Technical Note

Development and implementation of a custom integrated database with dashboards to assist with hematopathology specimen triage and traffic

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Abstract

Background: At some institutions, including ours, bone marrow aspirate specimen triage is complex, with hematopathology triage decisions that need to be communicated to downstream ancillary testing laboratories and many specimen aliquot transfers that are handled outside of the laboratory information system (LIS). We developed a custom integrated database with dashboards to facilitate and streamline this workflow. **Methods:** We developed user-specific dashboards that allow entry of specimen information by technologists in the hematology laboratory, have custom scripting to present relevant information for the hematopathology service and ancillary laboratories and allow communication of triage decisions from the hematopathology service to other laboratories. These dashboards are web-accessible on the local intranet and accessible from behind the hospital firewall on a computer or tablet. Secure user access and group rights ensure that relevant users can edit or access appropriate records. **Results:** After database and dashboard design, two-stage beta-testing and user education was performed, with the first focusing on technologist specimen entry and the second on downstream users. Commonly encountered issues and user functionality requests were resolved with database and dashboard redesign. Final implementation occurred within 6 months of initial design; users report improved triage efficiency and reduced need for interlaboratory communications. **Conclusions:** We successfully developed and implemented a custom database with dashboards that facilitates and streamlines our hematopathology bone marrow aspirate triage. This provides an example of a possible solution to specimen communications and traffic that are outside the purview of a standard LIS.

Key words: Custom informatics, custom laboratory database, dashboard, hematopathology, pathology informatics

INTRODUCTION

Hematopathologists play a crucial role in real-time evaluation of bone marrow aspirates, including a determination of specimen adequacy, test appropriateness and ancillary diagnostics, all of which affect downstream laboratories that can be distantly removed from the specimen processing and triage.[1] In large institutions that process a multitude of aspirates per week, this service line can be labor and

time intensive, requiring multiple communications to downstream laboratories and specimen hand-offs, especially when aspirate tests require a manual requisition form. At our institution, these manual requisition clinical orders, triage decisions and specimen transfers cannot occur inside the purview of our laboratory information system (LIS), requiring a secondary specimen traffic log and multiple interlaboratory communications, with nontrivial risk of human error and mishandled specimens. Since different institutions each have individualized workflows crafted to best suit their various laboratories, it can be difficult to find an appropriate vendor-supported solution.

As institutions begin to offer new technologies and services that cannot be captured by, or interfaced with, traditional LIS, custom informatic solutions are becoming increasingly common, often with significant advantages.[2,3] In order to improve efficiency, specimen transfer and communication in our hematopathology workflow, we created a database and dashboard for our hematopathology service that allows specimen log-in, tracking of specimen for the treating clinician- and hematopathologist-driven diagnostic testing, amount of remaining specimen available for additional testing, communication of triage decisions to downstream laboratories and detailed specimen review.

METHODS

We used FileMaker Pro, Version 12 (Santa Clara, CA, USA), database management software, to develop a database that captures relevant patient, specimen and triage decisions for all bone marrow aspirate specimens that are processed by our hematology laboratory. This database is web published and can be accessed behind the hospital's firewall on a computer or on a portable tablet computer.

DATABASE AND DASHBOARD OVERVIEW

At our institution, specimen traffic is complex and involves multiple groups, including central receiving, technologists in the hematology laboratory, hematopathology residents, fellows and attendings, who triage bone marrow aspirate specimens in a review area physically distant from the hematology laboratory, as well as residents and other personnel in the downstream laboratories (molecular pathology [MP], flow cytometry, genomics (Center for Personalized Diagnostics, [CPD]) and cytogenetics), which are located in a variety of buildings on and off the hospital main campus [Figure 1]. When a specimen arrives at the hematology laboratory, the bone marrow aspirate is accessioned into Cerner Millennium. The
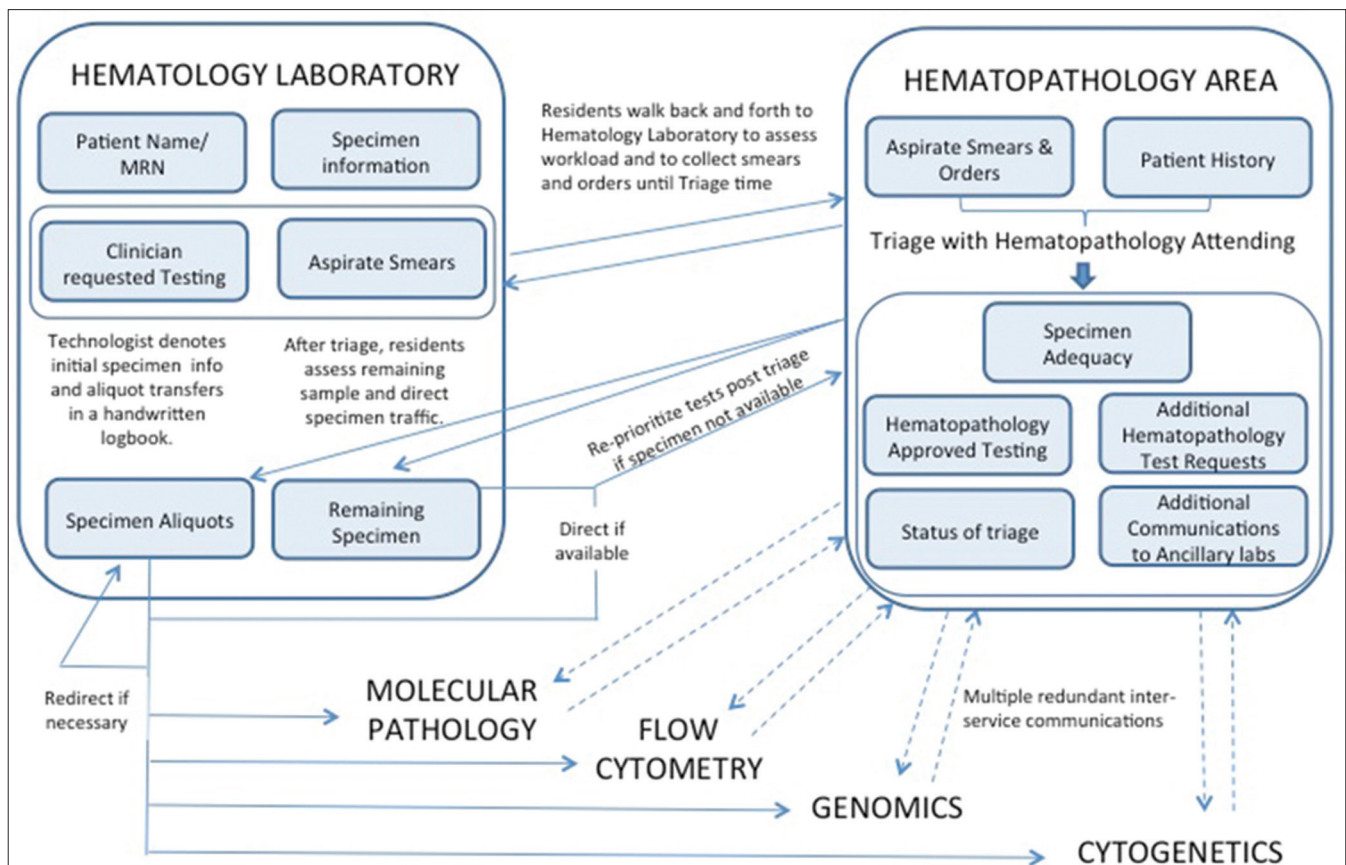

