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Clinical Decision Support for Hyperbilirubinemia Risk Assessment in the Electronic Health Record

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Abstract

Background: Physiologic neonatal hyperbilirubinemia (jaundice) is common and affects most newborn infants. However, there is a risk for permanent neurological damage if the bilirubin levels rise above a certain threshold. The management of neonatal jaundice includes the assessment of bilirubin laboratory values, consideration of patient-specific risk factors, and plotting on a bilirubin nomogram reference to determine risk and guide therapy. When performed manually, the process can be time consuming and error-prone. Therefore, web-based calculators such as BiliTool™ have been developed to assist in risk assessment.

Methods: To streamline the risk assessment calculation process further within our electronic health record (EHR), we created a "BiliReport" to display patient bilirubin-related data and automate transmission of deidentified patient data to the BiliTool™ website (https://bilitool.org). After implementation, we evaluated usage data, provider satisfaction, and accuracy of documentation.

Results: We demonstrated high provider use of the BiliReport and satisfaction with the workflow. We found a significant improvement in the accuracy of bilirubin risk level documentation, with a reduction in erroneous risk stratification from 4% (15/232) to 0.4% (1/243), $p<0.001$. We did not find significant a difference in erroneous documentation of the bilirubin lab value ($p = 0.07$).

Conclusions: Integrating the neonatal hyperbilirubinemia risk assessment process into the EHR may reduce errors and improve provider documentation and adherence to recommended guidelines.

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Keywords

Clinical decision support; neonatal hyperbilirubinemia; electronic health record

Background and Significance

Neonatal hyperbilirubinemia (jaundice) is common and affects up to 84% of infants born at greater than 35 weeks of gestation.[1] Most neonatal hyperbilirubinemia is physiologic and benign, but there are preventable and potentially severe complications of untreated pathologic hyperbilirubinemia, including chronic bilirubin encephalopathy (kernicterus) and subsequent permanent neurodevelopmental delay.[2] The American Academy of Pediatrics (AAP) guidelines for management of hyperbilirubinemia in the newborn infant of 35 weeks of gestation or more recommends specific monitoring of total bilirubin levels and consideration of risk factors (i.e. gestational age, post-natal age in hours, blood type, family history, and other medical problems) for pathologic hyperbilirubinemia in all neonates to prevent kernicterus.[3,4] The guideline utilizes multiple nomograms, including one to assess the risk of future hyperbilirubinemia and one to assess indication for treatment of pathologic hyperbilirubinemia with phototherapy or exchange transfusion.

Although neonatal hyperbilirubinemia risk has traditionally been assessed manually with printed nomograms and hand-plotted values, the digital age has led to the development of internet-based medical calculators, which have demonstrated increased usage and high ratings from medical providers.[5–7]

Although these tools automate the process of plotting on nomograms and evaluating risk categorization, they still require manual entry of the data inputs to an external tool, specifically the laboratory value (total bilirubin) and the patient age (in hours) at the time of sample collection. The manual calculation and plotting process is laborious and prone to errors, with potential risk for incorrect assessment of neonatal hyperbilirubinemia and downstream impact on clinical management.

Therefore, we sought to eliminate manual data transcription by transmitting data directly to the external hyperbilirubinemia risk assessment tool (BiliTool™) via a BiliReport data display created in our electronic health record (EHR). We chose BiliTool™, because their platform is familiar to many pediatric providers at our institution and allows direct submission of deidentified patient variables to the website through the EHR, which meets the standards of the Health Insurance Portability and Accountability Act (HIPAA). This process has been adopted by several institutions, including Cedars-Sinai Medical Center, Lucille Packard Children's Hospital Stanford, Seattle Children's Hospital, and C.S. Mott Children's Hospital at the University of Michigan.[8] However, there are no currently published outcomes regarding provider satisfaction or the impact on patient outcomes of this EHR-integrated process.

