BMJ Open Quality

Increasing utilisation of a rebound hyperbilirubinaemia calculator in two newborn nurseries

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To cite: Germana S, Shaikh SK. Increasing utilisation of a rebound hyperbilirubinaemia calculator in two newborn nurseries. *BMJ Open Quality* 2023;**12**:e002141. doi:10.1136/bmjoq-2022-002141

Received 3 October 2022
Accepted 22 June 2023

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ABSTRACT

Neonatal hyperbilirubinaemia requiring phototherapy treatment is a common problem impacting the length of hospital stay and rates of hospital readmission. Previous guidelines included guidance for initiating phototherapy treatment but not for discontinuing phototherapy treatment during initial newborn admission.

In response to dissatisfaction from trainees, staff and families regarding the variable approach to discontinuing phototherapy among attending nursery providers, we used quality improvement methodologies to increase utilisation of a rebound hyperbilirubinaemia calculator as a more consistent method for guiding the timing of phototherapy discontinuation. The aim was to increase utilisation of the rebound hyperbilirubinaemia calculator for newborns treated with phototherapy in two newborn nurseries to >90% within 2 years.

Sequential interventions focused on increasing provider awareness of the rebound hyperbilirubinaemia calculator and making the calculator simple to access and use.

At the university medical centre nursery, the use of the calculator increased from 8.7% to 100%, exceeding the project goal. In the community hospital nursery, there was a statistically significant increase in the rate of utilisation from 3.7% to 79.4%, but this fell slightly below the goal of >90%.

Electronic Health Record integration, along with education and addition of prompts to providers, increased utilisation of a rebound hyperbilirubinaemia calculator as a consistent approach for guiding decisions about discontinuing phototherapy treatment in newborns.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Quality improvement (QI) approaches can be used to improve the management of neonatal hyperbilirubinaemia and increase compliance with management guidelines.

WHAT THIS STUDY ADDS

⇒ A QI project that included the integration of a rebound hyperbilirubinaemia calculator into the Electronic Health Record (EHR) sustainably increased the use of the calculator as a more consistent strategy for guiding discontinuation of phototherapy in both a university medical centre with trainees and in a community hospital nursery setting.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ As institutions modify their hyperbilirubinaemia management protocols to reflect the 2022 American Academy of Pediatrics updates to the management of hyperbilirubinaemia guidelines, they may consider using lessons from this project, including the integration of tools into the EHR, to increase adherence and consistency of provider approach.

PROBLEM

Hyperbilirubinaemia is a frequent problem, affecting 60%–80% of newborns in the first week of life. Approximately 4%–9% of newborns are treated with phototherapy in the newborn nursery.[1 2] Need for phototherapy treatment impacts the length of hospital stay and is a common cause of readmission in newborns in the first week of life. The 2004 guidelines from the American Academy of Pediatrics (AAP) and 2009 commentary provided detailed guidance about thresholds for starting phototherapy based on gestational age and other risk factors.[3 4] These guidelines also included a statement that phototherapy could be discontinued when the serum bilirubin level falls below 13–14 mg/dL in a newborn readmitted for phototherapy but included no guidance about criteria for discontinuing phototherapy during the initial birth hospitalisation.[3] A 1991 review by Tan recommended stopping phototherapy treatment following two consecutive bilirubin levels <11 mg/dL.[5] Guidelines by the National Institute for Healthcare and Excellence in the UK include stopping phototherapy when the bilirubin level is 50 µmol/L (~3 mg/dL) below the treatment threshold.[6] More recently, two models were developed by Chang *et al* to predict the risk of rebound hyperbilirubinaemia within 72 hours of discontinuation of phototherapy treatment and, therefore, to guide decisions about the timing of phototherapy discontinuation. The original model, published in 2017, calculated the predicted risk of rebound hyperbilirubinaemia based on three variables: gestational age, age (in

days) at the initiation of phototherapy and the difference between the AAP phototherapy treatment threshold and the serum bilirubin at the time of phototherapy discontinuation.[7] A simplified model in 2019 included two variables: gestational age and the difference between the AAP phototherapy threshold at phototherapy initiation and the serum bilirubin at phototherapy discontinuation.[8] Prior to this project, there were no consistent criteria for discontinuation of phototherapy used by nursery providers in our health system, and trainees and nursing staff expressed frustration about this lack of consistency. Newborns being treated with phototherapy may be cared for on consecutive days by attending providers using different approaches, which was confusing not only for trainees and staff but also for families.

