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Evaluating the benefits of digital pathology implementation: time savings in laboratory logistics

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Evaluating the benefits of digital pathology implementation: time savings in laboratory logistics

Background: The benefits of digital pathology for workflow improvement and thereby cost savings in pathology, at least partly outweighing investment costs, are being increasingly recognised. Successful implementations in a variety of scenarios have started to demonstrate the cost benefits of digital pathology for both research and routine diagnosis, contributing to a sound business case encouraging further adoption. To further support new adopters, there is still a need for detailed assessment of the impact that this technology has on the relevant pathology workflows, with an emphasis on time-saving.

Aims: To assess the impact of digital pathology adoption on logistic laboratory tasks (i.e. not including pathologists’ time for diagnosis-making) in the Laboratorium Pathologie Oost Nederland, a large regional pathology laboratory in The Netherlands.

Methods and results: To quantify the benefits of digitalisation, we analysed the differences between the traditional analogue and new digital workflows, carried out detailed measurements of all relevant steps in key analogue and digital processes, and compared the time spent. We modelled and assessed the logistic savings in five workflows: (i) routine diagnosis; (ii) multidisciplinary meeting; (iii) external revision requests; (iv) extra stainings; and (v) external consultation. On average, >19 working hours were saved on a typical day by working digitally, with the highest savings in routine diagnosis and multidisciplinary meeting workflows.

Conclusions: By working digitally, a significant amount of time could be saved in a large regional pathology laboratory with a typical case mix. We also present the data in each workflow per task and concrete logistic steps to allow extrapolation to the context and case mix of other laboratories.

Keywords: business case, digital pathology, logistics, time savings, workflow modelling

Introduction

Working with digital whole slide images instead of the traditional microscope, usually denoted digital pathology, has many advantages and has been widely accepted for research and education. The implementation of a fully digital workflow for diagnostic purposes poses several important challenges to its implementation in diagnostic surgical pathology: workflow integration, technological infrastructure, pathologist acceptance, and standardisation. Also, investment and implementation costs are significant.
necessitating the creation of a business case for which there is, besides an increase in the quality of diagnoses, a return on investment. A diagnostic digital pathology infrastructure may facilitate substantial workflow improvements that may lead to higher efficiency, better utilisation of resources, higher throughput, and a lower turnaround time of cases, and also a streamlined collaboration both within a single pathology laboratory and across organisational boundaries, and thereby lower costs.²,³

Only a few previous studies have addressed whether a digital workflow is or could be more efficient. Ho et al.⁴ focused on identifying the needs of the pathologists and on designing the digital workflows to best address these needs. A total of six pathologists were interviewed and observed in a large academic medical centre. The study found the analogue workflow to be labour-intensive and to lack scalability. Several workflows that would benefit from the introduction of digital pathology were identified: case management, case examination and review, and final case reporting. In the study of Vodovnik,⁵ digital pathology required a shorter diagnosis time than traditional microscopy in 13 of the 20 diagnostic sessions after completion of an initial learning phase, optimisation of the diagnostic setting with a fully integrated laboratory management system, the installation of double displays, and the creation of a stable network. This was related to the absence of physical slide-handling and the consolidation of multiple tasks in digital reporting systems. This confirmed the potential of digital pathology to yield savings in both diagnostic and non-diagnostic tasks.

Ho et al.⁶ described an economic impact model for a very large pathology department that receives 219,000 cases annually and employs a network of pathologists located at both academic and community-based hospitals across a large geographical area. The potential operational cost savings for 5 years following the implementation of a digital pathology solution were estimated to be approximately $18 million. The main contributory factors were gains in pathologist time resulting from higher productivity and better workload distribution ($12.4 million), and reduced costs of incorrect treatment. The overtreatment and undertreatment costs in oncology were estimated to be $5.4 million. Workflow improvement benefits were also identified, including a refinement of the current ‘centre of excellence’ model and the ability to train all pathologists in the network in subspecialties based on the ability to distribute cases across the network. Furthermore, with the digital solution, pathologists at smaller hospitals could receive sufficient cases to train in subspecialties.

