

Technical Note

A real-time dashboard for managing pathology processes

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Abstract

Context: The Eastern Ontario Regional Laboratory Association (EORLA) is a newly established association of all the laboratory and pathology departments of Eastern Ontario that currently includes facilities from eight hospitals. All surgical specimens for EORLA are processed in one central location, the Department of Pathology and Laboratory Medicine (DPLM) at The Ottawa Hospital (TOH), where the rapid growth and influx of surgical and cytology specimens has created many challenges in ensuring the timely processing of cases and reports. Although the entire process is maintained and tracked in a clinical information system, this system lacks pre-emptive warnings that can help management address issues as they arise. **Aims:** Dashboard technology provides automated, real-time visual clues that could be used to alert management when a case or specimen is not being processed within predefined time frames. We describe the development of a dashboard helping pathology clinical management to make informed decisions on specimen allocation and tracking. **Methods:** The dashboard was designed and developed in two phases, following a prototyping approach. The first prototype of the dashboard helped monitor and manage pathology processes at the DPLM. **Results:** The use of this dashboard helped to uncover operational inefficiencies and contributed to an improvement of turn-around time within The Ottawa Hospital's DPLM. It also allowed the discovery of additional requirements, leading to a second prototype that provides finer-grained, real-time information about individual cases and specimens. **Conclusion:** We successfully developed a dashboard that enables managers to address delays and bottlenecks in specimen allocation and tracking. This support ensures that pathology reports are provided within time frame standards required for high-quality patient care. Given the importance of rapid diagnostics for a number of diseases, the use of real-time dashboards within pathology departments could contribute to improving the quality of patient care beyond EORLA's.

Key words: Dashboard, pathology informatics, pathology management

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INTRODUCTION

The practice of anatomical pathology is changing as a result of the introduction of new tests, services, and technologies, as well as the emergence of personalized medicine that asks for targeted pathological diagnoses.^[1,2] This situation is contributing to an increase in the volume

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of patient cases to be diagnosed, as well as an increased complexity of pathology processes in individual laboratories. These rapidly occurring changes pose a challenge not only for pathologists but also for clinical and operations managers of pathology facilities who are responsible for ensuring that pathology specimens be processed in a timely manner. Indeed, pathology managers need to be able to identify emerging process bottlenecks in real-time, conduct corrective actions, and assess their results. Given the current challenges being experienced in a number of pathology facilities, historical data about case processing and laboratory performance are no longer sufficient to manage them effectively.

The need for real-time monitoring in pathology can be addressed by systems providing graphical dashboards that integrate key performance indicators (KPIs). KPIs can communicate how well a facility is performing in regard to given quality standards (especially with regard to a time frame). In medicine, a dashboard should “provide clinicians with relevant and timely information they need to inform daily decisions that improve the quality of patient care.”^[3] Similarly, dashboards for managers of pathology facilities can provide relevant and timely information supporting proactive decision-making that improves the efficiency and effectiveness of these facilities. By optimizing patient case processing from case accession to diagnostic report, this could, in turn, positively impact the quality of patient care.

In this paper, we describe the development of a dashboard supporting decision-making for managers of the Department of Pathology and Laboratory Medicine (DPLM) located in a large teaching hospital- The Ottawa Hospital (TOH) in Ottawa, Canada. We also discuss how the clinical and operational managers of the DPLM used the dashboard’s data summaries and visualizations to improve the performance of the facility. TOH is a tertiary academic center that operates three, campuses Ottawa. The DPLM is primarily located on one of these campuses (General Campus), with smaller sister facilities on the Civic Campus. It is part of the Eastern Ontario Regional Laboratory Association (EORLA) that currently groups facilities from eight hospitals (rural, community, and academic). The DPLM, which houses grossing, histology, and cytology laboratories, is the primary service provider to eight Ottawa hospitals.

The large volume of specimens to be processed by EORLA gave rise to management issues regarding demand spikes, uneven service coverage, delays in the Grossing and Histology Laboratories, and longer wait times for the diagnostic reports. While the organization used the clinical pathology solution PowerPath® by Sunquest^[4] to record and track individual specimens, managers of the DPLM recognized that data generated by such a system could benefit from additional processing to

provide greater support for managerial decision-making. The dashboard described in this article was developed to address these needs, providing real-time monitoring and performance indicators that help managers identify root causes of process bottlenecks and implement corrective actions. While these improvements are presented and discussed, this article however focuses on the dashboard as a proof of concept system for pathology management and as such does not constitute a study of the DPLM.

The remainder of this paper is organized as follows: First, we present the prototyping approach that was used to support the development of the dashboard. We then describe the process-level and case-level dashboards developed, respectively, in the first and second prototyping cycles, followed by the impact of the dashboards’ use on managers’ activities at the DPLM. The dashboard presented in this paper is then compared with existing solutions in terms of how each solution meets the specific requirements of pathology managers. We conclude with the need to better integrate workload planning in dashboards for pathology management.

