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Evaluation of Home Phototherapy for Neonatal Hyperbilirubinemia

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Objective To characterize home phototherapy treatment for neonatal hyperbilirubinemia and assess the risk factors associated with the need for hospital admission during or after home phototherapy.

Study design This was a retrospective study of newborn infants born at ≥35 weeks of gestation who underwent comprehensive home phototherapy (that included daily in-home lactation support and blood draws) over an 18-month period. We excluded infants who lacked a recorded birth date or time, started treatment at age >14 days, or had a conjugated serum bilirubin level of ≥2 mg/dL (≥34.2 μmol/L). The primary study outcome was any hospital admission during or within 24 hours after completion of home phototherapy. Logistic regression was used to identify risk factors for hospitalization.

Results Of the cohort of 1385 infants, 1324 met the inclusion criteria. At the time home phototherapy was initiated, 376 infants (28%) were at or above the American Academy of Pediatrics phototherapy threshold. Twenty-five infants required hospitalization (1.9%; 95% CI, 1.3%-2.8%). Hospital admission was associated with a younger age at phototherapy initiation (OR, 0.63 for each day older in age; 95% CI, 0.44-0.91) and a higher total serum bilirubin level relative to the treatment threshold at phototherapy initiation (OR, 1.71 for each 1 mg/dL above the treatment threshold; 95% CI, 1.40-2.08).

Conclusions Comprehensive home phototherapy successfully treated hyperbilirubinemia in the vast majority of the infants in this cohort. *(J Pediatr 2020;220:80-5)*.

Home phototherapy has been available in the US for more than 25 years as an alternative to phototherapy in the hospital.[1-3] Treatment at home has potential advantages over treatment in the hospital. Disruptions to breastfeeding and parent–infant bonding are minimized at home, whereas in some hospital nurseries infants may be moved out of the mother's room for phototherapy.[4] Treatment at home also may be more convenient for families, and less costly than hospitalization.[1-3] However, compared with hospital phototherapy, in-home phototherapy may take longer. Furthermore, infants and their bilirubin levels cannot be monitored as closely in the home.[1-3]

Home phototherapy use among pediatric providers varies,[5] and according to the current American Academy of Pediatrics (AAP) hyperbilirubinemia guideline, should be considered only when an infant's total serum bilirubin (TSB) level is 2-3 mg/dL (34.2-51.3 μmol/L) below the treatment threshold.[6] This recommendation may be related to a paucity of evidence, given that few studies have examined the use of home phototherapy, and these studies had small sample sizes or restricted eligibility for home phototherapy.[1-3,7] A 2014 Cochrane Review intended to compare home and hospital-based phototherapy in newborns with uncomplicated jaundice could not be performed due to insufficient evidence.[8]

The objectives of the present study were to characterize home phototherapy treatment for neonatal hyperbilirubinemia and to assess the risk factors associated with home phototherapy failure.

Methods

We retrospectively studied a convenience sample of consecutive newborn infants, born at ≥35 weeks of gestation, who were treated with home phototherapy for the first time between September 1, 2015, and February 28, 2017. Home phototherapy was provided by a single provider in the Seattle-Tacoma-Bellevue, Washington metropolitan area. Information about the for-profit company was provided by its founder and owner (D. Gentry-Hayward, RN, MBA, personal communication, August 2017). The referring clinician makes all clinical decisions, including the frequency of laboratory testing (up to twice daily), discontinuation of home phototherapy, and hospitalization for inpatient photo-

AAP	American Academy of Pediatrics
DAT	Direct antiglobulin test
TSB	Total serum bilirubin

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Supported by a Seattle Children's Center for Clinical and Translational Research (CCTR) Academic Enrichment Fund grant (to P.C.). The funder played no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; and preparation, review, or approval of the manuscript. The authors have no affiliation with Infant Home Phototherapy, Inc. Neither the owner nor any employee of Infant Home Phototherapy, Inc, had any role in the collection or interpretation of study data.

Portions of this study were presented as a poster at the Pediatric Academic Societies annual meeting, May 5-8, 2018, Toronto, Canada.

0022-3476/$ - see front matter.
https://doi.org/10.1016/j.jpeds.2020.01.004

therapy. Although there are no specific criteria, depending on the combination of the TSB trend, gestational age, and weight, the company may decline to treat infants they deem to be too high risk for home phototherapy. The company accepts all private insurance and 3/5 Washington Medicaid insurance programs.

