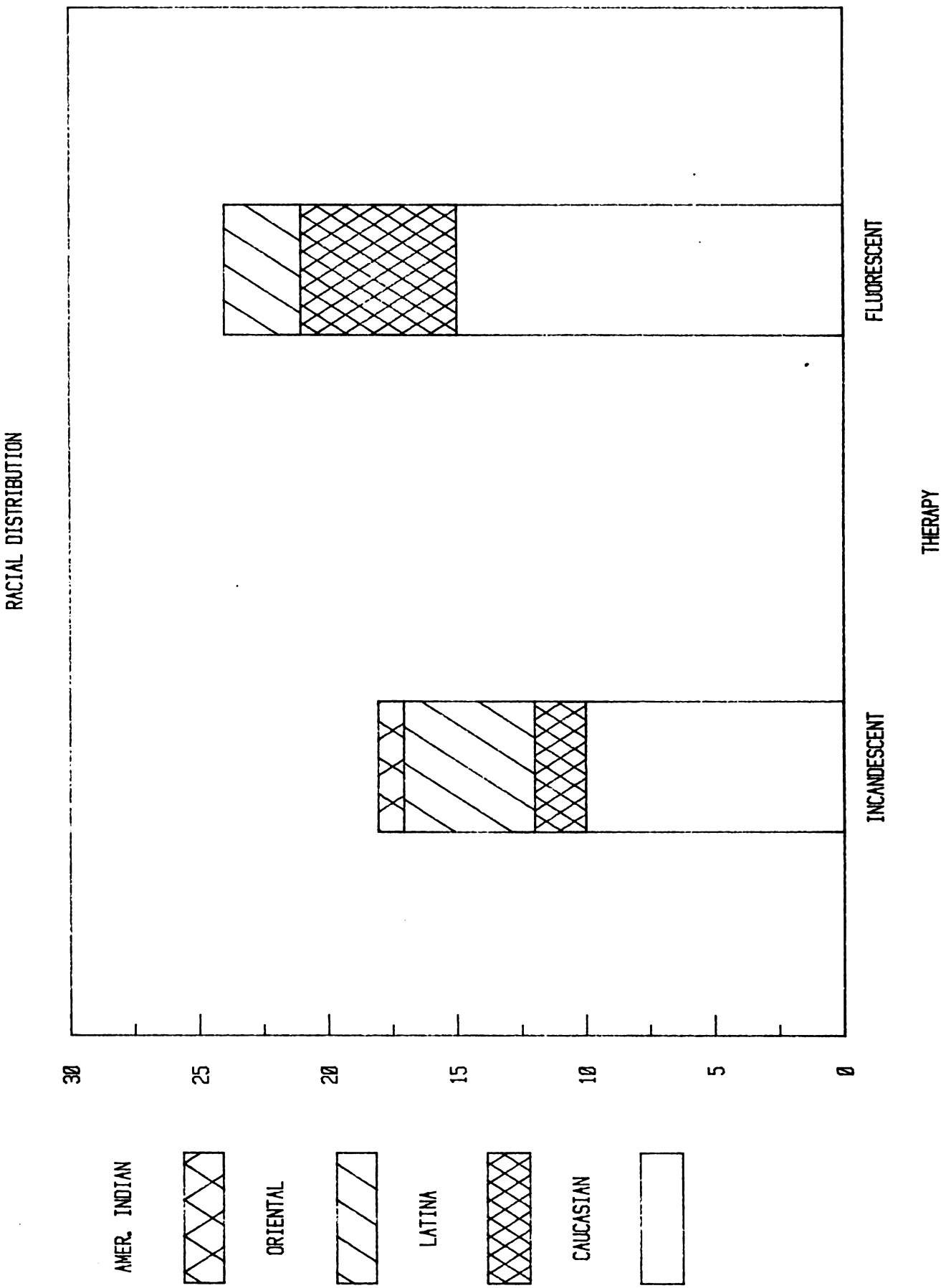
10) To be free of pressure when considering whether I wish to agree to be in the study.

