Pathology Resident Evaluation During the Pandemic: Testing and Implementation of a Comprehensive Online Pathology Exam

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Abstract

Despite global digitization, evaluating pathology trainees by paper exams remains the norm. As new social distancing practices require new ways of administering exams, we assessed the viability of an online format for in-house exams from the resident and examiner perspectives. First, pathology residents participated in a practice exam, while staff who were experienced in creating exams were given an online exam-creation demonstration. Subsequently, residents completed a formal 3-hour online exam comprised of multiple-choice, matching, short answer, and whole slide images in place of the paper exam regularly used to evaluate trainees. The experience of the participants was evaluated by surveys. Eighteen residents completed the practice exam; 67% were receptive to the new format and 94% were in favor of moving to digital exams. Seven staff evaluated the digital format and 6 were in favor of it. For the formal online in-house exam, 20 residents participated and 14 completed the survey. Feedback was generally positive with the most common issue being slow-loading digital slides. Exam scores stratified by postgraduate training years in a statistically significant manner, showing positive correlation with resident training level. The online exam format was preferred over paper exams by trainees, with support from both staff and trainees for a permanent transition. Online exams have clear advantages, but technical issues should be addressed before widespread implementation. Our study demonstrates that online exams are a feasible alternative for trainee assessment, especially in socially distanced environments.

Introduction

Technology is being increasingly integrated into the training and practice of laboratory medicine in many new and innovative ways.[1-3] While pathology resident education has been following suit, pathology examinations have been slow to adopt new technology. With the spread of the COVID-19 pandemic, anatomical pathology residency programs across the world have increasingly incorporated digital technology into their training programs to allow continuity in the residency curriculum without compromising trainee safety.[3-5] As examinations are a key component of that curriculum, the process of exam administration also needs to change.

At our anatomical pathology residency training program, residents complete an in-house exam biannually to gauge their

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progress through the training program and help them prepare for their Royal College Certification Exam. It is comprised of 3 components: a paper-based written exam, a slide exam, and an oral exam. The written and slide exams are completed back-to-back, while the oral exam is administered separately. The written exam typically includes short answer questions, matching questions, and questions related to photographs of gross specimens, while the slide exam is comprised of whole slide images (WSIs) with brief accompanying clinical information. These are meant to be quick or "spot" diagnoses, and the residents' answers to the slide exams are typically recorded on paper.

In this study, we first show data collected prior to the COVID-19 pandemic which explores the opinions of staff and residents on transitioning from a paper-based to an online exam format. For the residents, the data were collected after taking a practice online exam while the staff data were collected after they received a demonstration showing them how to create an online exam. We then show data collected during the pandemic when the formal in-house exam was moved online due to social distancing restrictions and we show residents' thoughts and experiences related to the new exam format.

Materials and Methods

Staff Participants

In January 2019, 7 anatomical pathology staff from different institutions across our training program were asked to participate in the study. They were selected based on having previous experience creating resident exams and/or having an interest in resident education. Six of these were staff pathologists and 1 was a program administrator.

Resident Participants

For the practice exam, all residents in postgraduate years 1 through 4 (PGY1-4) in January 2019 were invited to take part. For the formal residency in-house exam, all residents who were in PGY2-4 in June 2020 were required to take the exam. The exam was optional for PGY1s and PGY5s. Residents who completed the exam had the option to participate in the post-exam questionnaire.

Exam Descriptions

The resident practice online exam content was adapted from an exam that was created for a prior study.[6] The exam incorporated multiple-choice, matching, and short answer questions as well as questions associated with radiological and gross specimen images and WSIs. Residents were allowed to complete the practice online exam on their own time, over a 1-week period, with no time limit. They were permitted to use any computer they wanted in any setting (eg, home, hospital). Questions for the formal online exam were created by the author C.V.H. and included multiple-choice, short answer, and matching questions as well as "spot" diagnosis questions using WSIs.

All participating residents completed the formal exam on the same date during the same 3-hour period. The residents were based at multiple hospital sites across the city and were encouraged to complete the exam using their hospital desktop computer. However, some residents chose to complete the exam at home. The exam was divided into 2 parts. The first was designed to be like the written exam, including multiple choice, short answer, and matching questions, while the other part was comprised of questions with a brief clinical history accompanied by a WSI for "spot" diagnoses.

Exam Platforms

The staff online exam demonstration was done using Tutor (Philips) as well as Quercus (Instructure Inc). Tutor is a paid software that can be used for a number of purposes, including exam creation. It allows incorporation of WSIs and other image types into questions (Figure 1). Quercus is an online learning management system platform available exclusively at our university that can be used for a variety of purposes, including exam creation (Figure 2). While many image types can be incorporated into questions inputted into Quercus, it does not allow for the incorporation of WSIs. Therefore, for exams created using Quercus, questions involving WSIs were linked via the Digital Laboratory Medicine Library (DLM),[7] a WSI platform that is free and publicly available (Figure 3).

The resident practice exam was done entirely using Tutor. Residents had no prior experience using Tutor and were not given any training on this platform prior to the practice exam. The authors were available at any time should the residents wish to contact them with any questions. The formal resident exam was done on Quercus with links to the DLM for "spot" diagnosis questions. For these questions, all slides were scanned at ×40 magnification. Prior to the Quercus exam, they had the option of completing a mock exam whose purpose was to make them comfortable with the different question formats. During the exam, an invigilator was available remotely to address any questions or concerns.