During home phototherapy, infants are positioned on a BiliBed (Medela, McHenry, Illinois), which contains a fluorescent blue light providing an average light irradiance of 36 μW/cm^2/nm.[9] The referring clinician also can order an additional Ohmeda fiber optic pad to place over the baby's chest (Datex-Ohmeda, Madison, Wisconsin; provides an average light irradiance of 20 μW/cm^2/nm).[9] A pediatric nurse travels to the patient's home to set up the phototherapy equipment, weighs the infant and checks the TSB level at least daily, and provides lactation support as needed. The nurse reports back to the referring clinician with the infant's daily progress to obtain the plan for the next day. Nurses e-mail handoffs (regarding new patients, current patients, declined patients) to one another and the company's owner at the end of each shift.

We excluded infants who started home phototherapy after 14 days of age, had a conjugated bilirubin level of ≥2 mg/dL (≥34.2 μmol/L), or had a missing birth date or time. The lead author reviewed the daily e-mail communication between the on-call nurses and the company's owner during 2016 to identify the declined referrals for that year. E-mails from other years were not accessible. Reasons for declining home phototherapy as described by the nurses were grouped into 10 categories (**Table I**). All other data were extracted from patients' home phototherapy nursing and laboratory records and managed using REDCap tools hosted at the University of Washington's Institute of Translational Health Sciences.[10,11] REDCap is a secure, web-based software platform designed to support data capture for research studies.[10,11]

Predictor Variables and Cohort Characterization

The infants' gestational age, direct antiglobulin test (DAT) status, weight, TSB results, and previous inpatient phototherapy treatment were based on the nursing records. Data on race and ethnicity were not available. We approximated AAP risk groups as follows: (1) low risk, gestational age ≥38 weeks and no positive DAT result; (2) medium risk, either gestational age <38 weeks or a positive DAT result; (3) high risk, gestational age <38 weeks and a positive DAT result. These risk groups were used to determine the 2004 AAP hour-specific phototherapy treatment threshold.[6]

The time of equipment setup was used as the time of phototherapy initiation. If there was no specific documented stop time, then the time that the nurses received the order to stop treatment was considered the time of phototherapy termination. We obtained the range and median duration of treatment by calculating the number of hours between phototherapy initiation and termination. We recorded the number of home visits, including equipment setup and patient follow-up, based on the nursing records.

The TSB level at the time of referral for treatment was considered the starting TSB at home phototherapy inititation, unless there was another TSB checked at the time of equipment setup (23% of patients). We calculated the rate of bilirubin decline during home phototherapy using the difference between the starting TSB and the last TSB obtained before discontinuation of home phototherapy, divided by the number of lapsed hours. If the last TSB did not have a recorded blood draw time (6% of patients), then it was assumed to be 24 hours (the mean interval between visits) after the previous day's TSB. We also performed sensitivity analyses in which we excluded the 6% of patients who did not have a recorded blood draw time for their last TSB.

Outcome Variables

Our primary outcome was hospitalization for inpatient phototherapy during or within 24 hours after completion of home phototherapy. We chose a 24-hour timeframe because all patients, unless declined by the referring provider, have at least one follow-up visit the day after home phototherapy is stopped. The primary reason for hospitalization was abstracted and categorized based on the nursing descriptions.

Our secondary outcomes were hospitalization or the need for a repeat course of home phototherapy, and the total service charge by the home phototherapy company. During the study period, the home phototherapy company charged \$440 for the initial nursing visit and equipment setup and \$445 for each subsequent nursing visit and blood draw.

Statistical Analyses

We performed analyses using Stata version 14.2 (StataCorp, College Station, Texas). Normally distributed variables are presented as mean ± SD deviation, and non-normally distributed variables are presented as median with IQR. Because TSB levels in infants rise physiologically until approximately 96-120 hours of age,[12] we compared the duration of home phototherapy and the rate of TSB decline between infants who started home phototherapy at <96 hours of age and those who started at ≥96 hours of age. We used the 2-tailed t test to compare means and the Wilcoxon

Table I. Declined referrals in 2016 (N = 137)

Reasons for decline	N
Nonclinical reasons	
Insurance not accepted or no insurance	68
Out of geographical service area	18
Late referral time	9
Short-staffed	3
Clinical reasons	
Weight loss >13% from birth weight	17
Referring TSB >22 mg/dL plus additional hyperbilirubinemia risk factor	4
High rate of TSB rise	4
Gestational age <35 wk	3
Other clinical concerns (temperature instability; "multiple issues")	2
Miscellaneous (eg, TSB far below threshold, parents declined)	9

rank-sum test to compare medians. Statistical significance was set at a *P* value <.05.

