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

Andrew P. Norgan<sup>1</sup>, Mathew L. Okeson<sup>2</sup>, Justin E. Juskewitch<sup>1</sup>, Kabeer K. Shah<sup>1</sup>, William R. Sukov<sup>1</sup>

Departments of <sup>1</sup>Laboratory Medicine and Pathology and <sup>2</sup>Surgery, Mayo Clinic, Rochester, Minnesota, USA

Received: 30 September 2016

Accepted: 05 January 2017

Published: 28 February 2017

### 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 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.<sup>[1,2]</sup> 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.<sup>[3,4]</sup> 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,

#### Access this article online

Quick Response Code:

Website: www.jpathinformatics.org

**DOI:** 10.4103/2153-3539.201112

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.

> Address for correspondence: Dr. Andrew P. Norgan, 200 First Street SW, Rochester, Minnesota 55905, USA. E-mail: norgan.andrew@mayo.edu

This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as the author is credited and the new creations are licensed under the identical terms.

For reprints contact: reprints@medknow.com

How to cite this article: Norgan AP, Okeson ML, Juskewitch JE, Shah KK, Sukov WR. Implementation of a software application for presurgical case history review of frozen section pathology cases. J Pathol Inform 2017;8:3. Available FREE in open access from: http://www.jpathinformatics.org/text. asp?2017/8/1/3/201112

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.<sup>[5-7]</sup> 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;<sup>[8]</sup> in our practice, the average reported time to complete the list review and case annotation ( $\sim$ 125 total cases with  $\sim$ 35 frozen section cases)

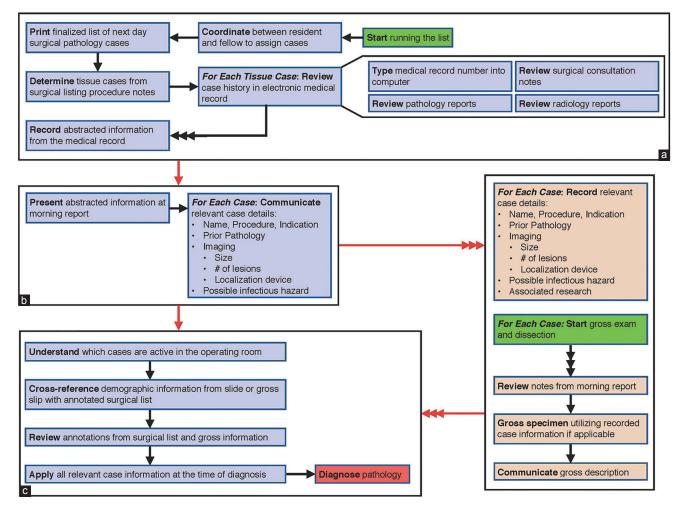


Figure 1: Process flow diagram for (a) presurgical case review, (b) morning report, and (c) real-time case review. An accessory process for surgical listing information recipients who participate in specimen grossing is shown in tan. Information flows between processes are designated by red arrows

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.<sup>[9,10]</sup>

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).<sup>[11]</sup> 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