Data Collection and Analysis

Surveys were created using Google Forms (Alphabet Inc), and different surveys were created for staff, the resident practice exams, and the resident formal exams. Staff and residents were provided links to the surveys after completing their platform training or exams. The staff answered questions related to both the Tutor and Quercus platforms and online exams in general. For the practice exam, the residents answered questions about the Tutor platform and online exams in general, while for the formal exam, residents were asked about the exam format, the questions, and environmental factors. In addition to the survey results, exam scores were compared between PGY levels. To measure how well the exam can stratify between training years (ie, a PGY4 doing better than a PGY2 resident), a 1-way ANOVA with Tukey post hoc analyses was performed.
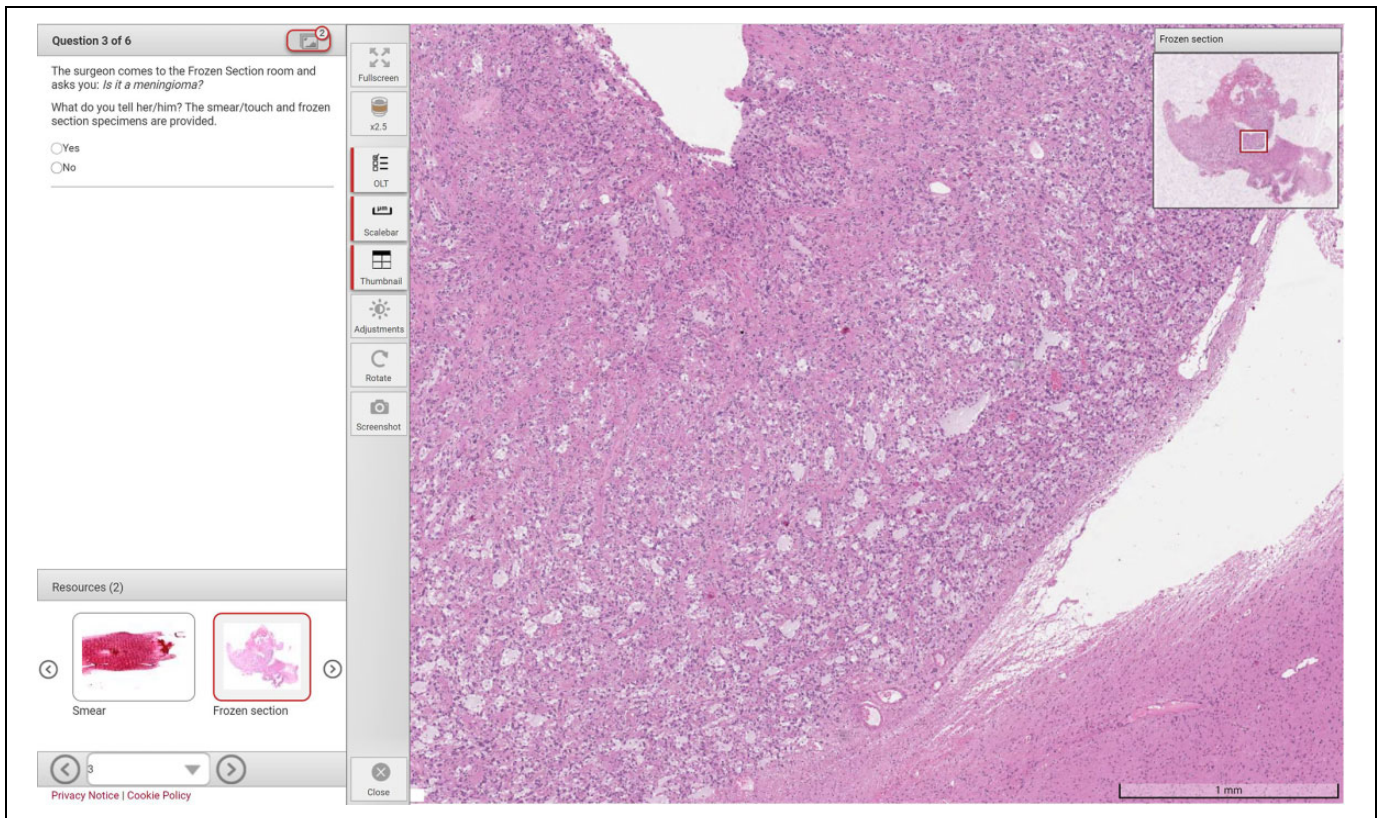
Figure 1. Screenshot from exam created using Tutor platform. Whole slide image is seen on the right-hand side of the screen. The question is on the upper left. Thumbnails on the lower left show the whole slide images that are associated with the question and available to be viewed. The thumbnail that is selected is outlined in red.

Results

Staff Participants

Of the staff invited to take part in the study, all agreed to participate (100%, n = 7). They varied in their level of experience, with 2 of the participants never having created a resident exam before, 2 having completed between 1 and 3, 2 between 4 and 6, and 1 participant having created 7 or more resident exams (Table 1).

Staff Perspective

The majority of staff thought that both platforms were user-friendly for inputting questions, images, and slides. Five (71%) staff believed both Tutor and Quercus were very user-friendly for entering questions, while 2 (29%) thought Quercus was somewhat user-friendly. Two participants found Tutor to be only somewhat or less user-friendly for entering questions (Figure 4A-B).

Four of the staff (57%) found Tutor to be very user-friendly for inputting WSIs and images, while 2 thought it was somewhat user-friendly and 1 thought it was not user-friendly. Staff did not have the opportunity to try inputting WSIs into the DLM, as this is done separately by the DLM team. However, based on their prior experience submitting slides to the DLM, 2

staff thought Tutor was the same, 2 thought the experience was better, and 1 thought it was worse. The 2 staff who did not have prior experience creating exams did not answer the question. When comparing viewing the slides in Tutor compared to the DLM, 3 staff thought they were the same, 2 thought it was better, and 1 thought it was much better. One participant did not respond.