We performed logistic regression to identify risk factors for hospital admission for inpatient phototherapy during or within 24 hours after completion of home phototherapy. The 6 risk factors assessed were gestational age, DAT status, AAP risk group, age at home phototherapy initiation, percent weight loss since birth, and TSB level relative to the AAP treatment threshold at phototherapy initiation. Each risk factor was assessed in an individual model; multivariable analysis was not performed owing to the small number of outcomes. The Seattle Children's Institutional Review Board approved this study.

Results

During the study period, a total of 1385 newborn infants underwent home phototherapy. We excluded 8 infants who began treatment after 14 days of age and 1 infant with a conjugated bilirubin level of ≥2 mg/dL (34.2 μmol/L). Information on the birth date or time was missing for 19 infants, and phototherapy records were missing for 33 infants; thus, the study cohort comprised 1324 infants (95.6% of those treated).

Characteristics of the cohort are summarized in **Table II** and **Table III**. Home phototherapy was initiated at a mean age of 94 ± 36 hours; 790 infants started treatment at <96 hours of age, and 534 infants started at ≥96 hours of age. Most infants (89.8%) were recorded to be breastfeeding or receiving expressed breast milk; the quantity of formula supplementation, if any, was not available. The mean TSB level at home phototherapy initiation was 16.9 ± 2.5 mg/dL (289.1 ± 42.8 μmol/L). Based on their TSB level, age, and risk classification, 28% of the infants started treatment at or above the AAP phototherapy threshold, and the remaining infants started home treatment at a mean of 0.96 ± 1.9 mg/dL (16.4 ± 32.5 μmol/L) below treatment threshold.

Of the 103 infants who received hospital-based phototherapy before home phototherapy, 32 were DAT-positive, 22 started home treatment at or above the phototherapy threshold, and 28 started home treatment at a TSB level of 3 mg/dL (51.3 μmol/L) or more below the phototherapy threshold. Infants who had previous inpatient phototherapy started home treatment at an older age (mean age, 113 ± 54 hours) compared with infants who did not have previous inpatient phototherapy (mean age, 92 ± 34 hours; *P* < .001).

The median duration of treatment for infants who completed a course of home phototherapy was 53 hours (IQR, 44-72 hours; range, 15-280 hours) and the median number of home visits was 4 (IQR, 4-5 visits; range, 3-13 visits). The median duration of treatment differed significantly between infants who started phototherapy at <96 hours of age and those who started at ≥96 hours of age (66 hours [IQR, 45-74 hours] vs 48 hours [IQR, 44-70 hours]; *P* < .001), as well as between infants whose starting TSB level was below phototherapy threshold vs those at or above phototherapy threshold (49 hours [IQR, 44-71 hours] vs 68 hours [IQR, 46-83 hours]; *P* < .001).

Home treatment included the fiber optic pad in addition to the BiliBed for 414 infants (31.3%), which included 238 for the entirety of treatment, and 176 for a portion of the treatment.

Table II. Cohort characteristics and unadjusted associations between risk factors and hospitalizations

Characteristic	All patients (N = 1324), n	Hospitalized patients (N = 25), n (%)	Unadjusted OR (95% CI)	*P* value
Sex				.97
Male	746	14 (1.9)	1 [reference]	
Female	578	11 (1.9)	1.01 (0.46-2.25)	
Gestational age, wk*				.71
35-36	151	4 (2.6)	1.52 (0.40-5.76)	
37	229	2 (0.9)	0.49 (0.09-2.57)	
38	277	5 (1.8)	1.03 (0.29-3.60)	
39	380	9 (2.4)	1.36 (0.45-4.10)	
40+	285	5 (1.8)	1 [reference]	
Direct antiglobulin test				.38
Negative/not done	1184	21 (1.8)	1 [reference]	
Positive	140	4 (2.9)	1.63 (0.55-4.82)	
AAP risk group				.74
Low	824	15 (1.8)	1 [reference]	
Medium	480	10 (2.1)	1.15 (0.51-2.57)	
High	20	0	–	
Age at phototherapy initiation, d, mean (SD)†	3.9 (1.5)	–	0.63 (0.44-0.91)	.014
% weight loss at phototherapy initiation, mean (SD)‡	6.9 (3.4)	–	0.95 (0.85-1.07)	.4
TSB level at phototherapy initiation				<.001
Below phototherapy threshold	948	7 (0.7)	1 [reference]	
At or above phototherapy threshold	376	18 (4.8)	6.76 (2.80-16.32)	
Previous inpatient phototherapy				.44
No	1221	24 (2.0)	1 [reference]	
Yes	103	1 (1.0)	0.49 (0.07-3.65)	

