Primerjalna raziskava virtualne in tradicionalne mikroskopije z namenom uvajanja v kurikulum Medicinske fakultete

A comparative study of Virtual Microscopy versus Traditional Microscopy for introduction into the Histology Curriculum at a Faculty of Medicine

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Izvleček

Namen: *Pri študiju histologije se trenutno uporabljajo tradicionalne tkivne rezine na stekelcih. Izvedli smo pilotno raziskavo morebitnega uvajanja virtualne mikroskopije z virtualnimi stekelci. V primerjalno raziskavo obeh metod mikroskopiranja so bili vključeni tutorji študenti. Osnovna raziskovalna izhodišča so bila: potrditev obstoja statistično pomembne razlike v času, potrebnem za prepoznavo strukture na virtualnih diapozitivih, morebitne prednosti ali pomanjkljivosti posamezne mikroskopirne metode in izpostavitev glavnih prednostnih lastnosti virtualne mikroskopije pred tradicionalno mikroskopijo pri študijskem procesu (1-3).*

Metode: *Vzorci na stekelcih so bili skenirani z Aperio ScanScope CS skenerjem in shranjeni kot virtualni diapozitivi. Starejši tutorji so na virtualnih diapozitivih in tradicionalnih vzorcih poiskali tri zahtevane vsebine oz. strukture. Meril se je čas iskanja*

Abstract

Purpose: *We currently employ traditional microscopy with glass slides for teaching purposes. Here, we performed a pilot survey on the potential implementation of virtual microscopy. Experienced peer tutors were asked to participate in the evaluation of virtual microscopy versus traditional microscopy. Our main objectives were to determine: whether there is a statistically significant difference in time to locating a structure on a glass slide versus a virtual slide, the possible advantages and disadvantages of each microscopy method, and the benefits of virtual microscopy over traditional microscopy (1-3).*

Methods: *Glass slides were scanned with the Aperio ScanScope CS slide scanner for use as virtual slides. Peer tutors were asked to locate the same structures on each glass slide and the corresponding virtual slides. Times needed to locate these structures were individually measured, and a question-*

posamezne strukture. Sodelujoči so izpolnili vprašalnik, v katerem so ocenili tako tradicionalno kot virtualno metodo (prirejena in prevedena verzija vprašalnika iz College of Veterinary Medicine – North Carolina State University virtual microscopy survey). Poudarek je bil na prednostih praktične uporabe virtualne mikropskopije v študijske namene.

Rezultati: *One sample t-test je pokazal statistično značilno razliko ($p < 0,01$) v povprečnem času iskanja strukture na stekelcu (23,0 s; SD = 5,65) v primerjavi z navideznim vzorcem (12,5 s; SD = 2,04). V pisni oceni so tutorji med drugim izrazili, da bi pri študiju najraje uporabljali kombinacijo obeh mikroskopirnih metod.*

Zaključek: *Ocenjevalci menijo, da je virtualna mikroskopija enostavna za uporabo. Čas za iskanje struktur pri tej metodi je znatno krajši. Po raziskavah, ki bodo še sledile, predvidevamo uspešno vključevanje virtualne mikroskopije v učni načrt histologije.*

naire (a modified and translated version of the College of Veterinary Medicine, North Carolina State University virtual microscopy survey) on the advantages of practical use of virtual microscopy provided at the end.

Results: *One sample t-test showed significant differences ($p<0.01$) in mean time to locate a structure on glass (23.0s) versus virtual slides (12.5s). In commentaries, peer tutors reported a preference for a combination of traditional and virtual microscopy in practical sessions.*

Conclusions: *Assessors considered virtual microscopy easy to use. Time needed to locate a structure on virtual slides was significantly shorter. After additional surveys, we envisage successful implementation of virtual microscopy in conjunction with traditional microscopy in the histology curriculum.*

INTRODUCTION

Complete understanding of histology and embryology starts with the correct interpretation of microscopy images, which leads to better comprehension of morphology and the morphogenesis of cells, tissues, and organs (1). However, until recently, access to this visual information by students was limited to periodic and short practical microscopy sessions, backed up by textbooks and printed atlases (1,2) the access to this new technology is restricted entirely to those living in cities and towns with an Information Technology (IT. For many years, microscopic details were stored for archival or teaching purposes in the form of glass slides. However, glass slides have many inherent problems, the most significant being the need for considerable space for storage and archival. Glass slides are fragile and difficult to transport. Moreover, they cannot be stored for an unlimited period of time, and will eventually fade and require replacement. In addition, they are not easily retrieved and shared for educational purposes, access times and technical requirements are comprehensive, and sometimes hard to coordinate (3).