When asked to express a preference between the 2 platforms, the staff were fairly evenly split: 2 preferred Quercus, 2 preferred Tutor, and 3 liked them equally. They were asked what they liked and disliked about both platforms. For Tutor, staff most commonly liked the ability to annotate slides and the ability to incorporate images and WSIs into questions, with each of these being mentioned by 3 staff independently. The next most commonly liked feature was that questions and WSIs could be shown on the same screen. Other items mentioned were the ability to incorporate embedded or "contingent" questions (where the question that appears is contingent on what was answered for the previous question) and the increased functionality and flexibility. The most common disliked feature of Tutor was the cost associated with it (mentioned by 3 staff). Other concerns included (i) that training would be required to use the platform, (ii) that images could not be directly uploaded, and (iii) that the platform was unnecessarily "fancy."
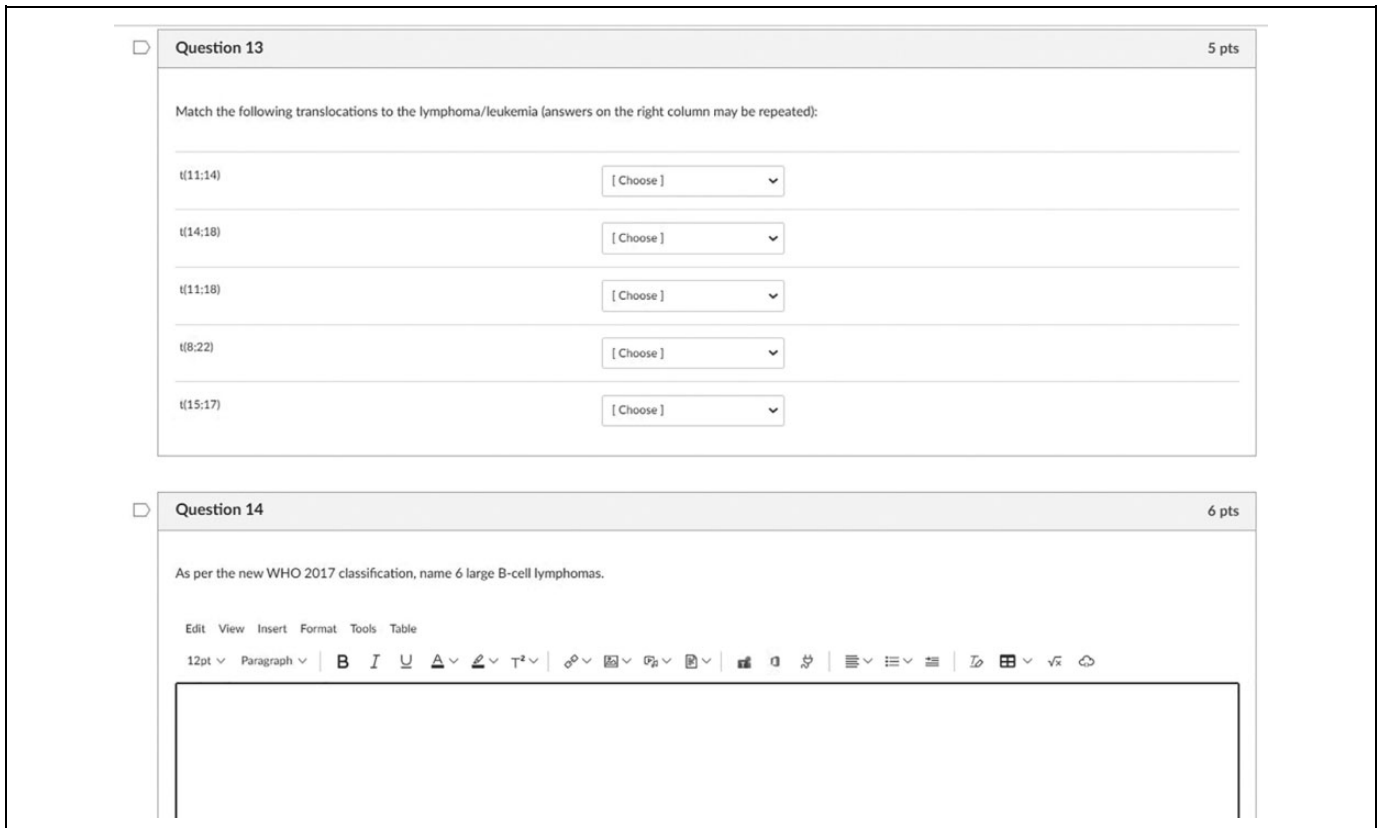
Figure 2. Screen shot from the quiz creation page of Quercus.

Two staff reported that they liked that Quercus was readily available. Other benefits listed by staff include: (i) that they were already familiar with the program, (ii) that Quercus was supported by the university, (iii) that it was simple to use, (iv) that it allowed incorporation of more question types, (v) that it allowed easy incorporation of exam time limits, and (vi) that the exam could be formatted using HTML coding. When asked what they disliked about Quercus, 3 staff cited that WSIs could not be incorporated into the platform and that, to view them, the students would need to go to a different screen. Three also thought that Quercus had limited functionality compared to Tutor, including the inability to annotate slides and the lack of "contingent" questions. One person also stated that it would take more time to organize questions.

Staff were also asked to compare how writing an exam online might compare to writing one using the paper-based format. One staff thought it would be the same, while 4 reported it would be better or much better (Figure 4C). They were then asked what they liked about computer-based exams compared to paper-based exams (Table 2), and the majority of staff responded that they would not need to decipher handwriting. When asked what they liked about paper-based exams compared to online exams, the majority stated that they would be easier to create (Table 3). The next most popular responses were that the paper-based exams would be faster to create and could be created without assistance.

Staff were also asked how long they thought an online exam would take to create compared to a paper-based exam. Five of 7 staff thought it would take longer to create an online exam compared to paper-based, while 1 thought it would take the same amount of time and 1 thought it would take less. Of the staff who thought it would take more time to make an online exam, 2 thought the online format would take twice the amount of time of a paper-based exam.

When asked for their thoughts about moving from a paper-based to a computer-based exam, most (4 of 7) of the staff were in favor of the transition (Table 4). One was neutral, stating that they did not have a problem with the online format, while another was in favor if they were given assistance with creating the questions. The other staff thought it was impractical for the in-house biannual exam but were in favor of the Royal College Certification Exam making this change.

