Implementation of a Software Application for Presurgical Case History Review of Frozen Section Pathology Cases

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Abstract

Background: The frozen section pathology practice at Mayo Clinic in Rochester performs ~20,000 intraoperative consultations a year (~70–80/weekday). To prepare for intraoperative consultations, surgical pathology fellows and residents review the case history, previous pathology, and relevant imaging the day before surgery. Before the work described herein, review of pending surgical pathology cases was a paper-based process requiring handwritten transcription from the electronic health record, a laborious and potentially error prone process. **Methods:** To facilitate more efficient case review, a modular extension of an existing surgical listing software application (Surgical and Procedure Scheduling [SPS]) was developed. The module (SPS-pathology-specific module [PM]) added pathology-specific functionality including recording case notes, prefetching of radiology, pathology, and operative reports from the medical record, flagging infectious cases, and real-time tracking of cases in the operating room. After implementation, users were surveyed about its impact on the surgical pathology practice. **Results:** There were 16 survey respondents (five staff pathologists and eleven residents or fellows). All trainees (11/11) responded that the application improved an aspect of surgical list review including abstraction from medical records (10/11), identification of possibly infectious cases (7/11), and speed of list preparation (10/11). The average reported time savings in list preparation was 1.4 h/day. Respondents indicated the application improved the speed (11/16), clarity (13/16), and accuracy (10/16) of morning report. During the workday, respondents reported the application improved real-time case review (14/16) and situational awareness of ongoing cases (13/16). **Conclusions:** A majority of respondents found the SPS-PM improved all preparatory and logistical aspects of the Mayo Clinic frozen section surgical pathology practice. In addition, use of the SPS-PM saved an average of 1.4 h/day for residents and fellows engaged in preparatory case review.

Keywords: Frozen section, intraoperative, software, surgical pathology

INTRODUCTION

In 1905, Dr. Louis Wilson, the first pathologist of the Mayo Clinic group practice in Rochester, Minnesota, described a reproducible method for rapid histologic evaluation of surgical specimens.[1,2] This methodology involves rapid freezing of fresh tissue on a specially designed microtome down to temperatures below those used in modern cryostat microtomes, allowing evaluation of a wider variety of tissue types while minimizing freezing artifacts.[3,4] The frozen section technique allows for intraoperative diagnosis and evaluation of tumor margin status, leading to improved patient outcomes. In 2014, approximately 20,000 frozen section intraoperative consultations were performed at Mayo Clinic in Rochester (i.e., 70–80 frozen section cases per weekday) using this technique, with the interpretation of more than 150,000 histologic blocks and 100,000 frozen section slides. To enable rapid diagnoses with such high case volumes,

pathologic, radiologic, surgical, and clinical information is gathered and synthesized for each case before the day of surgery by surgical pathology residents and fellows. On the day of surgery, the information is then disseminated to the frozen section laboratory team during a trainee-led morning report. Morning report involves a synoptic discussion of the day's patients and requires concise and accurate transmission of large volumes of case information to a diverse audience in a limited time frame. Case information is then applied in real time by laboratory staff to guide gross dissection and microscopic diagnosis.

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Before the work described herein, aspects of the case review process were carried out in an idiosyncratic and manual fashion. Review of pending surgical pathology cases was a largely paper-based process that required extensive transcription of information from the electronic health record (EHR). Transmission of the gathered information then occurred through a fast-paced verbal morning report in which all participants transcribed relevant case information onto their own printed copies of the day's surgical list. Although this challenging task was quite functional and well handled by trainees and staff, it was somewhat laborious and bore an inherent risk for errors to occur in either collection, transmission, or recording of clinical information.

To help address perceived inefficiencies in the list review process and to eliminate, where possible, the potential for errors in the communication of case information, a process improvement effort was undertaken. Herein, we describe that improvement effort, the software application that resulted from it, and the use of that application to facilitate improved communication of case review information and enable real-time case tracking during surgical pathology consultation.