*Data missing for 2 infants.
†Data missing for 3 infants.
‡Data missing for 20 infants.

Table III. Unadjusted associations between risk factors and need for hospitalization or restarting home phototherapy

Characteristics	All patients (N = 1324), n	Patients hospitalized or restarted on home phototherapy (N = 42), n (%)	Unadjusted OR (95% CI)	*P* value
Sex				.67
Male	746	25 (3.4)	1 [reference]	
Female	578	17 (2.9)	0.87 (0.47-1.62)	
Gestational age, wk*				.40
35-36	151	4 (2.6)	1.52 (0.40-5.76)	
37	229	8 (3.5)	2.03 (0.65-6.28)	
38	277	8 (2.9)	1.67 (0.54-5.15)	
39	380	17 (4.5)	2.62 (0.96-7.20)	
40+	285	5 (1.8)	1 [reference]	
Direct antiglobulin test				.08
Negative/not done	1184	34 (2.9)	1 [reference]	
Positive	140	8 (5.7)	2.05 (0.93-4.52)	
AAP risk group				.24
Low	824	24 (2.9)	1 [reference]	
Medium	480	16 (3.3)	1.15 (0.60-2.19)	
High	20	2 (10)	3.70 (0.81-16.87)	
Age at phototherapy initiation, d, mean (SD)†	3.9 (1.5)	–	0.82 (0.64-1.05)	.10
% weight loss at phototherapy initiation, mean (SD)‡	6.9 (3.4)	–	0.94 (0.86-1.03)	.21
TSB level at phototherapy initiation				<.001
Below phototherapy threshold	948	18 (1.9)	1 [reference]	
At or above phototherapy threshold	376	24 (6.4)	3.52 (1.89-6.57)	
Previous inpatient phototherapy				.34
No	1221	37 (3.0)	1 [reference]	
Yes	103	5 (4.9)	1.63 (0.63-4.25)	

*Data missing for 2 infants.
†Data missing for 3 infants.
‡Data missing for 20 infants.

The mean rate of TSB decline was similar between newborns using the BiliBed only vs those with the additional fiber optic pad (0.08 ± 0.06 mg/dL/hour [1.4 ± 1.0 μmol/L/hour] vs 0.09 ± 0.07 mg/dL/hour [1.5 ± 1.2 μmol/L/hour]; $P = .14$). The overall rate of TSB decline was slower in infants who started home phototherapy at <96 hours of age compared with those who started at ≥96 hours of age (mean rate, 0.07 ± 0.06 mg/dL/hour [1.2 ± 1.0 μmol/L/hour] vs 0.12 ± 0.06 mg/dL/hour [2.1 ± 1.0 μmol/L/hour]; $P < .001$). In the sensitivity analyses, exclusion of the 6% of patients without a recorded blood draw time for their last TSB did not alter any of the calculated rates of TSB decline.

In 403 infants who completed a course of treatment, the mean TSB level rose between the start of home phototherapy and the subsequent check (1.6 ± 1.4 mg/dL [27.4 ± 24.0 μmol/L]). These infants started home treatment at a mean age of 72 ± 26 hours, compared with infants without a rise in their TSB level who started at a mean age of 104 ± 36 hours ($P < .001$). A total of 996 infants (75%) had at least 1 postphototherapy TSB level. Of the remaining infants, 303 infants had referring providers who declined a postphototherapy TSB check by the company, and 25 infants did not complete a home treatment course. In 2016, 137 out of 1069 total referrals to the home phototherapy company were declined, for the reasons listed in Table I.

