Adoption of diagnostic digital pathology in Finland

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Abstract

Digital pathology (DP) means digitizing histological glass slides for the assessment on a computer screen. In clinical diagnostics, DP is expected to reduce costs due to improved pathologist productivity with the aid of image analysis, workload distribution, and more accurate subspecialty-based diagnoses. The digital workflow also provides many advantages to research and education. However, the adoption of DP into clinical diagnostics has been slow. In this study, the current state and attitudes of the adoption of DP were explored with a questionnaire sent to the persons in charge of digitalization in all public pathology laboratories in Finland.

Most of the respondents (75.0%) considered that there is a sufficient amount of validation studies about the safety of DP. The benefits of DP were seen in e.g. tumor boards (64.3%), logistics (64.3%), diagnostic quality (50.0%), and consultations (64.3%). All but one (92.9%) expected the level of digitalization to reach 100% in the following 12 years. The price of digitalization, specifically the cost of storage, was considered to be the most important barrier to a large-scale adoption of DP.

The results suggest that there is a need for a substantial governmental financing: the virtual slide images could be stored in a central national image archive (e.g. Kvarkki) after diagnostics, leading to a remarkably reduced cost of local storage and an accelerated large-scale adoption of DP in the Finnish pathology laboratories. This would lead to improved diagnostic efficacy and quality by enabling better workload management locally and nationally. A central DP repository could serve as an invaluable database for e.g. biobank research.

Keywords: archives, digital pathology, medical imaging, pathology, telepathology

Introduction

The diagnostics and research on histopathological tissue samples have been based on the use of light microscope for over 100 years. Digital pathology (DP), or whole slide imaging (WSI), means digitizing the physical glass slides with special slide scanners and assessing the resulting virtual slides on a computer screen. Recently, the technological advances have enabled the introduction of DP into primary diagnostics (for review, see [1]).

The diagnostic accuracy of DP with today's methods has been shown to be equal with the traditional way of sample assessment using light microscopy (LM) in several studies [2–4], and the satisfaction of pathologists participating in the studies has been high, increasing with time [5]. Importantly, one of the key barriers for DP adoption [6] has been removed as the US Food and Drug Administration (FDA) has approved a WSI system for primary diagnosis in surgical pathology [7] based on

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a large study showing non-inferiority of DP compared with LM [8].

The digital workflow brings many advantages compared with the traditional laboratory workflow, regarding not only clinical diagnostics, but (biobank) research and education, as well (table 1). In diagnostics, DP is expected to bring cost savings due to improved pathologist productivity, workload distribution, and more accurate subspecialty-based diagnoses leading to the reduction in the amount of incorrect treatments given [9]. However, scanning is an additional step in the laboratory process, and the resulting files are very large, 1-2 GB on the average. Considering that a small-medium sized pathology laboratory produces about 100 000 slides per year, handling and cumulative storing costs may become too expensive. Also, the integration of scanners with existing information systems (laboratory information systems, patient information systems, storage archives etc.) is still technically challenging and introduces a substantial economic burden on pathology laboratories. Virtual slides are widely used in teaching, but the adoption of DP into clinical diagnostics has been slow. In this study, we explored the current state, attitudes and the most important barriers of the adoption of DP in Finland. This is the first comprehensive evaluation of the subject in Finland.

Material and methods

A web-based questionnaire was sent to the directors and/or persons in charge of digitalization in all 17 public pathology laboratories in Finland. The questions covered e.g. the attitudes regarding the level of evidence of the safety of digital diagnostics, the presumed benefits of DP, the projected year of reaching 100% DP, the preconditions that would lead to the adoption of digital diagnostics, and the most important barriers preventing the adoption of DP.

Table 1. Benefits of digital pathology compared with traditional light microscopy.

Benefits
Enhanced distribution of slides for diagnostics, remote diagnostics
Telepathology, remote consultations for frozen sections and other cases
Enhanced laboratory logistics
Better control of laboratory quality
Better ergonomics
Fast comparison to digital archives
Easy and fast annotations (measures, margins etc.)
Possibility to review slides and serial sections parallel or as picture stacks
Color calibration
Enhanced logistics and reviewing of the cases in clinical meetings
Documentation of immunofluorescent stainings
Possible to create a national slide archive
Effective biobank and other research

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Results

Fourteen (82%) responses were obtained, one from each individual pathology laboratory. Most of the respondents (92.9%) were pathology specialists, and over a half of them (57.1%) were over 50 years old. DP was used in primary diagnostics in one center; and almost all others (78.6%) were interested in shifting diagnostics to the screen. One respondent (7.1%) favored LM as the golden standard, and two (14.3%) were skeptical about the technical maturity of DP. Most of the respondents (75.0%) considered that there is a sufficient amount of validation studies showing non-inferiority of DP compared to LM, while three (21.4%) did not find that the safety of DP in primary diagnostics has been proved. The benefits of DP were seen in many applications, including tumor boards (64.3%), logistics (64.3%), diagnostic quality (50.0%), and consultations (64.3%). All except one (92.9%) expected the level of digitalization to reach 100% in the following twelve years in Finland, and 85.8% would like to adopt DP as soon as economically possible.