METHODS

Process analysis

A lean process improvement strategy was utilized to identify areas of waste in the surgical pathology list review process.[5-7] A workflow process map [Figure 1] was developed to capture the essential inputs and outputs required to complete the list review process and then utilize the gathered information for surgical pathology diagnoses. Specific areas for process improvement were identified by interviewing stakeholders (residents, fellows, pathology assistants, and staff pathologists), with a focus on tasks perceived as inefficient or unproductive, and by independently observing and mapping the current processes. Presurgical case preparation was identified as an area of significant potential inefficiency, with residents and fellows reporting that case review using the EHR involved several repetitive activities. Abstraction of information from the EHR for pathological diagnosis can be a complex and time consuming;[8] in our practice, the average reported time to complete the list review and case annotation (~125 total cases with ~35 frozen section cases)
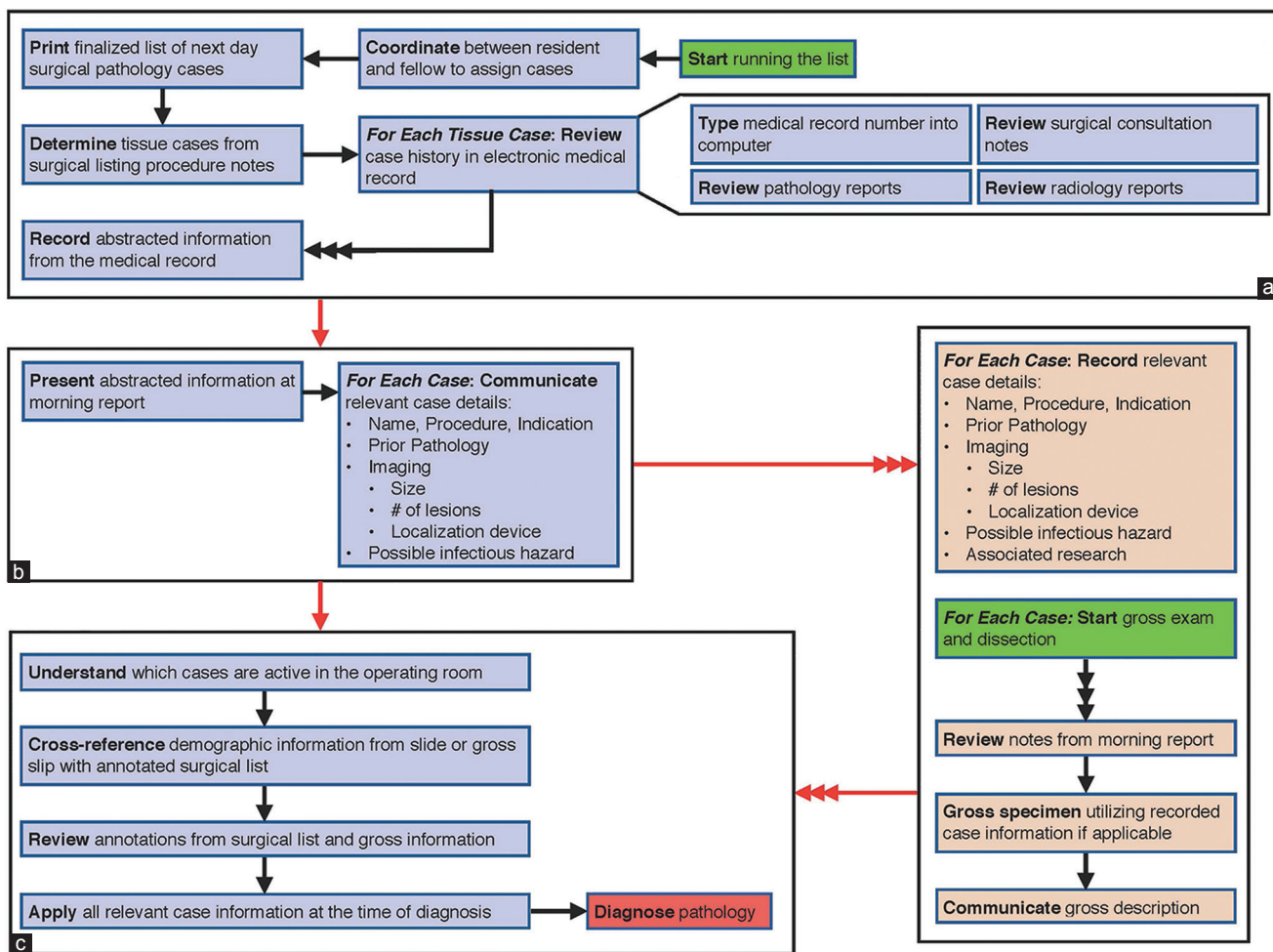