To further strengthen the literature and contribute to the evidence required to build a vital business case for digital pathology, we here report on the time savings following the adoption of digital pathology at the Laboratorium Pathologie Oost Nederland (LabPON), a large regional pathology laboratory in The Netherlands that was among the first laboratories to create a fully digital diagnostic workflow.⁷

Methods

With the adoption of a digital pathology solution, several steps in the workflow change and some of the human tasks are replaced by automatic digital transmission. Digitisation also enables the integration of new applications in the workflow that were not available before, such as automatic case distribution, automatic image analysis, and remote diagnosis. The implementation of digital pathology diagnostics therefore forced us to re-evaluate our pathology diagnosis processes to arrive at an optimal digital workflow. In the process of going digital, we faced several technical challenges in the laboratory with regard to slide covering, drying, and labelling, adapted workspaces and hardware of the pathologists, and installed storage, as detailed previously.⁷ The network went down only once at the start of the project, because of server collapse, but has performed surprisingly well ever since.

To accurately and systematically assess the differences between the digital and analogue laboratory processes with respect to logistic steps, we modelled the key workflows in the pathology laboratory that are affected by the transition to digital. The selected workflows are: (i) routine diagnosis (Figure 1); (ii) multidisciplinary meetings; (iii) external revisions (Figure 2); (iv) extra stainings (Figure 2); and (v) consultations (Figure 2). The time needed for pathologists to make diagnoses was outside the scope of the current study. Next, we identified task overlaps across these workflows to avoid accounting for the same task multiple times, as some tasks occur in multiple workflows.

Once we had identified the relevant tasks affected by digitisation, we measured their durations in the conventional (analogue) pathology setting during several sessions on days with a typical workload for LabPON. Similarly, we measured the duration of the corresponding tasks (if still present) or amended tasks in the digital workflows. The measurements of

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activities of the secretary, dispatchers and archivists were made over a period of 12 days with a typical workload, resulting in >10 full days of measurements. For these three groups, two people were monitored in half-day periods to record all relevant activities.

Tasks that were eliminated in the digital workflow were set to a duration of 0 s, and, for the remaining tasks, the analogue measurements were used. For amended tasks in the digital workflow (e.g. transport from administration to pathologists), the accurate time measurements were assigned. These measurements were facilitated by the fact that, whereas LabPON is almost fully digital with respect to diagnosis-making by pathologists, it still maintains the analogue workflows. The workflows were modelled with the Business Process Model and Notation (BPMN2.0) standard, which has been used to model anatomical pathology processes before.1

Figure 1. Analogue and digital workflows in the Laboratorium Pathologie Oost Nederland. In the digital workflow, several logistic steps are eliminated.

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Results

On a typical working day, 220 new cases are produced at LabPON. In the analogue workflow, the urgent cases (10%) go directly to the pathologists after being processed, whereas the rest are dispatched in batches. The dispatching takes place eight times per day and takes 10–15 min. Figures 3–7 and the corresponding Tables 1–5 depict the five analogue workflows annotated with the total durations per day of the relevant tasks.

In Figure 3 and Table 1, measurements of the logistics task durations in the routine diagnosis workflow are compared with those in the digital workflow. The ‘prepare case’ task in the digital workflow (corresponding to step A in the analogue workflow) includes putting the slides in the scanner, removing them from the scanner and putting them on the slide transportation trolley, and finally bringing the trolley to the archive for the daily average of ~220 cases. This amounts to approximately 32 min for the preparation of the 220 cases and 2–4 min for bringing them to the archive (one or two times per day), adding up to ~34–36 min/day. Therefore, from step A in the analogue workflow, we may save ~484 min/day.

Steps B and C of the analogue workflow could be entirely removed and replaced with digital transmission and handling, leading to savings of ~175 min/day. Step D remains in the digital workflow (putting the physical slides in the archive). Therefore, from the routine diagnosis workflow, we can save 659 min/day by going digital, which corresponds to ~3 min/case.