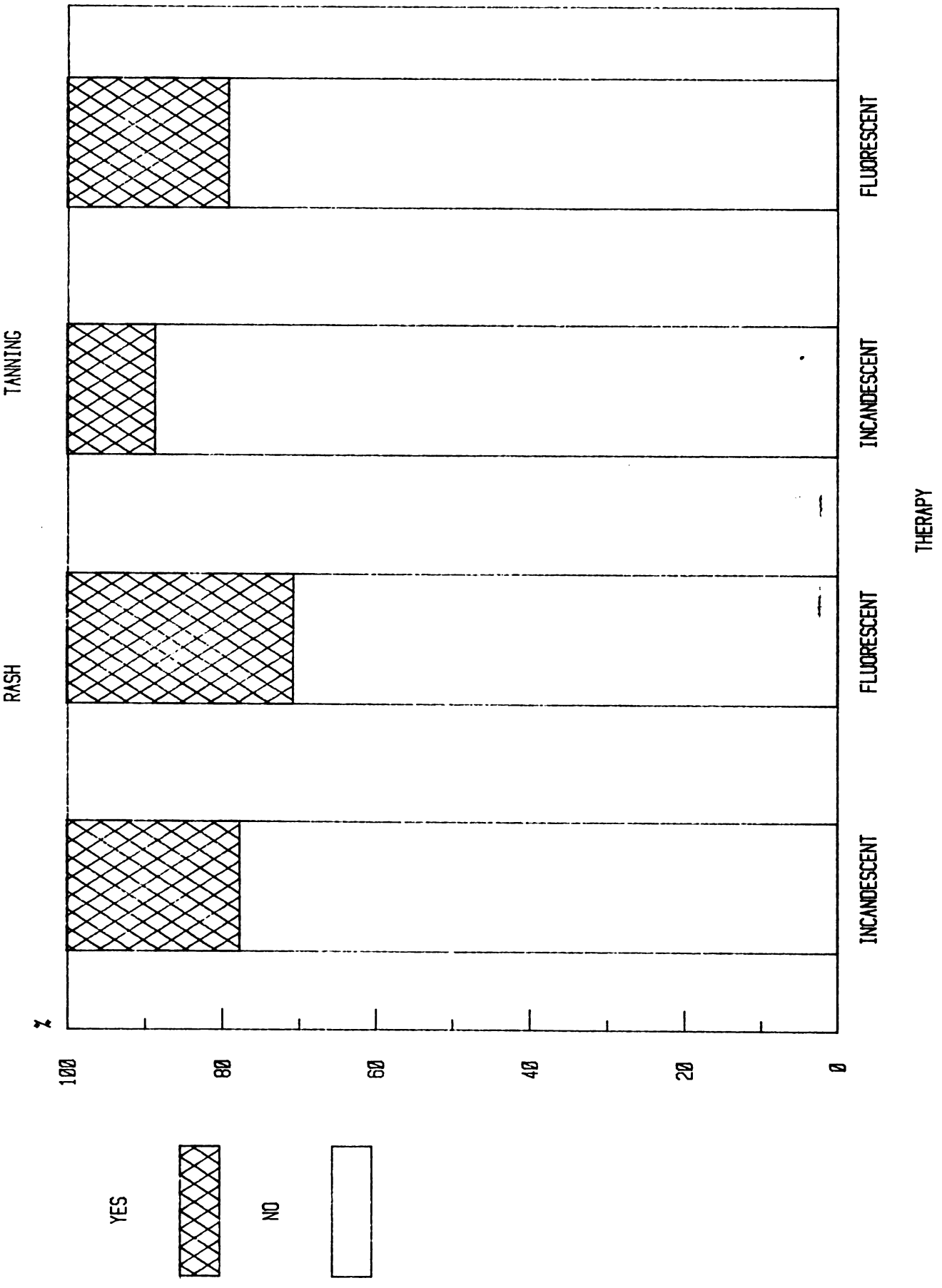
If I have other questions I should ask the researcher or the research assistant. In addition, I may contact the Committee on Human Research, which is concerned with protection of volunteers in research projects. I may reach the committee office by calling: (415) 666-1814 from 8:00 AM to 5:00 PM, Monday to Friday, or by writing to the Committee on Human Research, University of California, San Francisco, CA 94143.