The goal of this study was to assess how integration of the neonatal hyperbilirubinemia risk assessment process into the EHR is perceived by providers and affects documentation in the medical record. We hypothesized that this automation complements user workflow with

meaningful uptake and satisfaction, decreases provider time required to evaluate neonatal hyperbilirubinemia, and reduces potential errors in neonatal hyperbilirubinemia risk assessment and documentation.

Materials and Methods

The BiliReport (Figure 1) was built in the UCLA EHR (Epic Systems) by adapting cache code from Cedars-Sinai Medical Center. Modifications of the code included mapping the correct laboratory identifiers within the system, updating to support local documentation workflow, and specifying null values to prevent erroneous data displays. The report displays the date and time the bilirubin lab was collected, the bilirubin result, and the age (in hours) of the neonate at the time the bilirubin was collected. The total bilirubin value is hyper-linked to BiliTool™, allowing direct transmission of these patient variables to the external website and where the appropriate patient-specific risk stratification and recommendations are displayed to the end-user (Figure 2). Prior to implementation, the code was reviewed by UCLA compliance officers, to ensure that no breach of patient protected health information (PHI) would occur.

Limitations were imposed on the BiliReport to ensure it is only available for applicable patient populations. The tool is disabled in infants born <35 weeks gestation and lab values collected outside of the 12–146 hour of life range, as the original hyperbilirubinemia nomograms and associated recommendations are not validated or applicable in these infants.[3]

The study outcomes were measured from January 2018 to May 2018 in the newborn nurseries at two locations: The University of California Los Angeles (UCLA) Ronald Reagan Medical Center and UCLA Santa Monica Hospital. These healthcare facilities represent approximately 3,400 births per year.[9] We excluded infants less than 35 weeks gestation and those discharged from the NICU. An Institutional Review Board waiver of consent was obtained for this study.

Pre- and post-intervention surveys were administered by email via SurveyMonkey® to all providers (n=129) who potentially calculate the neonatal hyperbilirubinemia risk and document the plan – neonatal nurse practitioners, pediatric resident physicians, neonatology fellows, pediatric hospitalists, and neonatologists at both hospitals. The pre-intervention survey included questions to assess current provider workflow of neonatal hyperbilirubinemia risk evaluation, to estimate how much time is typically required for this process and which step(s) are most time consuming, to rate satisfaction with current workflow, to identify external hyperbilirubinemia risk assessment tools already in use, and to obtain examples of errors in this evaluation that have negatively affected patient care (Supplemental Figures 1 and 2).

The BiliReport tool was implemented into our EHR on March 07, 2018. End-users working in the newborn nursery, including bedside nursing staff, were provided online instructional training materials on the use of the BiliReport and suggested incorporation into daily workflows. To assess accuracy of the pre-intervention bilirubin risk assessment and

subsequent documentation of neonatal hyperbilirubinemia risk in the EHR, we examined all infant discharge summaries from both Ronald Reagan and Santa Monica Hospital newborn nurseries during the month of January 2018. If the total bilirubin values were documented, we assessed if the manually transcribed bilirubin values matched the true laboratory values and if the hyperbilirubinemia risk stratification was accurate and consistent with current AAP guidelines. We compared this to post-intervention discharge summaries for all infants discharged during the month of May 2018.

Statistical methods

We evaluated the proportions of infant charts with erroneous bilirubin value and erroneous bilirubin risk stratification before and after intervention. Charts without documented bilirubin values or risk stratification were excluded. The above proportions were compared between the time intervals using the Chi-square test or the Fisher's exact test as appropriate.

Results

The pre-intervention survey (n=61, response rate 47%) determined that the majority of respondents (93%) utilized BiliTool.org to assess neonatal hyperbilirubinemia prior to implementation of the BiliReport. One respondent reported use of Peditools in addition to BiliTool™.[10] The remainder of respondents (7%) reported that they hand-plot the bilirubin values on the available AAP nomograms and do not use support software. We had similar numbers of respondents by year of residency training and attending physicians. (Supplemental Table 1)

Forty respondents completed the post-intervention survey (response rate 31%). Of the respondents, 85% reported they utilized the BiliReport within the first two months after release. In examination of available medical charts at UCLA post-intervention, the BiliReport was accessed an average of 3.9 times per patient (range 0–9, SD 2.2). 88% of respondents reported they were "satisfied" or "very satisfied" using the BiliReport in comparison with their previous methodology for assessment of neonatal hyperbilirubinemia.

