Enhancing Transfusion Safety with an Innovative Bar-Code-Based Tracking System

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Abstract

In an effort to reduce transfusion errors, a novel, comprehensive, computerized wireless bar-code-based tracking system for matching patients, blood samples and blood products was created and deployed at a major academic medical centre. With a grant from the Agency for Healthcare Research and Quality, software was developed to track scans at the times of sample collection, sample arrival in the blood bank, blood product dispensation from the blood bank and blood product administration. The system was deployed in February 2005.

The system was well accepted from the outset, and the sample rejection rate due to clerical errors fell from 1.82 to 0.17%; incident reports fell by 83%. At the final blood administration step, the accumulated data as of November 2008 indicated that identification errors were being detected and prevented every 42.4 days and that the scan completion rate was stable at about 99%. Process analysis suggested that these were independent events and, thus, would be expected to coincide (and potentially produce a mis-transfusion) every 4,240 days (11.6 years) on average. We estimate that the system is 10 times safer than the manual system previously employed at our institution and may be 15–20 times safer than most systems employed in the United States.

The successful transfusion of blood products is dependent on a coordinated linkage of processes from blood sample collection to administration (Dzik 2003). Accurate patient identification is central to these processes, and errors may result in mis-transfusion (Andreu et al. 2002; Baele 1994; Linden et al. 1992, 2000; Murphy and Kay 2004b; Myhre and McRuer 2000; Novis et al. 2003; Sazama 1990). The most common sites of identification error occur at blood sample collection and blood product administration (final bedside check) (Andreu et al. 2002; Baele 1994; Linden et al. 1992, 2000; Murphy and Kay 2004b; Murphy et al. 2004; Myhre and McRuer 2000; Novis et al. 2003; Sazama 1990).

The development of new technologies has been advocated by the Agency for Healthcare Research and Quality (AHRQ) as a method for error reduction in the multi-step transfusion process (Kohn et al. 2000). A wide variety of new technologies have subsequently flourished, with most using bar-code and radiofrequency labels (Askeland et al. 2008; Dzik 2005, 2006; Dzik et al. 2003; Miyata et al. 2004; Murphy and Kay 2004a; Turner et al. 2003). The University of Iowa Hospitals and Clinics (UIHC) developed and implemented a comprehensive computerized bar-code-based patient and blood product identification system in February 2005 (Askeland et al. 2008). Additional data regarding our experience with this stand-alone technology are presented. These data and further process analysis continue to support the validity of probability calculations that suggest that the UIHC bar-code-based

tracking system may be 15–20 times safer than most transfusion systems employed in the United States.

Materials and Methods

The details of the development process, creation of the software and modifications have been described previously (Askeland et al. 2008). Key elements and modifications are summarized. With a grant from AHRQ in 2003, a multidisciplinary team was assembled from the Departments of Nursing, Pathology, Health Care Information Systems and Hospital Epidemiology. The team was responsible for the development and integration of the new bar-code-based tracking system. The project team met frequently to discuss equipment, workflow and a hospital-wide phased integration of the new system and to troubleshoot problems.

New bar-coded wristbands and blood sample tube labels were selected and printed using new bar-code printers that were localized to the blood bank, phlebotomy carts and nursing stations. Laser scanners, notebook computers, mobile carts and wireless cards were tested, and the staff provided feedback on which devices best fit their needs in a particular area. The bar-code technology was supported by wireless data network products purchased from Cisco Systems, Inc. (San Jose, CA), which were installed hospital-wide to provide point-of-care service.

The software supporting the system is a homegrown client-server application. The client is PowerBuilder, with a Sockets interface to an IBM mainframe server. The mainframe stores the data via DB2. The two main functions are Blood Product Transfusion Tracking and Blood Product Transfusion History. The Blood Product Transfusion Tracking function has four main transactions: blood sample collection, blood sample arrival in the blood bank, dispensation from the blood bank and blood product administration (Table 1). All bar-code scans must be completed in succession. A manual downtime protocol was also setup in the rare instance that the wireless network is not functional. The Blood Product Transfusion History function automatically records the operator and exact time of all scans. Authorized hospital staff can access this information to track the exact time and person involved in transfusing any blood product.

The bar-code-based tracking system was tested alongside the prior manual system in an outpatient clinic in April 2004 and was subsequently extended to in-patient units over an eight-month period. Validation studies were performed for all transactions prior to house-wide implementation and whenever the system was modified. The bar-code-based tracking system was fully implemented in February 2005.

The system was modified in response to specific issues that arose during implementation. An Operating Room Proxy function was created for anesthesiologists, who were unable to scan patients' wristbands located under sterile drapes. Using this function, anesthesiologists scan the patient's bar-coded wristband and a bar-coded label on the anesthesia record before the procedure. If the labels match, the bar code on the anesthesiology record can be used as patient identification.