Resident Participants

Of the residents invited to participate in the practice exam, 75% (n = 18) completed the digital exam and questionnaire. There were 5 residents from each of PGY1, PGY2, and PGY4 and 3 residents from PGY3. The majority of residents (n = 12) had taken 3 or fewer resident biannual exams prior to their participation in this study. Five residents had done 4 to 6 of these exams before and 1 reported they had done between 7 and 9.
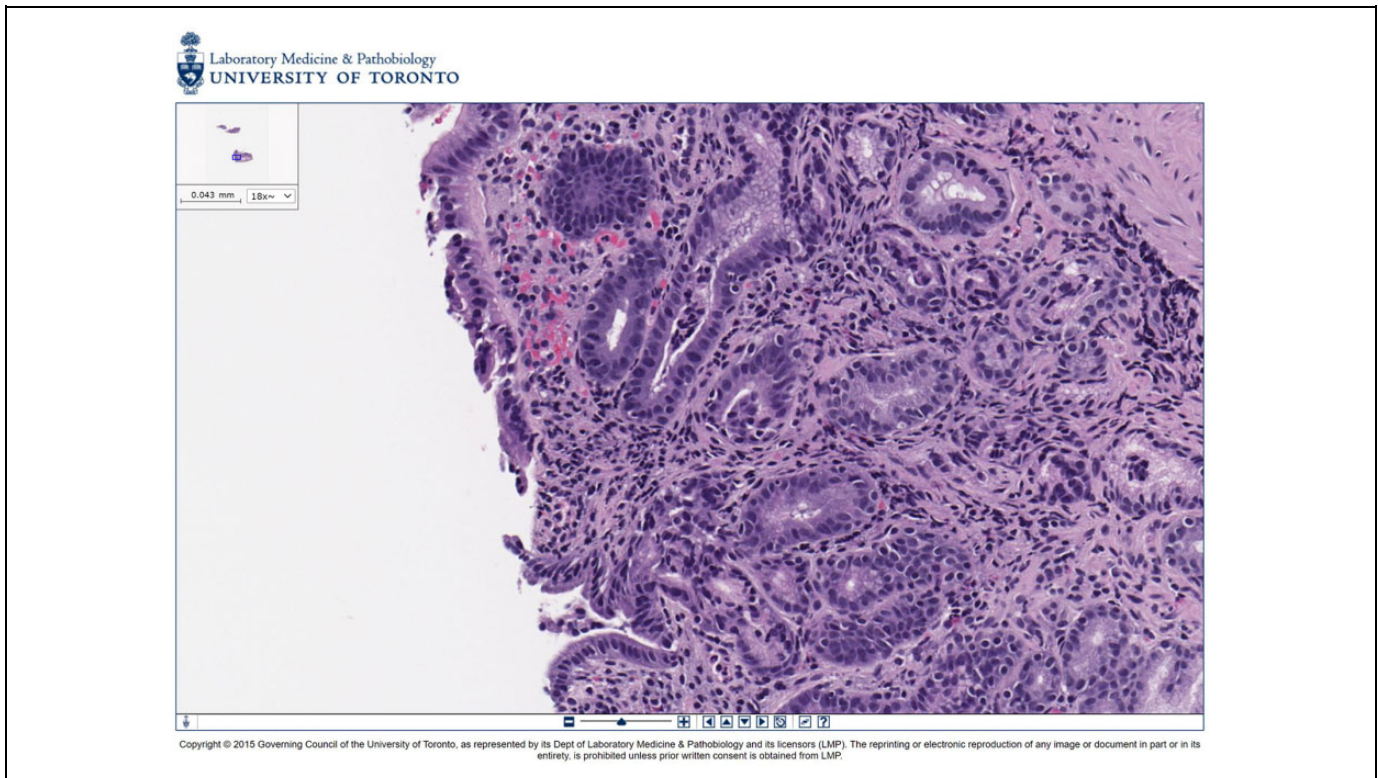
Figure 3. Screen shot from a whole slide image (WSI) from the Digital Laboratory Medicine Library (DLM). This screenshot was included with permission from the Department of Laboratory Medicine and Pathobiology at the University of Toronto.

Table 1. Staff Participant Experience in Exam Creation.

Number of exams created in the past	Number of staff (total n = 7)
0	2
≤3	2
4-6	2
≥7	1

Twenty residents completed the formal online exam, and of these, 14 completed the postexam survey (70%). Of these 14, 12 (86%) had prior experience with paper-based biannual exams and could compare the previous format to the new format. Four (29%) residents completed the exam at home, while the rest wrote it at 5 different hospitals across the city. Six residents (43%) reported that they were by themselves when they wrote the exam, 5 (36%) reported that there were others with them, with residents from one site reporting that 5 of them wrote it at the same location in a socially distanced manner.

Practice Online Exam, Resident Perspective

Regarding multiple choice questions, most (94%, n = 17) thought that Tutor was very user-friendly. On short answers, 78% (n = 14) said it was very user-friendly. The majority of residents also found the platform user-friendly for viewing slides, with 8 (44%) reporting this and 4 (22%) reporting it was somewhat user-friendly. The remaining 6 (33%) respondents were neutral as to whether it was user-friendly for viewing WSI slides. Four residents were neutral on viewing radiology, while 3 were neutral on gross images.

Ten (55%) of the residents thought that viewing WSIs in Tutor was the same or similar to viewing them using the DLM. Three residents preferred Tutor for viewing slides and 1 resident preferred the DLM platform. Five residents were neutral and said that either platform was acceptable.

When asked how the online format compared to the usual paper-based format, 67% (n = 12) of residents stated that the online format was similar to better or much better (Figure 5). One said it was worse. The remainder (28%, n = 5) did not have prior experience with paper-based biannual exams so were unable to answer the question.