Prior to implementation of the BiliReport at UCLA, the median estimated total provider time among all levels of practioner to assess hyperbilirubinemia in an infant was between two and three minutes per patient. The post-implementation survey of BiliReport users found that 98% of respondents estimated consistent use of this tool could save more than 30 seconds of provider time per patient. With over 3400 births per year at our institution and an average estimated provider time of 150 seconds saved per patient, we estimate more than one hundred hours of provider time could be saved each year through consistent use of this tool in the UCLA system. Similar results have been demonstrated during trials at Cedars-Sinai Medical Center, where the same software code demonstrated an average of 160 seconds of provider time saved per laboratory value for pediatric hospitalists.[11]

Overall, 93% of post-intervention respondents agreed they that the BiliReport improves accuracy in the assessment of neonatal hyperbilirubinemia risk. To evaluate this impact, we manually reviewed the medical charts of all newborn infants born at Ronald Reagan and UCLA Santa Monica hospitals in the month of January 2018 (n=250), two months prior to

release of the BiliReport. For comparison, we reviewed the medical charts of all infants born in the month of May 2018 (n=254), two months after release of the BiliReport. Six discharge summaries contained erroneously documented laboratory values pre-intervention compared to one discharge summary post-intervention (p=0.07). Fifteen pre-intervention discharge summaries contained erroneous hyperbilirubinemia risk stratification compared to one discharge summary post-intervention (p=<0.001). (Table 1) We excluded charts where the laboratory values or the risk stratification was not documented. There were not any quality and safety reporting incidents regarding erroneous interpretation of neonatal hyperbilirubinemia at our institution in the 12 months preceding or following the intervention.

Discussion

The AAP has developed strong recommendations regarding routine, universal assessment and measurement of neonatal jaundice and hyperbilirubinemia to prevent kernicterus.[3] Thought previously to be essentially eliminated in developed countries, recent limited data from Canada demonstrates an incidence of kernicterus at a rate of 1 in 44,000 live births.[12] This highlights the need for continued surveillance and vigilance in the monitoring of neonatal hyperbilirubinemia. Use of clinical decision support (CDS) has potential to decrease medical errors and improve adherence to available guidelines in the assessment of hyperbilirubinemia.[5]

We demonstrated additional benefits of automation of the assessment of neonatal hyperbilirubinemia through integration of an external hyperbilirubinemia risk assessment tool within the EHR. This project resulted in high user satisfaction, potential provider time saved, and improved accuracy of discharge summary documentation. We were able to successfully collaborate between institutions, as original code was adapted from the informatics group at Cedars-Sinai Medical Center to fit the requirements of the EHR and provider workflows at UCLA. This may represent an opportunity for further collaboration between independent hospital systems.

This work aligns with the Five Rights of Clinical Decision Support's framework to provide the right information, to the right people, in the right intervention formats, through the right channels, at the right points in workflow.[13,14] Other healthcare groups are also creating CDS software to address patient care needs. Beaumont Health and University of Utah Health have recently developed EHR integrated CDS for neonatal bilirubin risk level calculation and treatment indications.[15,16] This software is comparable to BiliTool™, but the applications are contained completely within the EHR and utilize a larger number of patient-specific variables to provide recommendations. The Epic Systems's App Orchard and Cerner App Gallery allow developers to publish their application program interfaces,[17,18] and we may see more availability of individual and institutional endeavors as these communities grow.

