The use of virtual pathology in teaching medical students: first experience of a medical school in Thailand

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Abstract

Background and objective: Conventional light microscopy (CLM) has long been used as a teaching modality in pathology courses. Virtual microscopy (VM) has recently challenged traditional practices and revolutionized pathology education. However, most medical schools in Thailand still use CLM to teach pathology to medical students. This study aims to evaluate the effectiveness of VM in terms of undergraduate teaching as the primary experience at Thammasat University.

Methods: Participants were 29 second-year medical students who sat in the practical session of the alimentary system pathology using VM as teaching modality. Students took pre- and post-tests with 12 questions covering common alimentary system diseases, followed by 10 survey questions with a five-point Likert-style scale. Test and satisfaction scores were analyzed.

Results: There was a significant difference (p<0.01) between student pre-test scores (mean ± SD, 1.7 ± 2.1) and post-test scores (7.1 ± 3.4). VM was viewed as a preferred learning modality, mainly because of its portability (mean: 4.9 on the five-point Likert-scale), satisfactory quality of images (4.4), permitting learning in less time (4.3), and stimulating cooperation between students while improving interaction with teachers (4).

Conclusions: Student perceptions of VM as a new teaching-learning tool and their outstanding performance on the knowledge exam suggest that VM has a potential role in undergraduate teaching. The results of this study help to improve pathology teaching strategy in the integrated curriculum.
Keywords: Virtual microscopy; Education; Medical students

Introduction

Histopathology practical sessions are essential for undergraduate students, including medical students, dental students, and other health professions students, in terms of a better understanding of the pathologic basis of diseases. These sessions allow them to see the actual morphological changes of a particular disease. Since the middle of the 19th century, conventional light microscopy (CLM) was regarded as a preferred teaching-learning modality and became the basis for pathology teaching (Blake, Lavoie, and Millette, 2003; Paulsen, Eichhorn, and Brauer, 2010). Despite its common use as an educational tool, there are many limitations to CLM. First, multiple students cannot view the slides simultaneously. Secondly, a large sum of money is needed not only to provide rooms with several microscopes and generate many glass slides but also to maintain their high level of quality (Saco, Bombi, Garcia, Ramirez, et al., 2016). Last but not least, due to the fading of the dye or slide damage, the slides are needed to be changed regularly (Sagol, Yorukoglu, Lebe, Durak, et al., 2015).

At the beginning of the 20th century, the emergence of digital video cameras and projectors resulted in a better learning experience, in which the histological images could be projected directly onto a screen, and participants could see these images at the same time (Paulsen, Eichhorn, Brauer, 2010; Saco, Bombi, Garcia, Ramirez, et al., 2016). The students preferred the projection images. It also reduced the need for pathology teachers to answer similar questions being asked by several students during scheduled laboratory hours (Blake, Lavoie, and Millette, 2003). One of the significant drawbacks of these devices was that only one person could move the slide at one time. Therefore, they could be used to augment the conventional teaching method but could not replace CLM (Saco, Bombi, Garcia, Ramirez, et al., 2016).

Digital pathology, also known as virtual microscopy (VM) or whole slide imaging (WSI), is a technology that can create a virtual image of the whole histological glass slide by slide scanners. Such scanners are automatic machines capable of generating digital images from the glass slide with different optical objectives. These digital slides can be viewed by specific software (Sagol, Yorukoglu, Lebe, Durak, et al., 2015). Some online platforms, such as PathPresenter, provide the ability to upload the user’s digital slides and use them for several purposes, particularly education. The integrated web viewer allows the slides to stream quickly, and the interaction with the digital slides makes the user feel like using the real microscope. Moreover, VM allows navigation, labeling, and annotations, which are not available with CLM. These advancements have permitted VM to be a method equivalent to conventional microscopy for pathology teaching (Dee, 2009).

Despite technological advancement, most medical schools in Thailand, including Thammasat University (the author’s institution), still use CLM to teach pathology for undergraduate students. Data on VM adoption for medical student learners in Thailand are minimal. This study aims to evaluate the effectiveness of digital pathology in terms of undergraduate teaching, which will be the first experience at Thammasat University.

Methods

Participating students

Participants were 29 second-year medical students at Chulabhorn International College of Medicine, Thammasat University. These students enrolled in the alimentary system and nutrition course. Before the beginning of the study, the students were informed that their participation was voluntary and that they would incur no penalties if they did not participate. This study was approved by the human ethics committee of Thammasat University No. 1 (Faculty of Medicine), in which the number of COA was 43/2020.
Teaching methods
Twelve common diseases of the alimentary system together with their clinical vignettes were selected according to the medical competency assessment criteria for national license 2012. Digital slides were uploaded on PathPresenter (https://pathpresenter.net), which is a web-based service providing the ability to upload the user’s digital slides and use them for several purposes, including education. The integrated web viewer allows the slides to stream quickly, and the interaction with the digital slides makes the user feel like using the real microscope (Figure 1A and B). Handouts, composed of clinical vignettes and QR code linked to digital slides, were distributed to the students before the beginning of the session.