In Figure 4 and Table 2, we focus on the multidisciplinary meetings preparation workflow. Every day, three or four multidisciplinary meetings are prepared, and each meeting concerns, on average, 17 cases (with a range from five to 30 cases). In the multidisciplinary meeting, workflow digitisation completely saves steps M, G, and K, amounting to 139 min/day. The time needed by the administration to prepare the case list for multidisciplinary meetings in a digital setting was estimated to be ~7 min per meeting (5 min for small meetings to 10 min for large meetings). In total, this will amount to ~21–28 min/day, on average ~25 min. Therefore, in step F we save ~188 min/day as compared with the analogue workflow, leading to savings of ~327 min/day.

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However, some cases are not yet in the archive when the multidisciplinary meeting is planned. In the analogue setting, these cases need to be found in the pathologist room. On average, this happens in \( \sim 10 \) cases per day and takes 4 min/case, amounting to 40 min. Therefore, the savings in this workflow can even amount to 367 min/day.

In Figure 5 and Table 3, we focus on the external requests workflow, covering incoming requests for revisions when a patient is referred to another hospital or when material is requested for panel or research purposes. On a typical working day, LabPON receives six external requests to review cases or material. Each case is screened by a pathologist (can be the same who diagnosed it). Using digital pathology, we completely save steps H, Q, and R, amounting to 24 min/day. Step P is reduced to 10 min, leading to a 31-min saving, giving a total saving of 55 min/day. This workflow requires the external pathologist to assess the case digitally as well.

Figure 6 and Table 4 show the measurements for the extra stainings workflow. On a typical day, the pathologists at LabPON order extra stainings for 35 cases (16% of the 220 cases), 10 of which are urgent (\( \sim 29\% \)). As in the case of routine workflow, the digital preparation (e.g. digital quality control instead of quality control under the microscope) will take less time in this workflow, amounting to \( \sim 5 \) min for the 35 cases. In the workflow in Figure 6, step N remains and we can save 47 min/day in step I.

Figure 7 and Table 5 detail the relevant logistic tasks in the consultation workflow. All pathologists together at LabPON typically make six requests for consultation each day, two of which concern an external pathologist, and four of which are internal requests to a colleague at LabPON. This process assumes that the external pathologist uses a digital system as well. In the workflow in Figure 7, the transition to digital saves steps O and M, giving a total of 19 min/day. Step P remains and focuses on the initiation of the request.
Thereby, in total, digitisation saves ~1147 min/day in the five key workflows, which is >19 h for a typical day. This amounts, on average, to >5 min saved in logistics for each case diagnosed. Saving ~19 h/day translates into 2.63 fte (fulltime-equivalent) laboratory staff (36-h working week), corresponding to €120 000/year.

Laboratory staff and administration were soon very happy with the efficiency of the system as a whole.
Pathologists were *a priori* less enthusiastic, as some feared that it would take them longer to complete their diagnosis, but this turned out not to be the case. After the training period, all agreed that working digitally is, on average, faster.

Clinical colleagues were, from the beginning, very positive about our switch to digital. Multidisciplinary meetings were more often illustrated with pathology images, which increased the level of discussion and mutual understanding; cases could be discussed *ad hoc* during the meeting as well. Moreover, additional questions could be answered on the spot over the telephone, as slides no longer needed to be retrieved from the archive, and full images and snapshots could be shared much more easily.

**Discussion**

The aim of this study was to assess the impact of digital pathology adoption on logistic laboratory tasks in
a large regional pathology laboratory in The Netherlands. We modelled and analysed, for the five most common workflows, the differences between the traditional analogue way and the new digital way of working, carried out detailed measurements of all relevant steps in key analogue and digital processes, and compared the time spent. On average, leaving out the time that individual pathologists needed for their evaluation of slides, in total >19 h (of which ~1 h was pathologists’ time) was saved on a typical day by working digitally, with the highest savings in the routine diagnosis and multidisciplinary meeting workflows. As far as we know, this is the first study on these important logistic aspects of digital pathology.