DEVELOPMENT APPROACH

The development of the dashboard followed a prototyping approach, which is an iterative process that cycles through the collection of user requirements, development of a dashboard prototype meeting these requirements, and evaluation of the prototype by users. The cycle continues until users accept the prototype, which is then implemented and deployed. This project underwent two major prototyping cycles, which led, respectively, to a process-level dashboard and a case-level dashboard. Within the second cycle, a number of paper prototypes and screenshots of the interface were provided to users that led to iterative adjustments and improvements of the dashboard. This article, however, focuses on the end result of this iterative process, namely, the case-level dashboard as it was accepted by users.

In the first cycle, the main author of this article designed and developed a dashboard labeled PowerJ based on his expert knowledge of process and management needs at the DPLM of TOH, with the participation of his colleagues. This first prototype closely followed the pathology process at the DPLM, as described below. The resulting dashboard was implemented on the computers of the Chief of the Division, the Operations Manager, and the Director of Informatics to be used in a selective manner by them. While this was a local initiative that was not formally organized as a quality improvement project, DPLM management made a dedicated effort to consult PowerJ daily and to use it to support decision-making. The prototype was thereafter evaluated for 3 months starting on November 1, 2014. This trial period showed encouraging results in terms of turnaround

time for processing surgical specimens. Specifically, the average turnaround time to process specimens decreased by 13% when taking into account the variability in available pathologists per period (monthly average for turnaround time in days/number of pathologist available that month). However, it also led to the discovery of a number of new requirements such as, for example, the need to track the status of specific specimens in real-time.

The development of the second prototype followed recommended guidelines for developing business intelligence (BI) dashboards,^[12] and the prototype was implemented using a commercial BI tool. In the second cycle, the Chief of the Division, the Director of Informatics, and the Operations Manager were interviewed by the second author of this paper to formalize their emerging requirements. This enabled the identification of dashboard objectives and KPIs for DPLM management. A case-level dashboard was then developed; it extended the functionality of PowerJ, for example, by allowing users to drill-down within a specific case and track individual specimens. This second prototype is then presented to and accepted by users and is now in the process of being implemented for managing day-to-day operations.

Before presenting the dashboard prototypes, we briefly explain the terminology used at the DPLM as well as their pathology processes as they relate to the dashboards. The terminology refers to the pathology-specific entities being tracked by the dashboard: Cases, specimens, blocks, and slides. A case is all specimens received from one patient-physician encounter. A specimen is one or more tissue fragments removed from an organ or specific site. A block is a container of one or multiple tissue fragments from the same specimen. A slide is a thin slice of tissue cut from the block and stained with a specific

set of reagents. These elements thus form a hierarchy of the inventory to be processed by the DPLM.

The first step in the DPLM process is the accessioning of cases, where specimens and clinical orders from physicians arrive and are given a unique ID case code. Each specimen is also associated with a pathology sub-code that determines how many blocks and slides will need to be created for this specimen. The second step is the grossing of specimens, where blocks are created from the tissue and automatically processed in a manner suitable for creating slides later on. In the third step, blocks are sent to the Histology Laboratory, where each one is manually sliced and stained as required by the pathology sub-code associated with it. In the fourth step, called dispatch, finished slides are checked to ensure that they are matched with the correct specimen and case. They are then organized by case and assigned to pathologists. The last step is the diagnosis, where pathologists receive complete cases to examine. During these diagnosis processes, a pathologist may order additional slides or blocks. The process ends when the pathologist makes a definite diagnosis for a case and writes a report. The first version of the dashboard closely reflected these entities and process steps, allowing a quick understanding of bottlenecks within the facility by showing how many of each entity were waiting to be processed, for example, a high number of pending blocks would indicate a bottleneck within the Histology Laboratory.

The output of this process is a diagnostic report to be sent to the physician who initiated the order. Given that the pathology report is a core component of the physician's clinical diagnosis, it is important that it be delivered within an acceptable time frame. Hence, DPLM management has defined business rules stating the target processing time for each specimen type and each step in this process. These target time frames are a key

Table 1: Stakeholder requirements

	Requirement	Description	Time of identification
1	Tabular data	Displaying summary or detailed data in a list or pivot table	Cycle I
2	Data visualization	Displaying summary data in a chart or diagram	Cycle I
3	Value filtering	Dynamic filtering of report output by user selection	Cycle II
4	Real-time reporting	Automatic updating of data analysis in real-time	Cycle I/II
5	Color indicators	Conveying performance status through a meaningful color scheme	Cycle I/II
6	Sorting	Dynamic sorting of report output by user setting	Cycle II
7	Drill down	Drilling down to event-level data for each case and each specimen	Cycle II
8	Interface customization	Switching between chart view/table views, or changing to different chart types	Cycle II
9	Stakeholder-oriented views	Tailoring of the dashboard for varied user groups/roles	Cycle II
10	Specimen-type customization	Specifying different business rules for different types of specimens	Cycle II
11	Automatic notifications	Sending alerts to users by email or other channels	Cycle III
12	Workload planning	Predicting future workloads based on historical data using prediction models	Cycle III

component of the second dashboard prototype, especially the latter indicates which cases contain specimens that exceed, or are close to exceeding, their target processing time.