Figure 1: Process flow diagram for (a) presurgical case review, (b) morning report, and (c) real-time case review. An accessory process for surgical listing information recipients who participate in specimen grossing is shown in tan. Information flows between processes are designated by red arrows

was 4 hours per person per day (with single fellow and/or resident participating). Significant time was consumed in shifting attention between a printed list of surgical patients (used by residents and fellows to identify potential cases for review) and the pathology, radiology, and clinical note sections within the EHR. Once cases were identified, pertinent details then had to be abstracted from the EHR by manual transcription to either a printed surgical patient list or separate note sheet. In the absence of an established mechanism for collating the list review work product before morning report, residents and fellows independently reviewing the list (typically accomplished at night and/or from home) sometimes duplicated case review work.

Other areas identified for improvement by stakeholders were clarity and completeness of morning report (during which information from the case review is disseminated to the frozen section laboratory team) and situational case awareness during the intraoperative case review. Interestingly, the physical size of the existing printed surgical list was identified as a potential logistical issue in case review. Although only 30–40 surgical cases in a day (out of 75–175) might require a frozen section consultation, the electronic listing system in place was only capable of printing a surgical list including all cases (typically 30–40 pages in length). Stakeholders reported that a nontrivial amount of time was used to simply search through the printed list to locate a specific listing (and associated case notes) when tissue from a new case would arrive in the laboratory.

After mapping the case review process in its entirety, three major subprocesses were identified [Figure 1] in the creation and application of the surgical list for frozen section pathology: (1) generation of the pathology notes for the surgical list; (2) communication of those findings to the laboratory staff; and (3) utilization of those notes to aid in the diagnostic process. Furthermore, the utilization of pathology notes by other staff (junior residents and pathology assistants) to perform the gross dissection of frozen section specimens was identified as an important accessory process [Figure 1].

Development process

To increase efficiency and reduce the possibility for errors in the gathering, recording, communicating, and application of case information, it was determined that a software application should be developed. Modification of an existing Surgical and Procedure Scheduling (SPS) software application was identified as the best approach for meeting the needs of the surgical pathology practice. The SPS application is custom software developed in-house and primarily used by the Mayo Clinic Department of Surgery to create and manage the institutional surgical schedule. A "listing" in the application contains patient demographics, procedure type, procedure indication, diagnosis (if available), medication orders, patient assessments, required equipment or supply notes, and pharmacy and anesthesia requests. The SPS application was designed to accommodate "modules" with additional

functionality from other departments, such as anesthesia or pharmacy, to facilitate total care of surgical patients. Taking advantage of this architecture, development of a pathology-specific module (PM) for the SPS application was undertaken using an Agile software development process.[9,10]

SPS-PM requirements [Table 1] were defined from the process map [Figure 1] and then further refined with stakeholder feedback on specific areas of waste or inefficiency. Over a 2-month period, several development cycles (sprints) were undertaken during which key functionality was added to the SPS-PM, tested by a resident serving as an end-user technical representative, and then formally integrated into the SPS-PM module. Once core functionality was present, the SPS-PM was launched to end users for an initial 2-month evaluation period. The software was designed for ease of use, with a user interface paradigm consistent with typical office productivity software. An initial basic demonstration of functionality, but no specific end-user training, was provided to a cohort of residents on the frozen section service. In turn, those residents demonstrated the software to fellows on the service. Residents and fellows then served as information sources and advocates for adoption by the frozen section staff including staff pathologists, pathology assistants, and technicians. The attending head of the Frozen Section Working Group was the physician champion for the project, and one of the residents directly involved in the development of the software acted as a superuser to provide real-time support for issues and also to serve as a recipient for evaluation feedback. During the initial evaluation period, ongoing user feedback was used to improve SPS-PM stability and to identify several additional key features (case searching and an operating room visual overview) to