Setting aside the exam questions, residents were asked to comment on what they liked and disliked about the computer-based format/platform (Tables 5 and 6). The most common themes were that they liked having the question appear on the same screen as the WSIs and that they preferred using a computer over writing by hand. Things that they disliked included (i) that the slides used for Tutor had only been scanned to ×20 resolution, (ii) navigation issues with Tutor, (iii) issues viewing slide annotations, (iv) issues with the size of the window used for viewing the WSIs, and (v) technical issues, predominantly related to images loading too slowly.

The majority of residents were in favor of switching to an online exam format (94%, n = 17), with only 1 respondent
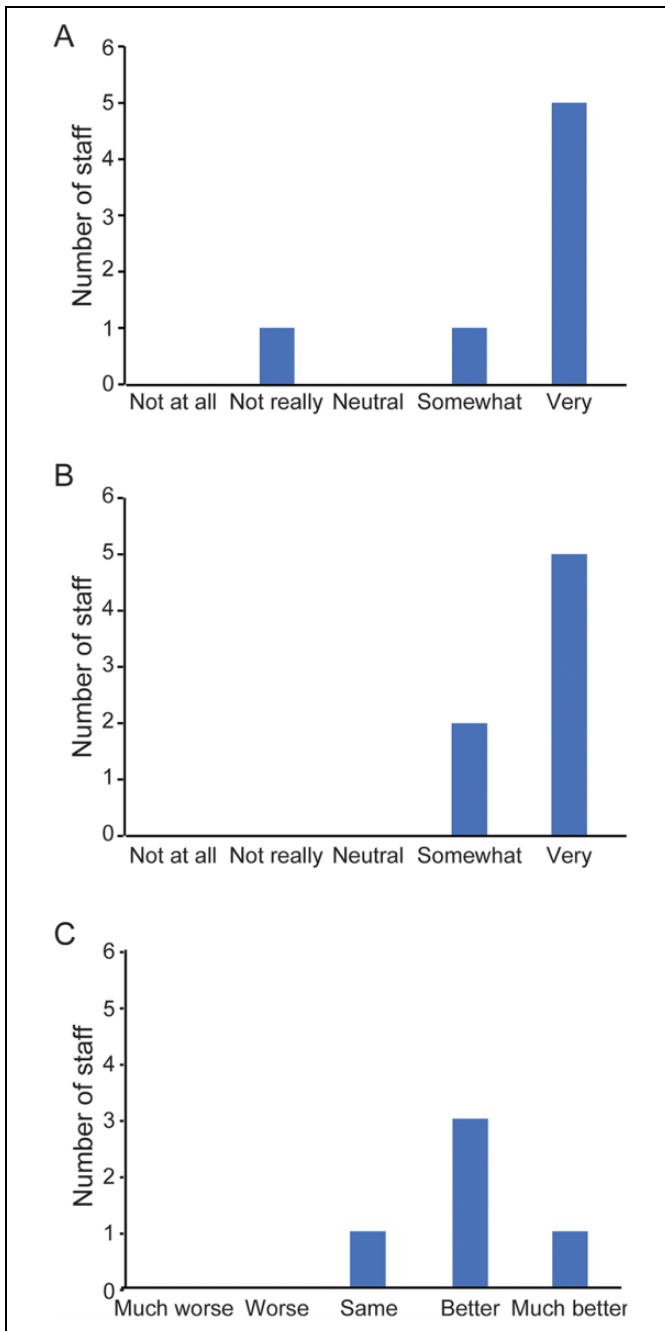
Figure 4. Staff responses when asked: (A) how user-friendly Tutor is for entering questions, (B) how user-friendly Quercus is for entering questions, and (C) how writing an exam online compared to writing an exam using the paper-based format.

preferring the old format (Table 7). Specifically, 10 residents were positive about the idea, while 3 were "fine with it." Some residents thought that the change was inevitable, and others expressed concerns about potential privacy issues related to an online exam platform and whether the computer-based format would adequately simulate a Royal College Certification Exam.

Formal Online Exam, Resident Perspective

Residents who took part in the mock exam (n = 11) were divided on whether they thought having the mock exam on Quercus prior to the real in-house exam was helpful. Four (36%) residents thought it was helpful while 4 did not and 3 (27%) indicated maybe. One participant said that the mock exam was good for acclimatizing them to the interface. Importantly the mock exam, did not reveal the issue with slow-loading slides.

Of the 14 residents who responded to the survey after the formal in-house exam, 8 (73%) residents found that having an invigilator available throughout the exam was helpful. Three (21%) said they were maybe helpful, while 2 (14%) residents did not find this helpful.

Residents were then asked to compare the computer-based exam to the usual paper-based format with respect to several different factors (Figure 6). Overall, the residents seemed to find the accessibility of the exam (ie, their ability to do the exam) and the ease and fairness of the questions to be about the same. Most residents preferred the computer interface (ie, typing/selecting) to the paper-based format (ie, writing by hand). However, in terms of the amount of time allotted for the exam and environmental factors (ie, the room, the computer, etc), most residents reported that the online exam was the same or worse than before.

For prior exams, students were required to complete the written and slide exams sequentially. With the new format, there were no restrictions on the order of completing both parts as both were made immediately available. Eleven (79%) residents reported that they preferred being able to do both exams simultaneously, while 3 (21%) expressed that they prefer sequential exams.

Residents were asked to rank their preferences in terms of device for completing the online exams (Table 8). Of the options provided, a desktop computer with a dual monitor setup was the most popular, while a personal tablet was the least popular option. They were also asked to rank their preferred exam environment in terms of room capacity and masking requirements (Table 9). The residents reported that they would prefer to do the exam in multiple small capacity settings, physically distanced, and without masks, while the least popular option would be to write the exam in a large capacity setting where residents were physically distanced and required to wear masks.