Surgical Systems - SPS - Surgical and	I Procedural Scheduling	δ
File Go Tools Help	What's New ( 2016) e-1	4ail
😒 Custom Views Zoom:	Reset	
Pathology (9)	Pathology X Room List	
Pathology Search	Criteria/Options	
Surg/Proc Listing by Day	Procedure Date: 2015 13 Planet Status Tiles: Pototo (s): Planet Status Tiles: Planet Status T	
<ul> <li>1970</li> <li>1970b</li> </ul>	Retrieve  Retrieve  Cear	
<ul> <li>all hospitals</li> </ul>	🕞 Add Note(s) 😥 Listing Detail 🔝 Listing History 🕞 Print 🔛 Ultra Dense Print	
🦓 OR 200s 🥥	62 Listings Retrieved at 2016 09:52:24; Date: /2016 Hospital: RMH; SMH; Filters: Show Notes;	
apatnameor O	GYNECOLOGY SURGERY	
C RMH on	RMH OR 12 - 08:30 Start Time	
Sk text	Last, Fallert B. F28 <u>3-982-50</u> OR 12(1) Surgeon, Primary X (GNNS) Estimated Time: 1:49 + 0:28 = 2:17 Procedure: Operative laparoscopy: Possible Right Salpingectomy. Indicator: Right adnexal mass. Localtade fluid collection in the right adnexa. Both ovaries are polycystic in appearance, and the right side	
	contains a 17-mm cystic structure. (VM) Last, Patient B. F57 3-982-540 Rot 12() Surgeon, Primary X (CMVS) Estimated Time: 2-84 - 0.25 = 31:3 Procedure: Operative laparococy: Blateral Sulpingo-oophorectomy (Proceed as Indicated). Indicatons: RRCA2 mutation carrier. BRCA2 mutation. Normal US. (WM)	
	RMH OR 14 - 08:15 Start Time           Colst, Patient B.         Fog         >>82-53-0         Tincision: 09:35           ORE 14(1)         Surgeon, Primary X (CrYIS)         Estimated Time: 13-4         >>           Ore 244(1)         Surgeon, Primary X (CrYIS)         Estimated Time: 13-4         >>           Ore 246 services carcinoma.         Mesentery, Signoid, and omentum; biopsy: focally involved by low grade serous carcinoma         Pekick Wash: Positive for neoplasm. C/W K & serous carcinoma.           Te omentum Which was positive for metastatic cancer did not have any macroscopic disease (WM)	
	List, Patient B. F42 3-962-540 Pending OR 13(2) Surgion, Primary X (GYNS) 54902-9402 92-926 92-93-86 Procedure: Lapacitory: Abdomial hyperectromy: Right Salingino-cohprotectomy; Left Salingingscohmy: Proceed as indicated. Indication: Pelvic Nass, Abnormal uterine bieding. La unge cycle: mass extending from the right the sen that he central abdomen without septations., measuring La unge cycle: mass extending from the right the right overy. Whit conditional as yratelenoma, cycladenocarcinoma, and others. No performed industry or ascites. 2. Multiple heterogeneous enhancing masses of the uters consistent with fibroids. 3. Multiple small science/ic foci within the spine, pelvis and proximal hips are favored to be beingin bone islands; sciencic metastases are considered less likely. 4. Small	
Pathology	RMH OR 20 - 08:15 Start Time           Last, Patient B.         F46         3-982-540         Pending           OR 20(2)         Surgeon, Primary X (GYNS)         Estimated Time: 5:38 + 0:30 = 6:08         Procedure: Robits Industrial Salpingectomy; Robotic sacrocolpopexy; Possible Posterior vaginal repair; Possible Cystoscopy; Proceed as Indicated.           Vibloav         Surgeon, Primary X (GYNS)         Estimated Time: 5:38 + 0:30 = 6:08	

