Neonatal bilirubin management as an implementation example of interdisciplinary continuum of care tools

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Abstract
Management of newborn bilirubin spans the inpatient and outpatient continuum of care. Intermountain Healthcare has developed and implemented a web-based tool for managing bilirubin that follows newborn patients across care settings and providers with a consistent plan of care. The underlying model for the tool is derived from published guidelines. The model divides the time-sensitive data into risk zones and associates each zone with the appropriate order set for follow-up care. The tool integrates Intermountain’s Help2 infrastructure for authoring terms, guidelines, and order sets, with alerts, results, and data entry within the context of the care model. Implementation of the bilirubin management tool is shown to improve communication, ease workflow, and improve guideline compliance. Lessons learned from the implementation include recommendations for handling point-of-care laboratory data and managing archival views, which are insightful to health networks managing longitudinal data.

Introduction
The management of neonatal bilirubin makes a good test case for the emerging clinical information systems infrastructure at Intermountain Healthcare, where health issues will be modeled and subsequently tracked through the continuum of care across providers and care settings. Personalized medicine is the vision, where for each person a tailored plan will be maintained and refreshed according to the best practice guidelines for each health issue specific to the patient’s wellness or illness. Beyond assessing the patient’s current state within the master care plan, the envisioned clinical information system will query for recent cases with comparable health issues in order to forecast costs and outcomes thereby facilitating informed decision making at the point of service. Neonatal bilirubin is a relatively simple health issue that has many of the properties convenient and necessary for testing the continuum of care concepts.

For Intermountain Healthcare to reach its vision of personalized healthcare, the essential elements of the clinical information system include 1) a content repository within an authoring environment; 2) an inference engine with both time and data driven rules; 3) integrated messaging and alerting; 4) data review and entry within context of the care model; 5) links to population data and valuation sets; and 6) physician access across care settings. The Help2 clinical information system developed at Intermountain Healthcare includes each of the required components and has been systematically implemented throughout Intermountain’s network of 22 hospitals and 130 outpatient clinics and urgent care centers. Furthermore, Intermountain has extended its physician access to the offices of nearly 500 highly aligned, non-employed physicians with admitting privileges, thereby providing longitudinal access to clinical applications supporting their patient’s electronic health record.

In recent years, neonatal bilirubin management has resurfaced as a pediatric health issue. Lifelong management of brain injury resulting from hyperbilirubinemia is tragic and extremely costly. Previous jaundice assessments relying on eye and skin observations were proven to be unreliable. In 1999 Bhutani et al. published recommendations for universal newborn screening that have subsequently been adopted as a quality measure by Intermountain Healthcare and have emerged as a national standard. By early 2003, Intermountain had achieved greater than 99% compliance for newborn screening, and the readmission rates for newborns with critical hyperbilirubinemia declined, providing a textbook example of data-driven quality improvement.

Despite the quality improvement success, the newly adopted guidelines are more workflow intensive than the previous standard practice. In addition to increased utilization from each infant having a blood test prior to discharge from the hospital (previous screening was less than 15%), those infants whose serum levels of bilirubin are within the high and high-intermediate quartiles are expected to return to the laboratory or physician office for follow-up.
testing in 12 hour intervals until the newborn liver matures and the risk of hyperbilirubinemia subsides. Intermountain hospitals deliver nearly 30,000 babies each year. Discharges were frequently delayed waiting for laboratory results. Patient expectations were impacted as discharge instructions changed. The impact to the pediatric provider workflow was severe. Whereas the former standard follow-up visit occurred a week to 10 days post discharge, with the new guidelines 25% of the infants require care the following day. The time-sensitive window of the guideline challenged the traditional pediatric practice pattern. Physician enthusiasm varied. Many had practiced for decades using the old standard without incident. Guideline compliance of the non-employed physicians has been difficult to gauge and sustain.

In response to the high impact of the guideline, Intermountain took the informatics opportunity to create a single management tool for newborn bilirubin within the Help2 clinical information system. The tool would be used in both the inpatient and outpatient settings with the goal to improve communication, ease workflow, and raise guideline compliance. The guidelines for bilirubin management are relatively simple, yet test most of the modalities of more complicated health issues envisioned for the next-generation personalized plan of care. The same approach could be implemented in regional data and guideline sharing programs as their infrastructure and adoption increases.