Figure 1: Previous workflow for bone marrow specimens. Solid arrows represent physical movement of residents and specimens. Dashed arrows represent communications. Laboratories are denoted in all capital letters

requisitions for clinician-driven downstream testing may be blank or incorrectly filled out; as such, the technologists aliquot specimen for each downstream laboratory with a requisition form and transfer the specimen to that laboratory. A record of the specimen quality, number of aspirate smears made, specimen transfers and other comments are manually recorded in a logbook in the hematology laboratory. As our LIS requires laboratory specimen log-in to have an associated test, the downstream laboratories do not accession the sample without a hematopathology-approved test request, so it waits in the ancillary laboratories for hematopathology triage. During this time, the aliquoted specimens have no searchable documentation as to their location and amount, other than the hematology logbook. Meanwhile, residents on various services repeatedly call the hematopathology service, while awaiting triage results so that either (1) the specimens can be properly accessioned or (2) detailed information can be provided to ordering physicians regarding test cancellation. Additional hematopathology attending-driven testing may be required; as such, residents must walk to the hematology laboratory to determine if remaining specimen is available and/or redirect specimens to ancillary laboratories. After triage, specimens are accessioned with the appropriate test request into Cerner by the downstream laboratories, or not, if hematopathology deems the specimen testing inappropriate or inadequate. This workflow processes approximately 50 bone marrow specimens per week.

As the responsibilities and data required for daily activities vary for each of the user groups (hematopathology, ancillary laboratories, hematology technologists, etc.), we developed separate user interfaces, or dashboards, with custom scripting that retrieve and present relevant information for each group. Secure user access and group rights ensure that only the relevant users can access and modify records. Specifically, user access is restricted to hematopathology attendings, residents rotating on the various services, hematology technologists and a few additional laboratory professionals who require access to the dashboard as part of their job responsibilities. Different user access is defined by group rights (Technologist, Laboratory Supervisor, Hematopathology Resident or Fellow, Hematopathology Attending, Ancillary Laboratory Personnel or Resident, and Administration) that limit which dashboards and views are visible. Descriptions of user specific access rights for each view are described below in the relevant section. Administrators have full access rights and can create and delete records, layouts and new users. Technologist and Laboratory Supervisor user groups can create and edit records; the Hematopathology Resident or Fellow user group can edit records. The Laboratory Supervisor user group has similar rights as the Technologist, but can also delete records (in case of error in record creation).

Hematopathology Attending and Ancillary Laboratory Personnel or Resident user groups can only view records.

Landing Page

This is the first view after a user logs in. Clickable buttons redirect users to appropriate layouts, which have information on relevant specimens. All users have access to the landing page [Figure 2].

Technologist View

The technologist accesses the database after he or she has accessioned the bone marrow aspirate into the LIS. When the technologist clicks on the TECHNOLOGIST SPECIMEN LOG-IN button, the user is redirected to the *HemePath Dashboard Tech* layout, a new record is created and specimen log-in time auto-populates. The technologist enters patient information and has the option to use the barcode scanner on the specimen accession barcode, which will populate the patient medical record number and specimen accession number. Received sample, sample type (bone marrow aspirate, the second core in saline, etc.), downstream laboratories that received an aliquot of sample due to clinician-requested ancillary testing (extracted from manual requisitions) and any remaining specimen, as well as comments to the hematopathology service, are entered into the database. There is also an option to log-in bone marrow core-only specimens, which are sent directly to surgical pathology through the hematology laboratory and have no ancillary testing requests. Below the main screen, there are two buttons, SAVE and DONE, and SAVE THEN NEW RECORD, which complete the record and either returns the user to the Landing page or creates a new record for the next bone marrow aspirate, respectively. Once the record is saved by the technologist, it is immediately accessible to other users. Only technologists have access to this view [Figure 3].
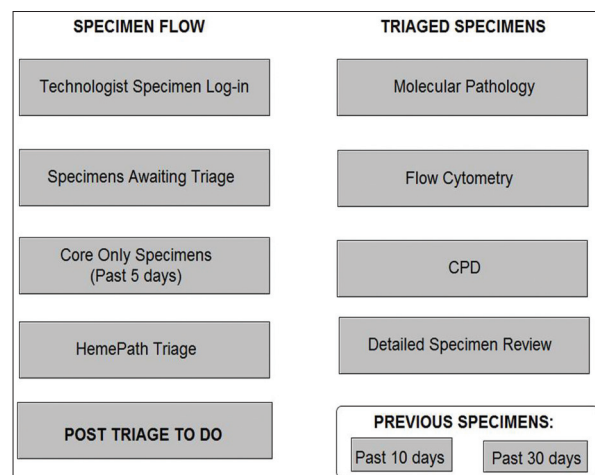
Figure 2: HemePath dashboard landing page. Web-published view after user initially logs into the database. Clickable buttons redirect the user to various layouts

Specimens Awaiting Triage

Selecting the SPECIMENS AWAITING TRIAGE button activates a custom script that finds all records in the database without a triage complete date and presents them in a tabular form on the *Triage List* layout [Figure 4]. This allows hematopathology residents and attendings to be aware of their workload and start collecting clinical information for samples, without walking to the hematology laboratory (and even from outside the medical system, provided they are behind the hospital firewall). Downstream laboratories now have an awareness of which specimens have not yet been triaged and can monitor response through the dashboard for the approval of clinician-driven test requests, instead of immediately calling the hematopathology residents for confirmation of specimen receipt. Attendings, fellows, residents and other personnel from downstream laboratories have access to this view.