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

Symptomatic cholelithilasis and mild gallbladder wall thickening. Hx prostate cancer, 3+3. (ERP)         Type       Description         Time       Image: Cholelithilasis and mild gallbladder wall thickening. Hx prostate cancer, 3+3. (ERP)         Type       Description         Time       Image: Cholelithilasis and mild gallbladder wall thickening. Hx prostate cancer, 3+3. (ERP)         Type       Description         Red       Elbow 2 vw         2015-09-08 16:41       Image: Cholelithilasis         Patl       Fi13 Mutation / 2015-12:01 09:30         Patl       Fi13 Mutation / 2015-12:01 09:30         Patl       Fi13 Mutation / 2015-10:10:930         Patl       Fi13 Mutation / 2015-09:30 16:40         Patl       Fi23 Mutation / 2015-09:30 16:40         Patl       Fi23 Mutation / 2015-09:30 16:40         Patl       Memotopatholog 2014-09:20 10:13         Patl       Hematopatholog 2014-09:20 10:13         Patl       Hematopatholog 2015-09:30 14:46         Patl       Homatopatholo	Ex 📃		Hood Required		
Rad       Elbow 2 vw       2015-09-08 16:43       07/28/2014 Hematopathology Report ( )         Pati       Epidermal Nerv       2012-06-28 10:26       Requested By: XXX, M.D. 999-9999         Pati       FLT3 Mutation / 2015-12-01 09:30       Pati Intradication / 2015-12-01 09:30       Operator: D. XXXX, M.D. 999-9999         Pati       FLT3 Mutation / 2015-12-01 09:30       Congo red stain, abdominal subcutaneous fat aspirate specimen: Armyloid is absent.         Rad       Foot 2 vw       2015-09-08 16:41       Pati Seneral Pathol       2015-09-03 16:46         Pati       General Patholc       2015-09-30 14:46       Pati Hematopatholog       2014-09-26 10:13         Pati       Hematopatholog       2015-09-30 14:46       Pati Hematopatholog       2015-09-30 14:46         Rad       Hometopatholog       2015-09-25 09:53       Pati Hematopatholog       2015-09-25 09:53         Pati       IGH Somatic Hy       2015-09-25 09:53       Pati ISUE DESCRIPTION:       A: Subcutaneous Fat Aspirate         TSUE DESCRIPTION:       A: Subcutaneous fat Aspirate: The subcutaneous fat aspirate used for diagnostic purposes consists of 0.5 mL fat. Sample collected in RPMI solution for possible mass spectrometry amyloid subtyping.         Pati       Immunoglobulir       2016-01-05 14:55       Pati         Pati       Immunoglobulir       2016-01-05 14:55       Pati	Note(s	): Symptomation	c cholelithiasis and n	nild ga	ilbladder wall thickening. Hx prostate cancer, 3+3. (ERP)
Rad       Exister MI New       2012-06-28 10:26         Pati       FLT3 Mutation / 2015-12-01 09:30         Pati       FORE T2-00 09:80 16:41         Pati       General Patholo       2015-09-30 14:46         Pati       General Patholo       2014-10-16 11:47         Pati       Hematopatholo;       2015-09-30 14:46         Pati       Hematopatholo;       2015-09-30 14:46         Rad       Humenus 2xw A       2015-09-30 14:46         Pati       Hematopatholo;       2015-09-30 14:46         Rad       Humenus 2xw A       2015-09-30 14:46         Rad       Humenus 2xw A       2015-09-30 14:46         Rad       Humenus 2xw A       2015-09-30 14:46         Rad       Homatopatholo;       2015-09-30 16:42					07/28/2014 Hamatonathology Report ( )