This quality improvement (QI) project sought to quantify baseline utilisation of the three-variable rebound hyperbilirubinaemia calculator in two newborn nurseries following its publication in 2017. It was hypothesised that the lack of utilisation of the calculator may be due to a lack of familiarity with its use as well as concern for time required or risk for error based on the complexity of the calculation. This project focused on newborn infants of ≥35 weeks gestation treated with phototherapy prior to discharge from two newborn nurseries in Durham, North Carolina, USA. One newborn nursery is located in a university medical centre and is staffed by paediatric primary care faculty and residents from the paediatric, internal medicine-paediatric and family medicine programmes. The second nursery is located in a community hospital and is staffed by paediatric primary care faculty and outpatient providers from community paediatric and family medicine practices. The goal of the project was to increase utilisation of the three-variable rebound hyperbilirubinaemia calculator in these nurseries as a consistent method for guiding phototherapy discontinuation without adversely affecting the length of stay or rate of hospital readmission.

We aimed to increase the rate of utilisation of the rebound hyperbilirubinaemia calculator in newborns treated with phototherapy prior to discharge from two newborn nurseries to >90% within a 2-year period. Our balancing measures included the length of hospital stay and total hospital days per infant, rate of readmission for rebound hyperbilirubinaemia and level of burden reported by resident physicians.

BACKGROUND

Neonatal hyperbilirubinaemia is a common problem even in otherwise healthy newborns due to relatively high haemoglobin levels, short red blood cell half-life and liver immaturity. Additional factors, such as quality of feeding, ethnicity, presence of bruising or cephalohematoma, preterm or early term gestation, and hemolysis from blood type incompatibility or other causes may further increase the risk of hyperbilirubinaemia in newborns. High levels of bilirubin place infants at risk of acute and chronic bilirubin encephalopathy.[3] Phototherapy is the standard of care treatment for unconjugated neonatal hyperbilirubinaemia but often requires 24 hours or more to be effective. Therefore, in the newborn nursery, where the length of routine newborn admission is most typically between 24 and 96 hours, the treatment of hyperbilirubinaemia may have a large relative impact on the length of stay. It is desirable to minimise the duration of phototherapy treatment to prevent disruption of breast feeding and bonding, to decrease potential risks related to phototherapy treatment and to decrease costs associated with prolonged hospital stay. The COVID-19 pandemic has added to many family's desire to minimise the length of hospital stay, as parents are struggling more with childcare and separation from other children due to hospital visitation policies. However, premature discontinuation of phototherapy treatment can lead to rebound hyperbilirubinaemia requiring hospital readmission and the associated costs and burden to the family. Bilirubin levels typically peak at 3–7 days of life, so there is a risk of bilirubin levels rebounding to treatment thresholds following phototherapy treatment if peak levels have not yet been reached at the time that phototherapy is discontinued.

A three-variable model was published by Chang *et al* in 2017 to guide decisions about the timing of discontinuation of phototherapy by predicting the risk of rebound hyperbilirubinaemia.[7] This model was developed using data from 16 Kaiser Permanente Northern California hospitals to predict the risk of rebound hyperbilirubinaemia, defined as bilirubin levels that return to the AAP threshold for phototherapy treatment within 72 hours of discontinuation of phototherapy. The formula to calculate a predicted rebound risk score using this model is:

Score=15 (if gestational age <38 weeks)−7×(age in days at phototherapy initiation)−4×(AAP phototherapy threshold−TsB at phototherapy termination)+50.