A significant challenge in any information technology (IT) intervention is end-user acceptance and use of new processes and tools. We demonstrated a high usage among providers with the BiliReport, in part because it integrates an existing, commonly-used, external CDS platform. In addition, this easily accessible tool was built within the end-user

workflow, rather than using other interruptive modalities, such as a best-practice alert. Our UCLA BiliReport code was adapted from code originally developed at Cedars-Sinai Medical Center, where they have found increasing usage over time since 2016 across provider roles, including nurses, nurse practitioners, physicians, and lactation consultants (Supplemental Figures 3 and 4). The University of Utah has successfully demonstrated EHR integration of other external calculation tools, including MDCalc, which is already utilized by more than 50% of US physicians monthly.[6,15] Thus, one strategy for software developers and technology leaders is to assess and integrate existing procedures and pathways into new tools. For institutions with limited IT resources, using existing external tools could be an efficient way to improve workflow processes without the need for complete redesign and complicated coding.

Physicians spend significant time interfacing with the EHR, as recent data demonstrates primary care clinicians spend more than 50% of their time (5.9 hours per 11.4-hour workday) working within the EHR.[19] Other studies have found stress related to health information technology is linked to physician burnout, with physicians reporting poor or marginal time for documentation having 2.8 times increased odds for also reporting symptoms of burnout.[20] These recent studies highlight the need for continued IT interventions to improve physician interactions with the EHR and decrease physician time spent working within the EHR.

Another challenge we encountered was the heterogeneity of providers and the associated lack of a common discharge summary template for documentation in the newborn nursery in the UCLA system. The newborn nursery is staffed by neonatal nurse practitioners, neonatal intensivists, pediatric hospitalists, and pediatric outpatient physicians, all of whom may utilize different EHR note templates when documenting hospital courses for similar infants. Although note templates may be developed to automatically include chart and laboratory data, some providers employ antiquated templates with blank tables, which are prone to transcription errors and require time-intensive manual data entry.

We found many discharge summaries where the bilirubin value and/or the bilirubin risk stratification was not documented. For these patient charts, it is not clear from the provided documentation if the neonatal hyperbilirubinemia risk assessment was performed per AAP guidelines. We advocate for the standardization of EHR documentation. Ideally, there would be a framework within the documentation to ensure evidence-based physician decision making, utilizing available and relevant patient data.

Limitations of our study include the decline of the post-intervention response rate (37%), which was a decrease from the pre-intervention survey response rate (47%). Thus, despite a high percentage of survey respondents reporting satisfaction with the new workflow, this may represent a selection bias. With our limited sample size, we may have inadequate statistical power to detect significant differences in outcomes.

Conclusion

This project demonstrates the EHR can be used to directly transmit patient variables to an existing external online hyperbilirubinemia risk assessment tool, while ensuring data integrity and avoiding transmission of patient PHI. The next step to increase provider acceptance and usage of new IT interventions is the integration of the risk assessment calculations into the EHR. Clinical decision support directly accessible within the provider's EHR workflow has potential to improve efficiency while encouraging adherence to available clinical care guidelines. In addition, standardized documentation (e.g. discharge summary templates) would further strengthen this process and ensure provider standards for evidence-based decision making.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations:

AAP	American Academy of Pediatrics
CDS	Clinical Decision Support
EHR	Electronic Health Record
HIPPA	Health Insurance Portability and Accountability Act
IT	Information Technology
PHI	Protected Health Information
UCLA	University of California Los Angeles

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What's New

We demonstrate electronic health record data directly transmitted to an external web-based clinical decision support tool quickly provides patient-specific treatment recommendations for neonatal hyperbilirubinemia risk assessment. This process can improve accuracy of documentation and achieve high usage and satisfaction from providers.