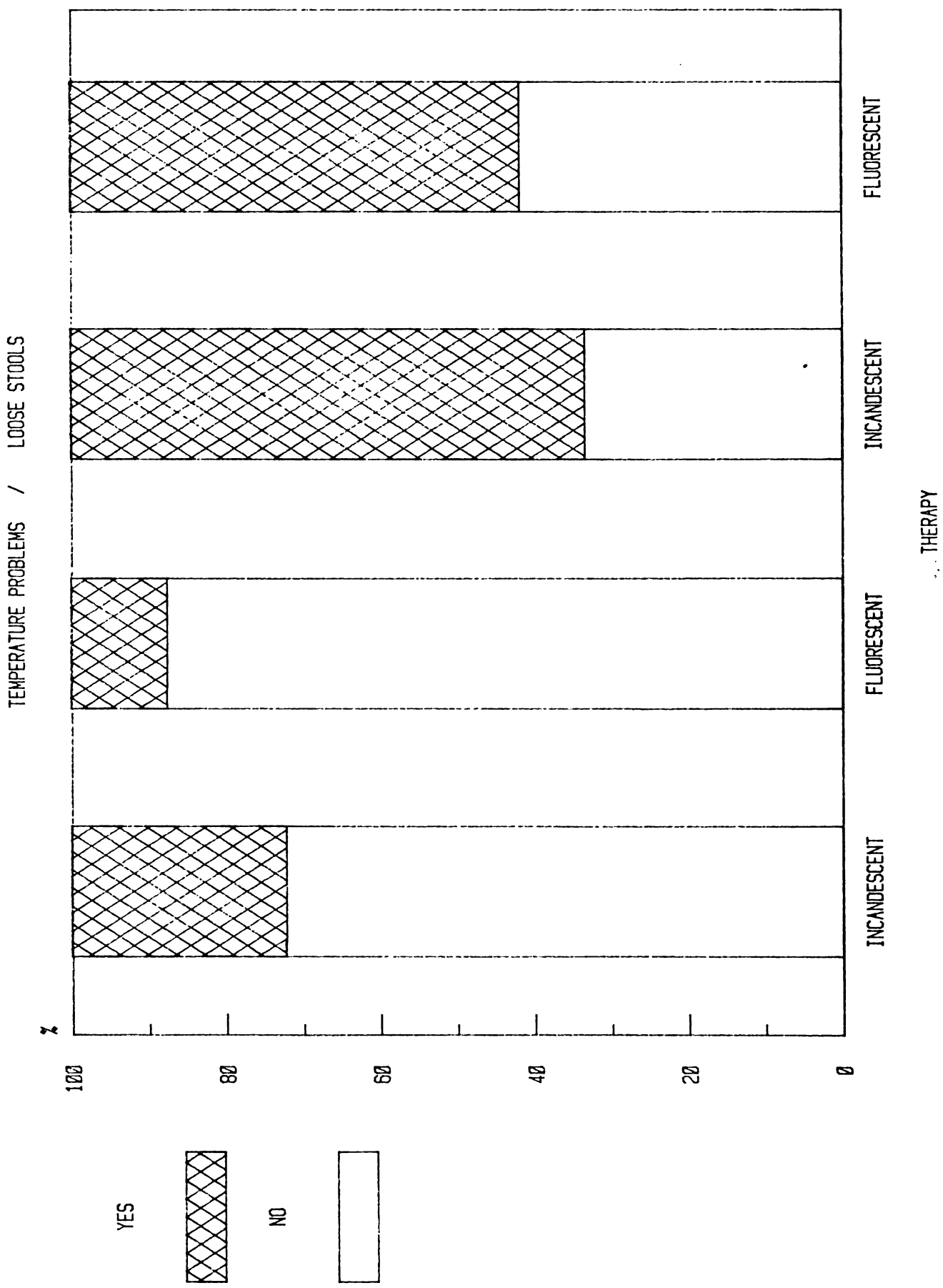
Call X1814 for information on translations.