The paper describing the development of this calculator reports the scores that correspond to a 4% and 10% risk of rebound hyperbilirubinaemia in their cohort. However, a complex calculation involving exponents is required to convert other scores to a predicted rebound risk.

Other QI projects to improve the management of hyperbilirubinaemia have been described in the literature. For example, Tartaglia *et al* demonstrated increased compliance with AAP guidelines for the management of neonatal hyperbilirubinaemia by increasing awareness of published guidelines.[9] Hunt *et al* demonstrated decreased readmission rates for hyperbilirubinaemia by implementing a hyperbilirubinaemia management guide.[10] Improvement in the management of hyperbilirubinaemia is amenable to a QI approach.

Other studies have specifically evaluated the use of web-based tools and Electronic Health Record (EHR) integration in the management of hyperbilirubinaemia. BiliTool is a website developed by Burgos and Turner to translate the AAP guidelines for the management of neonatal

hyperbilirubinaemia into a web-based tool.[11] Longhurst *et al* studied the use of the BiliTool website and concluded that web-based clinical decision support tools may increase the use of clinical guidelines.[12] However, transcribing data into an external website is inefficient and is vulnerable to a transcription error. Petersen *et al* evaluated the integration of neonatal hyperbilirubinaemia risk assessment into the EHR and concluded that EHR integration may decrease errors and further increase adherence to guidelines.[13] These publications demonstrate that web-based clinical decision support tools alone can increase adherence to guidelines but that integration of these tools into the EHR may have an additional benefit. A web-based version of Chang *et al*'s three-variable calculator to predict the risk of rebound hyperbilirubinaemia was developed by Knitter to increase the speed and accuracy of the calculation, but this calculator was not previously integrated into our EHR.[14]

Measurement

Baseline rates of utilisation of the rebound hyperbilirubinaemia calculator in two newborn nurseries were obtained from the EHR for a 2-year period (January 2018 to December 2019). Discharge summaries were reviewed for newborns ≥35 weeks gestation treated with phototherapy prior to discharge. Newborns were excluded if they were born at <35 weeks gestation or if they were discharged from the intensive care nursery or general paediatrics ward.

At baseline, the rate of utilisation was defined as the percentage of newborns treated with phototherapy prior to discharge from the nursery who had use of the rebound hyperbilirubinaemia calculator documented in the discharge summary. During the baseline period, 8.7% at a university medical centre nursery and 3.7% at a community hospital nursery had documented use of the rebound hyperbilirubinaemia calculator.

Following the build of the calculator in the EHR during this project, newborns were considered to have had the calculator used if there was either documentation of calculator use in the discharge summary or documentation within the fields of the newly built calculator tool. Length of stay and hospital readmission data were obtained from the EHR. Total hospital days per patient were calculated as a sum of the length of the initial hospital stay and the length of stay during hospital readmission for hyperbilirubinaemia, when applicable. Data were analysed using Statistical Process Control charts. Percentage use of the rebound hyperbilirubinaemia calculator and readmission rates were examined using p charts, and the average length of stay and average total hospital days were analysed using X-MR charts. Resident physicians were surveyed to assess their use of the calculator and their levels of perceived helpfulness and perceived burden.

Design

A QI project to increase utilisation of a rebound hyperbilirubinaemia calculator was conducted in two newborn nurseries in Durham, North Carolina, USA in an effort to encourage the use of more consistent criteria for discontinuing phototherapy. The university medical centre nursery has about 3400 deliveries/year and is staffed by paediatric primary care faculty precepting paediatric, medicine-paediatric and family medicine interns. The community hospital nursery has about 2400 deliveries/year and is staffed by paediatric primary care faculty, family medicine faculty and paediatricians from two community practices.

This project was developed in 2019 following the publication of the three-variable rebound hyperbilirubinaemia calculator in 2017. The project team included residents and attending providers from the two newborn nurseries. The goal of the QI project was to increase utilisation of the rebound hyperbilirubinaemia calculator to >90% over 2 years.