Table 1: Pathology module feature requirements associated with case review, communication of review information, and real-time intraoperative case management

Review
    Provide an electronic list of surgical cases
    Provide a direct link (i.e., hyperlink) from the surgical listing to patient record in EHR
    Allow persistent pathology notes to be attached to listings
    Allow cases to be classified as infectious hazards
    Prefetch relevant information from the electronic medical record (i.e., imaging, prior pathology, and surgical operative notes)
Communication
    Allow for a case list inclusive of only surgical pathology consultation cases
    Provide a high-density print view (i.e., minimize printed page count)
    Include pathology annotations on printed lists
Management
    Display status of cases in the operating room
    Allow surgical listings to be ordered in different ways (e.g., last name, surgeon, or number)
Overall
    Provide application security (HIPAA-compliant authenticated access only)

EHR: Electronic health record

be added. After the review period, the SPS-PM application was moved into a production environment, and additional presentations were given to key stakeholder groups (attending physicians and physician assistants) to demonstrate features and functionality.

Technical background

The SPS is a.Net C# Windows Presentation Foundation application that runs on the Microsoft Windows Operating System, version 7 or greater. It was developed using the CSLA.NET (http://cslanet.com/) and Model-View-ViewModel (MVVM) light (https://mvvmlight.codeplex.com/) frameworks, using a MVVM (https://msdn.microsoft.com/en-us/library/hh848246.aspx) design pattern to separate application logic from the presentation layer. Portions of the user interface were implemented using the MahApps.Metro user interface toolkit for Windows Presentation Foundation applications (http://mahapps.com/). Database and web service retrievals were achieved using the factory method pattern. Listing information was maintained in Sybase and MS Structured Query Language (SQL) databases accessible through standard SQL queries. Additional clinical information was retrieved from the Mayo Clinic Electronic Medical Record (GE Healthcare, Wauwatosa, WI, USA) through web service application programing interface requests. Access to protected health information through these systems is implemented through client authentication within a monitored HIPAA-compliant environment.

Survey

After 3 months of use, staff pathologists, residents, and fellows were surveyed to assess the SPS-PMs impact on practice workflow. Study survey data were captured and managed using the Research Electronic Data Capture (REDCap) system (Vanderbilt University, Nashville, TN, USA).[11] Fifty-five physicians, fellows, and residents involved in the frozen section pathology processes were surveyed. There were 21 respondents (34 non-respondents), of which five had not used the SPS-PM application and sixteen had used the application. The sixteen respondents included five staff pathologists, eleven trainees (residents or fellows).

RESULTS

Application features

The SPS-PM application was designed for three specific tasks within the list review process: (1) preconsultation case review, (2) communication of review information to frozen section laboratory staff, and (3) real-time intraoperative case management. The preconsultation case review functionality was intended to provide all pathology-relevant information on a surgical listing, while eliminating nonrelevant information (e.g. anesthesia or nursing notes) that slowed or obscured the review process. The listing information is presented to the user within a scrollable list [Figure 2] that allows all cases for a given day and surgical site to be viewed and annotated. By default, the list is organized by surgical

specialty, but it can be organized by patient name, operating room, or status (preoperative, in surgery, or postoperative) by the user.

Each SPS-PM case listing includes the patient's unique medical record number, which serves a direct link to that patient's record within the EHR. An annotation function then allows pathology-specific notes to be added to listing information by text entry or copy-paste from the medical record. In contrast to other listing notes, pathology notes are visible only to users within the Department of Pathology. The SPS-PM annotation screen is accessed by double-clicking on a patient's surgical listing [Figure 3]. In addition to providing for entry of case notes, the system prefetches case-associated radiology, pathology, and operative reports from the EHR and presents them within a sortable field for review. Once added and saved, pathology notes are visible within the main surgical listing view [Figure 2]. User initials appended to the end of the notes allow for identification of the note author. Cases without a requirement for intraoperative pathology consultation can be excluded in this annotation screen to hide them from the active case list. These excluded cases, however, do remain in the system and are retrievable at any time. Potentially, infectious cases can be designated as "Hood Required," which adds emphasis text to a surgical listing as a visible reminder that tissue should be processed in a biohazard safety cabinet. To facilitate morning report and real-time case tracking, two print views were created: a standard print view that prints in a format similar to the old printed surgical list minus excluded cases, and a "condensed" list view allowing the entire surgical list to be printed on as few sheets as possible [Figure 4].