Pati       FLT3 Mutation / 2015-12-01 09:30         Pati       FLT3 Mutation / 2015-09-08 16:41         Pati       General Patholo         Pati       General Patholo         Pati       Hematopatholog         2014-09-26 10:13         Pati       Hematopatholog         2014-09-26 10:13         Pati       Hematopatholog         2014-09-26 10:13         Pati       Hematopatholog         2015-09-08 16:42         Pati       Hematopatholog         Pati       Hematopatholog         2014-09-26 10:13         Pati       Hematopatholog         2015-09-08 16:42         Pati       Immunoglobulir         Pati       Jongolobulir         Pati       Jongolobulir         Pati       Immunoglobulir         Pati       Immunoglobulir         Pati       Immunoglobulir         Pati       Immunoglobulir         Pati       Immunoglobulir       2015-01-51 14:55					
Patt       FLT3 Mutation / 2015-12-01 09:36       Operator: D. XXXX, RN         Patt       FLT3 Mutation / 2015-12-01 09:26       Congo reador: D. XXXX, RN         Patt       Forearm 2vw Al       2015-09-08 16:41       Congo reador: D. XXXX, RN         Patt       General Patholo:       2015-09-08 16:41       Congo reador: D. XXXX, XDX, ADX, 0-000         Patt       General Patholo:       2015-09-30 14:46       T/30/2014 09:50 Interpreted by: XXXX,XXXX, M.D, 0-000         Patt       Hematopatholo:       2014-09-26 10:13       Transcribed by: XXXX,XXXX, M.D, 0-000         Patt       Hematopatholo:       2014-09-26 10:13       Transcribed by: XXXX,XXXXX, M.D, 0-000         Report electronically signed by: XXXX,XXXXX, M.D.       Transcribed by: XXXX,XXXXX, M.D.       Transcribed by: XXXX,XXXXX, M.D.         Patt       Hematopatholo:       2015-09-30 14:46       TSSUE DESCRIPTION:         Asubcutaneous Fat Aspirate       TISSUE DESCRIPTION:       Asubcutaneous fat Aspirate: The subcutaneous fat aspirate used for diagnostic purposes consists of 0.5 m. fat. Sample collected in RPMI solution for possible mass spectrometry amyloid subtyping.         Patt       Immunoglobulir       2016-01-05 14:55       Fat         Patt       Immunoglobulir       2016-01-05 14:55       Fat         Patt       Immunoglobulir       2016-01-05 14:55       Fat         Pa					Requested By: XXX, M.D. 999-9999
Patl       FLT3 Mutation /       2015-12-01 09:28         Rad       Foot 2 vw       2015-09-08 16:41         Rad       Forearm 2vw Al       2015-09-08 16:41         Patl       General Patholo       2015-09-08 16:41         Patl       General Patholo       2015-09-30 14:46         Patl       Hematopatholog       2014-09-26 10:13         Patl       Hematopatholog       2015-09-30 14:46         Rad       Hometopatholog       2015-09-20 19:30         Patl       Hematopatholog       2015-09-20 19:46         Rad       Hometopatholog       2015-09-20 19:46         Rad       Humerus Zvw A       2015-09-20 19:46         Rad       Histopatholog       2015-09-20 19:46         Rad       Hometopatholog       2015-09-20 19:50         Patl       IGH Somatic Hy       2015-09-20 09:53         Patl       Immunoglobulir       2015-09-20 09:53         Patl       Immunoglobulir       2015-01-30 09:45         Patl       Immunoglobulir       2016-01-05 14:55         Patl       Immunoglobulir       2016-01-05 14:55         Patl       Immunoglobulir       2016-01-05 14:55         Patl       Immunoglobulir       2013-03-06 11:23         Patl </td <td></td> <td></td> <td></td> <td></td> <td>Operator: D. XXXX, RN</td>					Operator: D. XXXX, RN