A key driver diagram was developed to identify potential interventions to improve awareness of the calculator and to address potential barriers to its use. We hypothesised that some providers may not be familiar with the use of the rebound hyperbilirubinaemia calculator or, if aware of the calculator, may avoid using it due to concern about time or risk for error in the calculation. Sequential interventions included building/integrating the calculator into the EHR, educating residents and attending nursery providers via email and staff meetings about its use, editing EHR note templates to include a prompt for the calculator, updating a resident guidebook to include information about the rebound calculator and reviewing data about calculator utilisation and recommended thresholds with providers at a journal club. The goal of the EHR build was to make the calculator easy and efficient to use. Subsequent interventions aimed to further increase and sustain calculator use by raising awareness and providing prompts for its use.

Patients and the public were not explicitly involved in the design, conduct, reporting, or dissemination plans for this project.

This project was reviewed by our institutional review board (IRB) and was exempt from IRB oversight. We used Statistical Process Control charts for analysis.

Strategy

This QI project aimed to increase utilisation of a rebound hyperbilirubinaemia calculator in two newborn nurseries in an effort to increase the consistency of phototherapy treatment practices. Interventions were designed with a goal of increasing utilisation of the rebound hyperbilirubinaemia calculator.

EHR integration of rebound hyperbilirubinaemia calculator (January 2020)

The project team worked with the information technology department to integrate the three-variable rebound hyperbilirubinaemia calculator into the EHR. The rebound hyperbilirubinaemia calculator gives a rebound risk score and predicted risk of rebound hyperbilirubinaemia based

on gestational age, the timing of initiation of phototherapy treatment and the difference between the AAP phototherapy treatment threshold and the serum bilirubin result at the time of phototherapy discontinuation. The team anticipated the use of the calculator would be more sustained if it was simple and quick to use. With this build, the provider is required only to enter the AAP phototherapy treatment threshold at the time of the most recent serum bilirubin result, and the calculator automatically pulls the other variables from the EHR and reports the rebound risk score and the predicted risk of rebound hyperbilirubinaemia.

Education of resident and attending nursery providers via email and staff meetings (April 2021)

Residents and paediatric attendings who work in the newborn nurseries received emails with detailed instructions and reminders to use the rebound hyperbilirubinaemia calculator, including information about recommended thresholds to use. This information was also reviewed with attending nursery providers at a quarterly staff meeting.

Addition of prompts to newborn nursery note templates and resident guidebook (July 2021—university medical centre nursery only)

Text was added to the newborn nursery note templates that included a statement about whether phototherapy treatment was required during the hospital course and, if so, a prompt to include the predicted risk of rebound hyperbilirubinaemia using the calculator. Following feedback provided by residents in a survey about the rebound calculator, information about the calculator and recommended thresholds for predicted risk were also included in annual updates to a resident guidebook. Note prompts and inclusion in the resident guide are expected to make the results more sustainable despite the annual turnover of residents working in the university medical centre nursery.

Review of recommendations and data with nursery and clinic providers at journal club presentation (October 2021)

General information about the rebound hyperbilirubinaemia calculator as well as specific data from our nurseries regarding utilisation of the calculator and the correlation of various risk thresholds and readmission rates were reviewed with both nursery and clinic providers at a journal club meeting.

RESULTS

In both newborn nurseries, we saw statistically significant increases in the use of the rebound hyperbilirubinaemia calculator but only met our project goal of >90% utilisation within 2 years in the university medical centre nursery. In the university medical centre nursery, the use of the calculator increased from a baseline percentage of 8.7% to 91.1% (meeting our project goal), and then had a second statistically significant improvement to 100% (figure 1A). This 100% use of the calculator was sustained for the 6 months that we continued to record data after the completion of the final intervention. The use of the calculator in the community hospital nursery increased from a baseline of 3.7% to 64.2% and then again to 79.4% (figure 1B), a significant increase falling slightly short of our project goal of 90% utilisation, but this improvement was also sustained for the 6 months of data collection following the final intervention.

