RESEARCH ARTICLE

Phototherapy for Neonatal Unconjugated Hyperbilirubinemia: Examining Outcomes by Level of Care

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ABSTRACT

OBJECTIVES: Newborns hospitalized with unconjugated hyperbilirubinemia without critical comorbidities may receive intensive phototherapy (IP) in non-ICU levels of care, such as a mother-newborn unit, or ICU levels of care. Our aim was to compare outcomes between each level.

METHODS: Using hospital discharge data from 2005 to 2011 in New York's State Inpatient Database, we performed multivariate analyses to compare outcomes that included total cost of hospitalization, length of stay, 30-day readmission rate after IP, and the number of cases of death, exchange transfusion, and γ globulin infusion. We included term newborns treated with IP in their first 30 days of life and without diagnosis codes for other critical illnesses. Explanatory variables included level of care, sex, race, insurance type, presence or absence of hemolysis, hospital, volume of IP performed at each hospital, and year of hospitalization.

RESULTS: Ninety-nine percent of IP was delivered in non-ICU levels of care. Incidence of major complications was rare (≤0.1%). After adjusting for confounders, ICU level of care was not associated with difference in length of stay (relative risk: 1.2; 95% confidence interval [CI]: 0.91 to 1.15) or 30-day readmission rate (odds ratio: 0.74; 95% CI: 0.50 to 1.09) but was associated with 1.51 (95% CI: 1.47 to 1.56) times higher costs.

CONCLUSIONS: For otherwise healthy term newborns with jaundice requiring IP, most received treatment in a non-ICU level of care, and those in intensive care had no difference in outcomes but incurred higher costs. IP guideline authors may want to be more prescriptive about IP level of care to improve value.

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An estimated 4 million live births occur in the United States per year.[1] In studies that include hundreds of thousands of patients between 1988 and 2011 from hospitals across the United States, authors report that 2.4% to 15.9% of newborns per year received intensive phototherapy (IP) for hyperbilirubinemia, with rates increasing over this time period.[2–6] In the American Academy of Pediatrics (AAP) policy statement on how to manage hyperbilirubinemia, there is no mention of what level of acuity to deliver IP in (eg, ward, mother-newborn unit, NICU), except in the case of severe hyperbilirubinemia, when bilirubin levels near thresholds for exchange transfusion or are expected to near these thresholds because of a rapid rate of rise.[7,8] Widespread use of IP in accordance with standards provided in the policy statement has made exchange transfusion for the prevention of bilirubin encephalopathy uncommon.[5,9,10] Although AAP guidelines do not recommend non-ICU versus ICU care except in the aforementioned circumstances, whether care is rendered in an ICU is relevant to health care costs, mother-newborn separation, and potential exposures to ICU pathogens. Thus, lack of guidance on the need for critical care for IP may increase resource use and care variation, which are both examples of low-value care.

Currently, hospitalized newborns with elevated unconjugated bilirubin levels receive IP either in a mother-newborn unit (also known as a level 1 nursery), on a pediatric ward, in a NICU (also known as a level 2, 3, or 4 nursery), or in a PICU.[11] Late-preterm and term newborns with unconjugated hyperbilirubinemia in need of IP without other clinical problems may receive IP in any of the listed levels of care, depending on factors such as the hospital in which they receive care, gestational age, or whether the newborn has been discharged after the initial birth hospitalization.

There are no available studies in which researchers compare outcomes between levels of care for IP while accounting for other factors. Thus, our aim in this study is to describe and compare outcomes associated with non-ICU versus ICU levels of care for hospitalized newborns with a diagnosis of unconjugated hyperbilirubinemia and no critical comorbidities who receive IP. We hypothesized that for this subset of newborns, apart from hospitalization cost, outcomes would not differ between newborns treated with IP in non-ICU versus ICU levels of care.

METHODS

In this study, we used the New York State Inpatient Database (SID) 2005–2011 provided by the Healthcare Cost and Utilization Project (HCUP). This database contains nearly all inpatient discharges from all hospitals in the state. The SID provides data at the discharge-level for patient demographics, procedures performed during hospitalization, discharge diagnoses, length of stay (LOS) (only available in days, not hours), and both total and individual item hospital charges.