APPENDIX C

SAMPLE CHARACTERISTICS

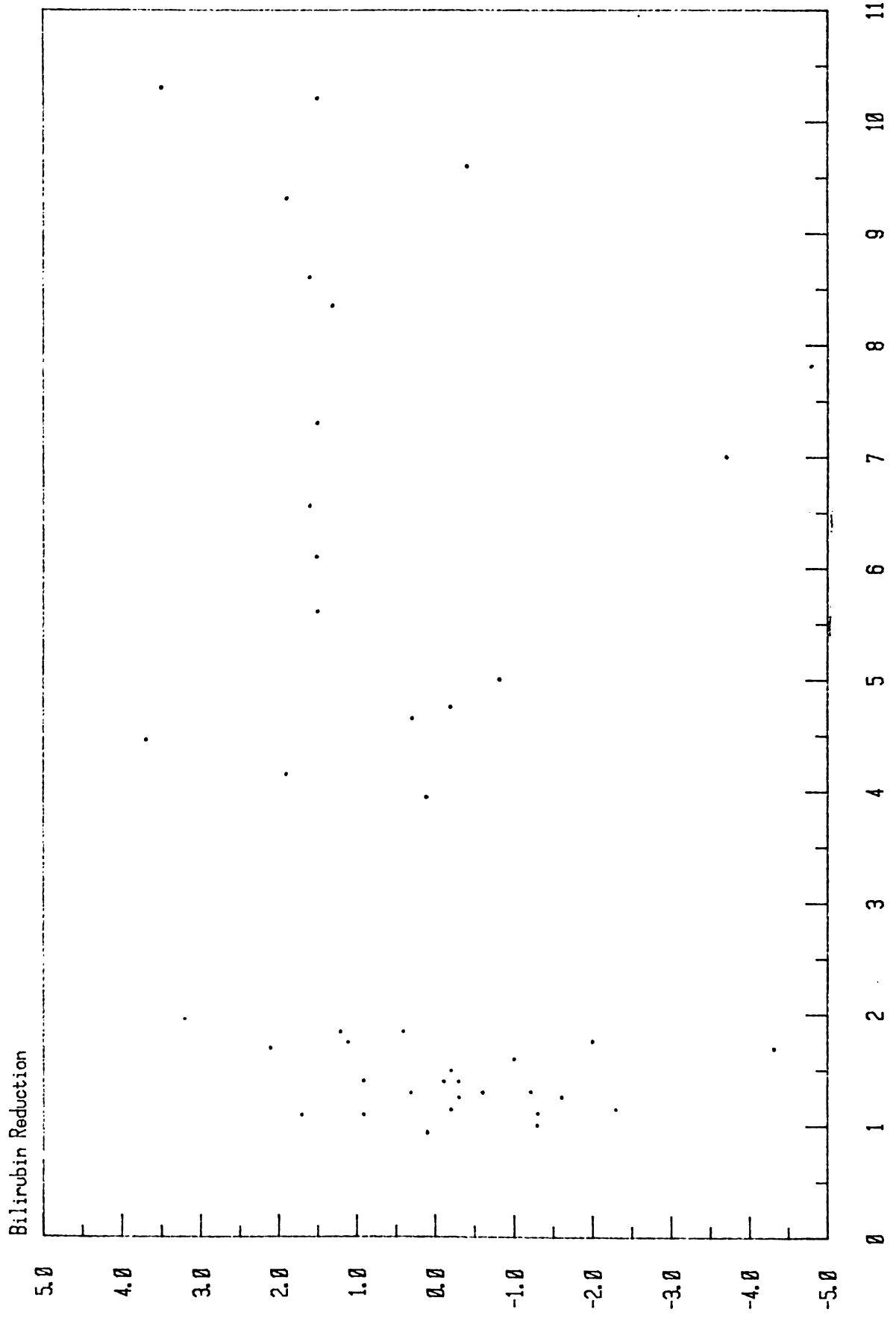

RACIAL DISTRIBUTION
30
25
20
15
10
5
0
INCANDESCENT
FLUORESCENT
THERAPY
AMER. INDIAN
ORIENTAL
LATINA
CAUCASIAN


RASH
TANNING
%
100
80
60
40
20
0
INCANDESCENT
FLUORESCENT
INCANDESCENT
FLUORESCENT
THERAPY
YES
NO

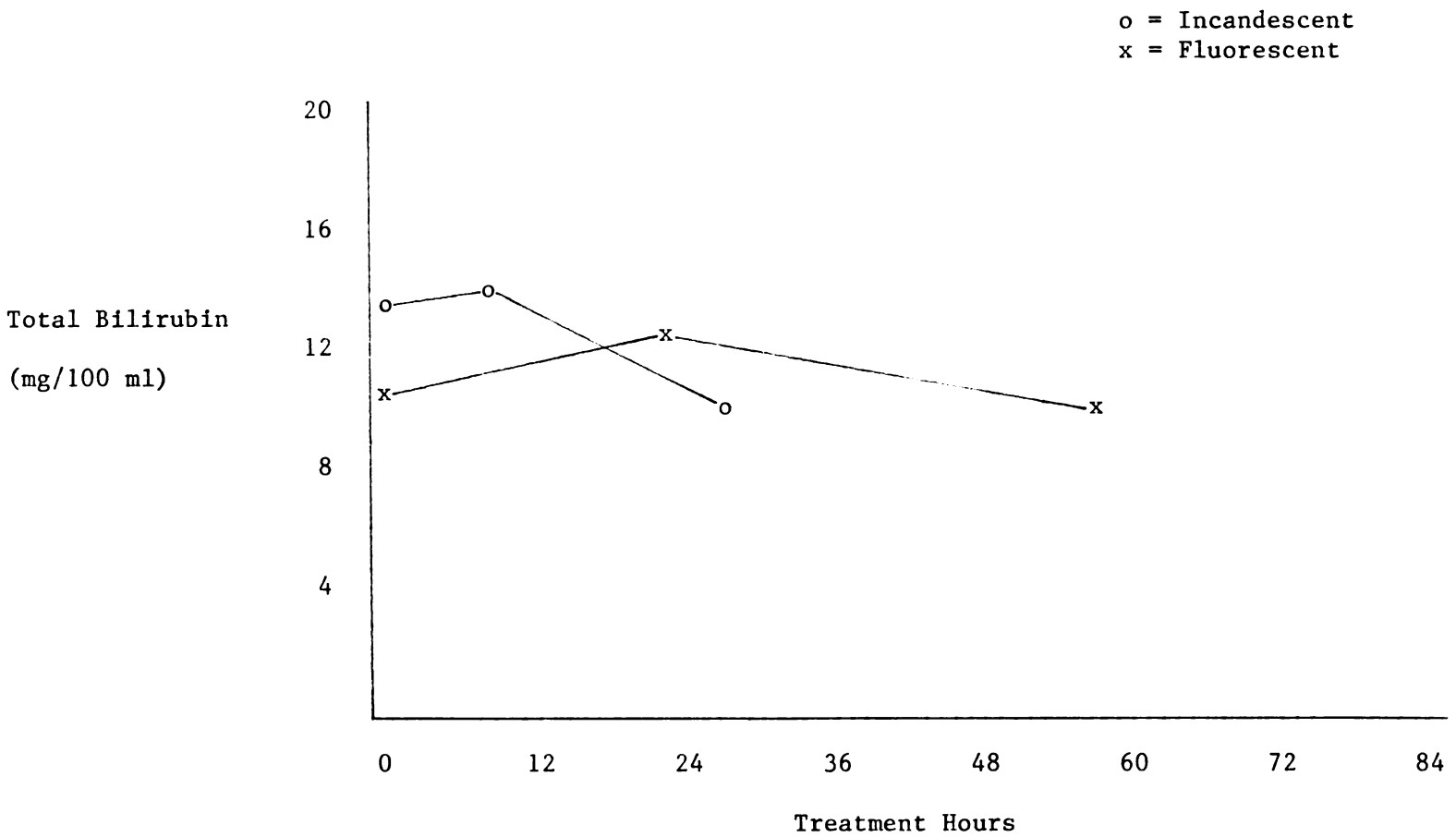

TEMPERATURE PROBLEMS / LOOSE STOOLS
%
100
80
60
40
20
0
INCANDESCENT
FLUORESCENT
INCANDESCENT
FLUORESCENT
THERAPY
YES
NO

APPENDIX D

RESPONSES OF BILIRUBIN TO FLUX


LIGHT INTENSITY vs. BILIRUBIN REDUCTION
Bilirubin Reduction
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
0
1
2
3
4
5
6
7
8
9
10
11
Light Intensity