HemePath Triage

When the user selects the HEMEPATH TRIAGE button, scripting finds all records without a triage complete date, excluding core only specimens that do not have an associated second core in saline or peripheral blood sample provided for ancillary testing. The records are sorted by the received timestamp, with older records presented first. The user is then directed to the *HemePath Dashboard Resident* layout. This layout is designed to be viewed on a portable tablet computer or on the desktop. Each specimen is presented individually,

with tabs that allow quick visualization of various aspects of triage. Every tab has access to the HOME SCREEN button, which redirects the user back to the *Landing page* layout. The default tab is the INFO tab. Patient name and medical record number autopopulate. This tab provides fields for residents to input relevant patient laboratory and clinical information, such as previous bone marrow biopsies and clinical notes that can be cut and pasted from the electronic medical record. Triage hematopathology attending can be selected from the drop-down menu. The SPECIMEN tab includes additional technologist-provided specimen information, such as LIS accession number and received timestamp. The residents have the option to note a concurrent peripheral blood smear that may have been reviewed earlier by the service, as well as provide comments. The ASPIRATE tab allows the residents to put in their initial impressions, as well as update to include attending comments. Bone marrow aspirate quality can be assessed using the aspirate quality drop down menu (acceptable, poor staining, and hemodilute) and an aspirate quality comment box, which can be used for quality assurance in the laboratory. Percent blast information can be denoted with a drop-down menu (blasts present, unable to quantify; no increase in blasts; <10%; ≥10%; ≥20%; N/A); this information can be used by downstream laboratories that have percentage blast requirements for some of their testing. The next four tabs, FLOW, MP (simplex or multiplex polymerase chain reaction-based assays), CPD (genomic/targeted high throughput sequencing analysis) and CYTOGENETICS (which includes fluorescence *in situ* hybridization [FISH]), allow the hematopathology team to approve or disapprove ancillary testing in the flow cytometry, MP, genomics and cytogenetics laboratories, respectively. Each tab has a Sample in Laboratory? Box, which says, "yes" when the downstream laboratory has already received a sample and a comments box that allows the hematopathology team to directly communicate with the personnel and residents in the downstream laboratory (i.e. prioritize testing, provide reasons for test cancellation, etc.). Common tests can be selected by clicking the checkbox next to the test name. The CYTOGENETICS tab has a space to write in percent plasma cells for our myeloma FISH panels. The penultimate tab, SAMPLE, provides a quick view of remaining ethylenediaminetetraacetic acid (EDTA) and heparin tubes, as well as any remaining filtrate. Attendings know immediately if there is remaining

Figure 3: Technologist view. The technologist can input specimen information into the database, including specimen redirection and remaining specimen

Figure 4: Specimens awaiting triage. A custom script finds all records in the database without a triage complete date and presents them in a tabular form

sample for additional testing, or if they need to reroute a previously distributed sample from one laboratory to another. Comments from the technologist can be viewed, as well as technologist initials, allowing the team to track down a technologist if there is a question or problem. The final tab is NEXT. When the specimen is finished being triaged, the resident can select this tab, which only shows a large button (Sample Triage Complete Click to →GO TO NEXT SAMPLE→). Clicking the button runs a script, which autofills the current date in a hidden field, triage complete. The resident is redirected to the next triage sample in the queue. Hematopathology attending, residents and fellows have access to this view. Select tabs from the *Hemepath Triage* view are presented in Figure 5.

Core Only Specimens

Our service will sometimes receive bone marrow core specimens without an associated aspirate. On occasion, the clinician will provide an associated second core in saline or a peripheral blood EDTA tube for ancillary testing. These specimens are captured in the *HemePath*