Methods

The concept of a personalized plan of care using the HELP 2 infrastructure was tested using the approach illustrated in Figure 1. In step 1, the terms, rules, guidelines and order sets are authored and stored within the HELP2 content management database. Laboratory data queried from the population-based clinical database allow the boundaries of the risk zones of the national recommendations (valuations of critical, high, high intermediate, low intermediate, and low) to be redrawn using Utah data. Validation and tailoring of the guidelines with Utah data eased some of the physician acceptance anxieties during the implementation. The time-sensitive acceptable ranges of the laboratory values form the contextual model of the bilirubin management plan of care.

In step 2, as laboratory results are stored in the patient database, the inference engine evaluates the risk zone and retrieves the standing order set for that risk zone. In step 3, notification of the risk is sent through messaging to the clinician desktop. When the resulting risk area is high or critical, the inference engine sends an alert through the paging network.

In step 4, the integrated plan of care is assembled within the clinician HELP2 desktop application, where the current and historical bilirubin levels are plotted over a contextual background of the risk zone boundaries. The applicable order set (phototherapy, follow-up lab order, etc.) is displayed along with the patient teaching and discharge instructions. After discharge, the provider continues to monitor the plan of care from home or office, receiving notification when the follow-up laboratory results are received, and monitoring the risk as the newborn matures over the first critical weeks.

In step 5, a portal for entering point-of-care (transcutaneous) bilirubin is available, from which the data stores to the patient database and the results are plotted in context with the other bilirubin results.

Figure 1. Summary view of newborn bilirubin data management at Intermountain Healthcare.
Initial development and QA cost of the bilirubin management tool approached $40K.

Acceptability and workflow impact of the tool were evaluated in a 2004 pilot implementation. In the subsequent years, the tool has been implemented generally across Intermountain Healthcare hospitals and clinics and available to the aligned, out-of-network provider offices through the web-based HELP2 application. Lessons learned have been incorporated in a second version of the tool released in early 2006 at a cost comparable to the initial development.

Foremost among the requirements gleaned from the implementation has been the issue of integrating point-of-care laboratory data. At the onset, slight variations in the displayed results were assumed to be sufficient for differentiating between sources of laboratory data. The issue proved to be more complex at the persistence level, where the traceability of laboratory certification must persist, and corrected results must be handled consistently. After months of internal review using national regulations and requirements, Intermountain accepted the recommendations for handling point-of-care laboratory values as summarized in Table 1. Guiding design principles include test-specific tailoring of data-entry and data review screens, reports and notifications. These requirements for laboratory data would be similarly applicable in a regional data sharing scenario. Other clinical data domains within Intermountain will soon generate comparable criteria for accepting and integrating external data.

A second issue of data quality emerged when patients arrived at the physician office with missing or incomplete instructions. Whereas the algorithm is time sensitive and the data screens are constructed in real time, the provider was unable to reconstruct the view precisely as it had appeared for the patient at the time of discharge. Notes typed into the report or handwritten on a printout were not viewable. To address this issue, a strategy to archive snapshots of the bilirubin management progression was incorporated into the tool. At the time of interest, independent of setting and auto-generated when finalized or printed, a PDF image of the bilirubin management report is stored with the patient EHR. Lists of reports with various sort and filter options provide the ability to reconstruct the report provided to the patient at any point in the continuum of care. Acceptability continues to be gauged by usage and enhancement requests from the clinicians. Due to varying insurance referral requirements, not all of the post-discharge follow-up exams are performed at Intermountain laboratory facilities, complicating the measurement of guideline compliance across the continuum of care. As an approximation valid only for trending, the ratio of tests performed within the Intermountain network to number of births is tracked by system and facility.

Results

Figure 2 captures the data entry view of the bilirubin management tool. Callout 1 shows the main features of integrated results review and data entry within the context of the population data that form the risk zone.