Fail       Forearm 2vw Al       2015-09-08 16:41       Imploit is absent.         Rad       Forearm 2vw Al       2015-09-08 16:41       Imploit is absent.         Patt       General Patholo       2014-10-16 11:47       Transcribed by: XXXXXXXXX, M.D. 0-000         Patt       Hematopatholo;       2014-09-26 10:13       Transcribed by: XXXXXXXXXX, M.D. 0-000         Patt       Hematopatholo;       2015-09-30 14:46       Y/30/2014 09:50 Integreted by: XXXXXXXXXX, M.D. 0-000         Patt       Hematopatholo;       2015-09-30 14:46       Y/30/2014 09:50 Integreted by: XXXXXXXXXXX, M.D. 0-000         Report leadow       Fata Spirate       Transcribed by: XXXXXXXXXXXXXXXXXXXXXX, M.D. 0-000         Report leadow       Fata Spirate       Transcribed by: XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX					DIAGNOSIS
Rad       Forearm 2vw AI       2015-09-08 16:40         Pati       General Patholo       2015-09-30 14:46         Pati       Hematopatholo       2014-09-26 10:13         Pati       Hematopatholo       2014-09-26 10:13         Pati       Hematopatholo       2014-09-26 10:13         Pati       Hematopatholo       2014-09-26 10:13         Pati       Hematopatholo       2015-09-30 14:46         Rad       Humerus 2vw A       2015-09-30 14:46         Rad       Kumerus 2vw A       2015-09-30 09:45         Pati       Immunoglobulir       2015-01-50 09:45         Pati       Jostova 10:45       Kashocutaneous Fat Aspirate: The subcutaneous fat aspirate used for diagnostic purposes consists of DS mL fat. Sample collected in RPMI solution for possible mass spectrometry amyloid subtyping.         Pati       Immunoglobulir				_	Congo red stain, abdominal subcutaneous fat aspirate specimen:
Pati       General Patholo       2015-09-30       14:46         Pati       Hematopatholo;       2014-10-16       11:47         Pati       Hematopatholo;       2014-09-26       10:13         Pati       Hematopatholo;       2015-09-30       14:46         Pati       Hematopatholo;       2015-09-30       14:46         Pati       Hematopatholo;       2015-09-30       16:42         Pati       Isomatic Hy       2015-09-30       16:42         Pati       IGH Somatic Hy       2015-09-30       16:42         Pati       Immunoglobulir       2015-09-30       16:42         Pati       Immunoglobulir       2015-09-30       16:42         Pati       Immunoglobulir       2015-01-30       10:36         Pati       Immunoglobulir       2016-01-05       14:55         Pati       Immunoglobulir       2016-01-05       14:55         Pati       Immunoglobulir					Amyloid is absent.
Pati       Hematopatholo;       2014-10-16 11:47         Pati       Hematopatholo;       2014-09-26 10:13         Pati       Hematopatholo;       2014-09-26 10:13         Pati       Hematopatholo;       2014-09-26 10:13         Pati       Hematopatholo;       2015-09-30 14-46         Rad       Humerus 2wr A       2015-09-30 14-46         Pati       IGH Somatic Hy       2015-09-20 99-81         Pati       IGH Somatic Hy       2015-09-20 99-81         Pati       Issue DisCRIPTION:       A: Subcutaneous Fat Aspirate         TISSUE DESCRIPTION:       A: Subcutaneous fat Aspirate: The subcutaneous fat aspirate used for diagnostic purposes consists of 0.5 m. fat. Sample collected in RPMI solution for possible mass spectrometry amyloid subtyping.         Pati       Immunoglobulir       2016-01-05 14:55         Pati       Immunoglobulir       2013-03-05-06 11:23					
Pati       Hematopatholog       2014-09-26       1013         Pati       Hematopatholog       2015-09-30       14:46         Pati       Hematopatholog       2015-09-30       14:46         Rad       Humerus Zwu A       2015-09-25       09:53         Pati       IGH Somatic Hy       2015-09-25       09:53         Pati       IGH Somatic Hy       2015-09-25       09:53         Pati       IGH Somatic Hy       2015-09-25       09:53         Pati       Immunoglobulir       2015-09-25       09:53         Pati       Immunoglobulir       2015-01-30       09:49         Pati       Immunoglobulir       2016-01-05       14:55         Pati       Immunoglobulir       2013-05-06       11:23					