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A second important modification was created to save time during massive transfusions. The Multiple Blood Product function was made available for both the dispensation and administration transactions. During the dispensation transaction, blood bank personnel scan the requisition order form once and complete the remaining scans without repeating the initial scan. During the administration transaction, the transfusionist scans the patient's wristband or the bar code on the anesthesia record once and then completes the scans for each blood component without repeating the initial wristband scan.

Table 1. Four transactions within the Blood Product Transfusion Tracking function and respective scans

Blood sample collection 1. Scan bar code on patient's wristband 2. Scan bar code on requisition 3. Scan bar code on collected blood sample tube
Blood sample arrival in blood bank 1. Scan bar code on requisition 2. Scan bar code on collected blood sample tube
Dispensation from blood bank 1. Scan bar code on blood product request form sent from physician 2. Scan bar code on blood product bag tag 3. Scan unit number on blood product bag tag 4. Scan unit number on blood product itself
Blood product administration 1. Scan bar code on patient's wristband 2. Scan bar code on blood product bag tag 3. Scan unit number on blood product bag tag

A third modification was that green and red computer screens were created to alert users that a transaction has been successfully completed or that a problem has occurred during scanning, respectively. Fourth, because there was originally no scanning step downstream of administration, a Blood Product Returned to Blood Bank function was developed to scan in blood products that have been dispensed but not transfused and are subsequently returned to the blood bank. Finally, a

separate Audit Administrations function was created to track those blood products that have been dispensed but for which no administration transaction or downtime procedure was successfully completed.

Results

The previous method for tracking transfusion errors at our institution relied on computerized incident reports (CIRs) that were completed by blood bank, nursing or anesthesiology staff. The CIRs were voluntarily submitted and frequently did not contain specific details and were difficult to investigate. The majority of CIRs were related to mislabelled blood samples, incomplete requisitions and illegible handwriting. Although staff can still initiate incident reports (now called Patient Safety Net reports as per the University Health Systems Consortium terminology, the number of reports related to clerical errors during the transfusion process dropped by 83% after the implementation of the bar-code-based system.

Prevented identification errors (PIEs) are recorded using the Blood Product Transfusion History software whenever mismatches occur between scanned bar-code labels. These bar-code mismatches result in the appearance of a red computer screen with an error warning that must be corrected prior to moving on to the next step. Therefore, the error is not propagated through the transfusion process.

The most recent cumulative data on blood sample collections indicate that a total of 107 PIEs (0.15% of total collections) were identified over a 46-month period between February 2005 and November 2008. This corresponds to a PIE every 7.6 days. At the blood product dispensation step, there were 247 PIEs (0.17% of total dispensations), corresponding to a PIE every 5.7 days. At the administration step, a total of 33 PIEs were recorded (0.03% of total administrations), corresponding to one PIE every 42.4 days. They were identified in both the operating room (15 PIEs) and other settings (18 PIEs).

Because PIEs at the administration step could be considered near-miss events, they were further analyzed in a follow-up study. The PIEs that took place in the operating room were the result of a blood product left in the operating room from a prior surgery (four PIEs), a blood product taken to the wrong operating room (two PIEs), an ordering error (one PIE) and the inadvertent scanning of a pre-printed bar-code label left in the operating room from a previous patient (eight PIEs). The first three kinds of events (a total of seven PIEs) pose a greater risk of an actual transfusion error than does scanning of leftover bar-code labels (eight PIEs) because, in the latter cases, the correct blood was present for the patient in the operating room. The 18 PIEs in the non–operating room settings occurred because the transfusionist was at a bedside with a blood product dispensed for a different patient. These events all posed a significant risk of mis-transfusion.

A failure to scan occurs when required bar-code scans are either not performed at all or not completed in succession. A failure to scan during the blood sample collection, blood sample arrival and blood product dispensations steps is unlikely to result in mis-transfusion because the subsequent downstream scans cannot be performed unless and until upstream steps are performed completely. The effect of a failure to scan at these steps is therefore primarily that of a delay in transfusion therapy. The most recent cumulative data for scan failure rates at blood sample collection, blood sample arrival and blood product dispensation are 2.0%, 0.3% and 0.2% respectively.

Failure to scan at administration was recognized as a significant issue following the implementation of the system, and a method was needed to quantify the problem. Because there was originally no scanning step downstream of administration, a Blood Product Returned to Blood Bank function was developed to scan blood products that were dispensed but not administered and that were subsequently returned to the blood bank. An Audit Administrations function was created to generate an audit trail on those blood products that were dispensed but not returned and for which no administration transaction or downtime procedure was successfully completed. These discrepancies were investigated in detail. The investigations revealed that from May 2007 to November 2008, there were 508 incidents of failure to scan at the administration step out of 50,652 successfully completed blood product administrations. Therefore, there was a 1% rate of failure to scan at the administration step. Since it is clear that any failure to scan at this step creates a risk of mis-tranfusion, current practice dictates that all such failures be reviewed by the blood centre quality assurance coordinator each morning; notifications are passed on to nursing managers and anesthesia staff for further investigation and follow-up.