OVERVIEW OF THE DASHBOARDS

The development of the dashboard was based on stakeholder requirements elicited from two user groups, clinical management, and operations management, as well as from the Operation Manager's knowledge of the needs of a third user group, namely supervisors of the Grossing and Histology Laboratories. While these user groups remained stable throughout the development process, their requirements evolved as a result of using the first prototype. The following subsections first describe the stakeholder requirements as they were identified in each prototyping cycle. We then describe the process-level and case-level dashboards developed, respectively, in the first and second cycles, along with the ability of each prototype to fulfill stakeholder requirements.

STAKEHOLDER REQUIREMENTS

Table 1 enumerates the stakeholder requirements identified either in the first or second prototyping cycle. Requirement 1, tabular data, is a common requirement for dashboards as it provides a type of report with more detailed and structured data than could be presented in a graphical format. Requirement 2, data visualization, is core to dashboard capabilities and helps pathology managers to quickly grasp the state of their facility and the presence of potential issues. As shown in Table 1, these two requirements were identified as part of the development of the first prototype. Requirement 3, value filtering, allows users to focus on a subset of data, for example only specimens that have been dispatched to pathologists for a diagnosis. Requirement 4, real-time reporting, was initially stated as the need for daily reporting of cases, slides, and specimen status. However, through the use of the first prototype, it evolved to the need for real-time reporting to identify delays and backlog more rapidly. Real-time here means automatic updates configurable to a refresh rate fast enough to support informed tracking and decision-making (e.g., in the order of minutes or even seconds).

Similarly, Requirement 5 informally guided the development of the first prototype; this requirement, color indicators, refers to the use of color coding to indicate performance status. A well-recognized color scheme is that of traffic lights, where green indicates that a target is being met (for example, a specimen is being processed well within a standard time frame), red indicates that a target is not being met (for example, a specimen has spent more time in the Histology Laboratory than what

is expected), and yellow indicates that the element being measured is approaching an undesired state (for example, a specimen has already spent 80% of the accepted time in the Histology Laboratory). While the first prototype used color to indicate status, it did not do so following clear business rules such as the time that specimen should be allowed to spend at each stage of the process. This requirement was however articulated explicitly for the second prototyping cycle [Table 1].

Requirements 6–10 represent additional needs of pathology managers that were identified through the use of the first prototype. Requirement 6, sorting, enables users of the dashboard to sort data according to varied criteria, for example by date. The ability to drill-down to event-level data for each case and each specimen (Requirement 7) is a key motivator for the development of the second prototype since it allows managers to pinpoint the exact source of delays within the pathology process. Requirement 8, interface customization, is a common stakeholder requirement for dashboards. Indeed, it is recognized that varied types of visualizations communicate information differently, for example line graphs to track trends over time versus bar charts to compare a set of values. Being able to customize the type of display helps align users' information needs with the most adequate type of visual display. Similarly, the ability to adapt the information presented to the needs and purpose of each stakeholder group – Requirement 9 (stakeholder-oriented views) – helps ensure that the right information is presented to the right group, in line with their decision-making needs. Requirement 10 – specimen-type customization – incorporates different business rules as per specimen type in the case performance calculation algorithm and enables the dashboard to measure the status of the cases by specimen type level.

Requirement 11 – automatic notifications – stems from the desire for managers to be alerted of issues proactively by E-mail or other channels rather than having to login to a system to check the status of the pathology facility. Requirement 12 – workload planning – forecasts future job duration using prediction models and assists managers with workflow planning to avoid bottlenecks. These last two requirements are identified when presenting the second prototype and their implementation is left as future work, in a third development cycle.

CYCLE I: PROCESS-LEVEL DASHBOARD

In the first development cycle, stakeholder requirements were mainly concerned with the need for pathology process data to be rendered in a graphical manner to enable users to quickly grasp the daily performance of the DPLM. This implied the ability to monitor the operations of the DPLM at key stages throughout the process of moving from tissue to a pathology diagnostic

report, namely, grossing, slide preparation, and pathologist assessments. The requirements guiding the development of the first prototype were thus Requirements 1 and 2 in Table 1, as well as partial components for Requirements 4 and 5, as explained in the previous section.

Given these requirements, the first dashboard prototype – PowerJ – pulled data in 2-h intervals from the clinical database already in use at the DPLM. Data did not need to be checked for quality since all data captured in the clinical database were done through barcode scanning without any manual input. PowerJ was then able to directly use event-level data produced at each step of the process (e.g., scanning specimens, blocks, and slides) to produce graphical reports. Moreover, PowerJ was audited twice against manual counts of pending cases and pending blocks and was shown to be accurate and reproducible. This application was written in the Java programming language to facilitate its implementation across computing platforms.

PowerJ presented summarized data in five graphical components within the dashboard. Three of those correspond to the three stages to be monitored, thus showing (1) number of pending and grossed cases; (2) number of pending and cut blocks; and (3) number of pending and routed slides. These data were visualized as a color-coded trend line showing daily measures for each stage. The two other components were related to workload. Specifically, the fourth component showed bar charts representing overflow slides ready for pathologists' diagnosis by subspecialty while the fifth component showed bar charts representing the workload of individual pathologists in terms of a number of pending slides. An illustration of the dashboard and its individual components is shown in Figure 1 using historical data from February 2015.