Average Bilirubin Response to Lights



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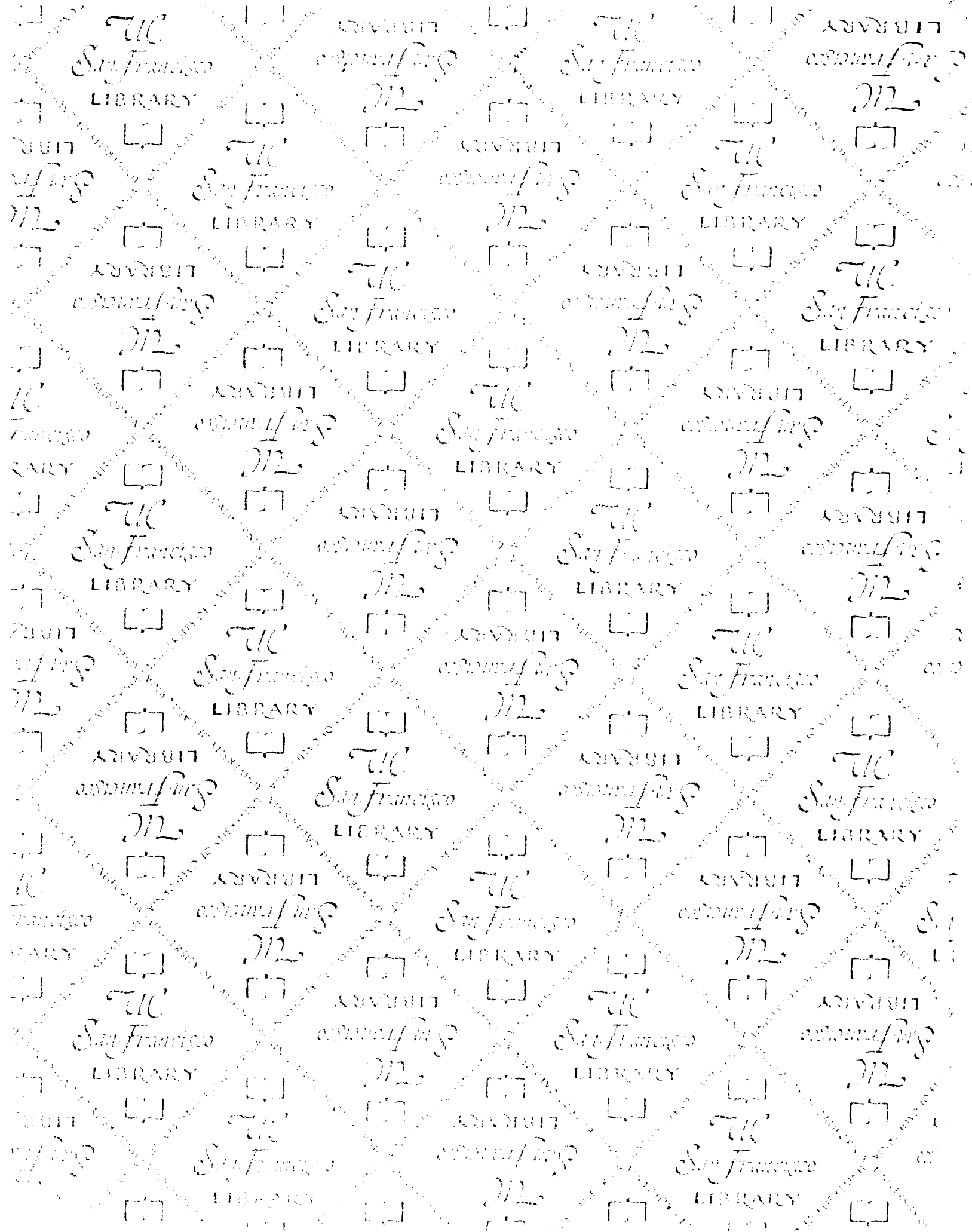
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