Kidz Medical Services
Phototherapy Procedure

Purpose:
To provide the clinicians of Kidz Medical Services with important information pertaining to the procedure of phototherapy.

Procedure:

I. Indications for phototherapy:
   A. Phototherapy should be used when the level of bilirubin may be hazardous to the infant if it were to increase.
   B. Prophylactic phototherapy may be indicated in special circumstances such as extremely low birth weight or severely bruised infant.

II. Contraindications:
   A. Phototherapy is contraindicated in infants with direct hyperbilirubinemia caused by liver disease or obstructive jaundice because it can lead to the “bronze baby” syndrome.
   B. Phototherapy is contraindicated in infants with congenital porphyria or those treated with photosensitizing drugs.
   C. Phototherapy has been associated with increased oxidant stress and lipid peroxidation and riboflavin deficiency.
   D. Reports of adverse outcomes (malignant melanoma, DNA damage and skin changes) have not been validated.
   E. Phototherapy does not exacerbate hemolysis.

III. Pathophysiology of phototherapy:
   A. Three types of photochemical reactions occur when bilirubin absorbs light:
      1. Photoisomerization occurs in the extravascular space of the skin.
         a) Natural isomer UCB is converted to a less toxic polar isomer that diffuses into the blood and is excreted into the bile without conjugation.
         b) However, excretion is slow and the photoisomer is readily converted back to UCB which is reabsorbed from the gut if the baby is not having stools.
         c) After about 12 hours of phototherapy, the photoisomers make up ~20% of the total bilirubin.
         d) Standard tests do not distinguish between naturally occurring bilirubin and the photoisomer so bilirubin levels may not change but the phototherapy has made the bilirubin present less toxic.
      2. Structural isomerization is the intramolecular cyclization of bilirubin to lumirubin.
         a) Lumirubin makes up 2-6% of the serum concentration of bilirubin during phototherapy and is rapidly excreted in the bile and urine without conjugation.
         b) The conversion is irreversible and it cannot be reabsorbed.
         c) It is the most important pathway for lowering bilirubin levels.
3. Photo-oxidation converts bilirubin to small polar products that are excreted in the urine.
   a) It is a slow process that is the least important reaction for lowering bilirubin levels.

IV. Lights sources:
   A. Fluorescent-tube devices that emit different colors (cool white daylight, blue (B), special blue (BB), turquoise, and green) and are straight, U-shaped or spiral shaped.
   B. Metal halide bulbs, used in spotlights and incubator lights.
   C. Light-emitting diodes (LEDs) or metal halide bulbs, used with fiber-optic light guides in pads, blankets or spotlights.
   D. High-intensity LEDs, used as over and under the body devices.

V. The Efficacy of phototherapy is influenced by:
   A. Emission range of the light source (light wavelength):
      1. Bilirubin absorbs visible light most strongly in the blue region of the spectrum (~460 nm).
      2. Lights with broader emission will work but not as effectively.
      3. **Devices with maximum emission within the 460–490 nm (blue-to-green range) region of the visible spectrum are probably the most effective for treating hyperbilirubinemia.**
   B. Light Intensity (irradiance):
      1. Light intensity or energy output is defined by irradiance and refers to the number of photons (spectral energy) that are delivered per unit area (cm²) of exposed skin.
      2. Irradiance is measured with a radiometer (W·cm⁻²) or spectroradiometer (μW·cm⁻²·nm⁻¹) over a given wavelength band
      3. The dose of phototherapy is a measure of the irradiance delivered for a specific duration and adjusted to the exposed body surface area.
      4. Irradiance of phototherapy should be at least 30 _W·cm⁻²·nm⁻¹_ (confirmed with an appropriate irradiance meter calibrated over the appropriate wavelength range).
         a) Devices that emit lower irradiance may be supplemented with auxiliary devices and much higher doses (>65) might have adverse effects.
         b) Visual estimations of brightness and use of ordinary photometric or colorimetric light meters are inappropriate.
         c) Maximal irradiance can be achieved by bringing the light source close to the infant; however, this should not be done with halogen or tungsten lights, because the heat generated can cause a burn. Furthermore, with some fixtures, increasing the proximity may reduce the exposed body surface area.
         d) Irradiance distribution in the illuminated area (footprint) is rarely uniform; measurements at the center of the footprint may greatly exceed those at the periphery and are variable among phototherapy devices. Thus, irradiance should be measured at several sites on the infant’s body surface.
e) The ideal distance and orientation of the light source should be maintained per the manufacturer's recommendations.
f) The irradiance of all lamps decreases with use; manufacturers may provide useful-lifetime estimates, which should not be exceeded.
g) The American Academy of Pediatrics has recommended that the irradiance for intensive phototherapy be at least 30 \( \mu \text{W} \cdot \text{cm}^{-2} \cdot \text{nm}^{-1} \) over the waveband interval 460 to 490 nm.