The case data component as shown in Figure 2 allows assessing the relationship between pending and grossed cases. In the interval of April 1 to May 8, 2015, illustrated in Figure 2, the gap between pending (red – top) and grossed (green – bottom) cases is diminishing. Specifically, the number of pending cases diminishes from 2,173 to 1,212, indicating improved efficiency of the Grossing Laboratory despite some remaining fluctuation to be expected given variations in demand and pathologists' schedule. However, a limitation of PowerJ is the inability to capture the total case volume per period, which has been addressed in the second dashboard [Figure 8].

Figure 3 shows the block data component, where a trend line for all pending blocks (in red) can be quickly evaluated in relation to cut blocks ready for slide staining (in green). The trend line for the 28-day interval as shown in Figure 3 shows a relatively large gap at the beginning of the period, indicating some

throughput problems in the Histology Laboratory. The line then shows an improvement of throughput due to corrective actions taken by the management, for example, the reallocation of cases to sister pathology facilities. Specifically, the gap between the 2 lines dropped from 5,926 to 2,562 uncut blocks.

Finally, Figure 4 shows data related to the throughput of slide assignment to pathologists. In the 28-day interval as shown in Figure 4, it can be observed that in practical terms, there is almost no gap between the number of pending slides (in red) and slides assigned to the pathologists for diagnosis (in green). The gap between the two lines remained almost constant throughout the period, and the majority of unassigned slides were cytology cases. Fluctuations that can be noticed, apart from being subject to the volume of cases received by the DPLM for diagnosis, can also result from pathologists' teaching and research schedules.

PowerJ fulfilled the first requirement, tabular data, by exporting the results to a set of MS Excel spreadsheets. The data visualization requirement was fulfilled through the use of line graphs to show the daily states and monthly trends regarding number of cases, slides, and blocks. The fourth and fifth requirements were partially fulfilled by updating the dashboard's data in 2-h intervals rather than by providing real-time reporting, and using color to convey the state of cases, blocks, and slides in a binary manner (pending vs. ready) rather than in terms of target performance time.

Beyond specific requirements, the improvements presented above in terms of reduced number of pending cases in blocks, as well as the overall decrease in turnaround time during the observation period of PowerJ operation allowed the administration to gain a better understanding of where the bottleneck in the delays lied (i.e., the Histology Laboratory embedding stations); however, it lacked sufficient granularity to allow management to react to any critical delay at the single case level in real-time. Addressing the global delay in the embedding station operations required long-term planning and resulted in creating two new technical positions in the Histology Laboratory (staffing still in progress) but could not help in managing and prioritizing the cases in the short-term. The dashboard developed in the second phase aimed to address this issue and also is designed to help management to identify critically delayed cases in real-time and initiate an immediate response by the responsible technicians or clinical staff to advance these cases to the front of the queue.

CYCLE II: CASE-LEVEL DASHBOARD

While the use of PowerJ had a positive impact on specimen processing turnaround times, it also helped

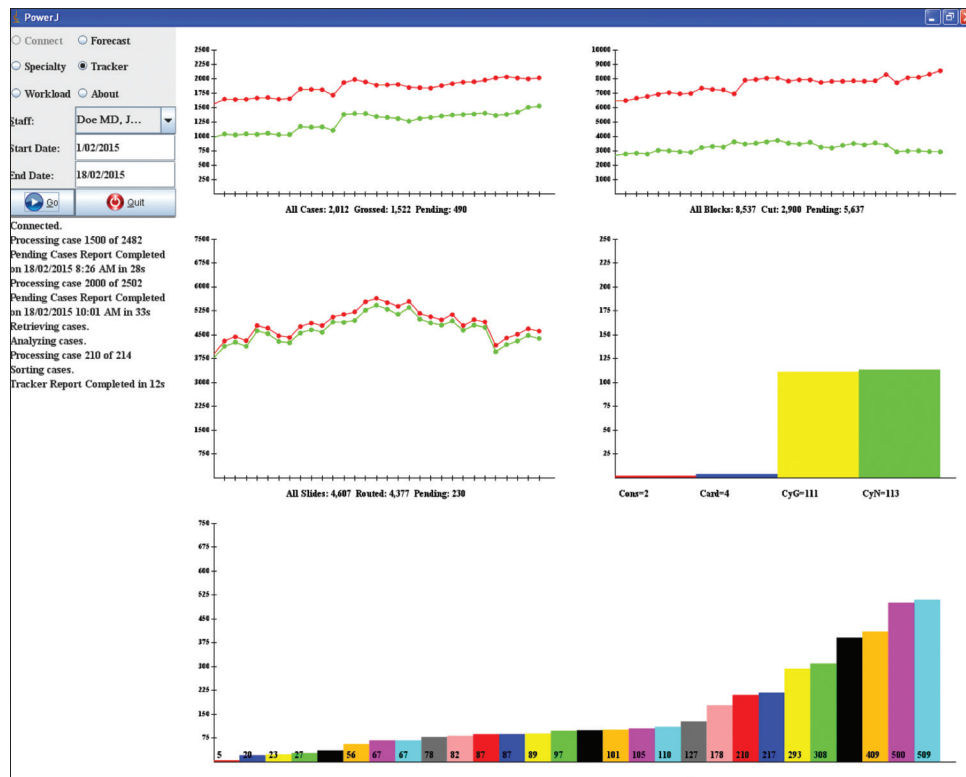


Figure 1: Screenshot of the first dashboard prototype (PowerJ). The two upper visual components and the middle left component show case, block, and slide data, respectively. The middle right and the lower components show subspecialties backlog and pathologists workloads (anonymized here)