Pati     Hematopatholo;     2015-09-30     14:46       Rad     Humerus 2vw A     2015-09-30     16:42       Pati     IGH Somatic Hy     2015-09-25     95:53       Pati     IGH Somatic Hy     2015-09-30     09:46       Pati     IGH Somatic Hy     2015-09-30     09:46       Pati     Immunoglobulir     2015-01-30     09:46       Pati     Immunoglobulir     2016-01-50     14:55       Pati     Immunoglobulir     2016-01-05     14:55	_				Transcribed by: XXX 7/30/2014 07:54:59
Rad       Humerus 2vw A       2015-09-08 16:42         Pati       IGH Somatic Hy       2015-09-25 09:53         Pati       IGH Somatic Hy       2015-01-30 09:49         Pati       IGH Somatic Hy       2015-01-30 09:49         Pati       Immunoglobulir       2015-05-06 12:16         Pati       Immunoglobulir       2015-01-05 14:56         Pati       Immunoglobulir       2015-01-05 14:56         Pati       Immunoglobulir       2015-01-05 14:56         Pati       Immunoglobulir       2016-01-05 14:56         Pati       Immunoglobulir       2016-01-05 14:56         Pati       Immunoglobulir       2013-05-06 11:23					
Pati       IGH Somatic Hy       2015-09-25 09:53         Pati       IGH Somatic Hy       2015-01-30 09:46         Pati       IGH Somatic Hy       2015-01-30 09:46         Pati       Immunoglobulir       2013-05:06 12:18         Pati       Immunoglobulir       2015-01:05 14:56         Pati       Immunoglobulir       2016-01:05 14:55					
Pati     IGH Somatic Hy     2015-01-30 09:49     for diagnostic purposes consists of 0.5 mL fat. Sample collected in RPMI solution for possible mass spectrometry amyloid subtyping.       Pati     Immunoglobulir     2013-01-05 14:55     Fat. Immunoglobulir       Pati     Immunoglobulir     2016-01-05 14:55     Fat. Immunoglobulir					
Pati     Immunoglobulir     2013-05-06 12:18       Pati     Immunoglobulir     2016-01-05 14:56       Pati     Immunoglobulir     2016-01-05 14:55       Pati     Immunoglobulir     2013-05-06 11:23					for diagnostic purposes consists of 0.5 mL fat. Sample collected in
Pati         Immunoglobulir         2016-01-05         14:55           Pati         Immunoglobulir         2015-01-30         10:36           Pati         Immunoglobulir         2016-01-05         14:55           Pati         Immunoglobulir         2016-01-05         14:55           Pati         Immunoglobulir         2016-01-05         14:55           Pati         Immunoglobulir         2013-05-06         11:23					KPIMI solution for possible mass spectrometry amyloid subtyping.
Pati         Immunoglobulir         2015-01-30         10:36           Pati         Immunoglobulir         2016-01-05         14:55           Pati         Immunoglobulir         2016-01-05         14:55           Pati         Immunoglobulir         2016-01-05         14:55           Pati         Immunoglobulir         2013-05-05         11:23	Pati	-	2016-01-05 14:56		
Pati         Immunoglobulir         2016-01-05         14:55           Pati         Immunoglobulir         2016-01-05         14:56           Pati         Immunoglobulir         2013-05-06         11:23		-	2015-01-30 10:36		
Pati Immunoglobulir 2016-01-05 14:56 Pati Immunoglobulir 2013-05-06 11:23	Pati	-	2016-01-05 14:55		
Pati Immunoglobulir 2013-05-06 11:23	Patł	-	2016-01-05 14:56		
Patt Immunoolohulir 2016-01-05 14:57	Pati	-	2013-05-06 11:23		
	Pati	Immunoglobulir	2016-01-05 14:57		
Pati Immunoglobulir 2015-01-30 10:37 🔻	Pati			-	