Virtual microscopy is a novel technique that may be used for teaching histology and pathology (4). Virtual microscopy (also designated 'virtual slide system' or 'remote patchwork') is a form of static telepathology, a subcategory within telemedicine in which digital imaging technology is used to digitize, store, and view slides. A digital representation of an entire slide at the resolution of a high-magnification objective is designated a 'virtual slide' (5).

An increasing tendency at some medical universities is to digitize microscope histopathological slides from teaching resources for interactive use anywhere at any time independent of class schedules (6). Medical schools in developing countries are confronted with numerous challenges, one being the large number of the students, particularly in relation to the limited resources. The high cost of acquisition and maintenance of microscopes, and especially glass slides, is a significant issue. Consequently, more than one student may have to share a single microscope in the teaching laboratory. Glass slide specimens also often have to be

shared among students, owing to the considerable expense of preparing new specimens and replacing broken slides. Moreover, laboratory hours are limited, and microscopes are often locked up and unavailable for use after class (7). Although medical schools in developed countries do not encounter these problems, a reported trial including 82 U.S. and Canadian medical schools showed that application of digital techniques provides advantages over the usual method of teaching histology and pathology with light microscopes and glass slides (2)as well as the rapid development of computer-based instructional technologies, laboratory instruction in medical schools in the United States has been undergoing dramatic change. In order to determine recent trends in histology laboratory instruction at U.S. medical schools, a detailed Web survey was administered to histology course directors, with about two-thirds of schools responding. The survey was designed to identify trends in the number of hours of histology laboratory instruction that each medical student receives, the amount of faculty effort devoted to histology laboratory instruction, and the use of various computer-based technologies (including virtual microscopy and virtual slides. The current trend at medical schools in the United States is to go entirely digital for pathology courses, discarding student light microscopes, and building virtual slide laboratories (8).

Emerging digital microscopy and newly developed scanning light microscopy systems have enabled histologists to transfer analog image data of entire slides into digital ones with identical content and quality for student use (9). Digital files available on Web servers can be viewed on a computer monitor with a Web browser (7). Digital slides produced using whole slide imaging (WSI) can be visualized at any magnification and moved in the x-y axis, perfectly imitating a traditional microscope and glass slides (6). Images can be viewed anytime and anywhere with an Internet or Intranet-connected desktop computer, portable or tablet computer, or even smartphones (7). With sophisticated test management software, WSI technology can also be used for examinations (6). The use of WSI facilitates questions about overall pathological diagnosis without specifically highlighting the key diagnostic features, as it must be performed in the field of view of a static image (6). This is essential for teaching students, both how to identify the key diagnostic fields within a whole slide and perceive how a diagnostic field fits into the surrounding non-diagnostic slide context (6).

While WSI technology has improved teaching circumstances significantly at some medical faculties, implementing digital histopathology in low-resource areas remains a major challenge. The most problematic barrier is the high cost of equipment for digitizing glass slides (7). We do not face this problem at the Medical Faculty of University of Maribor, which is the first in Slovenia to acquire one of the most sophisticated scanners for microscope slide digitalization, the Aperio ScanScope CS. The scanner system has been operating since 2014, and widely employed for healthcare, research and education. The ScanScope CS by Aperio Technologies (Leica Biosytems, Vista, California, USA) is a brightfield scanner that digitizes whole histology or pathology microscope slides at 20× and 40× magnification and produces quality high-resolution images (~0.5 microns/pixel for 20× and ~0.25 microns/pixel for 40× scans). These images can be easily viewed with Aperio's free image viewer, ImageScope, which also allows acquisition of snapshots and quantitative analysis.

The aim of this pilot study was to evaluate the potential benefits of using WSI, compared with traditional microscopy, for daily study and determine the best applicable advantages of each method, with a view to implementing the results in the curriculum.