Triage list. However, our service also receives bone marrow core specimens without any associated material for ancillary testing. These core specimens are accessioned in Surgical Pathology and will populate in the fellow's queue in Cerner. However, without any associated aspirate specimen, this occasionally led to confusion for some members of the service team, who could be unaware of the specimen before the associated H&E slides arrive in the service box. Now, when the technologist logs in a core-only specimen, information regarding it can be viewed by hitting the CORE ONLY SPECIMEN button. A script finds all core only specimens with no associated second core or peripheral blood specimen for ancillary testing and redirects the user to the *HemePath Core Only* layout. This layout is similar to the *HemePath Dashboard Resident* layout, albeit with fewer tabs. The INFO and SPECIMEN tabs are virtually the same, providing specimen and patient details, with space to input relevant clinical history and laboratory values. A COMMENTS tab allows the resident to make any additional comments and the SAVE tab has a button that creates a triage complete
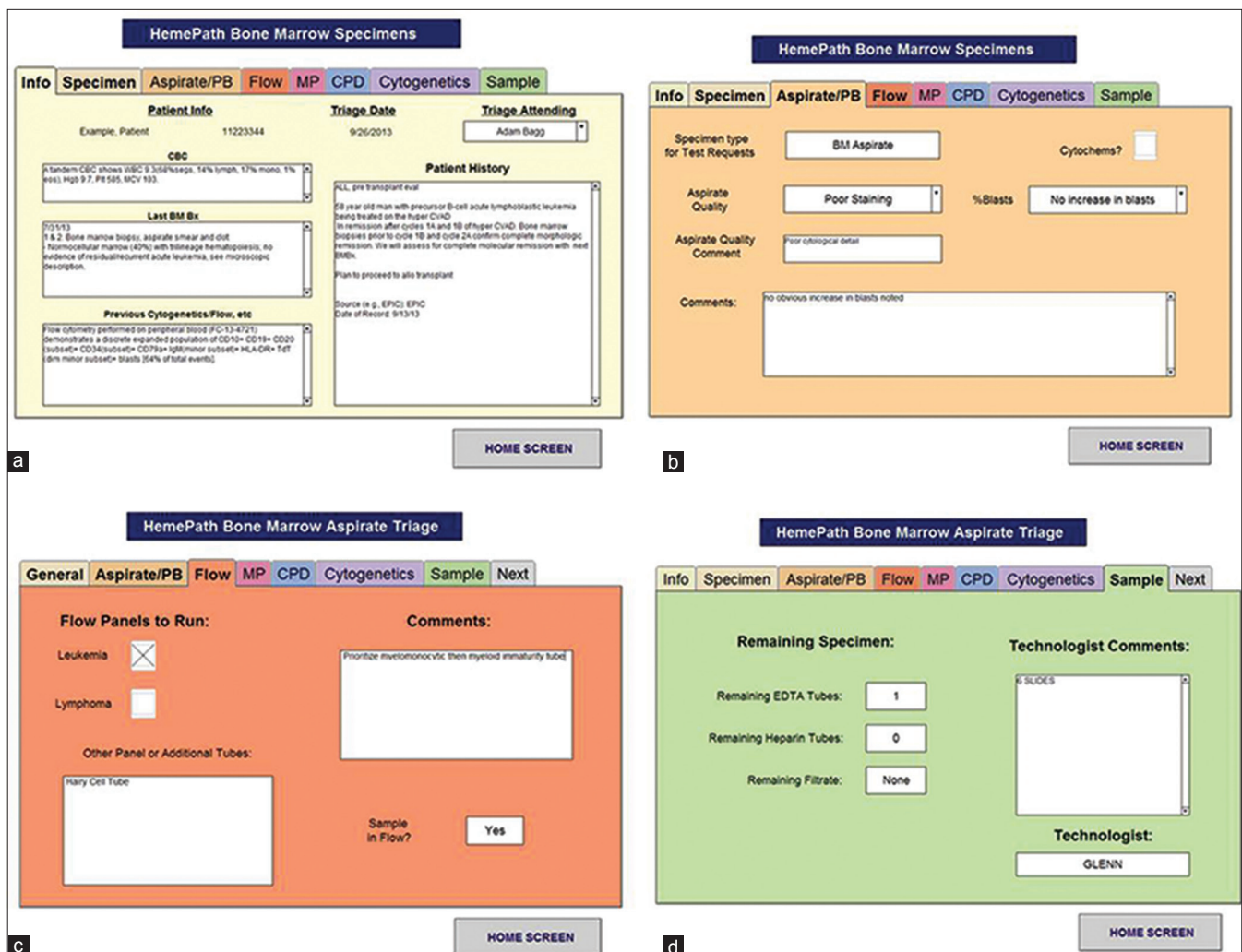

Figure 5: Selected tabs from hemepath triage view. The default tab is Info (a) Aspirate tab (b) To record aspirate impressions. Service tabs (flow cytometry, c, shown) allow approval of laboratory services. Sample tab (d) Provides specimen information

date, thereby removing the core-only specimen from the triage list. Hematopathology attending, residents, and fellows have access to this view.

Post Triage To Do

After triage, several new fields are calculated from existing data. For each laboratory, an Approved field is created if any testing is selected for that laboratory by the hematopathology team. Following triage, hematopathology residents need to ensure that, for all attending- and clinician-driven testing, appropriate downstream laboratories have a specimen. Normally, this would require contacting each laboratory to confirm that the sample was sent there by the technologist or walking to the hematology laboratory and checking the log-book. Using the dashboard, specimens that need to be transferred from the hematology laboratory to downstream laboratories can be viewed in real time after triage. In order to determine if a specimen is currently in the ancillary laboratory, the second variable, Take to Laboratory X is calculated. This field is "yes" if the Approved field for that laboratory is "yes," meaning the testing has been ordered and confirmed by the hematology service, and Sent to Laboratory X (initially inputted by technologist) is NOT "yes," meaning that the technologist did not send the specimen to the ancillary laboratory of interest. When the hematopathology team has finished triaging, the residents can select the POST TRIAGE TO DO button, which activates a script that finds all records with a Take to Laboratory X that is "yes," and has been triaged on the current date. This redirects the user to the *HemePath To Do* layout, which presents these specimens and relevant specimen data, such as the Take to Laboratory X field, accession number and remaining specimen, in a table. The after-triage specimen trafficking is now easily visible in one location, which can be printed or viewed on a portable tablet computer in the hematology laboratory. Hematopathology attending, fellows, and residents have access to this view.

Triaged Specimen Tables

Residents and other personnel from downstream laboratories can view their specimen lists by clicking their respective laboratory button under the triaged specimens heading. A script finds all triaged records (i.e. with a triage complete date) from the past 5 days that have been sent to the laboratory due to clinician-requested testing and/or have approved testing by the hematopathology service. The user is redirected to the respective page (e.g. MP, flow cytometry, etc.) where these specimens and their relevant information, such as patient information, specimen information (percent blasts, aspirate quality) and approved tests, are listed in table form. Attendings, residents, fellows, and other personnel from downstream laboratories have access to this view.

Detailed Specimen Review

If residents on the hematopathology service or at other ancillary laboratories wish to see more detailed information on a triaged specimen, either for clarification or during case sign out, they can do so by clicking the DETAILED SPECIMEN REVIEW button. A script finds all triaged records, sorts by specimen received timestamp (newest records presented first) and redirects the user to the *HemePath DashBoard Review* layout. This layout is nearly identical to the *HemePath Dashboard Resident* layout that is used during triage, with a few notable exceptions. None of the fields can be edited from this layout, but all information added to the specimen by the hematopathology service is visible to the user. A triage complete date is now visible on the INFO tab and the comment box for core only specimens can be viewed on the SPECIMEN tab. Finally, the NEXT tab is not available in this layout. It is possible to search by any of the fields, including patient name and medical record number. Attendings, fellows, residents and other personnel from downstream laboratories have access to this view.