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

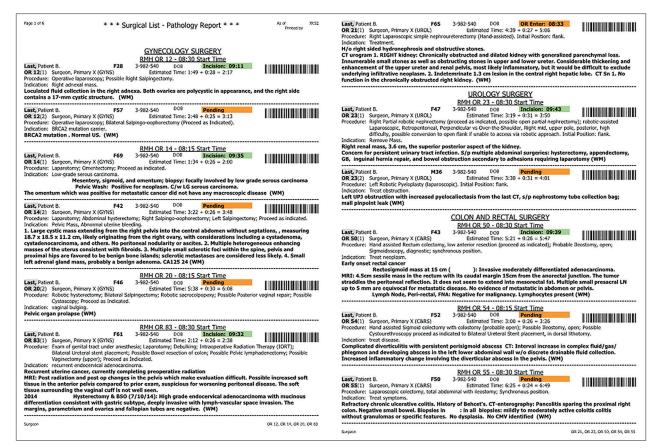


Figure 4: Print-friendly case listing view. An example of a densely formatted surgical list is shown. Listings are presented in two columns with minimal intervening space. The operating rooms included within a given column are listed for easy reference at the bottom of that column

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.

http://www.jpathinformatics.org/content/8/1/3

Surgical Systems - SPS - Surgical and	d Procedural Scheduling			Carter N.			0.997.	The Section Sector			0 X	
File Go Tools Help	a rioccould cenedaling								w	hat's New (	) e-Mail Us	
Custom Views Zoom:	Reset											
	Pathology × Room											
Pathology Search	Citeria/Options â											
Surg/Proc Listing by Day		Hospital:				OR Color Key						
Location Map	Procedure Date: /2016 55 RMH Auto Refresh: OFF											
- 🏇 Custom Listing View(s)	🤣 Retrieve 🌸 Sav	ve As 😑 Clear				Closure						
<u>    1970                                </u>	2016					<u></u>						
🥼 1970b 🥥	2016	[Saint Marys at	09:50:05]									
🔒 all hospitals 🥥	101	Proc	301		215							
🧐 OR 200s 🥥												
patnameor	102		302		216							
🚺 RMH on 🤤	Last, Patient B. Surgeon, Primary X.				Last, Patient B. Surgeon, Primary X.							
🧐 text 🥥	Incision 09:48				OR Enter 08:19							
'*' Default Calendar(Right click to set)	Last, Patient B.											
	Surgeon, Primary X. Incision 08:56											
	104		401	408	501	507	601		701	70	06	
	Last, Patient B. Surgeon, Primary X.	Last, Patient B. Surgeon, Primary	x.	Last, Patient B. Surgeon, Primary X.		Last, Patient B. Surgeon, Primary X.						
	Incision 09:15	Closure 09:36	208 402	Incision 09:04 409	502	OR Enter 08:47	OR Enter 08:40	OR Enter 08:59 606	OR Enter 08:18 702	70		
	Last, Patient B. Surgeon, Primary X.	202	Last, Patient B. Surgeon, Primary X.	Last, Patient B. Surgeon, Primary X.	502	Last, Patient B. Surgeon, Primary X.	Last, Patient B. Surgeon, Primary X.	Last, Patient B. Surgeon, Primary X.	/02	Last, Patient B. Surgeon, Primary X.		
	Incision 08:54		Incision 09:05	Incision 09:29		Incision 09:43	Closure 09:36	Incision 09:45		Closure 09:48		
	106 Last, Patient B.		209 403	410 Last, Patient B.	503	509 Last, Patient B.	603 Last, Patient B.	607	703 Last, Patient B.	70 Last, Patient B.	38	
	Surgeon, Primary X. Incision 09:39	Last, Patient 8. Surgeon, Primary X. Incision 09:11		Surgeon, Primary X. Incision 09:10	Last, Patient B. Surgeon, Primary X. Incision 09:24	Surgeon, Primary X. Incision 09:29	Surgeon, Primary X. OR Enter 08:52		Surgeon, Primary X. OR Enter 08:24	Surgeon, Primary X. OR Enter 08:27		
	107	The second s	210 404		504		604	608	704	70	09	
	Last, Patient B. Surgeon, Primary X.	Last, Patient B. Surgeon, Primary X. Last, Patient B. Surgeon, Primary		1 1				Last, Patient B. Surgeon, Primary X.	Last, Patient B. Surgeon, Primary X.	Last, Patient B. Surgeon, Primary X.		
	Incision 09:03	Incision 09:06 Incision 08:53						Incision 09:31	Incision 09:29	Incision 09:41		
	108 Last, Patient B.	205 205 Last, Patient B. Last, Patient B.	211 405	i 412	505			609	705 Last, Patient B.	Last, Patient B.		
	Surgeon, Primary X. Incision 09:38	Surgeon, Primary X. Surgeon, Primary Incision 09:20 Incision 09:02	x.						Surgeon, Primary X. Incision 09:39	Surgeon, Primary X. Incision 09:03		
	and the second se		212 400		506					71	11	
			Last, Patient B. Surgeon, Primary X.							Last, Patient B. Surgeon, Primary X.		
			Incision 09:40							Incision 09:28		
		Last, Patient B.		1								
		Surgeon, Primary Incision 09:11	x.									
				1								
P Entry												
C	Zoom:											
User: Okeson, Mathew ( ) - P	athology										d	