42/75 (56%) residents responded to a survey about the use of the rebound hyperbilirubinaemia calculator. In response to a question 'How helpful is the rebound bili calculator in determining when to stop phototherapy? (0=not helpful, 10=extremely helpful)', the mean response was 7.81 (n=36, SD 1.75).

Balancing measures included the rate of readmission for rebound hyperbilirubinaemia and length of hospital stay. At the university medical centre nursery, there was a decrease in the rate of readmission, from a baseline of 5.64% to 4.31% (figure 2A). Although there was a small increase in the average length of initial hospital stay from a baseline of 3.14 to 3.47 days, there was no change in the

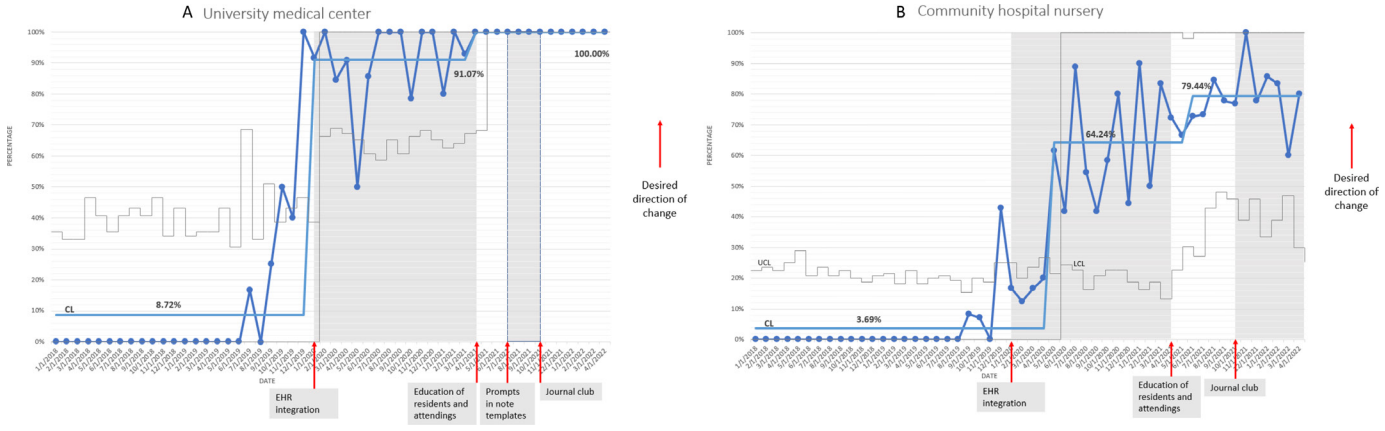

Figure 1 Rate of utilisation of rebound hyperbilirubinaemia calculator. (A) University medical centre and (B) community hospital nursery. EHR, Electronic Health Record.