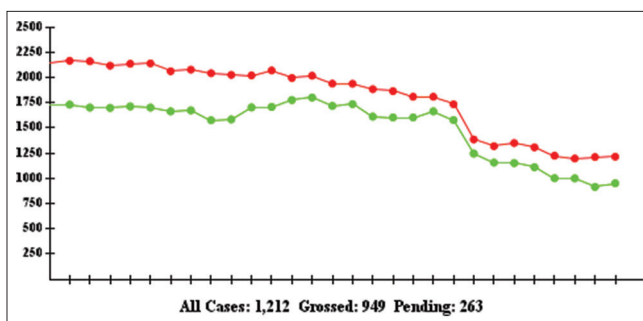


Figure 2: Case data component showing data for the observation period. The horizontal axis is a time axis with weekday intervals while the vertical axis shows the number of cases

uncover additional stakeholder requirements. A key requirement was the ability to identify specimens that are close to or above processing target times (Requirement 5 in Table 1), which include the ability to drill-down to a specific specimen in real-time (Requirement 7). Indeed, given the large amount of cases being processed, management required the dashboard to give an overview of the performance of the DPLM within a single screen to enable faster and more effective decision-making while being able to filter and sort data to answer specific questions (Requirements 3 and 6). For example, the Chief of Division needed to filter cases held in the Histology Laboratory by subspecialty to either revise the pathologists' schedule or the cases' priority. Drilling down

within a case would thus allow him to identify sources of backlog by dates, subspecialty, or pathologist. Given the varied user groups that would use the dashboard, the interface of the second prototype needed to be easily customized in terms of type of visualization (Requirement 8) and in terms of which data to be shown to which user (Requirement 9).

Moreover, DPLM management wanted the ability to specify different targets and thresholds for different types of specimens (Requirement 10). Real-time reporting, rather than updates at 2-h intervals, would allow DPLM management to react quickly to bottlenecks using interfaces customized for their roles and responsibilities, being clinical or operational (Requirement 4). By providing notifications and alerts to users in regards to specimens that are likely to exceed the time allocated for its current processing stage, the dashboard could help management reevaluate daily work priorities (Requirement 11). Ideally, the dashboard would predict bottlenecks in specimen processing rather than merely warning users when issues arose (Requirement 12).

To fulfill these requirements, the second pathology dashboard prototype was created using the IBM® Cognos® BI tool.^[13] This tool allows the development of metrics-based dashboards that provide users with the information they need to make management decisions. By providing real-time information about performance

based on agreed-upon metrics, the dashboard allows users to quickly grasp if and where they need to intervene to achieve key organizational goals. The BI tool is web-based and does not require the programming effort needed for developing the first prototype (PowerJ). The

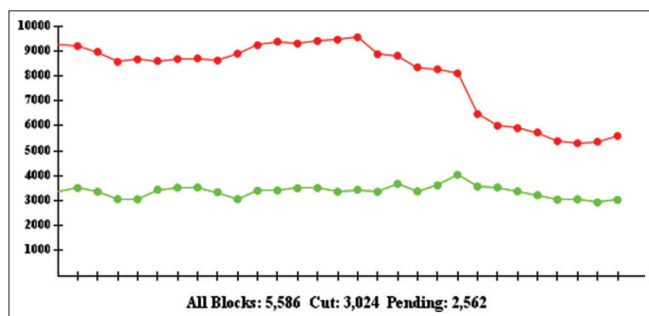


Figure 3: Block data component showing data for the observation period. The horizontal axis is a time axis with weekday intervals while the vertical axis shows the number of blocks

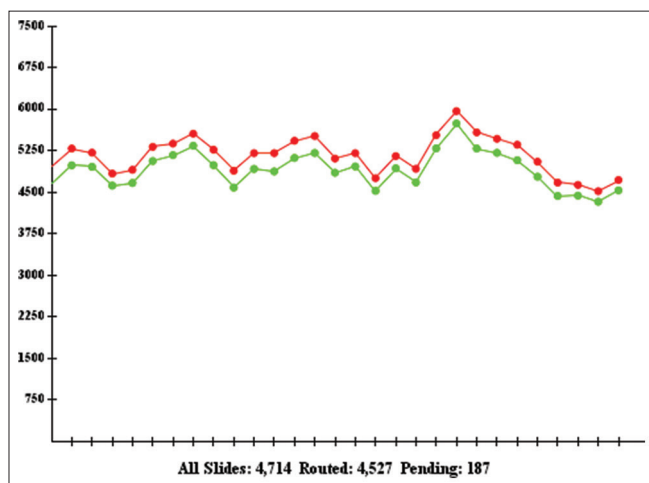


Figure 4: Slide data component showing data for the observation period. The horizontal axis is a time axis with weekday intervals while the vertical axis shows the number of slides