Previous Specimens Tables

If a user wishes to quickly see all specimens that have been processed through the hematology laboratory (triaged or not), to possibly preclude unnecessary repeat testing or confirm that the specimen has been received, he or she can select the buttons in the Previous Specimens box. A script will find all records that have been received during the past 10 or 30 days and redirect the user to the *Previous Specimens* layout, which presents all specimen data in a table. Attendings, fellows, residents and other personnel from downstream laboratories have access to this view.

No Results Match

When a user chooses a layout, and the script finds no relevant specimens, the user is redirected to the *No Results Match* layout. A message alerts the user that no records are found, and there is nothing to do; a button allows the user to return to the *Landing page* layout. This view will also appear when the hematopathology residents reach the end of the triage list in the *HemePath Dashboard Resident* view. Attendings, fellows, residents, and other personnel from downstream laboratories have access to this view.

No Access

When a user attempts to visit a page that he or she does not have access to, the user is redirected to the *No Access* page. A message alerts the user that they have no access, and a button is available to allow them to return to the *Landing page*. All users have access to this view.

Database Storage, Scalability and Maintenance

The database is housed on a hospital server. Currently, we have 36 user accounts for 8 resident users (3 hematopathology residents, 3 MP residents, 2 flow

cytometry residents), 2 fellow users (hematopathology and MP), 4 hematopathology attending users, 5 laboratory personnel users (hematology, MP, cytogenetics and CPD), 1 genetic counselor (CPD), 13 technologist users (hematology laboratory), 1 laboratory supervisor user (hematopathology) and 2 administrative accounts encompassing six privilege sets. As FileMaker Server does not restrict the number of networked clients, we have the ability to scale to handle additional users, although we currently do not anticipate a need to increase the number of users substantially. Vetting of technologist inputted data and editing errors is handled by the laboratory supervisor.

The system is currently utilized for pre-triage specimen tracking, collection and presentation of data relevant to triage and communication of triage decisions to ancillary laboratories. However, it is not surprising that previously collected information stored in the database can be helpful during case sign-out. Ideally, for optimum efficiency, relevant laboratory results and patient information available in the LIS could be presented in the Dashboard and vice versa. Although this is currently not operational, the database has the ability to interface with data in a variety of database architectures, including MySQL (Oracle Corporation, Redwood Shores, CA, USA), and has the potential to eventually interface with our LIS to present relevant ancillary laboratory results.

Database Security

As protected health information (PHI) is stored within the database, security is of the utmost concern. The database is stored on a server behind the hospital firewall, and therefore, is only accessible to individuals with hospital IT credentials. After this initial layer of security, individuals are required to enter a second user name and password to utilize the database. Individual user names are associated with specific user rights (including access to specific portals, ability to visualize and or edit data fields, etc.) determined by the user's role (i.e. MP resident or flow cytometry resident), and only technologists and hematopathology residents and fellows are able to enter patient data. During this initial implementation and feasibility phase, we have been hosting this database in our genomics laboratory; however, plans are currently in place to move responsibility of the database to our department's IT operation, which has extensive experience with PHI and can manage user access and security, as well as perform audit trails to determine that users are accessing the database appropriately.

IMPLEMENTATION

After the initial design was completed, the database and dashboard went through a proof of principle exercise. The resident who created the dashboard tool performed several specimen walk-throughs, personally utilizing the database under the user ID and password that had user rights specific to the task at hand; that is, at specimen log-in, she used a technologist user ID and during triage she used a hematopathology resident user ID. After it was clear the design could work within our workflow, additional feedback on the tool was sought from representative users and additional functionality was added to the dashboards (discussed in detail below). In addition, during this time period, discussions were held with all end-users to ensure that there was interest in the tool and that it was developed, in a way that allowed easy usability. Pathologist end-users were very interested in having a computer-based triage system. However, there was some concern expressed among the technologists about the new technology, so extra time was spent in their training and development of their dashboard to ensure that they were comfortable with the system.

Technologists were trained as they rotated through shifts on the hematology bench, ideally in pairs, with one individual having experience with the dashboard and the other being a new user. During training, every bone marrow could not be captured due to times when technologist training could not be performed, so the handwritten specimen log book was also kept. Throughout training, the laboratory supervisor and the database designer would review specimens and confirm proper logging of specimens was being performed. During this time, it was noted that several blank records were being saved, usually at the end of a string of inputted marrows, apparently when the technologist hit NEXT ASPIRATE in order to save the record, instead of returning the *Landing page*. A script was added requiring a patient name for a new record and the technologist screen was amended to have clear SAVE and DONE and SAVE and NEXT ASPIRATE buttons, to avoid confusion at the end of a group of aspirates.

After all the technologists had been trained, we went through another round of beta testing, involving hematopathology, flow cytometry, MP and the genomics laboratory. At this point, the residents had been keeping triage sheets for each bone marrow, which was a template Word document into which they cut and pasted relevant laboratory and clinical information then printed out for triage. Residents rotating through the service requested that this information also be incorporated into the dashboard. In addition, hematopathology attendings asked for inclusion of FISH approval for the cytogenetics laboratory, which they were currently handling by E-mail and were often delayed due to service responsibilities. After discussion with involved parties, these functions were added to the dashboard. After this, one final successful round of beta testing was performed, involving all laboratories and inputting patient information from the Word documents into the dashboard. During this

beta-testing, ancillary services asked for patient name to be on every tab in the *Detailed Specimen Review* layout to reduce possible specimen mix-up; this feature was added there and in the *Triage* view as well.

During the final two rounds of beta testing, downtime documentation and procedures were created, including an E-mail notification list and paper records, which could easily be incorporated into the dashboard when functionality was restored. Help documentation was created for each user group.

Final implementation occurred concurrently with a transition of a new group of residents and hematopathology fellow, who were trained on the new system as part of their service orientation. Currently, a 1-h formal training for new residents occurs at the beginning of each new 3-month service block. New technologists and hematopathology attendings are trained as necessary.

An updated workflow with the incorporation of the dashboard is shown in Figure 6. Currently, the database is fully functional and has been operational for 6 months. During this time period, 924 new bone marrow specimens have gone through the workflow, and users have logged into the system 4890 times. Average number of log-ins per week varies by service, with the hematopathology fellows, residents and attendings having the highest utilization [Figure 7].