<table>
<thead>
<tr>
<th>Laboratory Data Element</th>
<th>Data Entry</th>
<th>Final Report</th>
<th>Patient EHR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient 2nd identifier (eg, MM, MRN, SSN)</td>
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<td>√</td>
<td></td>
</tr>
<tr>
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<td>√</td>
<td></td>
</tr>
<tr>
<td>Ordering physician</td>
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</tr>
<tr>
<td>Specimen collection date and time</td>
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<tr>
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<tr>
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<td>Reference range (age- and gender-specific)</td>
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</tr>
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<td>Abnormal flag</td>
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<tr>
<td>Critical value alert and documentation</td>
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<td></td>
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<tr>
<td>Status (eg, final, preliminary, corrected)</td>
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<td></td>
</tr>
<tr>
<td>Comments (eg, specimen qualifier)</td>
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<tr>
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</tr>
<tr>
<td>Notice of corrected (modified) results</td>
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</table>
boundaries. Callout 2 highlights the order set tailored according to the risk area of the most recent lab result and the queried time of birth. Callout 2 also shows the integrated view of the bilirubin data with integrated patient teaching and discharge instructions. Callout 3 shows the point-of-care (transcutaneous) data entry form.

Post implementation usage of the bilirubin management tool continues to grow at an annualized rate of 24% after adjusting for birth rate. By January 2007, nearly 88% of births have at least one bilirubin report generated from the tool. For the years 2004-2006, orders for follow-up newborn bilirubin screening have averaged 3.9% above the system-wide baseline established in 2003 after being adjusted for the annual birth rate, which is indicative of a modest increase in compliance to the guideline for follow-up bilirubin screening. The highest system-wide rate occurred in 2005. Individual facility data varies with some sites increasing testing and others slightly declining. The sites using alerts within the bilirubin tool have sustained a significantly higher level of follow-up testing ($t = 3.51, p < .01$ df = 8) compared to those sites using the tool but not accepting alerts.

**Discussion**

Given the problem of managing a health issue across providers and care settings, Intermountain has developed and implemented a solution that leverages its HELP2 clinical information infrastructure. Although beyond the scope of this implementation, the basic components (rules authoring, content management, results integration and reporting) could be developed within a service oriented architecture or
Health Information Exchange (HIE) infrastructure and used independent of the Help2 client. The objectives of enhancing communication and easing workflow have been readily achieved in the implementation, while the objective of improving guideline compliance has been more challenging. Sustaining compliance to a guideline that spans the continuum of care and that relies on the participation of out of network providers requires energy and attention especially as the newness of the initiative fades over the course of years. Although the system-wide trend for compliance dipped slightly in 2006 from the 2005 peak, those facilities accepting alerts from the bilirubin tool in addition to the lab critical value alerting were able to continue improving their compliance levels. Concern over alert fatigue has been an ongoing debate. The sites that have aggressively prioritized the guidelines and agreed to receive the automated alerts have been able to sustain and improve their guideline compliance levels.

The implementation of the bilirubin management tool brought to light unanticipated issues of data quality and workflow impact that have had to be resolved to make compliance easier. The issues such as sharing point-of-care laboratory data entry and restoring historical views will need to be resolved for all systems and coalitions using information systems to manage patient care across providers and care settings whether using the Help2 client or other HIE strategy. The recommendations derived from the implementation will facilitate the modeling and configuration tasks of more complex health issues.

The first steps to achieving the vision of a clinical information system that anticipates total resource utilization were achieved with the bilirubin management tool. Although the context was static and the valuations were limited to risk zones, the infrastructure is established. Context could be refreshed in the same manner in which data is being fetched from the patient database. Valuation sets with their logic modules are limited only by authoring and maintenance within the content management database.

Conclusion

The neonatal bilirubin management tool within Intermountain Healthcare’s HELP2 clinical information system facilitates the care of newborn patients across inpatient and outpatient transitions, and can be a model implementation for other health issues. Insights from the implementation, particularly, around workflow impact and point-of-care laboratory data can be reused. The broad audience of providers in and out of the Intermountain network as well as the high volume of patients contributed to the successful evaluation. The relatively simple model of time-value coordinates with corresponding order sets, made the implementation practical while at the same time exercised much of the functionality envisioned for strategies of continuity of care and health information exchange.

References