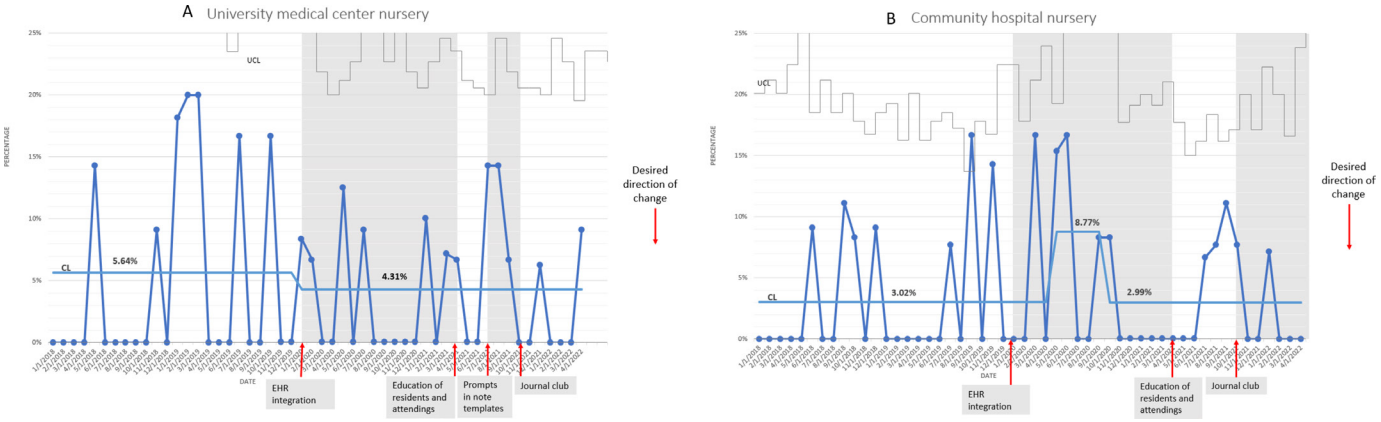

Figure 2 Rate of readmission for rebound hyperbilirubinaemia. (A) University medical centre nursery and (B) community hospital nursery. EHR, Electronic Health Record.

average total hospital days per patient (average 3.23 days). At the community hospital nursery there was a decrease in the rate of readmission from 3.02% to 2.99% following a brief interim increase to 8.77% (figure 2B) with no change in the average length of hospital stay (average 2.92 days).

A survey of residents included questions about perceived time and burden in using the calculator. In response to the question 'How time-consuming is using the rebound bili calculator (0 not time-consuming, 10 is extremely time-consuming)', the mean answer was 1.82 (n=33, SD 1.36). In response to the question 'Is using the rebound bili calculator burdensome in any way? (0 not burdensome, 10 is extremely time-burdensome)', the mean answer was 1.72 (n=25, SD 1.15). A section was included to allow for additional comments or suggestions, and this did not reveal any unintended consequences to the interventions that had occurred prior to the survey.

Lessons and limitations

In both nurseries, a statistically significant increase in rebound hyperbilirubinaemia calculator use was seen after integrating the calculator into the EHR, and another improvement was seen after additional education was provided about recommended use of the rebound calculator. Subsequent interventions aimed to improve sustainability. In both an academic and community nursery setting, we were able to produce results that were sustained for at least 6 months after the final intervention. This demonstrates that this project was amenable to a QI approach.

There was, however, a difference in the maximum rate of utilisation obtained in the two nurseries, with this rate meeting our goal in the university medical centre nursery but not in the community hospital nursery. The providers of the community hospital nursery do not consistently use shared note templates the way the university medical centre nursery providers do, so we were unable to add a prompt to all notes at the community hospital nursery. A large number of new providers began working in the community hospital nursery during the project, so there were many providers who did not receive the education intervention. Additionally, most of the providers at the community hospital nursery work primarily in the outpatient setting with only a small portion of their time in the newborn nursery, so they may have been less receptive to learn and adopt a new tool that they were only going to use a few times per year. This is in contrast to our university medical centre nursery, where the attending providers generally spend a significant portion of their clinical time in the nursery setting.

Although the educational sessions set the expectation that the rebound hyperbilirubinaemia calculator should be used to determine when to discontinue phototherapy within our nurseries, we attribute the sustained increase in use, in part, to the fact that the calculator was built into the EHR, making it readily available as well as quick and simple to use. This build made it easy for the providers to comply with the recommendation to use the calculator once they were aware of the expectation. Inclusion of prompts in note templates and information in the resident guidebook are expected to add to the sustainability in the university medical centre nursery, where there are new interns working in the nursery every 2–4 weeks.

We saw increased use of the calculator in each nursery before our first intervention. We attribute this to our creation of a hyperbilirubinaemia clinical pathway that included guidance on the use of the hyperbilirubinaemia rebound calculator, and this clinical pathway was disseminated within our department shortly before our first planned intervention. At the time, we had not intended the clinical pathway to be included as part of this QI project, but if we were to repeat this project, we would have planned the dissemination of the clinical pathway as a project intervention.