The sample included term newborns (those born at 37 weeks, 0 days to 40 weeks, 6 days after the mother's last menstrual period) who underwent phototherapy within the first 30 days of life. In our data set, term newborns were denoted with the *International Classification of Diseases, Ninth Revision* code 765.29. We separated newborns into non-ICU or ICU level of care on the basis of UB-04 revenue codes. We placed newborns in the non-ICU level for codes 0113 (ward), 0123 (ward), 0154 (ward), 0170 (nursery), or 0171 (newborn level I). Codes 0172 (newborn level II), 0173 (newborn level III), 0174 (newborn level IV), and 0203 (PICU) indicated an ICU level. We excluded cases from the sample if their record did not report codes to indicate level of care. Infants with both non-ICU and ICU codes were placed in the ICU group for the analysis. We thought that without another reason for ICU admission, there should be no clinical reason to receive ICU level of care for hyperbilirubinemia (apart from hemolysis, which we controlled for). If these patients nevertheless were admitted to the ICU, we felt we should exclude them from the non-ICU group.

Patients with other diagnoses were generally excluded from the study to minimize confounding by indication, unless their other diagnoses were not comorbidities requiring critical care. Patients with a diagnosis code that included "hemolysis" were included.

The outcomes of interest included the total cost, LOS, 30-day readmission rate after IP, level of care placement, number of deaths, and γ globulin infusion. Covariates used in the study include sex, race or ethnicity, insurance type, diagnosis of hemolysis, quartiles of hospital volume (in terms of cases of IP performed), and calendar year.

Researchers conducting analyses in the study examined predictors of level of care and their implications on cost, LOS, and 30-day readmission. Hierarchical multivariable linear regression was performed on the outcome of log-transformed total cost. Multivariable negative binomial regression was performed on the outcome of LOS. To perform sensitivity analysis of our initial results, propensity score matching was also used to study the outcomes of LOS, cost, and rate of 30-day readmission between levels of care. All analyses were performed using Stata 14.2 software (Stata Corp, College Station, TX). The Los Angeles Biomedical Research Institute Institutional Review Board exempted this investigation from review. Additional details can be found in the Supplemental Information.

The data set included 1 939 745 newborns <30 days old. Of those, 136 700 (7.0%) had discharges with codes for IP (Fig 1). After excluding those with critical comorbidities, missing linking variables, second or additional cases of IP for the same patient (which are included in the analysis under readmissions), and discharges without a listed level of care, 94 626 hospital discharges remained. Of the 1256 patients in the ICU level of care, 610 (nearly half) had both non-ICU and ICU levels of care coded within the same hospital discharge.

RESULTS

In Table 1, we show demographic information about our study population. Ninety-nine percent of IP was delivered in a non-ICU level of care. Our sample included 50.2% girls and 49.8% boys; 51 830 white, 14 709 Hispanic, 9218 other, 8858 African American, and 5658 Asian American infants; patients with private, public, and no insurance; and ~5% carried a diagnosis of

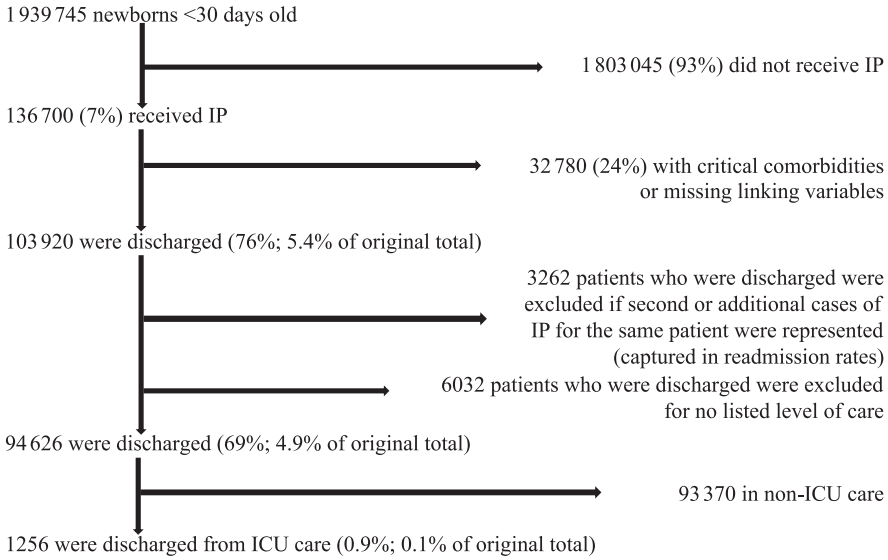

FIGURE 1 Flowchart of study cases.