MATERIALS AND METHODS

With the Aperio ScanScope CS slide scanner, we digitalized the 10 most common glass histology slides. In total, 25 undergraduate students, mainly peer tutors, participated in our pilot survey examination. Firstly, participants were asked to locate

the same three structures on glass slides and the corresponding virtual slides, and the time taken to perform the task was measured. Structures on the virtual slides were identical to those viewed on the glass slides. Compared with the glass slides, the virtual slides had a markedly larger preview region. To account that differences in histology knowledge among students can affect the time needed to locate structures, we allowed students to view a small diagnostic region of interest on the slide in a histology textbook. Students performed the tasks individually with a histology assistant, who measured the time needed to locate each structure and showed them how to use the software program during the virtual examination. Students were further required to complete a short anonymous questionnaire at the time of the examination (a modified and translated version of the College of Veterinary Medicine, North Carolina State University virtual microscopy survey) (10).

RESULTS

In general, in the initial test, students located structures on virtual slides quicker than those on glass slides. One sample t-test shows a statistically significant difference ($p<0.01$) in mean time to locate a structure on glass slides (23.0s; standard deviation (SD) =5.65) versus virtual slides (12.5 s; SD =2.04) in seconds (s). The mean time difference in location time was 11.5 s in favor of the WSI method.

Students were asked to complete a survey at the end of the examination, where they rated certain features of the virtual microscopy system on a scale of 1 (poor/I didn't like it at all) to 5 (excellent/I liked it a lot). Scores were as follows (Table 1).

Overall, students responded most favorably to ease of use, simplicity of access and convenience of the WSI system. Additionally, favorable responses were obtained in terms of rapidity of access and ability to locate micro-structures (e.g., cells) on the slide. Ability to use a computer instead of a microscope to view slides was perceived less favorably, with 40% responding neutrally or unfavorably, indicating some degree of dissatisfaction with this feature.

Students were asked to rate specific features of classic microscopy on a scale of 1 (poor/I didn't like it at all) to 5 (excellent/I liked it a lot). Ratings were as follows (Table 2).

Highest scores were evenly distributed with regard to resolution (ability to see detail) and subjective assessment of image quality (all parameters). Rapidity of access was perceived less favorably, with 88% responding neutrally or unfavorably, indicating dissatisfaction with this feature in classic microscopy.

Table 1. Assessment of specific features of virtual microscopy.

Virtual microscopy system features	Number Rating				
	1	2	3	4	5
Ease of use	0%	0%	8%	8%	84%
Resolution (ability to see detail)	0%	4%	24%	52%	20%
Search for micro-structures (e.g., cells) on the slide	0%	8%	16%	20%	56%
Ability to use a computer instead of a microscope to view slides	8%	12%	20%	32%	28%
Rapidity of access	0%	0%	8%	48%	44%
Simplicity of access	0%	0%	4%	12%	84%
Subjective perception of velocity until the result of work	0%	0%	16%	48%	36%
Subjective assessment of image quality (all parameters)	0%	4%	28%	48%	20%
Technical versatility / flexibility	0%	0%	20%	48%	32%
Convenience of the system	0%	0%	0%	20%	80%

Students were asked if they preferred the virtual microscopy or traditional glass microscopy system for learning, studying at home and practical examinations. Their responses are tabulated as follows (Table 3).
Students preferred to use a combination of both methods for teaching and further study, but virtual microscopy for practical tests.

Students were asked to rate how much additional time they would spend studying slides outside of scheduled laboratory sessions for practical examinations if virtual slides were available online on a scale of 1 (I wouldn't spend any more time) to 5 (a lot more time). The results are as follows (Table 4).

Most students indicated they would spend moderately to significantly more time studying available virtual slides. Only two students felt their study time would not increase and three students would spend significantly increased amounts of time studying if virtual slides were available.
Students were asked to indicate the advantages of specific virtual microscopy features, compared with traditional glass microscopy, on a scale of 1 (not advantageous at all) to 5 (major advantage). The results are as follows (Table 5).
Students clearly believed that improvement of practical knowledge using virtual microscopy at home independently of laboratory schedules and viewing of digital images via tablets or smartphones in any location were major advantages over traditional microscopy. Many additionally felt that the comments explaining the labeled structures on digital images were beneficial for learning.