functionalities of the IBM® Cognos® BI tool thus allowed us to develop a pathology-specific dashboard that met both initial requirements identified for the first prototype and new requirements that were identified through using PowerJ. Hence, the second dashboard provides similar functionalities to management as the first one did but extends these functionalities in line with the additional requirements. This new dashboard allows further understanding of case processing within the DPLM, through dynamic visualizations and drill-down possibilities. Specifically, three components were developed within the dashboard [Figure 5]; each is presented in detail below. The motivation behind developing these particular components was driven by a need to meet Requirements 5 and 7 with regards to ability to drill-down the analysis to individual case level, and also to meet Requirements 3 and 6 that ask for providing information that allows answering detailed questions by the users.

The first component [left part of Figure 5] is the Pending Case Analysis [Figure 6], which provides real-time monitoring (auto-refreshed every 2 min) of pending cases. It helps management answer questions such as “what is the total number of pending cases?,” “at which stage of the process are cases of interest?,” and “which cases need to be prioritized to avoid exceeding target processing times?”.

The upper section of the component display as shown in Figure 6 provides summary information about the status of pending cases, based on target processing times. It acts as an alert system for Operations Manager or Histology Laboratory supervisors, showing the total numbers of pending cases broken down by process stage and laboratory and enabling a quick understanding of their overall status.

The lower section of the component provides a dynamic, detailed list of pending cases that can be filtered by color-code and type of case (cytology, surgical, and autopsy).

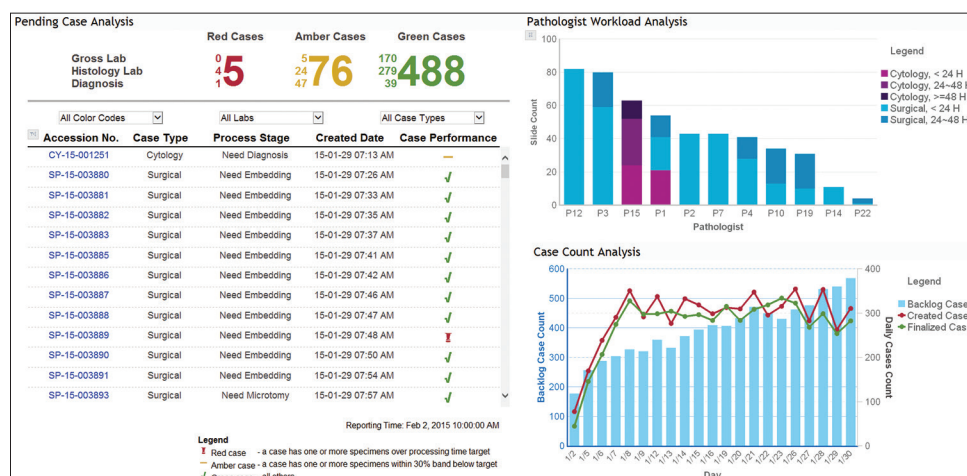


Figure 5: Overview of the second dashboard layout. The leftmost component shows and categorizes the number of pending cases for their monitoring. The upper right component shows pathologists' workload while the lower right component allows assessing the total case volume per period

The list can also be sorted by case processing stage (needs embedding, needs microtomy, needs quality control and distribution, needs diagnosis, and needs finalized) and case date of creation. This allows each user group at the DPLM to personalize the component's display according to their interests and responsibilities.

For example, the first entry in the lower section of Figure 6 shows the surgical case SP-15-003914 that needs embedding in the Histology Laboratory. The red icon in the "case performance" column indicates that at least one of its specimens has exceeded its target processing time. To access more detailed information about this case, the user could click its accession number; a detailed report would then open in a new window, showing all the specimens and time-stamped events related to it. The upper section of the component shows that there are three other such cases at the moment, for a total of four. In addition, one more case that is waiting for diagnosis has also exceeded its target processing time. There are thus a total of five cases in the category "Red Cases."

The dashboard's second component [upper-right part of Figure 5] is the pathologist workload analysis. It shows the total number of slides allocated to each pathologist as a bar (initials of the pathologists are provided in the dashboard but were deidentified in this figure to ensure their privacy), and breaks down each bar by case type and the time spent on each type of case [Figure 7]. This component enables the Chief of the Division to answer questions such as "what is each pathologist's workload?" and "which type of cases is each pathologist currently processing?" This can help, for example, the Operations Manager decide to whom new specimens should be allocated.

The third component in the dashboard [lower-right part of Figure 5] is the case count analysis [Figure 8]. This component summarizes two distinct types of information: Number of backlog cases and the amount of created versus finalized cases. Since the scale for case count differs from that of backlog case count, there are two y-axes set in the chart. The y-axis on the left, in blue, is the primary axis and is used for the backlog case count whereas the secondary axis on the right, in gray, is used for created and finalized case counts. This component thus helps Operations Manager and Chief of the Division to answer the following questions: "How many cases are created and finalized daily over a month" and "how many cases have been backlogged in the past month, and what is the trend?" This layering of information allows to understand if, for example, a widening gap between created and finalized cases is due to a sudden increase in incoming cases, or due to a gradual accumulation of cases to be processed because of the demand being beyond current capacities (the latter being an explanation for the situation in Figure 8).