Several application features were designed to facilitate intraoperative case management. Inclusive within each surgical listing is a color status indicator. Cases are automatically designated as pending (orange), active (green; time of incision noted), or complete (blue; time of closure noted). This indicator allows for an "at a glance" assessment of case status and serves as a filterable field whereby users can select only pending cases, active cases, or not yet completed cases. The list can also be organized by surgical specialty, patient name, or operating room number to facilitate different workflows within the frozen section laboratory. Text search functionality is available for rapid filtering based on text matching to any portion of the surgical listing including the pathology notes.

Before the development of the SPS-PM application, a different software tool was used to provide situational awareness in the frozen section laboratory. That tool provided a map-like overview of the operating rooms and was much prized for its ability to provide a quick overview of workload status. Based on user feedback, a similar feature was added to the SPS-PM application [Figure 5]. This feature consists of a pseudogeographic overview of the operating rooms at either hospital, with coloration and text providing essential real-time case information. The overview screen can be refreshed manually at any time, and automatically refreshes at 2 minute intervals
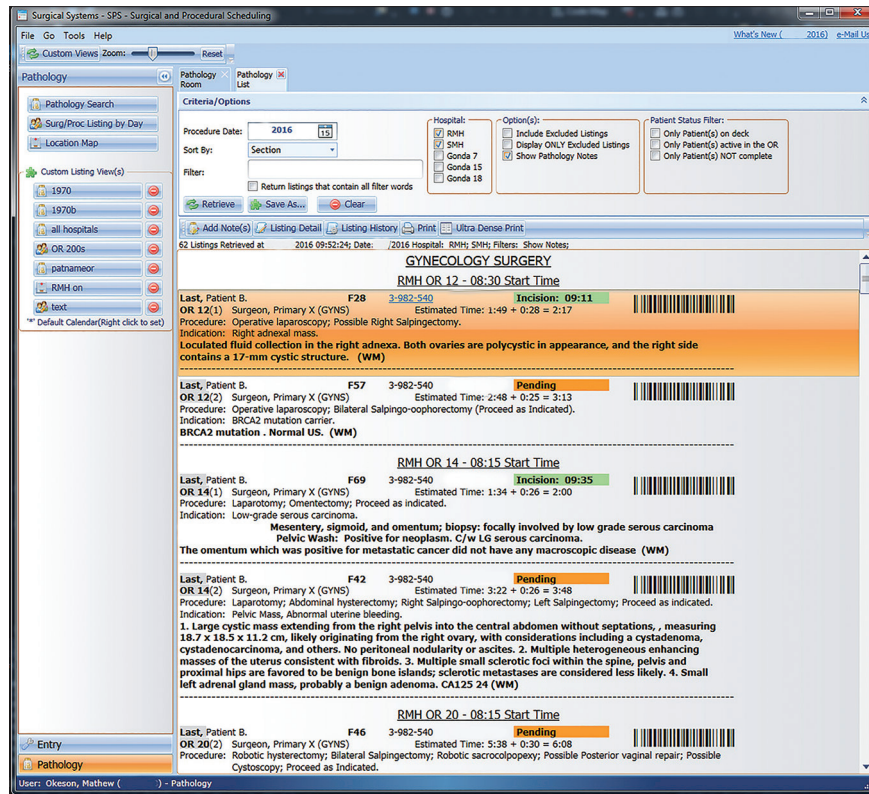
Figure 2: Surgical pathology listing viewer application. Surgical listings are presented as a scrollable list. Pathology notes are shown in bold lettering at the bottom of each listing, with author identified by initials. Options allow for showing cases that have been excluded and also filtering of cases by status in the operating room
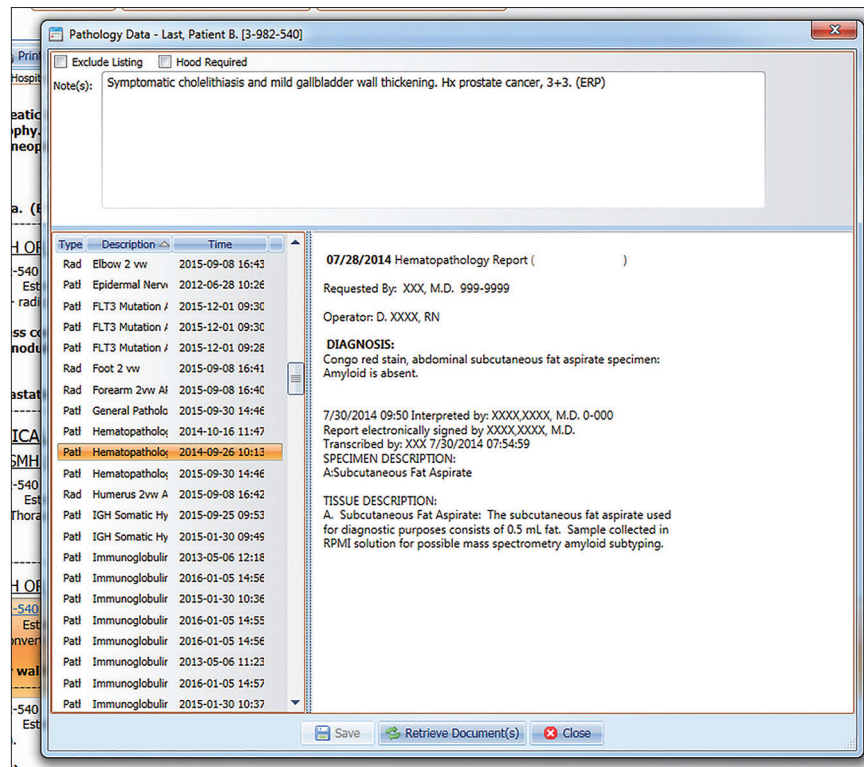