**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

201	Las	207 t, Patient B.	401	408 Last, Patient B.	501	507 Last, Patient B.	601 Last, Patient B. L	605 ast, Patient B.	Ē		
	Surge Clos		1	F73 3-982-540	) Ti	ncision: 09:24		× 9			
202		OR 503(1) S	urgeon, Primary X (TH	RS) Es	timated Time: 4:32 +	0:30 = 5:02		606			
		Po	onchoscopy - Flexible F ssible Mediastinal Lymp ogression of invasive so	hadenectomy; Enroll	ed in	Identification of prog	nostic biomarkers for	; x.			
203 nt B.		sei co	nt to pathology, 1 biops ntact study coordinator	sy from each site trac , , , with questi	hea, carina, right mai		, 1 other area of interest,	607			
hary X. 9:11		Indication: Dia RT-sided lune	agnosis, resection, stag	ing.	67						
204								608			
nt B. hary X.	Last Surge	Ind Imaging: 3.8 cm RUL FDG-avid mass abutting and splaying the right middle and right upper lobe bronchi, with									
9:06	Inci										
205 nt B.	Las	associated necrosis. RT hilar and paratracheal LAD worrisome for nodal involvement. (ERP)									
nary X. 9:20	Surge	on, Primary X. ision 09:02							-		
		212	406 Last, Patient B. Surgeon, Primary X. Incision 09:40		506						

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.

### Financial support and sponsorship

## Nil.

### **Conflicts of interest**

There are no conflicts of interest.

### REFERENCES

- 1. Wilson LB. A method for the rapid preparation of fresh tissue for the microscope. JAMA 1905;45:1737.
- Gal AA, Cagle PT. The 100-year anniversary of the description of the frozen section procedure. JAMA 2005;294:3135-7.
- Dahlin DC. Seventy-five years' experience with frozen sections at the Mayo Clinic. Mayo Clin Proc 1980;55:721-3.
- Keeney G, Leslie K. Preparing fresh tissues for the microscope. JAMA 2008;300:1074-6.
- Going Lean in Health Care. IHI Innovation Series White Paper. Cambridge, MA: Institute for Healthcare Improvement; 2005. Available from: http://www.ihi.org/resources/pages/ihiwhitepapers/ goingleaninhealthcare.aspx. [Last accessed on 2016 Nov 11].
- 6. Spear SJ. Learning to lead at Toyota. Harv Bus Rev 2004;82:78-86, 151.
- Serrano L, Hegge P, Sato B, Richmond B, Stahnke L. Using LEAN principles to improve quality, patient safety, and workflow in histology and anatomic pathology. Adv Anat Pathol 2010;17:215-21.
- Ho J, Aridor O, Parwani AV. Use of contextual inquiry to understand anatomic pathology workflow: Implications for digital pathology adoption. J Pathol Inform 2012;3:35.
- Beck K, Beedle M, Bennekum A, Cockburn A, Cunningham W, Fowler M, et al. Manifesto for Agile Software Development. Available from: http://www.agilemanifesto.org/. [Last accessed on 2016 Nov 11].
- Sinard JH, Gershkovich P. Custom software development for use in a clinical laboratory. J Pathol Inform 2012;3:44.
- Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap) – A metadata-driven methodology and workflow process for providing translational research informatics support. J Biomed Inform 2009;42:377-81.