Comparison of Online Exam Results Between Resident Cohorts

As residents advance through the training program, their scores on the biannual exams are expected to improve. Thus, it is expected that more senior residents will score higher than their less experienced junior colleagues. Indeed, the exam averages increased accordingly with advanced training year. We used a 1-way ANOVA analysis to show that the exam averages were significantly different for both the written (F statistic = 6.0387,

Table 2. Staff Responses to "What Do You Like About the Computer-Based Exam Format Compared to the Written Format?"

What do you like about the computer-based exam format compared to the written format?	Number of staff
No need to decipher handwriting	4
Easier to mark	1
Easier to change and add questions	1
Examinees can write remotely	1
Can combine slide questions with written questions	1
Can annotate slides	1
Interactive	1

Table 3. Staff Responses to "What Do You Like About the Written Exam Format Compared to the Computer-Based Exam Format?"

What do you like about the written exam format compared to the computer-based exam format?	Number of staff
Easier to create	4
Faster to create	2
Need less assistance to create	2
Potential for computer glitches	1
Easier to make changes	1
Easier to separate into sections for different markers	1

Table 4. Staff Responses to "What Are Your Thoughts on Moving Away From Paper Exams to a Computer-Based Exam Format."

What are your thoughts on moving away from paper exams to a computer-based exam format?	Number of staff
In favor of transitioning to online exams	4
Impractical for biannual exam, positive for board exams	1
Positive if assistance creating questions	1
Neutral	1
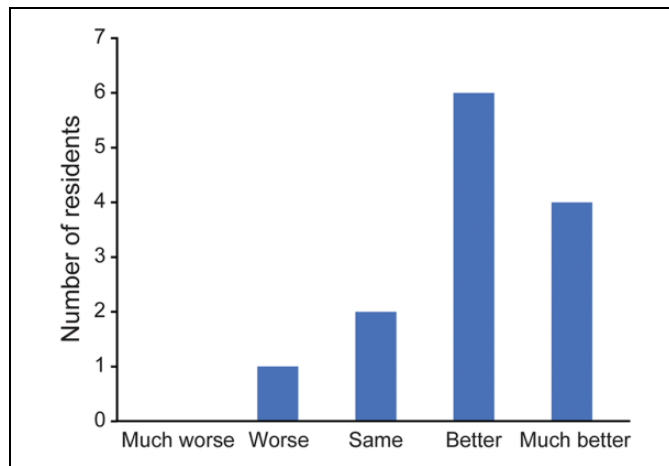
Figure 5. Resident responses related to the practice exam when asked how the online format compared to the written format.

$P = .0074$) as well as the WSI slide component (F statistic = 4.3035, $P = .0239$). Furthermore, Tukey post hoc analyses between the training years showed significantly higher averages for the PGY4 cohort compared to the junior years for both the written ($P < .05$) and the WSI slide components ($P < .05$) of the exam.

Discussion

In this study, we demonstrate the feasibility of a computer-based pathology residency exam by considering both the examiner and examinee perspectives. To demonstrate this, 2 different computer-based platforms were employed, Quercus and Tutor.

Overall, both staff and residents were in favor of converting from a paper-based to a computer-based exam. This transition has been made for a number of medical exams in the past, including the Medical College Admissions Test (MCAT)[8] and the United States Medical Licensing Exam (USMLE).[9] The Royal College Certification Exam transitioned from glass slides to digital slides in 2017.

Computer-based platforms that allow exam administration have become quite versatile allowing a range of question types with some types (eg, multiple choice, true/false) allowing immediate grading. Many prior studies looking at the use of computer-based exams in medical education have been limited to multiple choice exams.[10-12] However, the ability to integrate different question types into the same test may create a richer exam experience and allow examiners to probe a resident's understanding of a topic in a deeper way. This varied experience can help trainees with different exam formats including the American Society for Clinical Pathology

Table 5. Resident Responses to "What Did You Like About the Computer-Based Exam Platform/Format?"

What did you like about the computer-based exam platform/format?	Number of residents
Slides and questions on the same screen	6
Prefer computer over writing	5
Ease of use	2
Environmentally friendly	1
Interactive	1

Table 6. Resident Responses to "What Did You Dislike About the Computer-Based Exam Platform/Format?"

What did you dislike about the computer-based exam platform/format?	Number of residents
Slides only magnified to ×20	4
Platform-specific issues	4
Viewing screen too small	3
Technical difficulties (images loaded slowly)	3
Harder to jump back and forth between questions	1
Not representative of the Royal College	1
Prefers glass slides	1

Table 7. Resident Responses to "What Are Your Thoughts on Moving Away From Paper Exams to a Computer-Based Exam Platform/Format?"

What are your thoughts on moving away from paper exams to a computer-based exam platform/format?	Number of residents
Positive about making the transition	10
"Fine with it" or neutral	3
Inevitable, way of the future	3
Concerns about whether or not it simulates board exam	2
Concerns about privacy (if using personal computers)	1
Prefers paper exams	1

Resident In-Service Examination, in which Canadian residents often take part and where the questions are entirely multiple choice or the Canadian Royal College Certification Exam, where the questions are predominantly short-answer type. Computer exams also facilitate the integration of various types of media into exams, particularly high-quality images, which is critical in pathology exams.[13,14]

Our practice and formal exams demonstrated that computer-based exams increase the flexibility of exam administration. For example, several residents were able to complete the exam from home. Similarly, this format would allow residents to complete the exam from anywhere, provided there is internet access, allowing completion during off-site electives or international conferences. In the past, residents were required to do the written exam and WSI sequentially, with specific time allotted for each. Now, residents could choose whether they did the exams sequentially or simultaneously. Although this freedom puts the onus on the residents to manage their time properly, most residents (11 of 14) preferred this option. With awareness of increasing stressors and mental health issues brought on by the COVID-19 pandemic,[15] having the option to write an exam in the comfort and safety of one's home, the flexibility to complete the exam in nonsequential manner, and even having access to an online invigilator should problems arise may help alleviate some of the stress associated with exams, especially during the pandemic. The flexibility of the computer-based format could also allow students to write an exam on the date and time of their choosing, although this could make the use of an online invigilator more challenging.[11] Computer exams also have the potential to employ adaptive testing methods, where the difficulty of subsequent questions are contingent on whether the preceding question was answered correctly or incorrectly.[16] Finally, having an archive of old digitized exams can serve as additional practice options for trainees undertaking certification exams.