An end-user Likert survey was sent out to 6 months after implementation to determine user satisfaction and assess if the workflow was improved by the dashboard system. All individuals who utilized the Dashboard during the initial beta testing and the first 6 months were offered the opportunity to respond (N = 38); we had a 95% response rate (N = 36). The majority of respondents agreed or strongly agreed that the Dashboard was an improvement from the old workflow (N = 32, 89%), with the remainder neither disagreeing nor agreeing. Most resident, fellow and laboratory professional end-users (N = 23) agreed or strongly agreed that the dashboard system improves triage efficiency (90%), improves specimen documentation (96%), reduces time walking back and forth to the hematology laboratory (96%), and reduces the number of service-to-service phone calls and pages (96%). In order to gauge technologist comfort with the new system, they were queried in a separate survey; all technologist users (N = 13) reported that the system was easy to use. Among all users, 86% (N = 31) were satisfied with the Dashboard, with four individuals reporting they were neither satisfied nor dissatisfied, and one technologist end-user feeling dissatisfied with the new system.

CASE EXAMPLES

Example 1

Overnight, the hematology laboratory received a bone marrow aspirate (three EDTA tubes, one heparin tube) and core specimen from a 42-year-old man with a 3 week history of fever, chills, and malaise/fatigue, status post a course of antibiotics without improvement. His complete blood count was notable for a low hemoglobin (10.0 g/dL) and low platelet count (50,000/μL), and there was clinical concern for leukemia. The clinician requested
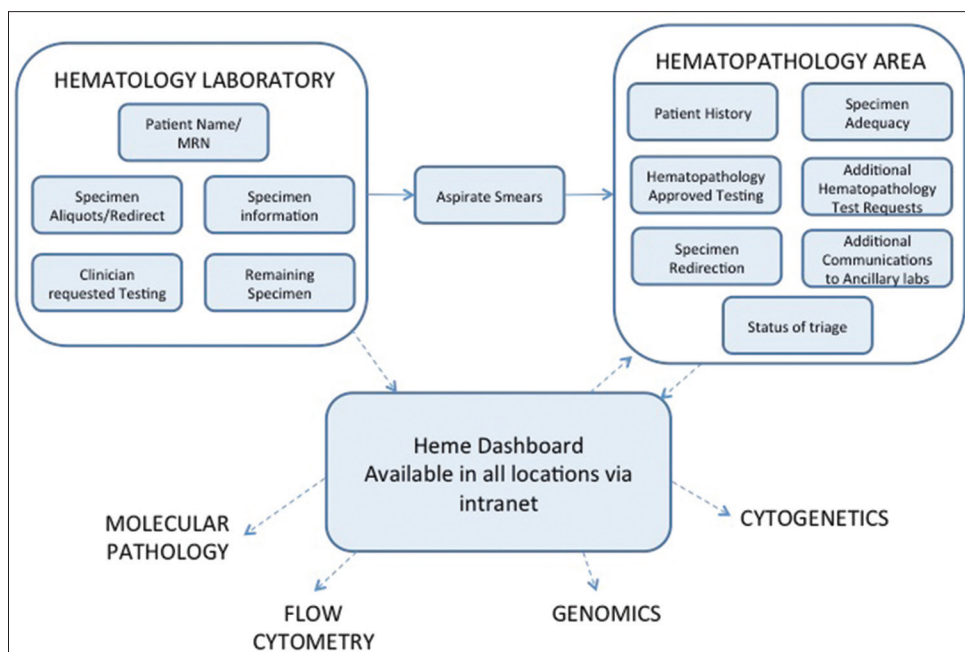

Figure 6: Updated workflow utilizing the hemepath database and dashboard. Solid arrows represent physical movement of residents and specimens. Dashed arrows represent communications. For simplification, bone marrow aliquot transfers to downstream laboratories are not shown in this figure
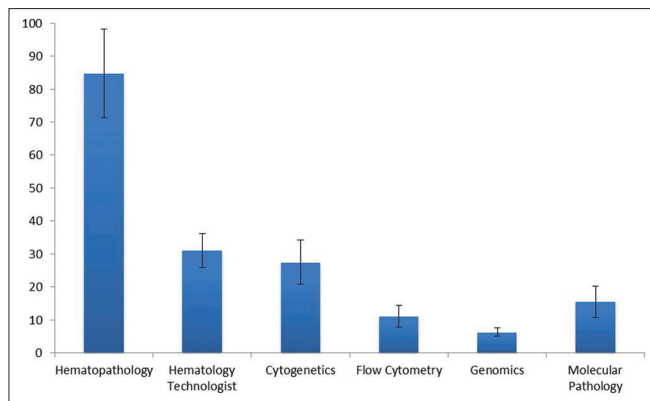
Figure 7: Average weekly dashboard usage, by service. Average number of log-ins per week into the HemePath database and Dashboard by service over the first 6 months after implementation. Hematopathology includes fellows, residents and attendings on the service. Bars represent standard deviation

Figure 8: Case example 1 technologist view. Technologist accessioning of case example 1 into the Dashboard through the technologist view

flow cytometry (leukemia panel), MP testing (leukemia translocation panel, *FLT3*, *NPM1*), liquid tumor next generation sequencing panel (genomics, CPD), and a conventional karyotype through the cytogenetics laboratory. The technologist rerouted the bone marrow core to surgical pathology and then accessioned the bone marrow aspirate into Cerner. Next, the technologist prepared aspirate smears, aliquoted specimen for the various laboratories and accessioned the sample into the dashboard, including the received specimen, remaining specimen, number of aspirate smears, and comments [all information that was previously manually recorded in a logbook, Figure 8]. Once the record was saved, it becomes visible to other users in the *HemePath Awaiting Triage* list. Meanwhile, the technologist transferred the specimen aliquots to the ancillary laboratories, and the hematopathology residents can begin to collect patient information in preparation for triage and input it into the INFO tab in the *HemePath Dashboard Resident* layout. The next morning, the hematopathology residents pick up this patient's aspirate smear with the rest of their workload. Meanwhile, residents on the ancillary services view the *HemePath Triage* list to determine if triage has occurred for their specimen. During the triage with the attending, patient history and specimen test requests are easily accessible through the *HemePath Dashboard Resident* layout. It is determined that there are increased blasts on the aspirate smear (>20%) and the specimen is adequate and appropriate for all requested testing; the testing is selected for each laboratory under their Dashboard tab [Figure 9]. Sample triage is completed by hitting the GO TO NEXT SAMPLE button on the NEXT tab, which automatically removes the specimen from the *HemePath Awaiting Triage* list and populates it on the service-specific lists and in the *Hemepath Dashboard Review* view. Residents in downstream laboratories see that the testing is approved, and the specimens are handled accordingly.