Table 2. Assessment of specific features of classic microscopy

Traditional microscopy system features	Number Rating				
	1	2	3	4	5
Ease of use	0%	8%	60%	24%	8%
Resolution (ability to see detail)	0%	0%	8%	44%	48%
Search for micro-structures (e.g., cells) on the slide	0%	16%	24%	36%	24%
Using a microscope instead of a computer to view slides	4%	8%	56%	20%	12%
Rapidity of access	8%	32%	48%	12%	0%
Simplicity of access	0%	32%	48%	20%	0%
Subjective perception of velocity until the result of work	0%	32%	48%	20%	0%
Subjective assessment of image quality (all parameters)	0%	0%	8%	44%	48%
Technical versatility / flexibility	4%	8%	48%	36%	4%
Convenience of the system	4%	16%	56%	24%	0%

Table 3. Preferred microscopy system for a particular purpose

Activity	Preference		
	Virtual	Traditional	Combination
Teaching	4%	24%	72%
Further study	48%	0%	52%
Practical examinations	36%	32%	32%

Table 4. Assessment of expected additional time studying virtual slides

Studying habits	Number Rating				
	1	2	3	4	5
Additional time you would spend studying outside of scheduled laboratory sessions if virtual slides were available on the internet	8%	8%	40%	32%	12%

Table 5. Assessment of the advantages of virtual over traditional microscopy

Virtual microscopy test features	Number Rating				
	1	2	3	4	5
Not having to adjust a microscope	0%	12%	12%	40%	36%
No problems with focusing the image	0%	32%	8%	32%	28%
Practical knowledge on virtual microscopy can be strengthened at home independently of laboratory schedules	0%	0%	0%	12%	88%
Digital images can be viewed via tablets or smartphones in any location	0%	0%	0%	12%	88%
Comments explaining the labeled structures on the digital images facilitate understanding and learning	0%	0%	4%	12%	84%

Table 6: Assessment of opinions on implementation of virtual microscopy

Statement	Answers
I think it is a great idea and see no problems in implementing it for laboratory sessions. I propose it as the only method for laboratory sessions.	16%
Virtual microscopy is the best tool for studying at home, but traditional microscopy must remain the main technique for laboratory sessions and practical examinations.	84%
Virtual microscopy does not represent progress, and as such, should not be implemented in the learning process.	0%

Students were asked to select the statement that best described their opinions on implementation of virtual microscopy and digital slides in the histology curriculum. The results are as follows (Table 6).
The majority (84%) of students believed that virtual microscopy was the best tool for home study, while a low proportion (16%) supported its utility as the sole method for laboratory sessions. No students considered that virtual microscopy did not represent progress or opposed its implementation in the learning process.

DISCUSSION

In the initial examination, students were tested not only on recognition skills but also their ability to successfully navigate the slides. The results support better performance using virtual slides. Structures on virtual slides were identified significantly more rapidly than those on glass slides, even though the technology was new. Students did not have the opportunity to accustom themselves with the computer program or virtual slides prior to being oriented at the time of the examination.

Our survey results indicate that the majority of students found the virtual microscopy system relatively easy to use. This is a significant benefit considering their lack of prior exposure to virtual slides, and indicates the technology can be easily integrated into the histology curriculum. Rapidity and simplicity of access, convenience of the system, and ability to identify micro-structures on slides were perceived favorably relative to the corresponding features in classic microscopy, whereby responses were mostly neutral or unfavorable.

Students were assessed regarding their views on the use of virtual microscopy in the curriculum based on this first exposure to the technology. Overall, the results are encouraging. Based on just around 30 minutes of exposure to virtual slides, the results indicate that the vast majority of students would like to have virtual slides available in some form. The overwhelming preference was to have virtual microscopy in combination with traditional microscopy for teaching, further study and practical examinations. Overall, 84% of students considered virtual microscopy as the best tool for home study, with traditional microscopy as the main technique for laboratory sessions and practical examinations. In addition, students felt that it was important to continue to use glass slides and microscopes in the curriculum, as proficiency with these items is essential in clinical practice.

We anticipate that increased use of virtual microscopy will enhance students' ability to successful navigate slides, both glass and virtual, by facilitating increased study using slides rather than static digital images or notes. The major advantage over traditional microscopy is that digital images can be viewed via tablets or smartphones, facilitating revision and strengthening of knowledge in any location independently of laboratory sessions.

In conclusion, initial examinations and survey results are encouraging. Students found the technology relatively easy to use and most were satisfied with the features of the virtual microscopy system. The majority of students recognize the potential advantage of the availability of virtual microscopy for study, supplementing laboratory experience and practical examinations. The student participants were mostly peer tutors aware of our curriculum and learning habits. Therefore, on the basis of their opinions, we envisage successful integration of this technology, in conjunction with traditional microscopy, in the histology curriculum at the Medical Faculty University of Maribor, and anticipate that availability of virtual slides will enhance student learning and improve overall microscopy skills. This pilot study will be followed by a larger-scale investigation involving all Histology students.

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