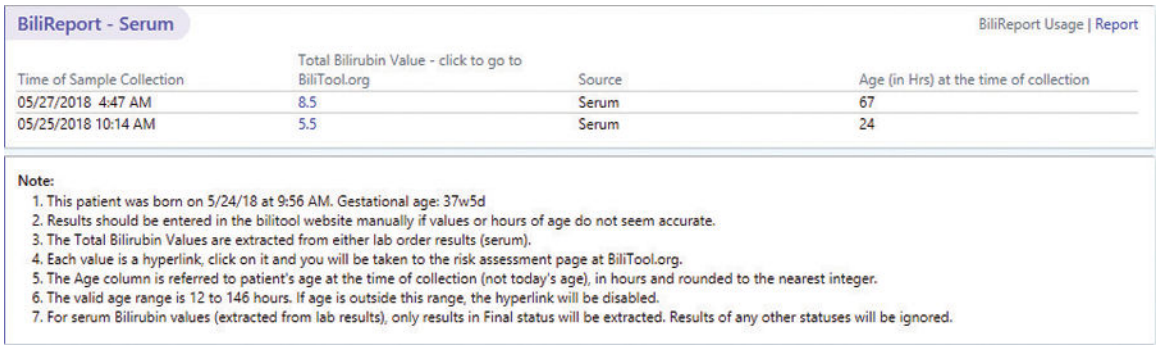
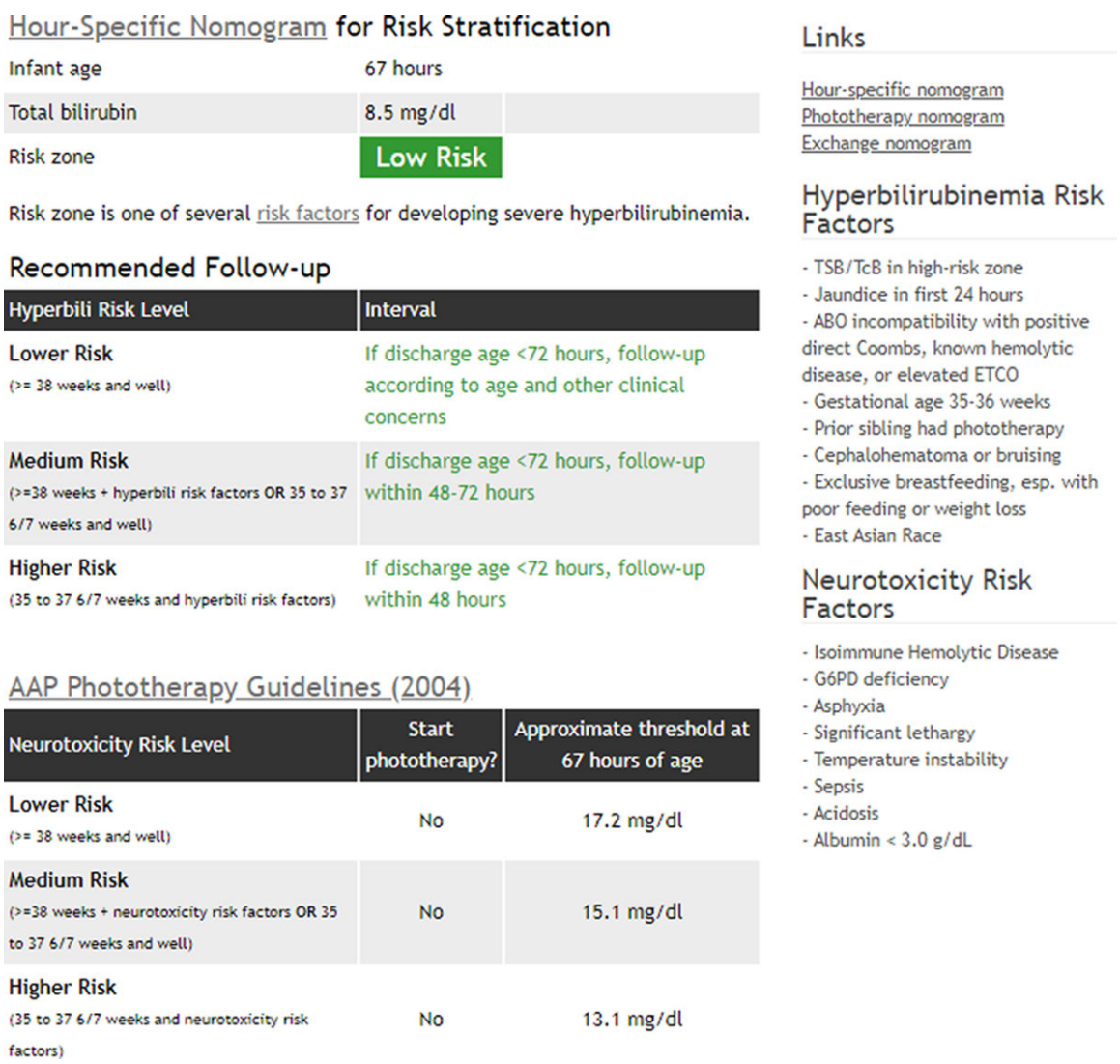