The most important preconditions for the diagnostic shift from LM to DP were the reliability of the system (64.3%), the option to use LM in difficult cases (57.1%), and cost neutrality (50.0%). The price of digitalization in general, specifically the cost of storage, was considered to be the most important factor preventing a large-scale adoption of DP (78.6%). However, when estimating the economic effect of 100% digitalization in diagnostics, seven respondents (50%) expected cost-neutrality, while three (21.4%) expect lower, and only four (28.6%) a higher total cost than with today's workflow.

Discussion

The results show that the overall attitude towards DP in Finland is mostly positive, and the respondents can see many benefits with DP. Most of them found that DP is non-inferior to LM, which is in line with the reported accuracy of DP-based diagnostics [2–4,8].

Despite the advantages of DP, it is at this point hard to arrive at a financially neutral business case regarding DP at the level of a pathology laboratory – partly due to the lack of reports with actual use cases with economic calculations. However, when the expected leap in diagnostic quality leading to cost savings in the departments treating the patients (e.g. being able to choose more accurate treatments) are taken in account, remarkable overall savings are projected [9]. Scanning of the slides is an extra step in the laboratory workflow and could thus be an added cost in the implementation of DP. Interestingly, a recent publication from a pathology laboratory that has implemented a full digital workflow showed that there are on the contrary substantial time savings in the laboratory process to be achieved compared with an "analogical" workflow [10]. Two obvious examples of the gains in the digital workflow are the shift from manual case dispatching to digital sorting, and retrieval of the cases for tumor boards.

Some studies have shown a reduced efficacy for DP [2,11], while some studies have found the speed of digital diagnostics even with today's tools comparable to LM [12]. For improved efficacy, a seamless integration with existing laboratory and patient information systems and better slide viewing software with optimal digital tools and computer hardware are needed.

If the traditional and digital workflows are maintained parallelly, the time savings with better efficacy most likely cannot be achieved and thus the full implementation of digital workflow should be pursued. This would also allow the efficient use of artificial intelligence (AI) including image analysis tools. AI could help in the education of specializing pathologists and laboratory quality assurance, and the AI-based image analysis would improve the speed and accuracy of diagnostics (for review, see [13]). The intended goal of the algorithms is to help pathologists with tasks known to have great observer variability and/or being tedious and time consuming: e.g. quantification of immunohistochemical stainings, nuclear morphometry, mitotic figures counting, and detection of metastases [14]. Mass scanning of slides for primary diagnosis would allow the AI algorithms needing more computational power and time to be run in the background on a server computer, i.e. the

analysis results would be readily available to aid diagnostics already when the pathologist starts the assessment of digital slides and save time.

The introduction of personalized medicine means that there is an increasing number of analyses that must be performed on individual surgical specimens studied in pathology laboratories. Together with advanced cancer surgery this has led to an increased workload and a need for further subspecialization of pathologists. As a result, there is an emerging shortage of pathologists in Finland, and the assumed efficacy of DP, including the possibility for remote diagnostics ("telepathology") and fast digital consultation networks, would be an important factor in managing the challenge.

When the obvious benefits of education and research are added to the calculations, it is obvious that a positive push for the adoption of DP is needed. In Sweden, as a result of a substantial shortage of pathologists, there have been several government-supported projects aiming to implement DP in diagnostics, leading to adoption of DP already several years ago in some institutions [15]. In Finland, an important ignition was the support from the Academy of Finland enabling the acquisition of five slide scanners to five local biobanks, who decided to locate the scanners to different Finnish pathology laboratories (where the physical slides are produced), but a large-scale adoption of routine digital diagnostics is currently ongoing only in Oulu University Hospital. The main reason holding back a wider adoption is most probably related to economic concerns as the technology has matured enough to efficiently digitize large amounts of histological glass slides with sufficient quality.

In our study, the economic concerns and most importantly the cumulative long-time archival of digital slides were considered the most important factors preventing a large-scale adoption of DP. The digital slides are very large, averaging 1-2 GB even after a lossy compression (e.g. jpeg quality 80). To take the full advantage of digitized histological material, and from a juridical point of view, the digital slides need to be saved long term, for at least twenty years (The Finnish National Archive, personal communication). Further,

most of the histological material of pathology laboratories in Finland will be a part of biobank collections, and the digitalized material should be reachable from a central user interface to make an efficient retrieval of research collections possible. Optimally, the digitized slides should be stored permanently.

