Phototherapy Units

Phototherapy has been in use since 1958. Phototherapy involves exposure of the skin of the jaundiced baby to blue or cool white light of wavelength 400–520 nm. Detoxification begins immediately by the production of configurational and structural photo-isomers of bilirubin in the skin and precedes the fall in serum bilirubin. Special lamps emitting light predominantly in these wavelengths are considered to be the most effective and specific for administering phototherapy. Light is effective in the treatment of hyperbilirubinemia mainly because of its blue content. Sunlight is relatively ineffective despite its ability to bleach the infant's skin because its blue content is low. Besides, hyperpyrexia and skin burns may occur due to prolonged sunlight exposure.

Mechanism of Phototherapy

Phototherapy reduces the serum concentration of bilirubin and the risk of bilirubin toxicity. It has been found to be effective in treating hyperbilirubinemia in hemolytic as well as in non-hemolytic settings. Unconjugated bilirubin in skin gets converted into water-soluble photo-products on exposure to light of a particular wavelength (400-520 mm). These photo-products are water soluble, nontoxic and excreted through the intestine and in the urine. Phototherapy acts upon bilirubin bound in the skin and sub-cutaneous tissue upto a depth of around 2 mm. For phototherapy to be effective bilirubin needs to be present in skin, hence there is no role for prophylactic phototherapy.

(a) *Configurational isomerization*: The normal *Z*-isomer of bilirubin is converted into yellow *E*-isomers. (*Z* and *E* are chemical terms, akin to the terms *cis* and *trans*, that denote the stereochemistry of double bonds). Although this reaction is instantaneous upon exposure to light, the clearance of *E*-isomers is slow. These photoisomers revert to native bilirubin in bile. Depending on the light dosage and spectral quality up to about 25% of total bilirubin (TB) may be converted to the presumably less toxic *E*-isomers within a few hours.

(b) *Structural isomerization*: This is a relatively slow, but irreversible reaction whereby bilirubin is converted into another yellow isomer, lumirubin, which is excreted rapidly. The formation of lumirubin is directly proportional to the dose of phototherapy.

(c) Photo-*oxidation*: This is an even slower reaction which leads to colorless water-soluble photo-products that are excreted in urine.

The relative contributions of these different mechanisms to the overall elimination of bilirubin are not known.

The effectiveness of phototherapy depends upon:

(1) *The level of initial bilirubin level*

(2) *Area of skin exposed.* Body surface area exposed to phototherapy determines the efficacy. Therefore, babies exposed to double surface phototherapy are reported to have faster decline of bilirubin levels.

(3) *The dose of light* (measured as irradiance x duration of treatment x % BSA treated).

There is a dose-response relationship; with increasing dosage of light, the fall of bilirubin is faster. The rate depends on the spectrum of light delivered and the irradiance, which is affected by the distance of light source from the baby. The farther the phototherapy unit is from the patient, the less will be the irradiance delivered. Halogen lights should not be placed close to the baby as they deliver considerable heat. Light emitting diode (LED) lights emit little heat and, like fluorescent lights, can be brought close (up to 10 cm) to the baby.

Increasing the surface area exposed can be achieved by using a light source above and below the infant or by placing reflecting material around the inside of the bassinette or incubator.

Indications for Phototherapy

Simply put, phototherapy should be initiated whenever it appears that bilirubin could reach such levels that can cause bilirubin induced brain damage (BIND). The question is how does one predict that? In actual life, there are a number of variables which determine the rate of rise of bilirubin and the susceptibility to BIND. The vulnerability of the brain for BIND increases with immaturity, acidosis, asphyxia, higher free bilirubin levels etc.

Each institution must create it's own guidelines. For an individual case, here are a few general guidelines that the pediatrician must be aware of before deciding to start phototherapy:

1. For term healthy babies, American Academy of Pediatrics guidelines can be followed.

2. Guidelines are provided for very low birth weight babies. As a rough guide, phototherapy is indicated at a level equal to 1% of the body weight (for e.g. 10 mg/dl in a 1000 gm baby or 15 mg/dl in a 1500 gm baby). Exchange blood transfusion is warranted when the TSB level is 5 mg/dl higher than the phototherapy level. However, the overall clinical situation needs to be considered to arrive at a proper decision.

3. In case of hemolysis, start phototherapy at a lower level.

4. Acidosis, asphyxia, hypoglycemia or sepsis make the blood brain barrier more porous to bilirubin. So, consider to start early phototherapy.

5. In case of prolonged jaundice (>3 wk), one should always check fractional bilirubin estimation. Phototherapy is contraindicated in the presence of conjugated hyperbilirubinemia (≥ 2mg/dl) because it may result in Bronze Baby Syndrome.

Phototherapy light sources

Emitted light should be filtered to remove harmful infra-red and ultraviolet radiation. Light should be focused on the baby. Mobile units are preferred because they can be used for babies nursed in cots, incubators or radiant warmers. The height should be adjustable, while a few units may be tilted on axis. Phototherapy lights may be mounted on the radiant warmers themselves.

(a) Halogen spotlights

Spotlight phototherapy units generally use a 150 Watt, 21V halogen bulb with a specially coated reflector which absorbs infrared wave length. A fan continuously cools the hot bulb. Options for varying aperture diameter and different filters are available. Positioning of the light on the baby is critically important in maximizing the spotlight's effectiveness. They are most effective when located directly above the infant at a distance of 45-50 cm. A few halogen spotlights incorporate a dosimeter which depicts how much dose of phototherapy the baby has received. It considers the total irradiance received by the baby and multiplies this by the duration in hours.