Evaluation methods
The study was divided into three phases: a pre-test, a post-test, and a questionnaire. Both pre- and post-tests were to evaluate students’ ability to correctly identify the common gastrointestinal, hepatobiliary, and pancreatic diseases shown in static images that were captured from snapshots of virtual slides being used in the classroom. After that, students were asked to complete the 10 survey questions with a five-point Likert-style scale from 1 to 5 (5 = strongly agree, 4 = agree, 3 = not sure, 2 = disagree, and 1 = strongly disagree). Some of them also provided additional feedbacks regarding their first experience in VM after finishing the questionnaire.

Statistical analyses
The data from the students’ test and satisfaction scores were summarized using descriptive statistics (means and standard deviation). Statistical analysis was conducted using the software Microsoft Excel for Windows 10 (Microsoft Corporation, Redmond, Washington, USA). Data are presented as means ± SD. Statistical analysis between pre-test and post-test scores was evaluated using paired T-tests, in which a p-value of less than 0.05 was considered statistically significant.

Figure 1: A virtual slide of hepatocellular carcinoma in the background of the cirrhotic liver. At the scanning magnification, the hepatocellular carcinoma is distinct compared with the cirrhotic nodules (A). At the higher magnification, the thumbnail (lower left) allows a better orientation of the tissue in virtual microscopy (B). Of note, such scanning magnification cannot be obtained by CLM.
Results/Analysis

A total of 29 medical students participated in the study. During the class, VM was used as a learning-teaching tool. Students could see digital images at variable magnification which were similar to that of CLM (Figure 1A and B). A pre-test at the beginning of the course and a post-test at the end of the session were organized to evaluate the students' knowledge gain. The differences in the test scores were analyzed. Students' performance on pre- and post-test was shown in Table 1. There was a significant statistical difference (p<0.01) between students' pre-test scores (mean ± SD, 1.7 ± 2.1) and post-test scores (7.1 ± 3.4).

The results of the students' ratings are given in Table 2. VM was viewed as a preferred learning modality, mainly because of its portability (mean: 4.9 on the five-point Likert-scale), satisfactory quality of images (4.4), allowing learning in less time (4.3), and stimulating team-based learning with improving interaction with pathology teachers (4). Of note, students suggested that VM should be used in combination with CLM in pathology education. Most of the students were satisfied with their first experience of whole slide imaging in the pathology classroom.
Table 1: Students’ performance on pre- and post-test scores (N=29)

<table>
<thead>
<tr>
<th>Diseases</th>
<th>Pre-test Number of correct answer (%)</th>
<th>Post-test Number of correct answer (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Esophagus: squamous cell carcinoma</td>
<td>1 (3.4)</td>
<td>9 (31.0)</td>
</tr>
<tr>
<td>Stomach: adenocarcinoma, intestinal type</td>
<td>0 (0)</td>
<td>13 (44.8)</td>
</tr>
<tr>
<td>Stomach: adenocarcinoma, diffuse type</td>
<td>0 (0)</td>
<td>11 (37.9)</td>
</tr>
<tr>
<td>Colon: diverticulum</td>
<td>1 (3.4)</td>
<td>18 (62.1)</td>
</tr>
<tr>
<td>Colon: adenocarcinoma</td>
<td>1 (3.4)</td>
<td>18 (62.1)</td>
</tr>
<tr>
<td>Appendix: acute suppurative appendicitis</td>
<td>14 (48.3)</td>
<td>24 (82.8)</td>
</tr>
<tr>
<td>Anus: hemorrhoid</td>
<td>6 (20.7)</td>
<td>17 (58.6)</td>
</tr>
<tr>
<td>Liver: cirrhosis</td>
<td>6 (20.7)</td>
<td>24 (82.8)</td>
</tr>
<tr>
<td>Liver: hepatocellular carcinoma</td>
<td>0 (0)</td>
<td>21 (72.4)</td>
</tr>
<tr>
<td>Liver: cholangiocarcinoma</td>
<td>1 (3.4)</td>
<td>18 (62.1)</td>
</tr>
<tr>
<td>Gallbladder: chronic cholecystitis</td>
<td>3 (10.3)</td>
<td>15 (51.7)</td>
</tr>
<tr>
<td>Pancreas: adenocarcinoma</td>
<td>0 (0)</td>
<td>14 (48.3)</td>
</tr>
</tbody>
</table>