Figure 1: The BiliReport

Example of a BiliReport in the UCLA EHR. Patient's age (in hours) is displayed within the EHR. The laboratory values (total bilirubin) are hyperlinks directly to BiliTool™, where patient age and laboratory value are transmitted through the EHR, providing a one-click reference to patient-specific risk stratification and recommendations.



Hour-Specific Nomogram for Risk Stratification

Infant age	67 hours	
Total bilirubin	8.5 mg/dl	
Risk zone	Low Risk	

Risk zone is one of several risk factors for developing severe hyperbilirubinemia.

Recommended Follow-up

Hyperbili Risk Level	Interval
Lower Risk (>= 38 weeks and well)	If discharge age <72 hours, follow-up according to age and other clinical concerns
Medium Risk (>=38 weeks + hyperbili risk factors OR 35 to 37 6/7 weeks and well)	If discharge age <72 hours, follow-up within 48-72 hours
Higher Risk (35 to 37 6/7 weeks and hyperbili risk factors)	If discharge age <72 hours, follow-up within 48 hours

AAP Phototherapy Guidelines (2004)

Neurotoxicity Risk Level	Start phototherapy?	Approximate threshold at 67 hours of age
Lower Risk (>= 38 weeks and well)	No	17.2 mg/dl
Medium Risk (>=38 weeks + neurotoxicity risk factors OR 35 to 37 6/7 weeks and well)	No	15.1 mg/dl
Higher Risk (35 to 37 6/7 weeks and neurotoxicity risk factors)	No	13.1 mg/dl

Links

Hour-specific nomogram
Phototherapy nomogram
Exchange nomogram

Hyperbilirubinemia Risk Factors

- TSB/TcB in high-risk zone
- Jaundice in first 24 hours
- ABO incompatibility with positive direct Coombs, known hemolytic disease, or elevated ETCO
- Gestational age 35-36 weeks
- Prior sibling had phototherapy
- Cephalohematoma or bruising
- Exclusive breastfeeding, esp. with poor feeding or weight loss
- East Asian Race

Neurotoxicity Risk Factors

- Isoimmune Hemolytic Disease
- G6PD deficiency
- Asphyxia
- Significant lethargy
- Temperature instability
- Sepsis
- Acidosis
- Albumin < 3.0 g/dL

Figure 2: BiliTool™

Example of bilirubin level risk stratification on BiliTool™ linked directly from the BiliReport page in the UCLA EHR. The patient is risk-stratified and recommendations for management are given based on existing hyperbilirubinemia nomograms. BiliTool™ is a registered trademark of BiliTool, Inc. This image is reproduced with permission from BiliTool Inc. Images are copyright 2004–2019 BiliTool, Inc.

Table 1:

Neonatal Hyperbilirubinemia Chart Deficiencies Pre- and Post-Intervention

	January 2018 Pre-intervention (n = 250)	**May 2018 Post-intervention (n = 254)**	**p-value**
Charts with documented hyperbilirubinemia risk stratification	232	243	
Erroneous hyperbilirubinemia risk stratification	15 (4%)	1 (0.4%)	<0.001
Charts with documented bilirubin value	241	243	
Erroneous bilirubin value	6 (2.4%)	1 (0.4%)	0.07

Evaluation of charts comparing documentation and accuracy of discharge summaries in the assessment of neonatal hyperbilirubinemia risk-related information in January 2018 (pre-implementation) and May 2018 (post-implementation).