The virtual slides should be saved in a standardized format, but there has not been a standard for virtual slide files due to the proprietary file formats used by scanner vendors. However, Digital Imaging and Communications in Medicine (DICOM®), a standard used widely in radiology and other medical images, has been extended to support DP [16] and is starting to get adoption in pathology [17]. Implementation of DICOM would allow efficient access to image data as well as the associated metadata [18] and enable vendor neutral archive systems for virtual slide storage [14]. Furthermore, the use of Picture Archiving and Communication System (PACS) along with radiology, would form an institution-wide or even nation-wide common imaging infrastructure. In general, the use of open standards for both digital slide storage and scanner management could help in the integration of different information systems and in the acceptance of DP [14]. In a wider picture, the standardization of digital slide image formats is only one of the several necessary steps pathology needs to take. A nation-wide harmonization of structural pathology data and the ongoing SNOMED-CT project related to standardization of the pathology nomenclature are essential for data mining. The structural data and digital slides can be used together e.g. for finding similar cases and, especially when linked with other health data, for the development of AI-aided intelligent decision support systems.

To achieve a wider adoption of DP in Finland, a substantial governmental financing is needed: the virtual slide images could be stored to a central national image archive (e.g. Kvarkki) after diagnostics. The files from the operative slide archives at the individual pathology departments would automatically be transferred to the central archive after a certain time (suggestedly 2 or 3 years), where they could be accessed for biobank research (Figure 1). When the slides would be needed for clinical use (e.g. when new samples are taken on a pa-

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tient, or when a patient is referred to a clinical meeting), they could be automatically retrieved to the operational archive and used without time delay for assessment. Furthermore, the central archive could act as a national consultation hub. With the aid of a national long-term image archive, the investments for the individual pathology laboratories would be significantly

reduced, which could lead to a rapid large-scale adoption of DP in the Finnish pathology laboratories. As a result, a more intelligent workload management locally and nationally could be achieved, leading to improved diagnostic efficacy and quality. An unforeseen boost in biobank research would be expected as a by-product.
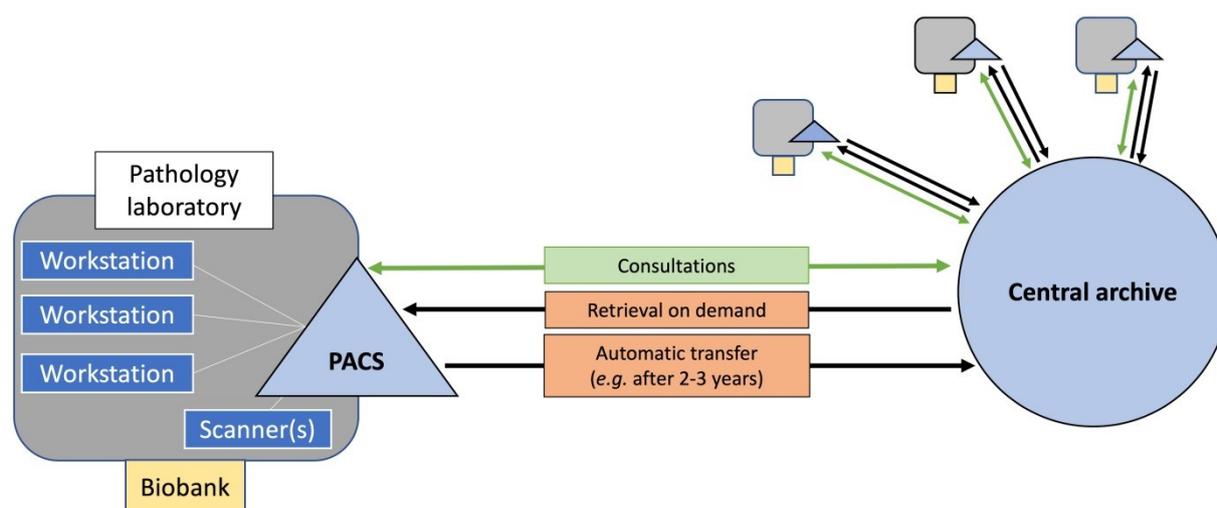

Figure 1. A schematic presentation of the suggested use of a national central archive for storing digital pathology slides. The pathology laboratories store the scanned digital slides in their operational archives (Picture Archiving and Communication System, PACS). The digital slides are transferred to a central archive after a certain time, where they can be accessed for research and retrieved to the operational archive e.g. when new samples are taken on a patient, or when a patient is referred to a clinical meeting. The central archive may also act as a consultation hub.

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