Table 2: Mean ratings of students’ response to survey questions with a five-point Likert-style scale (N=29)

<table>
<thead>
<tr>
<th>Survey question</th>
<th>Mean ± SD</th>
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<tbody>
<tr>
<td>1. I prefer clinically oriented pathology to the conventional one.</td>
<td>4.4 ± 1.1</td>
</tr>
<tr>
<td>2. Virtual microscopy is user-friendly, easy-to-use and effective for the practical session.</td>
<td>3.5 ± 1.2</td>
</tr>
<tr>
<td>3. Virtual microscopy permits learning in less time.</td>
<td>4.3 ± 1.1</td>
</tr>
<tr>
<td>4. I can quickly access virtual slides.</td>
<td>3.3 ± 1.3</td>
</tr>
<tr>
<td>5. The quality of the image of virtual slides is satisfactory.</td>
<td>4.4 ± 0.6</td>
</tr>
<tr>
<td>6. Virtual microscopy can stimulate cooperation between students and improve the interaction with the teachers when compared with conventional microscopy.</td>
<td>4 ± 1.2</td>
</tr>
<tr>
<td>7. I like the possibility to access the images anywhere, at any time, and from any device.</td>
<td>4.9 ± 0.3</td>
</tr>
<tr>
<td>8. Navigation with whole slide imaging is easier and more practical than with conventional microscopy.</td>
<td>3.1 ± 1.1</td>
</tr>
<tr>
<td>9. Marks and annotations on specific fields are useful for studying histomorphology.</td>
<td>3.5 ± 1.7</td>
</tr>
<tr>
<td>10. Only virtual microscopy is necessary for learning.</td>
<td>3.0 ± 1.6</td>
</tr>
<tr>
<td>11. Virtual microscopy should be used in combination with conventional microscopy in pathology education.</td>
<td>3.4 ± 1.6</td>
</tr>
</tbody>
</table>

Discussion

Historically, CLM was the preferred learning modality in histology and pathology courses. Digital pathology and artificial intelligence (also referred to as computational pathology) have been recently challenging traditional practices and providing a new realm for pathology diagnostics. These technologies could also be regarded as the third revolution in pathology, following immunohistochemistry and mutational assays, respectively (Salto-Tellez, Maxwell, and Hamilton, 2019). Recently, leading digital pathology companies have gained FDA approval for a whole slide imaging system for primary diagnosis is the US. Digital pathology offers several opportunities, including education (both undergraduates and postgraduates), research, and routine service (primary diagnosis and consultation with experts).

Before this class, medical students were loaned a collection of glass slides that they viewed with light microscopes that they rented. At the beginning of the practical session, the pathology teacher projected histological images on the screen using a light microscope attached with a digital video camera. Of note, this teaching modality allows only one person to move the slide. After the end of the practical session, they had to return both slides and light microscopes. If they want to review the slides before the examination, they have to ask for permission from the faculty. These are the old-fashioned learning and teaching methods, which are unscalable and limited by time and place. Tissue orientation was another critical issue for the practical session. Since students had limited experience in histopathology, most of them could not catch up with the histomorphology demonstrated in the practical session.
Students performed significantly better after participating in the practical session using whole slide imaging. Their post-test scores were statistically significantly higher than those of the pre-test. In the summative assessment, in which students were graded based on their marks, the overall performance was comparable with those in previous courses. However, further studies are needed to assess the efficacy of VM compared with CLM at the author's institution.

Several published articles revealed that there was no difference in terms of medical students’ performance using VM or CLM (Neel, Grindem, and Bristol, 2007; Scoville and Buskirk, 2007; Braun and Kearns, 2008; Mione, Valcke and Cornelissen, 2013; Brown, Fews and Bell, 2016; Rinaldi, Lorr and Williams, 2017). Such newest tool is not always superior to the conventional one, but it may complement the traditional teaching and learning methods. Some studies stated that medical students performed significantly better using VM (Husmann, O'Loughlin and Braun, 2009; Anyanwu, Agu and Anyaehie, 2012).