Hospitalization for Inpatient Phototherapy

Twenty-five infants were admitted to the hospital (1.9%; 95% CI, 1.3%-2.8%). All of the admissions occurred early during the course of home treatment. Table II shows the associations between patient characteristics and hospitalization. Odds of admission were increased by 1.71 (95% CI, 1.40-2.08) for each 1 mg/dL that the TSB at initiation exceeded the treatment threshold.

Fifteen of the 25 infants were hospitalized for rising TSB levels. Of these, 3 were described as noncompliant with use of the home phototherapy equipment due to "fussiness." All but 1 of these 15 infants (who was hospitalized with a TSB level 1.2 mg/dL [20.5 μmol/L] below the AAP phototherapy threshold) were admitted with a TSB level above the treatment threshold (mean of 3.7 ± 2.6 mg/dL [63.3 ± 44.5 μmol/L]). The remaining reasons for hospitalization were parental request (3 patients), other clinical concerns (eg, heart murmur, tachypnea, temperature instability; 6 patients), and power outage (1 patient). Of these 10 infants, 5 were admitted with a TSB level at or above the AAP phototherapy threshold (a mean of 0.9 ± 0.9 mg/dL [15.4 ± 15.4 μmol/L] above), and 5 were admitted with a TSB level below the treatment threshold (a mean of 3.2 ± 1.9 mg/dL [54.7 ± 32.5 μmol/L] below).

Hospitalization and/or Recurrent Home Phototherapy

Eighteen infants were retreated with a second course of home phototherapy (1.4%; 95% CI, 0.9%-2.1%). One infant was DAT-positive with ABO incompatibility and was hospitalized shortly after starting home phototherapy when the TSB drawn at treatment initiation returned 24.4 mg/

dL(treatment threshold 18 mg/dL). This same infant was later retreated with home phototherapy 2 days after discharge from inpatient phototherapy. Thus, 42 infants (3.2%; 95% CI, 2.4%-4.3%) required either hospitalization or a repeat course of home phototherapy. Table III shows the associations between patient characteristics and hospitalization or retreatment with home phototherapy. Starting home phototherapy at or above the treatment threshold was a risk factor for hospitalization or repeat home phototherapy, but in contrast to hospitalization alone, age at home phototherapy initiation was no longer a statistical risk factor.

Service Charges

For infants who completed a home treatment course, the mean and median service charges for the home phototherapy and nursing visits were $2073 ± $529 and $1775 (IQR, $1775-2220), respectively. Service charges ranged from $1330 to $5780.

Discussion

In this retrospective cohort of newborns treated with home phototherapy for neonatal hyperbilirubinemia, we found that few infants required hospitalization for inpatient phototherapy (1.9%) or required hospitalization or repeated home phototherapy (3.2%). Our frequency of hospitalization is at the lower end of the range (0-8%) reported in previous studies.[1-3] Of the 25 infants who were hospitalized, 15 were hospitalized for a rising TSB level (including 3 noted to be noncompliant with equipment use) and 10 were hospitalized for reasons unrelated to hyperbilirubinemia.

In 403 infants, the TSB level rose between the first and second days of home phototherapy, but they were not hospitalized. The TSB level at the time of referral was considered the TSB at the start of home phototherapy, and there was usually a lapse of several hours between the time of the TSB blood draw and the time of treatment initiation. Thus, the TSB level at the start of home phototherapy may have been higher than the referral TSB level, which may explain in part the rise in TSB between the first and second days of home phototherapy. Another possible factor is that the TSB level was rising faster than the rate of decline with home phototherapy.

The majority of infants started home phototherapy with a TSB level below the AAP phototherapy threshold, which is perhaps not surprising given that home phototherapy is mentioned as an option in the AAP guideline only for infants with a TSB level 2-3 mg/dL below the treatment threshold.[6] Though infants who started home phototherapy at or above the treatment threshold were more likely to be hospitalized, possibly because there was greater urgency to bring down their TSB level, the percentage of infants hospitalized was still <5%.

The AAP guideline states that home phototherapy should not be used in infants with isoimmune hemolytic disease.[6] In our cohort, approximately 3% of the infants who were DAT-positive required hospitalization for inpatient phototherapy, and 5.7% required hospitalization or repeat home phototherapy. A positive DAT test was not a risk factor for either outcome. There is, however, a wide spectrum of disease severity with ABO hemolytic disease,[13] and it is unlikely that the infants who were DAT-positive in our cohort had severe hemolysis, which often presents by 24-48 hours of age with a rapid TSB rise.[14] A positive DAT is also not always associated with hemolytic disease.[15] In addition, our statistical power was limited due to the modest number of infants who were DAT-positive and the overall low rate of hospitalization and repeated home phototherapy in this cohort. For infants with DAT positivity who do not have significant hemolysis, home phototherapy may still be a treatment option for hyperbilirubinemia.

