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Original contribution

Cytopathology whole slide images and adaptive tutorials for postgraduate pathology trainees: a randomized crossover trial☆,☆☆

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Summary To determine whether cytopathology whole slide images and virtual microscopy adaptive tutorials aid learning by postgraduate trainees, we designed a randomized crossover trial to evaluate the quantitative and qualitative impact of whole slide images and virtual microscopy adaptive tutorials compared with traditional glass slide and textbook methods of learning cytopathology. Forty-three anatomical pathology registrars were recruited from Australia, New Zealand, and Malaysia. Online assessments were used to determine efficacy, whereas user experience and perceptions of efficiency were evaluated using online Likert scales and open-ended questions. Outcomes of online assessments indicated that, with respect to performance, learning with whole slide images and virtual microscopy adaptive tutorials was equivalent to using traditional methods. High-impact learning, efficiency, and equity of learning from virtual microscopy adaptive tutorials were strong themes identified in open-ended responses. Participants raised concern about the lack of z-axis capability in the cytopathology whole slide images, suggesting that delivery of z-stacked whole slide images online may be important for future educational development. In this trial, learning cytopathology with whole slide images and virtual microscopy adaptive tutorials was found to be as effective as and perceived as more efficient than learning from glass slides and textbooks. The use of whole slide images and virtual microscopy adaptive tutorials has the potential to provide equitable access to effective learning from teaching material of consistently high quality. It also has broader implications for continuing professional development and maintenance of competence and quality assurance in specialist practice.
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1. Introduction

There are extensive descriptions in the literature of the use of digital imaging technology in pathology. "Digital" or "virtual" slides (vslides) or "whole slide images" (WSI) with x- and y-axis capability are widely used [1,2]; these are scanned images of tissue sections or cytology smears, typically stored in a multiresolution format. Scanning devices for creating digital images are well described and illustrated by Khalbuss et al [1]. Other technologies include telepathology [3,4], transmitted still images [5], WSI with z-axis capability (so-called z-stacking) [6-9], WSI with extended-focus imaging [10] or so-called focus fusion [11], video image capture [12], and virtual pathology tracking software for training and assessment purposes [13-15].

Numerous groups have examined the use of virtual histopathology for teaching [16-22] and the use of virtual histopathology and cytopathology for diagnosis [6,23,24]. The value and reliability of virtual microscopy compared with traditional microscopy have been extensively assessed [6,16-20,22] with virtual methods scored as equal or even superior [6,17,18,22]. Most studies show strong acceptance of digital pathology as a learning tool, although there is some reluctance in using it for assessment purposes [23], especially in cytopathology [6], due to the perceived slower speed of analyzing cytology WSI [6,9,25].

Cytopathology is z-axis dependent. Microscopic examination of a traditional slide is not limited by focal depth, whereas focusing through different planes cannot be achieved with a wholly or partially 2-dimensional WSI. Nevertheless, studies comparing diagnostic accuracy between virtual versus traditional cytopathology have concluded either that both methods were similar [6,25] or that the degree of inaccuracy was small [26-28]. Moreover, the number of included z-stacks did not seem to make a great deal of difference to reliability of the diagnosis [9]. However, in several studies, participants felt more comfortable if vertical focus was available [6,9,29].

It has therefore been established in non-Australian settings that WSI are an acceptable and accurate way to learn both histopathology and cytopathology. However, the use of cytopathology WSI for education and proficiency has never been assessed in the Australasian pathology setting.

Although virtual microscopy has been shown to be a very useful learning tool, provision of WSI alone for teaching may also not be sufficient to convey salient teaching features [30]. Additional support in an interactive e-learning environment is readily achievable and may be valuable with image-based subjects such as microscopic pathology. Interactive virtual teaching modules have been shown to improve general pattern recognition [31] and pathology examination performance [32] and are an effective and acceptable way for medical students to learn pathology [33].

We have previously reported the successful use of virtual microscopy adaptive tutorials (VMATs) to effectively engage medical students in learning basic histopathology from WSI [33]. VMATs are built on a platform that readily allows an expert to create an interactive educational module around a selection of WSI. The platform enables real-time tracking and monitoring of participant responses, allowing feedback to be adapted as appropriate to help remediate common misconceptions.

No published evidence of efficacy and efficiency of cytology VMATs currently exists. Consequently, in the present study, we aimed to compare the efficacy and efficiency of both cytology WSI and VMATs to traditional glass slides and textbooks for learning by postgraduate anatomical pathology trainees.

2. Materials and methods

2.1. Virtual slides

An Aperio Scanscope XT (Aperio Technologies Inc., Vista, CA) was used for image acquisition at original magnification ×40. Additional focal points were manually inserted to maximize the in-focus areas on the final WSI. Files were cropped to reduce final size to less than 2 GB. The WSI were stored in a biomedical image database known as Slice (https://www.best.edu.au/slice/featured) and delivered using a custom-built whole slide viewer. Accompanying VMATs were developed to augment the majority of WSI, whereas a subset was used for online assessments. An example of our WSI and the Slice viewer interface can be seen via the following link: https://www.best.edu.au/s/ft8pw2tc/l8iw37sx.

2.2. Development of VMATS

VMATs were created using the Adaptive e-Learning Platform, an intelligent tutoring system developed by Smart Sparrow (https://www.smartsparrow.com/). Feedback on 3 online pilot cytopathology VMATs was sought from pathology trainees and specialist pathologists. This was taken into account when developing a further 22 VMATs for the trial. Adobe Captivate was used to create short instructional videos to augment some VMATs. The VMAT interface can be seen in Figs. 1 and 2. These VMATs can be accessed via the following links: https://aelp.smartsparrow.com/bronte/viewer/open/9r43hp68 and https://aelp.smartsparrow.com/bronte/viewer/open/nrreaien.

2.3. Trial design and analysis

The trial focused on the main themes of specialist cytopathology training, including gynecology, fine needle aspiration (FNA), and exfoliative/effusion fluid cytopathology. The diagnostic categories of the 22 VMAT-supported cases are listed in Table 1. The trial was approved by the UNSW Medicine Human Research Ethics Committee (HREC 1311). Participants were volunteer anatomical pathology trainees from all states in Australia as well as from New Zealand and Malaysia. They were recruited by advertisement and broadcast email through the college. Informed consent was obtained from all participants, who

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