TABLE 1 Study Population, $N = 94\,626$

Level of Care	*n* (%)
Ward or newborn level 1, non-ICU	93 370 (98.7)
NICU level 2–4 or PICU	1256 (1.3)
Sex	
Girls	47 521 (50.2)
Boys	47 105 (49.8)
Race	
White	51 830 (57.4)
Hispanic	14 709 (16.3)
Other	9218 (10.2)
African American	8858 (9.8)
Asian American	5658 (6.3)
Insurance	
Private	50 974 (53.9)
Medicaid	35 596 (37.6)
Self-pay	5236 (5.5)
Other	2789 (3.0)
Hemolysis	
No hemolysis	89 609 (94.7)
Hemolysis	5017 (5.3)
Higher acuity treatments	
γ globulin	51 (0.1)
Exchange transfusion	26 (0.0)
Serious complications	
Deaths	≤10 (0.0)
Kernicterus	≤10 (0.0)

hemolysis. Serious complication rates were rare but not absent (≤0.1%). Of note, HCUP has a mandatory prohibition of reporting numerical results with ≤10 patients.

In the unadjusted analysis, ICU level of care was associated with a 0.15-day longer LOS ($P < .01$; Table 2), but this difference became nonsignificant after adjusting for confounders (Table 3). ICU level of care was associated with $712 ($P < .01$) in additional cost (not including physician labor cost), a difference that remained statistically significant after adjusting for confounders (Table 3). Thirty-day readmission rates of ∼3% in both groups were not significantly different (Table 2), even after adjusting for confounders (Table 3; odds ratio [OR] for ICU versus non-ICU level of care = 0.74 [0.50–1.09]).

Apart from the expected finding that newborns with hemolysis were more likely to go to the ICU, the explanatory variable associated with the greatest impact on IP rates was the volume of IP performed at each hospital. To put the impact in absolute terms, if a reference hospital (highest IP volume) had a NICU admission rate for IP of 1.3%, those hospitals in the lowest quartile of IP volume would have had NICU admission rates of 4.0% ($P < .01$) or 1 additional ICU admission for every 37 IPs rendered. Lowest-volume hospitals were also 11% ($P < .01$) costlier than the highest-volume hospitals.

Additional noteworthy findings in Table 3 include the following: girls had a shorter LOS ($P < .01$), lower cost ($P < .01$), lower readmission rate ($P < .05$), and lower chance of IP in the ICU ($P < .05$). Racial disparities were largest in magnitude in African American infants in relation to white infants. African American infants had a longer LOS ($P < .01$), higher costs ($P < .01$), and lower likelihood of 30-day readmission rates ($P < .05$) but statistically were still not more likely to be treated in the ICU level of care.

Insurance status was not associated with statistical differences in level of care. Medicaid and "self-pay" patients (ie, uninsured) had slightly shorter LOS ($P < .01$) and slightly lower costs, but Medicaid patients and those with "other" insurance were slightly more likely ($P < .01$) to be readmitted over the subsequent 30 days.

Newborns with hemolysis were more likely to experience a longer LOS, incur higher cost, and have a higher chance of receiving IP in the ICU ($P < .01$). Trends noted over the study period included the following: LOS decreased modestly; cost increased more sharply; and odds of 30-day readmission decreased modestly, whereas odds of going into ICU level of care did not display a discernible pattern. When researchers conducted sensitivity analysis, using propensity score matching did not change the major outcomes or statistical significance of findings (Table 4).