Example 2

The hematology laboratory received a bone marrow aspirate (two EDTA tubes and one heparin tube) and core specimen from a 64-year-old man with a history of chronic lymphocytic leukemia (CLL). The clinician requested the CLL FISH panel (evaluating *ATM*, *TP53*, Del13q14 and Trisomy 12) and a conventional karyotype from the cytogenetics laboratory. The technologist rerouted the bone marrow core to surgical pathology, accessioned the bone marrow aspirate into Cerner, prepared aspirate smears and sent the heparin tube to cytogenetics. After this, remaining specimen included one EDTA tube and 1 mL of filtrate. As previously, the specimen was accessioned into the database [Figure 10], and the hematopathology residents collected information for triage. During the triage, the aspirate was noted to have lymphocytosis in a background of trilineage hematopoiesis. The hematopathology team desired flow cytometry on this specimen; however, since there was no clinician-driven flow cytometry request, no sample was in the laboratory. This was apparent when the residents clicked on the FLOW tab in the *HemePath Dashboard Resident* layout and saw the empty Specimen in Laboratory? field. By looking in the SAMPLE tab, the service team then checks to see if there is remaining sample, which there is, and returns to the FLOW tab to select the Lymphoma Panel. The CLL FISH panel is deemed appropriate, and "Approved" is selected from the FISH approval dropdown field in the CYTOGENETICS tab [Figure 11]. After sample triage is complete, the specimen is automatically added to the *Post Triage ToDo* list, as a resident or technologist needs to redirect some of the remaining specimen to the flow cytometry laboratory [Figure 11e]. As described in the previous example, the sample is also removed from the *Triage* list and populates in the service-specific lists and in the *Hemepath Dashboard Review* view.
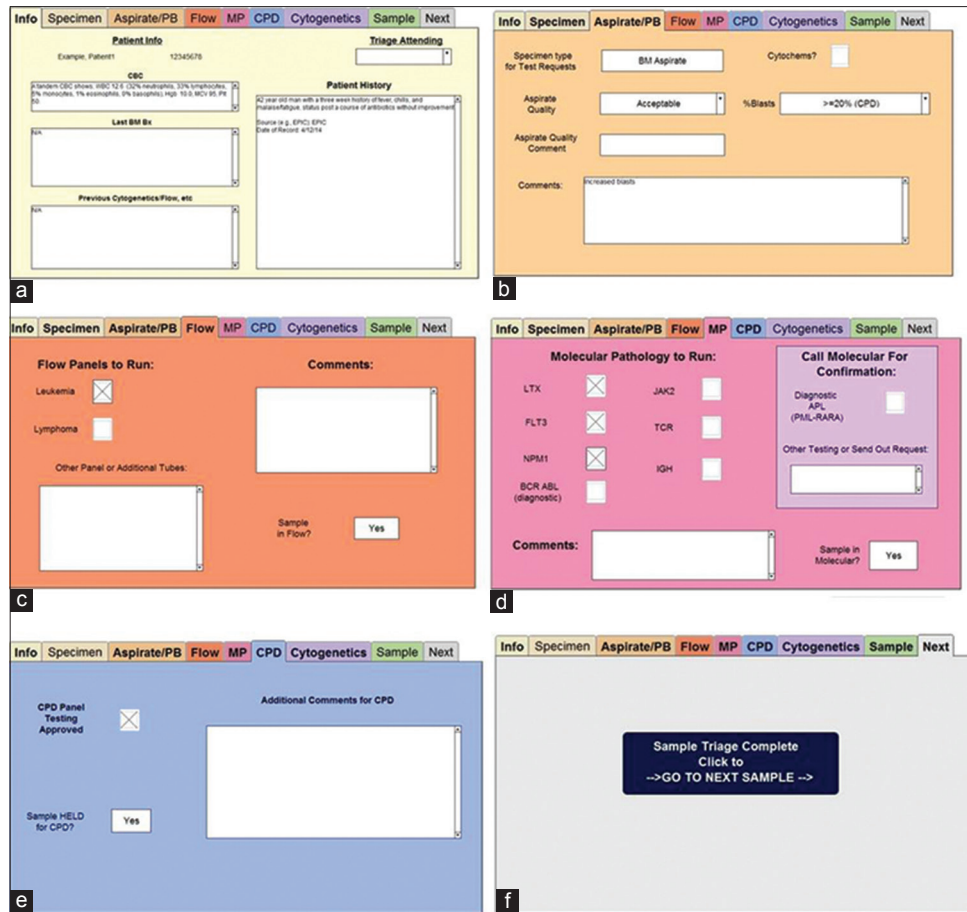
Figure 9: Select tab views from HemePath Triage for case example 1. (a) Patient history is added to the Info tab prior to triage as seen. During triage, (b) Aspirate impressions are recorded, and (c-e) Ancillary laboratory testing is approved. (f) The SAMPLE TRIAGE COMPLETE button in the Next tab is hit to save the record and move it off the triage queue

Figure 10: Case example 2 technologist view. Technologist accessioning of case example 2 into the Dashboard through the technologist view