Approximately 8% of infants were noted to have received hospital-based phototherapy before home phototherapy, which was not a risk factor for hospitalization alone or for hospitalization and/or repeat home phototherapy. This may be because the infants who had previous inpatient phototherapy started home treatment at a mean age of nearly 5 days old, when the physiologic rise in neonatal TSB levels slows.[12] Unfortunately, we do not know exactly which infants were discharged from inpatient phototherapy to continue treatment at home and which infants received home phototherapy for rebound hyperbilirubinemia after inpatient phototherapy. Our limited data suggest that home phototherapy could be an option in either scenario. Further studies are needed to assess the use of home phototherapy in these situations, especially for infants who are discharged from inpatient phototherapy to continue treatment at home.

The median duration of home phototherapy was 53 hours (IQR, 44-72 hours), and infants who started home treatment at <96 hours of age were more likely to have a longer course. This is longer than the average length of stay of 1.4 days (which is likely longer than the actual duration of phototherapy) for inpatient hyperbilirubinemia admissions according to 2014 Healthcare Cost and Utilization Projection data.[16] This is likely in part because the rate of TSB decline on home phototherapy was slower than that reported during inpatient phototherapy (up to 0.27 ± 0.25 mg/dL/hour [4.62 ± 4.28 μmol/L/hour] using fluorescent lights).[17] Although the equipment used by this cohort met the AAP recommendation for intensive phototherapy,[6] infants in the hospital setting often receive double or triple phototherapy that provides a higher light irradiance and faster TSB decline.[18-20] In addition, the amount of time that infants spend out of phototherapy lights cannot be as closely monitored in the home.

Despite the longer service time, the charges for home phototherapy were still significantly lower than those for inpatient phototherapy. The mean hospital charges for inpatient phototherapy in 2014 were almost $6000 in Washington state,[16] nearly 3-fold higher than the average home phototherapy charges for newborns in this study. Of course, charges do not equate to actual costs (reported mean ranging from approximately $2100 to $4400 for an inpatient phototherapy admission),[16,21] and whether home phototherapy is cost-effective warrants further research.

This study has several limitations and possible biases. First, the study cohort consisted of infants who clinicians felt comfortable treating with home phototherapy and were less likely to be at high risk for severe hyperbilirubinemia or have high rates of rise in their TSB levels. It is also likely that clinicians trusted these families to follow a home treatment plan. The home phototherapy company declined service to a small percentage of infants deemed to be high risk. Not all Medicaid insurance plans were accepted by the company. Finally, 90% of the infants in the cohort were breastfed, which is reflective of the Washington state breastfeeding rate, but slightly higher than the US average of 83%.[22] Breastfeeding jaundice or breast milk jaundice may have been common etiologies for the hyperbilirubinemia in this cohort, and this may not be the case in a different cohort with a lower breastfeeding rate.

Our results might not be generalizable to home phototherapy programs that do not include comprehensive in-home support or those that use different equipment, such as LED phototherapy blankets that have higher irradiance. Finally, approximately 25% of the patients were not ordered to have a post-treatment TSB, and we do not know the outcomes of most patients beyond 24 hours after home phototherapy termination, when rebound hyperbilirubinemia could have occurred, which should be examined in future studies. Although the results of this study are not generalizable to the entire population of newborn infants with hyperbilirubinemia, our findings may help inform clinicians who might be good candidates for home treatment and what might be expected in a treatment course. A matched comparison between newborns treated with home vs hospital-based phototherapy should be considered in future studies, as well as further assessment of the efficacy and cost-effectiveness of home phototherapy. ■

We thank Infant Home Phototherapy, Inc for allowing us access to their data, and Dr James Taylor for his invaluable guidance and critical reviews of the manuscript. J.T. is a cofounder and employee of BiliCam, LLC, a company developing a noninvasive method to assess neonatal jaundice.

Submitted for publication Aug 16, 2019; last revision received Dec 3, 2019; accepted Jan 3, 2020.

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Data Statement

Data sharing statement available at www.jpeds.com.

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