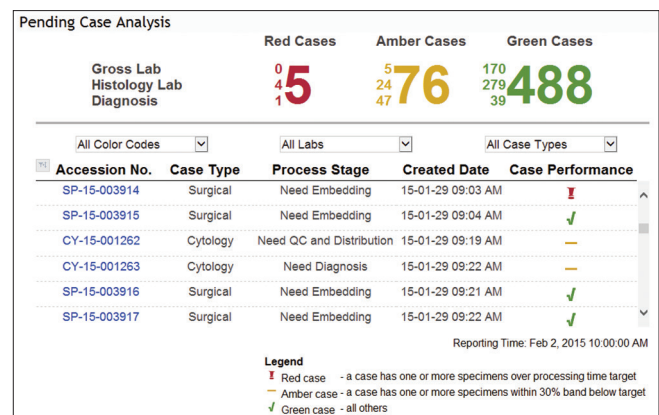


Figure 6: Pending case analysis component

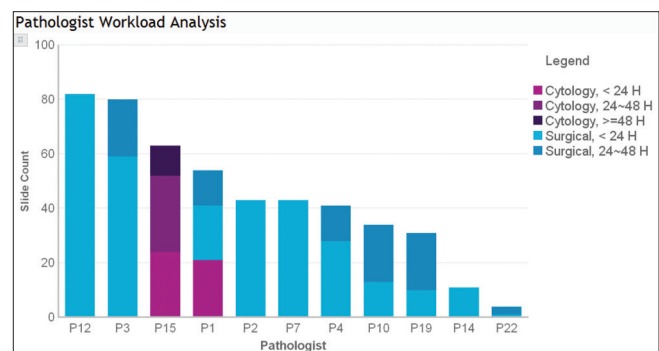


Figure 7: Pathologist workload analysis component

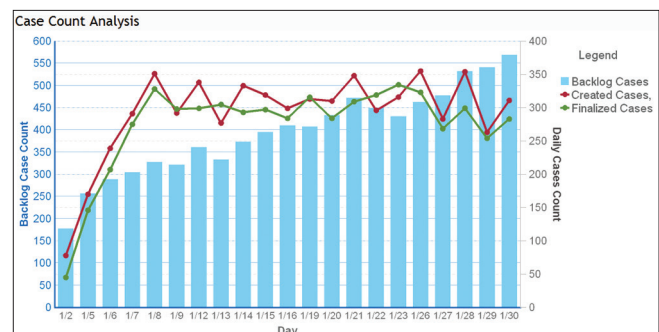


Figure 8: Case count analysis component

The dashboard developed in the second prototyping cycle satisfies the first ten requirements identified in Table 1. However, it does not fulfill Requirement 11 of automatically generating and sending alerts to users by E-mail or other channels. Moreover, even though the second prototype has not been fully implemented, its presentation to operations and clinical managers of the DPLM led to the identification of an additional requirement, namely workload planning. These requirements are thus a motivation to expand the functionality of the dashboard before its full deployment.

IMPACT OF DASHBOARD USE

The first dashboard prototype was used daily by

the DPLM managers for monitoring and decision-making during the 3-month observation period. For example, the chief of the DPLM consulted the dashboard every morning and sometimes again later in the day to get a better picture of the state in which operations of the DPLM were. This proved to be successful, helping the DPLM to improve its turnaround time. An analysis conducted by DPLM managers within the observation period revealed that the number of pending cases and the number of uncut blocks decreased significantly.

The use of the dashboard also helped DPLM managers to uncover and address bottlenecks in case processing. This improvement can be attributed to the corrective actions the managers took as a result of new and up-to-date data that were made available to them. For example, the component showing pending versus grossed cases [Figure 2] enabled the Operations Manager to improve the scheduling of the pathologist assistants working in the Grossing Laboratory. Another corrective action taken when the gap widened beyond DPLM capacity was to transfer some cases to a satellite facility located on the Civic Campus of the hospital. The block data component [Figure 3] led the Operations Manager to reexamine staffing patterns in the Histology Laboratory and to discuss with histotechnologists about efficiency within the process. The component showing individual pathologists' workload [bottom of Figure 1] enabled the Chief of the Division to adjust pathologists' schedules and to counsel pathologists with the highest number of backlogged slides on issues such as time management.

The second prototype, once implemented, should be used in a similar manner by DPLM management, but with more timely access to more detailed and meaningful information that could prevent delays from happening. In particular, detailed information about performance at each step in the pathology process could help management intervene in a pointed and rapid manner to solve

bottleneck issues. In the longer term, data about case processing performance at the DPLM could also lead to discussions to revise general staffing policy to better adjust staffing levels to the incoming demand. For instance, if the dashboard showed recurrent issues in the Histology Laboratory (high number of cases beyond target time), clinical decisions leading to a decrease in the number of blocks required per type of case could be made. However, such an action, while having the potential to improve the throughput, would need to be taken with caution so as not to impede the quality of patient care.