CONCLUSIONS

Occasionally, pathologists have to handle specimens and test requests outside of their LIS, including manual requisitions or testing requiring pathologist review prior to test completion that cannot be easily incorporated into a standard LIS. To properly integrate unique institution workflow into a commercial LIS can require significant time, money and programming expertise. With these significant barriers, it is not surprising that manual methods, such as handwritten logbooks, are instituted as a stop-gap. With increasing volume and complexity of testing, this places a large burden on already overburdened technologists and residents to direct specimen flow, with a very real danger of specimen loss and laboratory miscommunications. The challenge to develop solutions that are cost-effective, quickly built and easily implementable is increasingly falling on pathologists and pathology residents, who are at the center of specimen traffic and best understand the needs of the laboratory.[4] As such, emphasis is currently being placed on the emerging field of Pathology Informatics, which will help create the leaders in our field to address many of these issues.[5] However, in the meantime, there are many pathologists with informatic challenges unique to their institution. Here, we present a database and dashboard solution, developed on a FileMaker backbone, which was created by a pathology resident with only limited programming experience. This dashboard was beta tested,
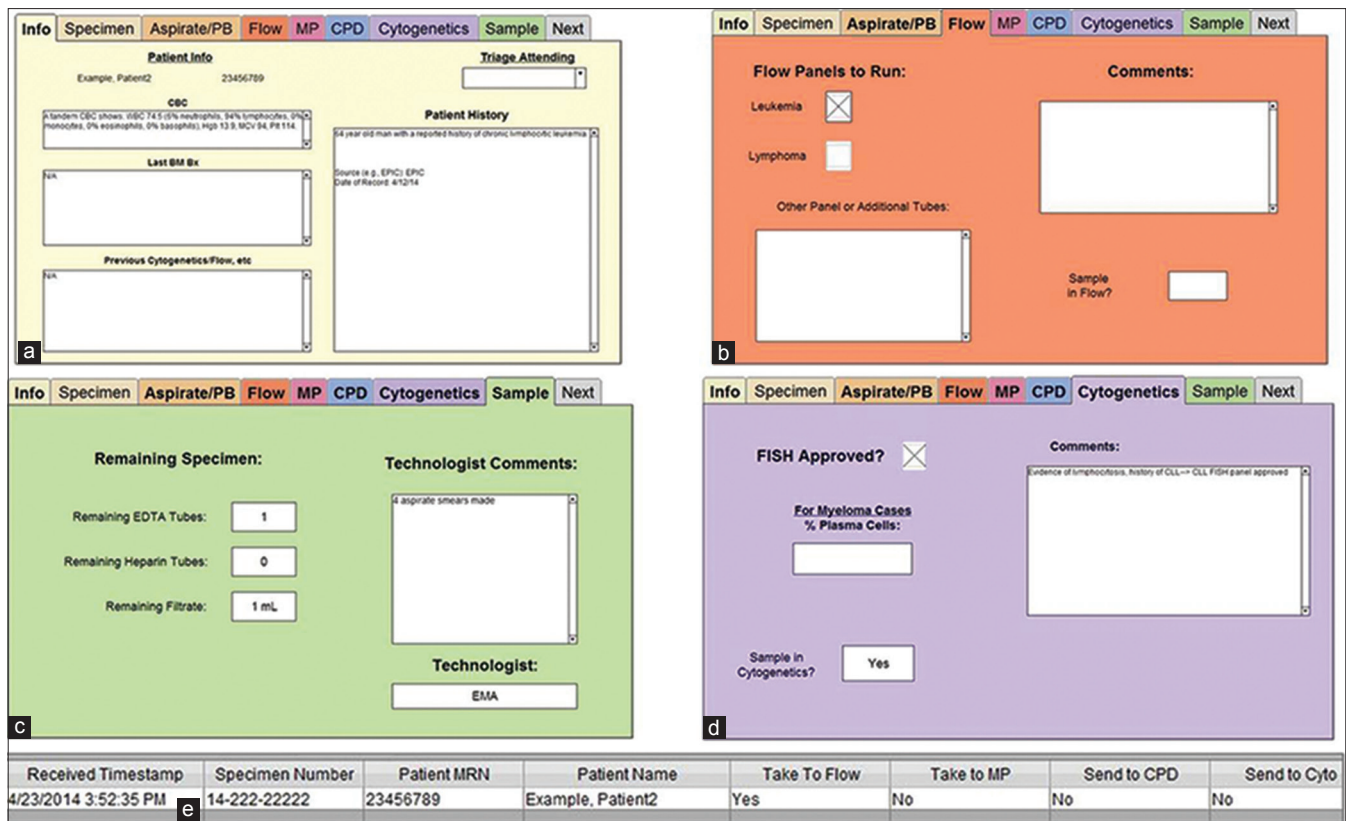
Figure 11: Case example 2 hemepath triage. (a) Info tab, (b) Flow cytometry is approved, but there is no sample in the lab, (c) Sample tab shows available remaining specimen for flow cytometry, (d) Chronic lymphocytic leukemia fluorescence *in situ* hybridization panel is approved in the cytogenetics tab. Clicking on the POST TRIAGE TO DO button on the Landing page creates a to do list, (e) Showing that specimen needs redirected to the flow cytometry laboratory

improved upon and implemented, all within 6 months and provides our institution with a way to track bone marrow specimen aliquots prior to hematopathology triage and test approval/accession, document triage decisions for ancillary laboratories and later review, as well as allow quick communications between complementary services.

A few aspects of our experience are of particular note. First, it was vitally important to involve residents and technologists in the initial phases of development and implementation. These individuals are "on the ground," and can provide perspective on what is important to include and what can actually be accomplished. Furthermore, without the support of these stakeholders, implementation of a new technology can be met with resistance. Second, as technologist-inputted data affected all downstream programming and an error by a technologist could mean incorrect sorting of specimens and triaging, we spent a significant amount of time training the technologists, as well as providing many weeks of "practice," where they kept using the handwritten log book along with the database. This allowed us to anticipate common technologist input errors and adapt the custom scripting accordingly. In addition, technologist initials allowed us to see which, if any, individual was having problems. Finally, beta testing and initial

implementation was done with the database designer, who had already rotated through the hematopathology service as a resident, actually walking through the daily workflow. During this process, feedback was requested from all users, including attendings and ancillary residents, and the designer was also able to appreciate what problems could arise, in real-time. This allowed quick adaptation of the dashboard and smooth implementation.

In addition, the system is currently flexible enough to modify or add additional fields to current dashboards, as needed. Our workflow is very specific to our institution; however, such a system could be adapted to other institutions with differing downstream testing by merely changing the ancillary test names, adding additional tests and/or tabs for different laboratories. Although we present an example of a custom database to address a very specific problem, similar dashboards could be developed for other laboratories and institutions to deal with specimen tracking and/or documentation of decision making that may need to occur outside of the LIS.

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