Figure 3: Dialog screen for case review and pathology note entry. A note textbox can be used to enter typed or copied text. In the lower right, prefetched pathology, radiology, and operative note information can be seen and selected for review. This screen also allows a case to be excluded from the active set of listings or defined as requiring a biosafety hood

Figure 4: Print-friendly case listing view. An example of a densely formatted surgical list is shown. Listings are presented in two columns with minimal intervening space. The operating rooms included within a given column are listed for easy reference at the bottom of that column

may be enabled with a toggle button. To facilitate diagnostic workflow when using this view, a "specimen jar" icon was added to denote cases with pathology notes. Pathology-specific notes in this view can be accessed by hovering over the specimen jar icon as a tooltip or by double-clicking on the operating room to reveal a modal dialog box [Figure 6].

User perceptions

Adoption of SPS-PM by residents and fellows was nearly instantaneous upon its introduction into clinical use. A REDCap survey of perceptions of the SPS-PM application was sent to 21 staff, fellows, and residents; there were 16 respondents (five staff pathologists and eleven trainees). The survey asked questions about three areas of practice: preconsultation case preparation, morning report, and real-time case awareness. Overall, trainees indicated a significant improvement of the surgical pathology practice. Nearly all trainees (10/11; 91%) reported that the application both improved abstracting information from the EHR and the time required to complete case preparation. Time saved by the application was a mean of 1.4 h/day (range of 0–4 h; one trainee reported no time savings). The SPS-PM application also improved identification of potentially infectious cases (7/11; 64%).

For morning report and surgical day performance, the opinions of both trainees and attending pathologists were solicited.

Respondents indicated the application improved the speed (11/16; 69%), clarity (13/16; 81%), and accuracy (10/16; 63%) of morning presurgical case review. The survey was conducted before the addition of the operating room map overview feature; even so, a majority surveyed reported case review at the time of diagnosis (14/16; 88%) and situational awareness of multiple ongoing cases (13/16; 81%) was improved by the SPS-PM.