(b) Florescent lamp devices

These have optimized blue light emission at 400-520 nm wavelengths. Special blue fluorescent are labeled F20T12/BB or TL 20W/52. Regular blue fluorescent tubes (F20T12/B) deliver much less irradiance. If possible, the irradiance should be measured at regular time intervals to ensure that an adequate dose is being delivered. Fluorescent tubes lose about 35-40% of blue light irradiance after 1200 hours of use. Directing the light from the side of the infant significantly reduces the dose delivered. These lights can provide an irradiance of >25-30 $\mu W/cm^2/nm$ in the 400-520 nm range when placed closely, thus making phototherapy maximally effective particularly when the greatest body surface area is exposed.

(c) Fiber-optic pads

These devices use plastic fiber-optic light guides to deliver light from a halogen lamp to illuminate a blanket or pad which is wrapped around or placed under the baby. These devices deliver light in the 400 to 550 nm spectral band. The pad is cool and can be placed in direct contact with the baby. They can be used as an auxiliary light source to increase the surface area exposed or as the sole source of phototherapy, particularly in preterm infants. In recent models, the halogen light source has been replaced by high intensity high power LED bulbs. This increases the irradiance delivered by the pads.

(d) Compact fluorescent tubes

These are short (approx. 5 to 7 inch) double folded tubes (9-18 Watts) that emit blue or white light. Several tubes (6-8) are housed in a panel with reflectors. As they do not produce much heat the distance to baby can be relatively short thus increasing the irradiance delivered. Most of them produce an irradiance of 20-30 $\mu W/cm^2/nm$ when placed close to the baby.

(e) Light emitting diodes (LED)

Blue LED devices emit a narrow spectrum that overlaps the absorption spectrum of bilirubin. They are power-efficient, portable devices with low heat production that can be kept close to the baby. They are durable and long lasting with low power consumption.

Tips towards delivering safe and effective phototherapy

1. Protect the eyes with eye patches

2. Keep the baby naked with a small nappy to cover the genitalia

3. After switching on the unit check that all tubes/bulbs are on

4. Place the baby as close to the lights as the manufacturers' instructions allow. Use white cloth or aluminum foil to reflect light back onto the baby, making sure not to impede the air flow that cools the bulbs.

5. Encourage frequent breastfeeding. Unless there is evidence of dehydration, supplementing breastfeeding or providing IV fluids is unnecessary.

6. Keep diaper area dry and clean

7. Phototherapy does not have to be continuous and can be interrupted for feeding, clinical procedures, and to allow maternal bonding.

8. Monitor temperature every 4 hours and weight every 24 hours.

9. Measure plasma/ serum bilirubin frequently ~ every 12 hours. Visual assessment of jaundice during phototherapy is unreliable.

Side effects

The predominant adverse effects of phototherapy include rash, overheating, dehydration and diarrhea. Retinal damage is prevented by shielding the eyes. In vitro studies have suggested that DNA damage may be caused by phototherapy. Recently, the effect of phototherapy on cerebral blood flow velocity (CBFV) has been reported. Phototherapy increased mean CBFV in all preterm infants, which returned to pre-therapy values after discontinuation of phototherapy only in non-ventilated babies. Even in term babies, phototherapy increased CBFV, which returned to pre-therapy level upon discontinuation of phototherapy. In addition, phototherapy influences cytokine production by peripheral mononuclear blood cells. Phototherapy also has photo-oxidative effects on intravenous lipids, proteins and drugs like amphotericin B. Phototherapy has been shown to affect short-term behavior of the term infant, which has been attributed to maternal separation. This least discussed and often overlooked aspect, is the most common side effect. So one should encourage the mother to breast-feed and interact with her baby regularly during phototherapy.

Caution

(1) Do not use phototherapy without trying to find the cause of jaundice.
(2) Phototherapy results in dehydration and iatrogenic hyperthermia/hypothermia.
(3) Blue light may interfere with monitoring of cyanosis. Blue light causes nausea, giddiness and headache, which may disturb the staff.
(4) In direct hyperbilirubinemia, phototherapy results in Bronze Baby syndrome (green color)

Maintenance tips for phototherapy units

If possible, use a spectroradiometer (calibrated for 430-490 nm waveband) to measure the irradiance and replace the tubes or halogen light sources with new bulbs if the irradiance has fallen below 10-12uW/cm^2/nm or to two thirds of its original value. It is not necessary to measure irradiance before each use of phototherapy; but it is important to perform periodic checks of phototherapy units to make sure that an adequate irradiance is being delivered. Note that irradiance meter is designed to measure specific light source for precise bandwidth.
If a spectroradiometer is not available, halogen bulbs and fluorescent tubes should be changed every 1200 hours or 3 months of intermittent use, whichever is earlier, or when fluorescent bulbs flicker or tube ends blacken. Maintaining a logbook for duration of use or built-in timer in the device is useful. Keep bulbs and reflectors dust free and do not cover the unit with cloth, charts or files as this will prevent circulation of air and heat the bulbs.

Most of us do not have a flux-meter to measure blue light output of phototherapy unit. We must remember that the phototherapy unit is not just a source of a visual illumination. It is biomedical equipment which needs to be serviced by a trained and knowledgeable person. Ensure that supplier/dealer of phototherapy unit has flux-meter with him and checks the efficiency of the phototherapy unit periodically.

Conclusion

Phototherapy continues to be the preferred method of treatment for neonatal hyperbilirubinemia by virtue of its safety and non-invasive nature. Appropriate use of phototherapy has significantly reduced the need for exchange blood transfusion It is convenient and inexpensive. Hence, it has been immensely popular even in small hospitals and nursing homes.