DISCUSSION

To the authors' knowledge, this is the first published report in which researchers have analyzed IP outcomes associated with levels of care for otherwise healthy term newborns. The vast majority (99%) of these patients received IP in non-ICU levels of care, and receiving IP in an ICU level of care was associated with increased costs but not increased LOS or 30-day readmission rate. With these results, it is suggested that most of New York's providers and administrators considered IP safe to render in non-ICU levels. Although we included data from only 1 state, New York is large and

TABLE 2 Bivariate Analyses by Level of Care

Variable	Ward or Newborn Level 1	NICU Level 2–4 or PICU	*P*
Patients	93 370	1256	
LOS, d, mean (SD)	2.69 (1.05)	2.84 (1.43)	< .001
Cost, US$, mean (SD)	1566 (1465)	2278 (2551)	< .001
30-d readmissions rate, *n* (%)	2901 (3.1)	37 (3.0)	.99
Girls, *n* (%)	46 937 (50.3)	584 (46.5)	.007
Race, *n* (%)			< .001
White	51 096 (57.4)	734 (60.3)	
African American	8610 (9.7)	248 (20.4)	
Hispanic	14 622 (16.4)	87 (7.2)	
Asian American	5614 (6.3)	44 (3.6)	
Other	9144 (10.2)	104 (8.6)	
Insurance, *n* (%)			< .001
Private	49 609 (54.2)	634 (50.6)	
Medicaid	34 301 (37.5)	478 (38.1)	
Self-pay	4889 (5.3)	65 (5.2)	
Other	2683 (2.9)	75 (6.0)	
Hemolysis	4721 (5.1)	296 (23.6)	< .001
Year, *n* (%)			< .001
2005	14 477 (15.5)	222 (17.7)	
2006	14 407 (15.4)	241 (19.2)	
2007	13 615 (14.6)	181 (14.4)	
2008	13 208 (14.2)	188 (15.0)	
2009	14 035 (15.0)	168 (13.4)	
2010	12 614 (13.5)	134 (10.7)	
2011	11 014 (11.8)	122 (9.7)	

heterogeneous, with infants of many ethnicities, insurance categories, income levels, and types of hospitals and thus at least gives us the first point estimate for this phenomenon in the literature. Currently, we are not aware of any other publications in which authors document the frequency at which term newborns with no other critical comorbidities receive IP in an ICU. The fact that it only occurred in 1.3% of the cases is reassuring, but this still equates to 1256 infants over the course of the study period in the state of New York. The extent to which this occurs in other geographic areas is unknown. Hospitals that commonly admit newborns who need IP to ICU level of care, regardless of the acuity of their other conditions, may want to reconsider this practice.

Aside from hemolysis, hospital IP volume is inversely associated with the largest difference in ICU admission. This may reflect either a lack of comfort with non–ICU-level IP at lower-volume hospitals or another factor about providers, administrators, or patients at these hospitals not measured here. In any case, although the relative difference was large, the absolute difference was small. Outcomes varied only slightly by race and more so for African Americans than other races. African American race was associated with longer LOS, higher costs, and lower odds of 30-day readmission.

Also of note, insurance status did not drive ICU admission rates. Perhaps sorting insurance by fee for service versus global payment instead of source of insurance would have provided different results, with financial incentives to hospitals favoring ICU level of care for fee for service and non-ICU level of care for global payment. This variable was not included in our analysis and would be difficult to study given the difficulty in ascertaining this information by year and carrier.

In further study, researchers could investigate the frequency of this practice, with more current and nationally representative data, or if the practice of delivering all IP in ICU level of care is associated with fee-for-service reimbursement.

High-value care depends on safely minimizing care variation at the lowest cost. Those writing AAP guidelines may wish to include more prescriptive language about which level of care to deliver IP on the basis of our findings.[12–17] Additionally, although we cannot comment on the degree of mother-newborn separation that occurs in a non-ICU versus an ICU setting, it is not unreasonable to surmise that separation is more likely to occur for more hours of the day in ICU levels of care. Broadly speaking, safely minimizing mother-newborn separation is the crux of many current quality of newborn care efforts (from neonatal abstinence syndrome[18] to neonatal sepsis evaluation and management[19]), and prescriptive IP AAP guidelines with respect to level of care would help keep more mothers and newborns together when appropriate.