Discussion

Review of clinical information, prior pathology, and imaging are an essential component of pathological diagnosis in all settings. The frozen section practice at Mayo Clinic in Rochester is unique in that its rapid turn-around time and large case volumes require that a large number of individuals take part in rendering an intraoperative consultation. As all team members require working knowledge of the relevant case information, gathering and dissemination of that information take on a vital significance. While the time-tested method of manual record abstraction from the EHR followed by verbal communication of the information to the laboratory staff was effective, it was also inefficient. Development of the SPS-PM application allowed many of those inefficiencies to be addressed, resulting in expected improvements in both trainee's time required and effort expended.
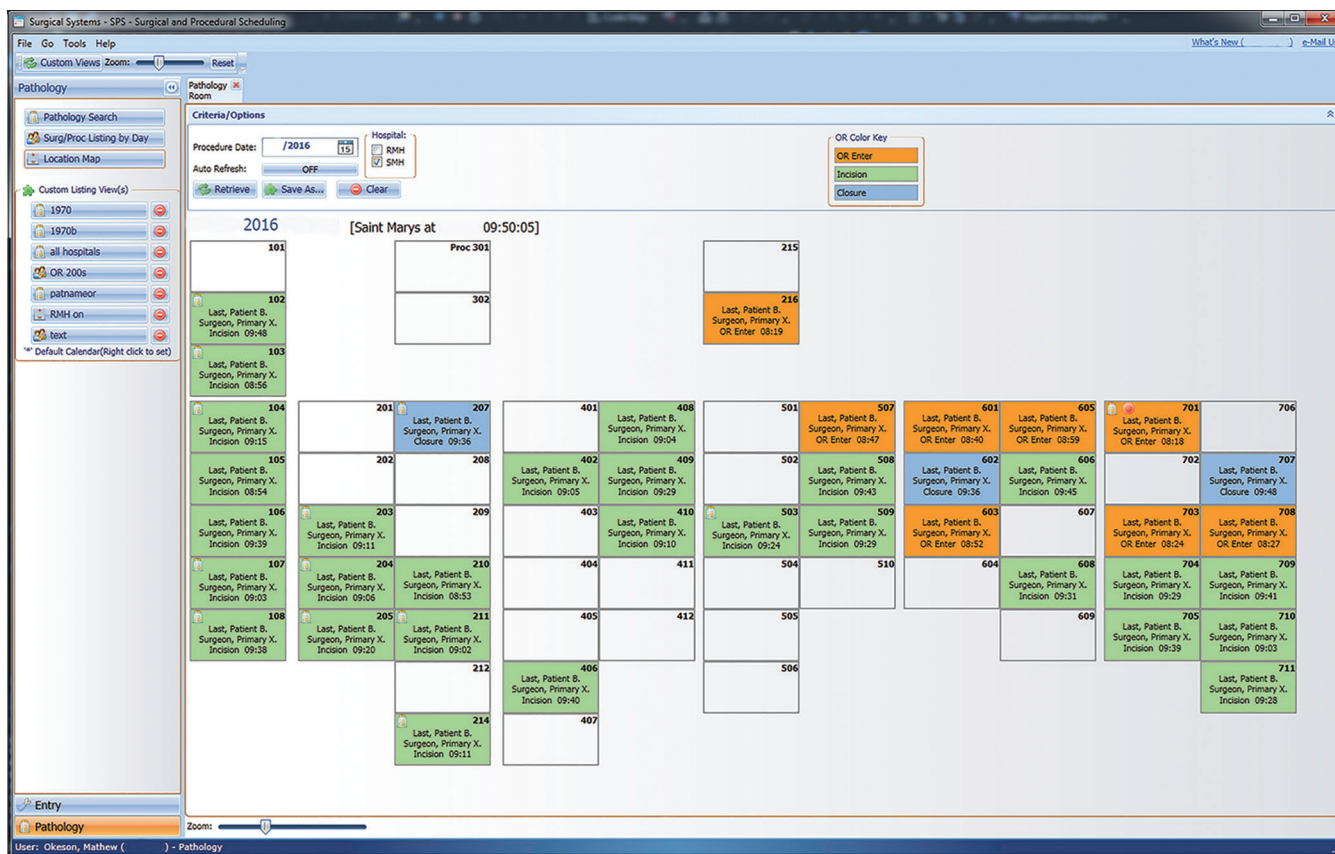
Figure 5: Operating room map view. A pseudotopological map representing the operating room layout at Mayo Clinic in Rochester – Saint Mary's Campus. Case status in each operating room is color coded: entry (orange), incision (green), and closure (blue). A "specimen jar" icon in the upper left indicates cases with associated pathology notes
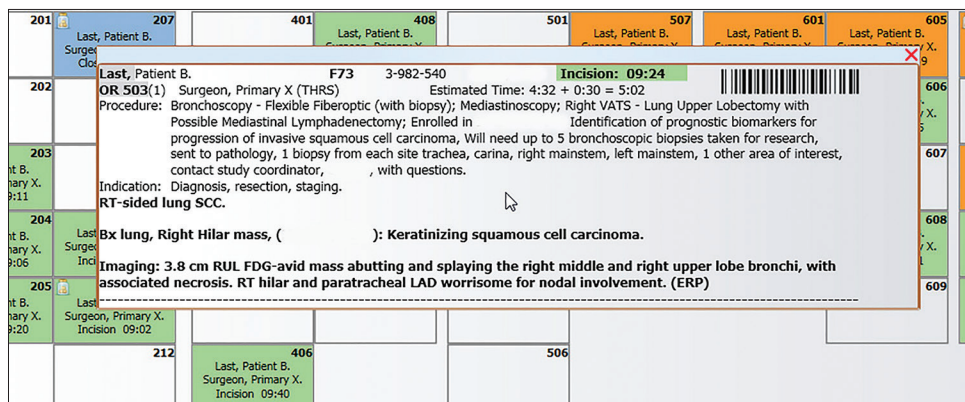