Finally, it is worth emphasizing that, as it now functions, the bar-code-based transfusion tracking system effectively provides a nearly comprehensive audit of all blood product administrations at UIHC.

Discussion

The bar-code-based tracking system was well accepted and has been running smoothly since implementation. It is a stand-alone system that functions independently of our current laboratory and clinical information systems, which are both in the process of being replaced. As currently configured and operated, it provides an audit trail for nearly all transfusion activities. And since the vast majority of transfusion activities at our institution use the bar-code system, they are almost all audited in a systematic, efficient and cost-effective manner. Comprehensive transfusion auditing is nearly impossible to achieve in most institutions because of system or personnel limitations.

The system appears to be very safe. With the exception of a

single mis-transfusion that occurred the first night the system was deployed in an intensive care unit in early 2005, we have not detected any mis-transfusion events. The level of safety has been very impressive but has occurred in the presence of ongoing documentation of non-trivial frequencies of human error at all steps in the system. How has the high level of safety actually been produced? In an attempt to answer that question, we began with the general hypothesis that the system must provide enough checks and corrections for human error so that the probability of a mis-transfusion event is actually reduced to a very low level. From there, we decided to analyze the transfusion process in an effort to construct a series of more focused, step-specific hypothetical probability calculations.

Arguably, the most important of those calculations focuses on the administration step in the transfusion process. A potential mis-transfusion event (a PIE) is detected and prevented every 42.4 days (based on the most recent analysis of the cumulative data). We also know that employees fail to scan approximately 1% of the time. If PIEs and scan failures are derived from independent processes, then the probability is that they will coincide (and a mis-transfusion event will occur) every 4,240 days (11.6 years) on average. It needs to be emphasized that this calculation is only useful if the two processes are, indeed, independent; but all of our follow-up process analysis to date suggests that they are.

If the calculation just described is valid (ultimately, only time will tell), this suggests that the bar-code system is at least five times safer than its two-witness, two-signature predecessor, which resulted in a clinically detectable mis-transfusion event every 2.5 years. However, since it is an accepted fact that only about half of all mis-transfusion events are clinically detectable, then the current data – when considered in conjunction with the nearly comprehensive auditing feature of the bar-code system – actually suggest that the bar-code system may be 10 times safer than its predecessor. Calculations for the administration step are the most important because similar calculations from the upstream steps suggest that the probability of an error being successfully propagated all the way through the subsequent scanning steps is very small and therefore predict much greater intervals between mis-transfusion events (data not shown). Therefore, it does seem appropriate and practical to make the administration step the focal point for the analysis of system safety.

Before leaving the discussion of error at the administration step, it is worth pointing out that eight out of the total 33 PIEs detected arose from a very-low-risk situation in the operating room. If those eight PIEs are removed from consideration, significant PIEs actually occurred every 56 days, and mis-transfusion events would then be predicted to occur every 5,597 days or 15.3 years.

There is, however, another kind of error that is of some continuing concern, and it is the type of error that we believe was most likely responsible for the single mis-transfusion event at the time of house-wide implementation. Our retrospective analysis suggests that this event probably resulted from an error of the wrong blood in the tube, with or without an inappropriate double scan of a single bar-code label. The scan would have appeared successful and would not have generated error messages downstream. At this time, we are not sure how to estimate the probability of such an event, but we are testing possible calculations. However, as previously noted, there has been no evidence of similar events since February 2005. In particular, there have been no clinically detectable mis-transfusion events, and there have been no instances in which there was an unexpected change in blood type when subsequent samples were obtained. These observations suggest that the early mis-transfusion event may have resulted from confusion associated with the changeover of systems, and that another occurrence is now unlikely.

The number of reports related to clerical errors during the transfusion process dropped by 83% after the implementation of the bar-code-based system.

Summary

In summary, a stand-alone bar-code-based transfusion system has been developed and implemented at UIHC. The software in use is not complex and could most likely be used just as well with a different client-server configuration or as a web application. The system was well accepted at the outset and has now been functioning without incident since early 2005. It provides a nearly comprehensive audit trail for all bar-code-based transfusion activities, and it appears to be a very safe system. The available data suggest that it may be 10 times safer than its predecessor. If one uses a comparison based on published estimates of transfusion error rates relative to transfusion volumes (Linden et al. 1992, 2000), then the data suggest that the bar-code system is between 15 and 20 times safer than the systems in use at most other hospitals. Because the software can be written in other platforms and since wireless bar-code scanning technology is now more common, it seems quite possible that this system, or others like it, could be fairly easily deployed in other hospitals to improve transfusion safety. HQ

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