Among the staff, the greatest perceived benefit was that illegible handwriting while marking would be a nonissue. However, concerns were expressed regarding how long the exam would take to create. It was unclear from the responses why they thought the computer-based exam would take longer to create as both exams require inputting questions and images via a computer interface. It could be related to lack of familiarity with the user interface, suggesting a learning curve that would be slow at first but could be overcome with time. Whether other factors might make online exam creation slower will need to be evaluated further.

Residents also preferred the computer-based exam format to the paper-based format overall, citing their preference for the
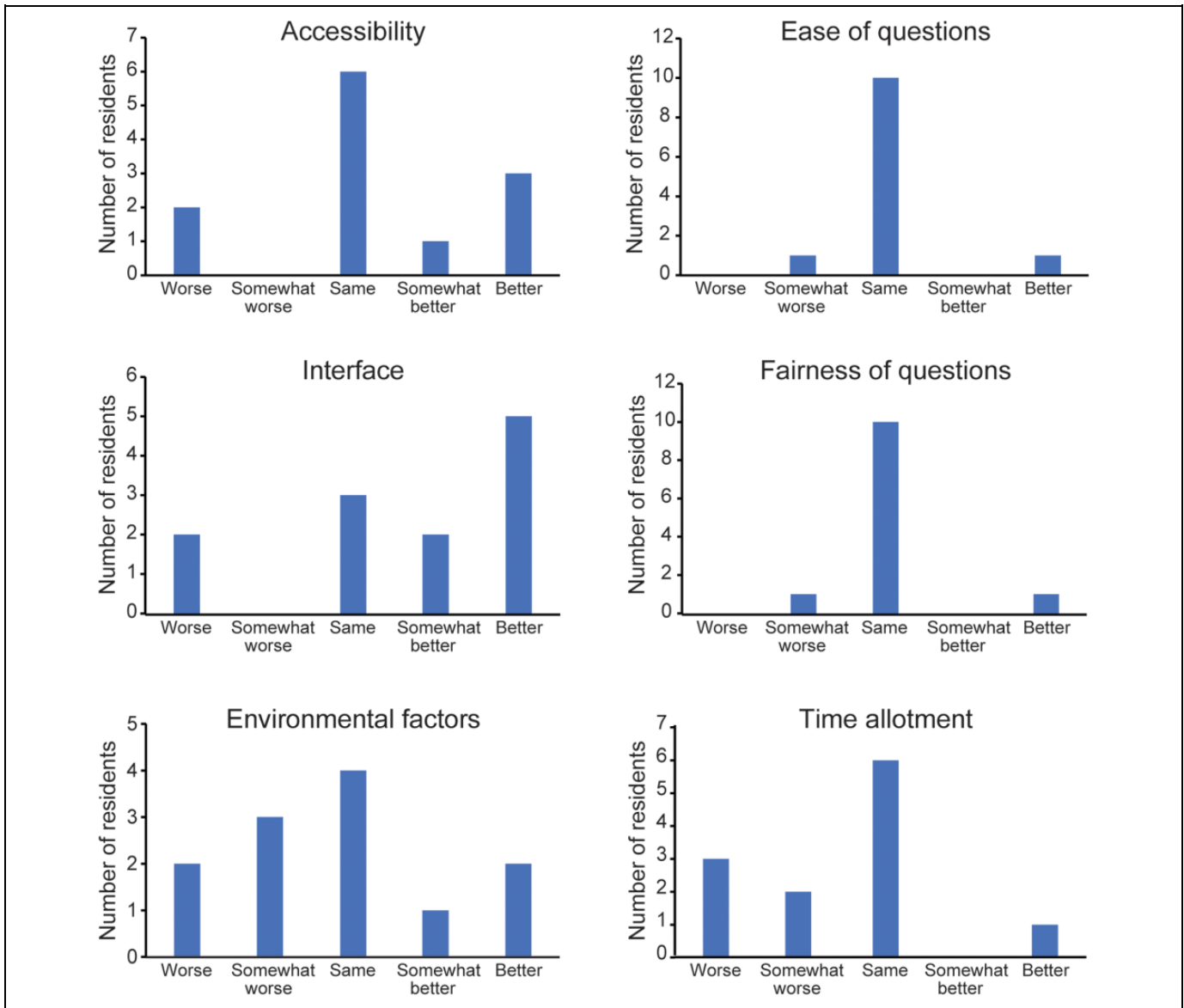
Figure 6. Resident responses comparing the formal in-house online exam to different aspects of previous paper-based exams.

Table 8. Resident Ranking for Their Preference Regarding Various Environmental Factors.*

	Least preferred	Less preferred	Equivocal	More preferred	Most preferred	Weighted average
Personal laptop	4	1	6	2	1	3.36
Department-issued laptop	1	5	4	3	1	3.14
Single monitor desktop setup	2	2	4	3	3	2.79
Dual monitor desktop setup	1	4	0	3	6	2.36
Personal tablet	8	0	1	0	5	3.43

* Residents were asked to rank each item from most preferred (rank 1) to least preferred (rank 5). The numbers in the boxes indicate the number of residents who ranked the option at the indicated level. For the weighted average, the lowest number indicates the highest preference.

computer interface over the need to handwrite answers as the major advantage. With regard to disadvantages, the main concern was technical issues, particularly that slides loaded too slowly. While our residency program had already been using the DLM for the WSI component of the exam for several years, in the past the students have completed this exam in one room, which contained multiple desktop computers with similar internet speeds. For both the practice and the formal exams, residents completed them at multiple sites using various devices, so there was likely variability in internet speeds that would