C. Illumination of maximal body surface:
1. Complete (100%) exposure of the total body surface to light is impractical and limited by use of eye masks and diapers.
2. Circumferential illumination (total body surface exposure from multiple directions) phototherapy maximizes the exposed and achieves exposure of approximately 80% of the total body surface.
3. In clinical practice, exposure is usually planar: ventral with overhead light sources and dorsal with lighted mattresses. Approximately 35% of the total body surface (ventral or dorsal) is exposed with either method.
4. Changing the infant's posture every 2 to 3 hours may maximize the area exposed to light.
5. Concerns for the long-term effects of continuous phototherapy exposure of the reproductive system have been raised but not substantiated.
6. Diapers may be used for hygiene but are not essential.
7. Combining several devices, such as fluorescent tubes with fiber-optic pads or LED mattresses placed below the infant or bassinet, will increase the surface area exposed.
8. Physical obstruction of light by equipment, such as radiant warmers, head covers, large diapers, eye masks that enclose large areas of the scalp, tape, electrode patches, and insulating plastic covers, decrease the exposed skin surface area.
9. If the infant is in an incubator, the light rays should be perpendicular to the surface of the incubator to minimize reflectance and loss of efficacy.
10. Exposed body surface area treated rather than the number of devices (double, triple, etc) used is clinically more important. Since maximal skin surface illumination allows for a more intensive exposure. It may require combined use of more than 1 phototherapy device.
11. If TSB levels approach or exceed the exchange transfusion line, the sides of the bassinet, incubator or warmer should be lined with aluminum foil or white material. This will increase the surface area by (reflects the light to reach lateral surfaces of body) of the infant exposed and increase efficacy of phototherapy.

D. Rate of response measured by decrease in serum bilirubin concentration
1. The clinical impact of phototherapy should be evident within the first 4 to 6 hours of exposure with an anticipated decrease of more than 2 mg/dL in TSB.
2. The clinical response depends on:
   a) The rates of bilirubin production, enterohepatic circulation and bilirubin elimination.
b) The degree of tissue bilirubin deposition
c) The rates of the photochemical reactions of bilirubin.

VI. Side effects of phototherapy;
   A. Four decades of neonatal phototherapy use has revealed no serious adverse effects in newborns \( \geq 35 \) weeks gestational age.
      1. For preterm infants, who are usually treated prophylactic rather than therapeutic this may not be true.
   B. Insensible water loss (IWL):
      1. Phototherapy may increase IWL by way of increasing body temperature and increasing peripheral blood flow.
      2. Generally, it is recommended to increase fluids for preterm infants 10-20 ml/kg/d.
      3. This may not be necessary with newer phototherapy lights using LEDs because they generate very little heat.
      4. Term infants receiving adequate fluid intake may not need added fluid.
      5. Occasionally, phototherapy induces loose stools and IWL would need to be considered.
   C. Redistribution of blood flow:
      1. In term infants, left ventricular output and renal blood flow velocity decrease, whereas left pulmonary artery and cerebral blood flow velocity increase. All velocities return to baseline after discontinuation of phototherapy.
      2. In preterm infant, cerebral blood flow velocity also increases and renal vascular resistance increase with a reduction of renal blood flow velocity but no detrimental clinical effects due to these changes have been determined.
   D. Low calcium levels have been described in preterm infants under phototherapy.
   E. Newman et al (2016) found that phototherapy use was associated with increased cancer rates (particularly nonlymphocytic leukemia), but control for confounding variables eliminated or attenuated the associations. Nonetheless, the possibility of even partial causality suggests that avoiding unnecessary phototherapy may be prudent.
   G. Wu Y et al found no association between phototherapy and autism.
   H. Stevenson et al review (2016) of the possible risks of photo-oxidative injury in ELBW infants. Their conclusion was:
      1. The current state of knowledge requires that clinicians reserve judgment of the safety of ELW infants until further randomized controlled trials are conducted.
      2. Although treatment of hyperbilirubinemia is still required to protect ELBW infants from bilirubin-induced neurologic dysfunction caution with the application of light is warranted.
   I. Known complications include exposure to high energy light, malposition and obstruction of the nares, inadequate securing of the patch that allows lid opening resulting on corneal abrasion and conjunctivitis from use of eye patches without removal to assess the condition of covered tissues.
VII. Safety and protective measures
   A. Instructions for routine clinical use of the device should be available.
   B. Staff should be educated regarding the importance of safely minimizing the
distance of device from the infant and recognize physical factors that could
impede or obstruct light exposure
   C. Staff should be aware the phototherapy does not use ultraviolet light and that
exposure to the lights is mostly harmless
   D. Staff should be aware that the intensity of light decreases at the outer
perimeter of the light footprint and recognize the effects of physical factors that
could impede or obstruct light exposure.
   E. Devices must comply with general safety standards listed by the International
Electrotechnical Commission.
   F. Staff should educate parents regarding the care of their newborn while
undergoing phototherapy.
   G. Interruption of phototherapy: After documented decrease in bilirubin
concentration, continuous exposure to the light source may be interrupted and the
eye mask removed to allow for feeding and parental bonding
   H. Eye masks:
      1. Use of eye masks to prevent retinal damage are used routinely although
         there is no evidence to support this recommendation.
      2. Retinal damage has been documented in unpatched eyes of newborn
         monkeys exposed to phototherapy but no similar data available from human
         newborns because eye masks have always been used.
      3. Purulent eye discharge and conjunctivitis in term infants have been
         reported with prolonged eye patch use.
   I. Use of diapers:
      1. Concerns for long-term effects of continuous phototherapy exposure of the
         reproductive system have been raised but not substantiated.
      2. Diapers may be used for hygiene but are not essential.
      3. Devices used in environments with high humidly and oxygen must meet
         electrical and fire hazard safety standards.
   J. Preserve temperature control.