In our data, we captured admissions only up through 2011, which may or may not represent North American practices since, but no new AAP IP guidelines have come out since 2004, so it is unlikely that practices have changed significantly. Because we relied on retrospective hospital discharges, we cannot argue that our findings are causal. We also cannot comment on the safety of non-ICU or ICU levels of care given the low frequency of exchange transfusion and death. We lack data on the impact of levels of care on patient satisfaction; breastfeeding initiation, exclusivity, and duration; and whether the hospital was certified as Baby-Friendly. In addition, we cannot comment on the frequency of diagnosis of glucose-6 phosphate dehydrogenase deficiency for reasons stated in the Supplemental Information, but hemolysis as a diagnostic category was included in our analysis.

The size of our data set should attenuate effects from random error, but systematic

TABLE 3 Multivariate Analysis

Variables	LOS	Cost	30-d Readmission Rate	NICU Level 2–4 or PICU
	Relative Risk (95% CI)	Relative Cost (95% CI)	OR (95% CI)	OR (95% CI)
NICU level 2–4 or PICU	1.02 (0.91 to 1.15)	1.51 (1.47 to 1.56)[a]	0.74 (0.50 to 1.09)	—
Girls	0.99 (0.98 to 0.99)[a]	0.92 (0.92 to 0.93)[a]	0.85 (0.73 to 0.99)[b]	0.81 (0.70 to 0.94)[a]
Race				
White (reference)	—	—	—	—
African American	1.12 (1.08 to 1.16)[a]	1.07 (1.06 to 1.08)[a]	0.85 (0.73 to 0.99)[b]	0.97 (0.70 to 1.22)
Hispanic	1.06 (1.03 to 1.08)[a]	1.01 (0.99 to 1.02)	0.99 (0.88 to 1.13)	1.11 (0.78 to 1.49)
Asian American	1.03 (0.99 to 1.07)	1.04 (1.03 to 1.05)[a]	1.11 (0.95 to 1.31)	1.24 (0.78 to 1.92)
Other	1.02 (0.97 to 1.07)	1.05 (1.04 to 1.07)[a]	1.04 (0.90 to 1.20)	0.95 (0.72 to 1.25)
Insurance				
Private (reference)	—	—	—	—
Medicaid	0.93 (0.92 to 0.95)[a]	0.97 (0.96 to 0.97)[a]	1.23 (1.12 to 1.35)[a]	1.00 (0.84 to 1.21)
Self-pay	0.90 (0.87 to 0.93)[a]	0.97 (0.96 to 0.99)[a]	1.14 (0.95 to 1.38)	1.02 (0.69 to 1.51)
Other[c]	0.97 (0.90 to 1.05)	0.99 (0.98 to 1.01)	1.34 (1.08 to 1.67)[a]	0.98 (0.71 to 1.36)
Hemolysis	1.24 (1.19 to 1.29)[a]	1.38 (1.37 to 1.40)[a]	1.07 (0.91 to 1.27)	3.43 (2.74 to 4.28)[a]
No. cases of IP performed per hospital per year				
Q1 (0–25th percentile)	0.96 (0.91 to 1.01)	1.11 (1.08 to 1.14)[a]	1.18 (0.92 to 1.52)	3.14 (1.98 to 4.97)[a]
Q2 (25–50th percentile)	0.98 (0.93 to 1.04)	1.05 (1.04 to 1.07)[a]	1.18 (0.99 to 1.42)	2.46 (1.69 to 3.58)[a]
Q3 (50–75th percentile)	0.99 (0.96 to 1.02)	1.04 (1.02 to 1.05)[a]	1.02 (0.88 to 1.18)	1.54 (1.15 to 2.05)[a]
Q4 (75–100th percentile; reference)	—	—	—	—
Year				
2005 (reference)	—	—	—	—
2006	0.98 (0.97 to 1.00)	0.97 (0.96 to 0.98)[a]	0.86 (0.75 to 0.99)[b]	1.30 (1.02 to 1.66)[b]
2007	0.97 (0.96 to 0.99)[a]	0.99 (0.98 to 1.00)	0.84 (0.73 to 0.97)[b]	0.89 (0.67 to 1.18)
2008	0.97 (0.95 to 0.99)[b]	0.98 (0.97 to 0.99)[a]	0.89 (0.78 to 1.03)	1.38 (1.06 to 1.79)[b]
2009	0.97 (0.95 to 0.99)[a]	1.00 (0.99 to 1.01)	0.96 (0.84 to 1.09)	1.04 (0.79 to 1.38)
2010	0.95 (0.93 to 0.97)[a]	1.05 (1.03 to 1.06)[a]	0.84 (0.73 to 0.97)[b]	0.94 (0.69 to 1.26)
2011	0.94 (0.91 to 0.96)[a]	1.12 (1.11 to 1.14)[a]	0.79 (0.68 to 0.92)[a]	0.81 (0.58 to 1.12)