The current study provides the data from a large regional laboratory, but the way in which we model the different steps and provide a detailed view of the different logistic activities and their ratio in the overall workflow allows us to extrapolate estimated savings to laboratories with different volumes and workflows in each category. For instance, on the basis of these numbers, a good estimation can be made of the amount of savings in a laboratory that has a different ratio of routine versus external consultation workflow cases.

The described time savings benefited the department. Basically, we now perform more work with the same number of staff. In particular, since 2015, when we started the project, there has been an increasing demand on multidisciplinary conferences for patient care in the multiple hospitals that LabPON is serving. At that time, we were slightly understaffed, so time savings were used to balance this out. When we eventually go fully digital (all pathologists 100% digital diagnostics with histology material and including cytology slides), we expect to have an even greater benefit from the optimised logistics.

On top of the described savings, we expect additional time savings for specific, often low-volume, subspecialties such as nephropathology, for which pathologists of smaller laboratories could digitally

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### Table 1. Analogue workflow of routine diagnosis with the measured durations of key tasks: detailed time measurements in both the analogue and digital situations (see Figure 3 for the workflow diagram)

<table>
<thead>
<tr>
<th>Task</th>
<th>Cases/day</th>
<th>Activity</th>
<th>Performed by</th>
<th>Time per day analogue (min)</th>
<th>Time per day digital (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>220</td>
<td>Prepare (find form; retrieve case; scan barcode; put in folder)</td>
<td>Technician</td>
<td>520</td>
<td>36</td>
</tr>
<tr>
<td>B</td>
<td>198</td>
<td>Transfer cases to pathologist with the slide transportation trolley (in batches)</td>
<td>Archivist/technician</td>
<td>120</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>220</td>
<td>Case-handling by pathologist. Retrieve from case; sort cases; inspect; open; scan barcode (slide handling); close case</td>
<td>Path</td>
<td>55</td>
<td>0</td>
</tr>
<tr>
<td>D</td>
<td>220</td>
<td>Archive (archivist puts slides in folders and places them in the archive)</td>
<td>Archivist</td>
<td>117</td>
<td>117</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Total</strong></td>
<td></td>
<td><strong>812</strong></td>
<td><strong>153</strong></td>
</tr>
</tbody>
</table>

### Table 2. Analogue workflow of multidisciplinary meetings with the measured durations of key tasks: detailed time measurements in both the analogue and digital situations (see Figure 4 for the workflow diagram)

<table>
<thead>
<tr>
<th>Task</th>
<th>Cases/day</th>
<th>Activity</th>
<th>Performed by</th>
<th>Time per day analogue (min)</th>
<th>Time per day digital (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>65</td>
<td>Administrator (print, identify and mark); request slides from archivist; prepare package after slides are received from archivist</td>
<td>Administrator</td>
<td>213</td>
<td>25</td>
</tr>
<tr>
<td>F</td>
<td>65</td>
<td>Collect from archive and anywhere else</td>
<td>Archivist</td>
<td>97</td>
<td>0</td>
</tr>
<tr>
<td>G</td>
<td>65</td>
<td>Direct transfer to administrator/secretary</td>
<td>Archivist</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>H</td>
<td>65</td>
<td>Archive (put case back into archive)</td>
<td>Archivist</td>
<td>34</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Total</strong></td>
<td></td>
<td><strong>352</strong></td>
<td><strong>25</strong></td>
</tr>
</tbody>
</table>

### Table 3. Analogue workflow of external revision requests with the measured durations of key tasks: detailed time measurements in both the analogue and digital situations (see Figure 5 for the workflow diagram)