It is important to note that the use of the rebound hyperbilirubinaemia calculator is one available method for guiding decisions about phototherapy discontinuation, but other nurseries may use alternative methods for determining when to discontinue phototherapy. In addition, the AAP recently published a revised version of the

guideline for the management of hyperbilirubinaemia in infants of 35 or more weeks of gestation, which now includes some guidance for discontinuing phototherapy based loosely on the simplified two-variable rebound hyperbilirubinaemia calculator from 2019.[15] However, this project can be used as a generalisable demonstration of methods for increasing consistency of approach between providers in managing hyperbilirubinaemia in both university medical centre and community hospital settings rather than strictly an example of how to implement this tool. This consistency and predictability of approach are important to families, staff and trainees.

A limitation to this project is that the resident survey, designed as a balancing measure, was completed only once during the project duration, following the second intervention. It is possible that subsequent interventions caused unintended consequences that would not have been captured in the survey. Additionally, the resident survey was only completed at the university medical centre nursery, as no learners rotate at the community hospital nursery. If there was a difference in perceived burden by providers at the two nurseries, we would not have captured it. The survey included a question about whether they found the calculator helpful in making decisions about discontinuing phototherapy treatment but could have been improved by specifically asking about satisfaction with consistency of management, since feedback about inconsistency was an impetus for the project.

The project team included resident and attending providers because they were the users of the rebound calculator and so were felt to be the primary targets of any interventions. However, there was an unanticipated influx of new providers to the community hospital nursery during the course of the project. Given the higher continuity of nursing staff compared with providers in that nursery during this time period, inclusion of nursing staff in the project team and as targets of interventions may have further improved the consistency of utilisation of the calculator at that site. Inclusion of more community providers from the community hospital nursery in the project team or surveying of those providers may have also been beneficial given the differences in provider staffing of the two nurseries.

Another limitation is that this project took place during the COVID-19 pandemic. While we cannot fully discern what effects the pandemic had on our project, we do not expect it to account for changes seen in our data for length of stay or readmission for hyperbilirubinaemia. Anecdotally, we witnessed a trend of families asking for earlier discharge from the nursery during the outbreak, but there were also factors that may have increased the length of stay for some infants, such as maternal COVID-19 infection or lack of timely outpatient follow-up. The length of stay for infants being treated for hyperbilirubinaemia in our project did not change in one nursery and increased very slightly in the other, but we do not know how this compared with trends in length of stay for newborns without hyperbilirubinaemia during the same time period. Additionally, we were only able to capture readmissions that occurred in our health system or in one with a linked EHR. However, we have no reason to believe that rates of readmissions occurring at other institutions would have differed during our baseline period versus our intervention period.

CONCLUSION

We were able to use QI methodologies to increase the use of a rebound hyperbilirubinaemia calculator in newborns treated with phototherapy within both a university medical centre and a community hospital nursery setting. While we did not quite meet our goal of >90% use within a 2-year period in the community hospital nursery, we demonstrated statistically significant improvement in that setting and exceeded our goal in the university medical centre nursery. Both of these improvements were sustained for 6 months, which we attribute largely to the integration of the calculator into the EHR, making it quick and easy for providers to access and use the calculator. While we saw a small but statistically significant increase in the balancing measure of the length of stay at one nursery, the average total hospital days per patient remained unchanged, and readmission rates decreased at both nurseries. An important lesson from our project is that QI initiatives such as this can be used to promote standardisation of provider approach to hyperbilirubinaemia management within a nursery setting. A similar approach could be used to implement the changes in hyperbilirubinaemia management as recommended by the recent AAP guideline revision, to ensure that all providers within a nursery or institution are managing hyperbilirubinaemia in a consistent manner.

Acknowledgements The authors would like to acknowledge Amanda Zayek for her contribution to the design and implementation of the project.

Contributors SG and SKS participated in the conception and design of the project, data analysis and drafting of the manuscript. SG is guarantor and accepts responsibility for manuscript content.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This quality improvement project was reviewed by the Duke University Health System Institutional Review Board and was determined to be exempt from IRB oversight.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request.

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