Table 9. Resident Ranking for Their Preference Regarding Various Environmental Factors.*

	Least preferred	Less preferred	More preferred	Most preferred	Weighted average
Multiple small capacity settings, physically distanced, and masked	6	2	3	3	2.79
Multiple small capacity settings, physically distanced, and not masked	2	2	5	5	2.07
One large capacity setting, physically distanced, and masked	6	4	2	2	3.00
One large capacity setting, physically distanced, and not masked	3	3	2	6	2.21

* Residents were asked to rank each item for from most preferred (rank 1) to least preferred (rank 4). The numbers in the boxes indicate the number of residents who ranked the option at the indicated level. For the weighted average, the lowest number indicates the highest preference.

have made some user experiences worse than others. Another possible explanation could be the expanded bandwidth use globally due to the pandemic forcing more people to work and connect online from home. The slow internet speed may also be why several residents felt the time was too short, although the time allotted for the computer-based exam was the same as it had been for previous exams.

Several solutions to address slow WSI loading can include dividing the group to stagger access to the WSIs, with one-half starting with the "written" component and the other starting with the digital images. As the DLM is always available as a study tool, going forward residents will be encouraged to test image loading speed in order to optimize the selection of their exam setting (location, device used, etc). This can include allowing residents to write from home (where their setup might be faster) and where they will be required to self-invigilate. Ideally exams should be taken at hospital sites, where the computers should be updated, decluttered, and standardized to ensure maximum functionality. Alternatively, third-party sites designed for computer-based exam administration could be employed, similar to MCAT and USMLE exams. However, the cost for this may be prohibitive.

Another issue with residents writing their exam at a hospital site was that many residents were still at their work desk. This meant that some residents were interrupted by staff pathologists and colleagues who were unaware or unconcerned that they were writing an exam. In the future, clearer communication to staff in the form of email notifications and signs will be used to mitigate this issue.

The preference for residents in terms of writing environment was multiple small venues as opposed to one large venue. As previously stated, this could introduce variability in terms of internet speed, but it could also mean variability in screen size and quality as well as environmental factors such as noise or other distractions. Going forward, efforts will be made to control these variables, including recommending the use of earplugs or noise-canceling headphones. Writing at multiple venues may also require multiple invigilators, especially for larger exam settings. Having online invigilators may also help alleviate this issue.

While historically the biannual in-house exam has always had an invigilator who was there to answer questions as well as to monitor the examinees, as would occur during a licensing exam, this was not feasible when writing at multiple locations. A remote invigilator was available to answer questions via video chat throughout the exam. However, the residents were not formally monitored during the exam. While this may in theory increase the risk of academic dishonesty, it was deemed not to be a concern during the in-house exam for several reasons. First, these exams are meant primarily to give the residents a reference point of their progress, so the academic stakes are very low and it is in the residents' best interest not to refer to study materials during the exam. Second, the exam is designed to have a limited time frame, partly to increase the challenge and also to deter extracurricular consultations. Third and most importantly, professionalism is one of the core behaviors expected from all trainees. A reminder of this expectation and to treat the exam as "closed book" were sent along with the email detailing this exam.

The other stated preference among the residents was that they do not wear masks during the exam. While this issue will hopefully be moot after the pandemic passes, it remains an issue in the current climate. The formal online exam was administered in the early days of implementation of universal masking policies, so this preference may be because residents were not yet accustomed to wearing masks over long periods of time. Going forward, residents will be expected to adhere to local infection prevention and control policies or government regulations wherever they are taking the exam.

One of the facets of this study was the use of 2 different online exam platforms to administer pathology exams, one which is free and widely available to students at our institution (Quercus) and the other which is a paid platform (Tutor). While the 2 platforms each had advantages and disadvantages, both were able to be used effectively to administer pathology residency training exams. The downside, of course, is that Quercus is not available to students external to our program and training programs may be unwilling to incur the cost of a program like Tutor. We are fortunate to have access to a program like the DLM where WSI slides can be incorporated into trainee examinations. For other institutions wishing to implement an online exam format choosing a platform that allows for exam creation and can incorporate WSIs seems the most ideal solution. As the cost of storing data continues to decline,

hopefully the cost of these programs will also decrease, allowing more widespread use.

A key consideration when changing the format of an exam is the potential impact of that change on student performance. This is an issue that has been studied in the past, and most commonly no difference is found, although one study found that students performed better on the computer-based exam than the paper-based exam.[17-19] Importantly, in the formal exam taken by the residents in this study, the exam was able to stratify the residents by training year, as it has done on previous exams (author experience, C.V.H.), and which is to be expected as their knowledge and experience improve over the course of the 5-year training program. The perception of the residents was also that the exam questions were fair and at the same level of difficulty as in previous years.

One thing that could affect the difficulty of the exam is that residents who are more adept at typing/selecting than handwriting may take less time to record their answers enabling them to complete their exam in less time, while others who are less computer literate may require more time. A prior study did objectively find that the computer-based exam took less time than a paper-based exam even though the exam was purely multiple choice, while in another study students perceived that a paper-based multiple-choice exam took longer than a computer-based multiple choice exam.[20,21] In the current study, the time the exam took to complete may have been significantly impacted by internet and computer speeds. Thus, this issue needs to be addressed once the technical issues are resolved.

In conclusion, computer-based exams are an effective and feasible way to evaluate resident progress and can be used as a substitute for paper-based exams. While this study was borne out of necessity due to the COVID-19 pandemic restrictions, we believe that changes incorporated in our training program will continue even after pandemic-related physical distancing requirements are no longer needed. Both staff and residents were in favor of this transition. However, details such as staff training, environmental factors, and technical issues should be addressed before widespread implementation.

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