The preference survey at the author's institution showed that students preferred VM as a new teaching and learning modality because of its portability, good quality of images, permitting learning in less time, stimulating cooperation between students with improving interaction with teachers, marks with annotations, and its easy-to-use feature. Almost every student felt more comfortable with the use of a VM due to its portability. With internet access, they can access the virtual slides anywhere, anytime, and from any device. Such advantages of VM were well described in many studies (Saco, Bombi, Garcia, Ramirez, et al., 2016; Mills, Bradley, Woodall and Wildermoth, 2007). On the other hand, students need to be physically at university using light microscopes for self-study. Similar to other published literatures, students stated that VM is a flexible tool, allowing them to simultaneously view the slide, learned by their own pace, discussed with their friends and pathology teachers, and continued self-study after the session (Saco, Bombi, Garcia, Ramirez, et al., 2016; Mills, Bradley, Woodall and Wildermoth, 2007; Schmidt, Reinehr, Leucht, Behrendt, et al., 2011; Ariana, Amin, Pakneshan, Dolan-Evans, et al., 2016). Learning pathology using collaborative annotation of whole slide images also improves understanding of microscopic morphology for students (Sahota, Leung, Dowdell, and Velan, 2016). It should not be overemphasized that VM can replace CLM for educational purposes. Although one study concluded that VM is a highly preferred substitute for CLM in teaching histology and pathology (Alotaibi and Qahtani, 2016), participants in the present study were not sure about that. They preferred the availability of both VM and CLM. This finding was similar to that of Braun and Kearns in 2008 (Braun and Kearns, 2008). A recently published systematic review also summarized that medical students favored VM as a learning modality. Besides, such a learning tool was not inferior to CLM in the laboratory session (Kuo and Leo, 2019).

There have been some concerns regarding embracing VM. First, the quality of the image may not be suitable as that of directly visualized using CLM (Neel, Grindem, and Bristol, 2007). However, most of the students in the present study agreed that the quality of the image of virtual slides is satisfactory. Secondly, there can be a limited selection of slides available as learning material through VM (Pratt, 2009). This may not be an issue at a medical school which is affiliated with a tertiary hospital. Of note, pathology teachers should be aware that after graduation, medical students will be general practitioners, not pathologists. If they would like to learn more details in pathology, they can apply for a residency training program afterward. Third, one study revealed that medical students had better performance using CLM in abnormal histology. It also suggested that high-quality digitized slides alone were not enough to boost learning outcomes (Helle, Nivala, and Kronqvist, 2013). In order to better adapt VM as a teaching and learning tool, one should note that the appropriate teaching method, i.e., the application of morphologic changes in the clinical context, is also crucial. Of note, application of such technology in postgraduate education may result in the different result (Kuo and Leo, 2019).

A US national survey indicated that the use of virtual microscopy in microscopic anatomy teaching increased by 129% from 2014 to 2017 (McBride and Drake, 2018). Despite such technological advancement, most medical
schools in Thailand, including Thammasat University, still use CLM to teach pathology for undergraduate students. Data on VM adoption for medical student learners are minimal. Few published articles are available (Choomchuay, 2011; Titipungul, 2015). Similar to the present study, both articles revealed that VM is the preferred modality for medical student learners in terms of its portability and good quality of the image. On the contrary, one study concluded that there was no difference in performance using CLM or VM in 2nd-year medical students (Choomchuay, 2011).

There were some potential drawbacks to this study. Since this was the first experience of virtual pathology for teaching medical students at the author's university, there was no comparison group in this study. However, students' feedback regarding their understanding of pathology with clinical context and their satisfaction while attending the practical session using whole slide imaging system was excellent. Another limitation was that the number of participants, compared with previous studies, was relatively low. Nevertheless, this represents a class of medical students at the author's institution.

Further study is needed to validate the effectiveness of VM for undergraduate education, particularly in Thailand, in which the data of such adoption is somewhat limited. VM has a potential role for teaching pathology in other clinical contexts, including cytopathology (fine needle aspiration and other body fluids), intraoperative consultation, and autopsy. Combining VM with a team-based learning approach may also increase learning efficiency for students. Apart from medical students, other health science professional students can gain a better understanding of pathology by the adoption of VM.

**Conclusion**

The students' perceptions regarding VM as a new teaching-learning tool and their excellent performance on the knowledge exam suggest that VM has a potential role in undergraduate teaching. The result of this study helps to improve the pathology teaching strategy in the integrated curriculum. Besides, the present study suggested that VM should be used in combination with CLM in undergraduate pathology education. At the time of this writing, the data of VM for medical student teaching in Thailand is minimal. Further study is needed to validate if VM is appropriate for such teaching in Thailand's context. To maximize the advantages of adopting VM for pathological education, careful preparation is needed.

**Take Home Messages**

1. Virtual microscopy (VM) has recently challenged traditional practices and revolutionized pathology education.
2. Medical students' perceptions regarding VM as a new educational tool suggest that VM has a potential role in undergraduate teaching.
3. To maximize the advantages of adopting VM for pathological education, careful preparation is needed.

**Notes On Contributors**

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**Appendices**

None.

**Declarations**

*The author has declared that there are no conflicts of interest.*

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**Ethics Statement**

This study was approved by the human ethics committee of Thammasat University No. 1 (Faculty of Medicine), in which the number of COA was 43/2020.

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