Figure 6: Operating room map view pathology notes detail. Clicking on the "specimen jar" icon reveals a case's associated pathology notes

One immediate benefit of moving the surgical list review process to an electronic platform was the transferability of completed case annotations when a surgical date would change. Before implementation of the SPS-PM, trainees would usually be required to wait until the next day's surgical schedule was finalized at 19:00 h before embarking on the several hour processes of running the list. Three factors drove this behavior: (1) a requirement that the list be discussed at morning report in the correct final order (no list changes in operating room assignments or case order), (2) a desire to avoid reviewing cases that might be cancelled or postponed, (3) a need to ensure all cases requiring frozen section diagnosis were identified and researched (i.e., no omission of late add-on cases). The SPS-PM application has largely nullified these concerns. If the order of cases is changed or a patient's surgery moved, the surgical list is automatically reordered with all associated pathology notes; therefore, there was no risk of lost effort in reviewing a case. Indeed, the persistence of case notes has enabled trainees to begin the list review process several days in advance of the surgical date (as soon as a listing is made), thereby easing the

caseload for review on the evening before the surgical day. Finally, because the case list can be quickly scanned in real time with associated notes, seemingly "last minute" add-on cases can be easily identified and efficiently reviewed before morning report.

In addition, there were several unintended but beneficial outcomes associated with the SPS-PM application. Although not a planned feature, the visibility of notes in a central repository allowed for better coordination between trainees reviewing the same list, largely eliminating the problem of duplicate case review. Trainee hand-off between rotations was also streamlined. Furthermore, the addition of text searching within the surgical list led to organ system-specific subspecialty groups (e.g., hematopathology and neuropathology) preemptively screening the day's cases to identify those likely to require intraoperative subspecialty consultation or special handling at frozen section. Finally, the recent integration of research protocol information into the SPS-PM has allowed for expedited research collections, replacing the previously performed daily manual list abstraction work performed by pathology assistants and technicians.

Conclusion

The SPS-PM application was rapidly adopted into the frozen section pathology laboratory practice at Mayo Clinic. The survey results suggest user acceptance was, at least in part, due to the perception that the application significantly improved essential aspects of case review workflow. While it is unlikely that a software application for frozen section case review would be necessary at all institutions practicing frozen section pathology, the user-centered development process and rapid prototyping design process may be useful approaches for process improvement initiatives in many settings. In addition,

this work provides a practical example of how software applications can assist pathology workflows by enabling extraction (from the EHR) and presentation of diagnostically relevant patient information.

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Conflicts of interest

There are no conflicts of interest.

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