RELATED WORK AND SOLUTIONS

The process-level and case-level dashboards developed for the DPLM can be compared to existing academic propositions and commercial solutions. We do so by evaluating how existing dashboards fulfill the stakeholder requirements identified through our development process [Table 2].

The first four articles (rows) in the matrix as shown in Table 2 refer to dashboards proposed in the literature but not necessarily available on the market. McLaughlin *et al.*^[5] introduced a quality dashboard developed for the University of California Los Angeles Department of Neurosurgery. The dashboard gathers patient satisfaction, quality and safety, and operations information, and assists managers with monitoring impact and improving strategies. A web-based clinical dashboard described by Nagy *et al.*^[6] is designed to aggregate and display clinical operation data to the surgical managers. The dashboard has enhanced data visualization and can act as a decision support tool to help management with the continuous quality improvement. The reporting tool used by the Ohio State University Medical Center is discussed by Nash *et al.*^[7] This tool includes dashboard, scorecard, and detail reports and provides data-driven strategy for patient

Table 2: Evaluation matrix for dashboards

[illegible]

experience improvement. A case study of using a BI dashboard at Cleveland Clinic is described by Wadsworth *et al.*^[8] This dashboard is designed for the performance management program and helps improve healthcare quality while reducing cost for the organization. While these solutions address basic stakeholder requirements such as the need for data to be presented both in a tabular and in a graphical manner, they lack a number of key capabilities for pathology management such as the ability to specify different business rules for different types of specimens.

The next three rows in Table 2 refer to commercial-grade dashboards; each dashboard was informally evaluated based on its description and visual renderings provided online. The Clinical Pathology Dashboard for the University of Michigan, Department of Pathology^[9] generates information to the management that includes pathology operation data, for example, turnaround time for specimens, and aggregate monthly data, to provide a high-level overview of the operations during the last month compared to historical data. The Anatomic Pathology Solutions developed by Viewics Inc.,^[10] is a set of dashboards and reports concerned with quality, productivity, and workload information. By aggregating data of different granularities, this tool brings insight to management about quality and productivity improvement. The information provided on this dashboard states that it can capture data in real-time, but no supporting evidence is provided. Another example is the pathology dashboard developed by Kofax.^[11] This dashboard supports sorting, filtering, and drilling down, and supports monitoring of the operations and identification of problem areas. However, the refresh of Kofax's dashboard is manual and hence not truly real-time. While the above-mentioned tools were specifically developed to address the needs of pathology, none of them addresses all of the requirements identified as key to supporting pathology management, including the ability to: Support real-time reporting, modify the interface according to varied stakeholder groups; notify users of upcoming issues; and support workload planning.

The row identified by a "1st cycle" in Table 2 refers to the process-level dashboard (first prototype – PowerJ) discussed in the paper while the row identified by "2nd cycle" refers to the case-level dashboard (second prototype). While the second prototype fulfills most of the stakeholder requirement, a third version of the dashboard will be necessary to address the need for automatic notifications and workload planning.

CONCLUSION

The pathology dashboard developed for the DPLM at TOH includes graphical components that help clinical

and operations managers to monitor and improve the performance of the DPLM. By providing real-time data about a state of case processing, the dashboard enables managers to identify individual specimens or groups of specimens that need to be taken care quickly to ensure that pathology diagnostic reports are generated within standards required for high-quality patient care. Future work will, however, be required to formally evaluate the specific performance improvements that can be derived from the use of this dashboard in the DPLM.

Given that the DPLM now processes all surgical and cytology specimens for the EORLA, it is no longer possible for clinical and operations managers to have an overall understanding of how well the DPLM achieves its objectives just relying on historical data and static reports. They need to be able to have timely access on the one hand to aggregate data about the cases, laboratories' operations, and pathologists' workload and, on the other hand, to drillable data about the status of individual cases and specimens that may require immediate intervention. The increase in volume experienced by the DPLM and in similar large pathology facilities leads to an increased complexity in managing overall operations, so each case is processed within the required time frame since varied types of specimens require different turnaround times.

Dynamic, real-time dashboards such as the one discussed in this paper provide pathology managers with a powerful means to identify bottlenecks and analyze data related to exceptions to identify the root causes of the delays in processing. The use of graphical and tabular views, instead of simply text-based information, is key to effective decision support provided by dashboards; indeed, such views enable managers to quickly grasp the performance status of a pathology facility.^[14]

To move beyond problem resolution and support proactive managerial decision-making before issues arise, these dashboards should further support workload planning. This could be achieved by integrating analytical abilities, for example, using predictive models to forecast workloads and therefore identify potential bottlenecks. Furthermore, solutions could be assessed with the help of what-if analysis or simulations enabling the understanding of the way in which changes would affect current plans and future results.

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Conflicts of Interest

Wei Chen Li and Randy Giffen are employees of IBM Canada. As the IBM Cognos Business Intelligence (BI) tool (provided to the researchers by IBM Canada through its educational program) was used in our proof-of-concept, it could be perceived that IBM Canada may benefit from the publication of this manuscript. However, the pathology dashboard being described in this paper is independent from specific BI tools, and it can be implemented using any available BI software.

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