Includes all variables in the table. Q1, first quartile; Q2, second quartile; Q3, third quartile; Q4, fourth quartile; —, not applicable.
[a] $P < .01$.
[b] $P < .05$.
[c] Includes insurance through workers' compensation, the US Department of Veterans Affairs, and other government insurance and insurance provided to New York federal, state, and local corrections officers.

coding errors may still bias our findings. However, some findings from these data, suggest that our findings are valid: 7% of newborns in our sample received IP, which falls in the middle of the range cited in the introduction (2.4%–15.9%); the frequency of IP admissions does not differ drastically from year to year; newborns with hemolysis have longer LOS and higher cost; and

TABLE 4 Propensity Score Matching to Estimate the Effect of NICU Levels 2 Through 4 or PICU Compared With Newborn Level 1 or Ward

	LOS, d	Cost, Adjusted 2010 US $	Probability of 30-d Readmission
Estimated difference from propensity score matching	0.11 (−0.02 to 0.26)[a]	506 (325 to 688)[a,b]	.00 (−0.02 to 0.02)[a]
Multivariable regression coefficients	1.02 (0.91 to 1.15)[a]	1.51 (1.47 to 1.56)[a,b]	.74 (0.50 to 1.09)[a]
Estimated difference from multivariable regression models	0.03	602[b]	−.01

From propensity score matching, one assumes an increase of 0.11 d in LOS for NICU. Instead, researchers used a model to predict a 0.03-d greater LOS in the NICU. In cost, one assumes an increase of $506 on the basis of propensity scores, whereas in the model, we instead expect $602. The difference in probability of revisit is almost identical between the 2 methods. With the possible exception of cost, there does not seem to be a practical difference between findings from the 2 different statistical methods, and there seem to be no statistically significant differences.
[a] Values in parentheses in data cells are 95% confidence intervals of point estimates.
[b] $P < .01$.

exchange transfusion and receipt of γ globulin are exceedingly rare.

Another limitation of our study is confounding by indication, as with all retrospective observational studies. We attempted to control for this by including only infants with a limited menu of diagnostic codes, but these are assigned retrospectively, whereas clinicians make level-of-care decisions prospectively. In terms of our cost outcomes, including newborns who had both ICU and non-ICU admission codes in the group requiring ICU care may deflate cost findings in the ICU group because a hospitalization that mixes ICU and non-ICU admission is likely cheaper than a pure ICU hospitalization when other factors are held constant.

Knowing LOS in hours, as opposed to days, would allow for more precise findings. A newborn discharged early in the morning versus at the end of the evening would still register as the same LOS in our data. Unfortunately, HCUP did not provide LOS in hours.

When controlling for insurance status, we found that shorter LOS was associated with a higher 30-day readmission rate. We did not construct our model to assess interactions between insurance status and LOS and whether these interactions would be associated with any changes in 30-day readmission rates. What we can say is that 30-day readmission rates did not differ by whether the patient received IP in an ICU.

CONCLUSIONS

For noncritically ill term newborns in the state of New York with unconjugated hyperbilirubinemia from 2005 to 2012, most hospitals delivered IP in non-ICU levels of care. These patients did not have significantly different LOS or odds of being readmitted to the hospital over the subsequent 30 days than those in an ICU level of care, but the ICU level was associated with higher cost. Authors of AAP guidelines may wish to include specific recommendations on which level of care to deliver IP to reduce newborn care variation and deliver care of higher value.

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