<table>
<thead>
<tr>
<th>Task</th>
<th>Cases/day</th>
<th>Activity</th>
<th>Performed by</th>
<th>Time per day analogue (min)</th>
<th>Time per day digital (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>6</td>
<td>Administrator (check papers); order slides and materials; prepare package when received from archive</td>
<td>Administrator</td>
<td>41</td>
<td>10</td>
</tr>
<tr>
<td>J</td>
<td>6</td>
<td>Receive request from secretary and retrieve from archive</td>
<td>Archivist</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>K</td>
<td>6</td>
<td>Direct transfer to administrator/secretary</td>
<td>Archivist</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>L</td>
<td>6</td>
<td>Put case back into archive when received back</td>
<td>Archivist</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Total</strong></td>
<td></td>
<td><strong>65</strong></td>
<td><strong>10</strong></td>
</tr>
</tbody>
</table>
consult experienced pathologists in larger laboratories such as LabPON and/or participate in regular digital meetings to discuss the cases. Moreover, as most countries face a shortage of pathologists and a higher demand on specific knowledge in all areas of pathology, a need to optimise the time spent on reading cases and participating in conferences (including the travelling time to hospitals), will be highly desirable in the coming years. The general perception in our department is that working digitally is faster, but a formal evaluation of whether the diagnostic process performed by pathologists is itself is more efficient when they are working digitally will be the subject of a future study.

We would like to point out that savings in logistics, and perhaps also in time spent by the pathologists, will probably not be enough to arrive at a financially neutral business case for digital diagnostic pathology, as the investments in hardware and software are significant. However, we argue that a business case should not only contain financial items, but should also be concerned with increased user satisfaction of pathology and clinical staff, greater attraction of young doctors to the residency programme, increased speed of diagnosis (and thereby lower anxiety and work dropout of patients and their relatives), and last, but not least, high patient safety and increased quality of diagnosis, saving significant costs outside the pathology laboratory, as pointed out by Ho et al.

In conclusion, a significant amount of time can be saved in a large regional laboratory for a typical case workload by working digitally. Our in-depth analysis of all components may help other laboratories to introduce digital pathology, and to justify the investments.

Author contributions

A. Baidoshvili and A. Bucur conceived and planned the experiments. A. Baidoshvili, A. Bucur and J. van Leeuwen carried out the experiments. P. J. van Diest, J. van der Laak and P. Kluin encouraged A. Baidoshvili to investigate, supervised the research, and contributed to the interpretation of the results. A. Baidoshvili wrote the manuscript with support from A. Bucur and P. J. van Diest. All authors provided critical feedback and helped shape the research, analysis, and manuscript.

Table 4. Analog workflow of extra staining with the measured durations of key tasks: detailed time measurements in both the analogue and digital situations (see Figure 6 for the workflow diagram)

<table>
<thead>
<tr>
<th>Task</th>
<th>Cases/day</th>
<th>Activity</th>
<th>Performed by</th>
<th>Time per day analogue (min)</th>
<th>Time per day digital (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>35</td>
<td>Prepare case (staining, processing in the laboratory)</td>
<td>Technician</td>
<td>52</td>
<td>5</td>
</tr>
<tr>
<td>N</td>
<td>10</td>
<td>Transfer directly to pathologist when urgent or to dispatching room otherwise</td>
<td>Technician</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>O</td>
<td>35</td>
<td>Archive (place slides in folder, put into archive)</td>
<td>Archivist</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>86</td>
<td>39</td>
</tr>
</tbody>
</table>

Table 5. Analogue workflow of external consultations with the measured durations of key tasks: detailed time measurements in both the analogue and digital situations (see Figure 7 for the workflow diagram)

<table>
<thead>
<tr>
<th>Task</th>
<th>Cases/day</th>
<th>Activity</th>
<th>Performed by</th>
<th>Time per day analogue (min)</th>
<th>Time per day digital (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>2</td>
<td>Write request (initiate)</td>
<td>Pathologist</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Q</td>
<td>2</td>
<td>Secretary print/request the consultation to external pathologist and send case</td>
<td>Administrator</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>R</td>
<td>2</td>
<td>Receive case back from external reviewer and dispatch into routine flow</td>
<td>Administrator</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td></td>
<td></td>
<td>23</td>
<td>4</td>
</tr>
</tbody>
</table>
References


