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Digital Pathology in Clinical Use: Where are we now and what is holding us back?

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Abstract

Whole slide imaging is being increasingly used in research applications and in frozen section, consultation and external quality assurance practice. Digital pathology when integrated with other digital tools such as barcoding, specimen tracking and digital dictation can be integrated into the histopathology workflow, from specimen accession to report sign-out. These elements can bring about improvements in the safety, quality and efficiency of a histopathology department. The present paper reviews the evidence for these benefits. We then discuss the challenges of implementing a fully digital pathology workflow including the regulatory environment, validation of whole slide imaging and the evidence for the design of a digital pathology workstation.

Introduction

Digital pathology and whole slide imaging (WSI) - the complete digitisation of slides - has the potential to transform the practice of diagnostic pathology. Radiology has been revolutionised by the introduction of digital imaging over the past 30 years with a resulting improvement in quality and safety of reporting, and innovation in the analysis and manipulation of radiological images. However, despite the promise of digital pathology to offer similar benefits, its uptake in clinical practice has been slow.

Pathologists have been making diagnoses using digital images of glass microscope slides for many decades. Telepathology is a term coined in the 1980s to describe remote pathology diagnosis using digital image transmission, after the first clinical uses of telepathology in the late 1960s (1). Such telepathology systems are confined to live transmission of a digital image of part of a pathology slide, and only a small proportion of overall laboratory workload is examined digitally with these systems, usually where remote diagnosis is essential (such as intra operative frozen sections or second opinion practice).

For the purposes of this article we draw a distinction between whole slide imaging (WSI) and digital pathology (DP). The former refers only to the high-resolution digitization and storage of entire glass pathology slides as digital slides (figure 1). These images can be stored, viewed locally or transmitted over a network for remote viewing. Whole slide imaging systems are available from many vendors (2) and reviews of the technology have been published elsewhere (2,3). Digital pathology encompasses all the associated technologies that leverage digital slides to allow improvements and innovations in workflow. These include image and laboratory management systems, digital dictation, dashboards and workflow management, digital image analysis, electronic specimen labelling and tracking, and synoptic reporting tools. In this review article we evaluate the safety, quality and efficiency benefits that can be realized with a fully digital workflow and discuss the validation of digital

slides for primary diagnosis. We then explore some of the perceived barriers to full clinical use of digital pathology including financial cost, regulatory factors and the acceptance of new ways of working amongst pathologists.

Figure 1. A typical arrangement of slide scanners and servers required for full digitization of a laboratory workflow.

The digital pathology workflow

Digital technologies have been used in most pathology laboratories for a number of decades. The laboratory information management system is used at every stage of a specimen's progress through the laboratory from accession to publication of a finished report. A variety of additional digital technologies can enhance this process thereby improving safety, quality and efficiency at the pre-analytical, analytical and post analytical phases (figure 2).
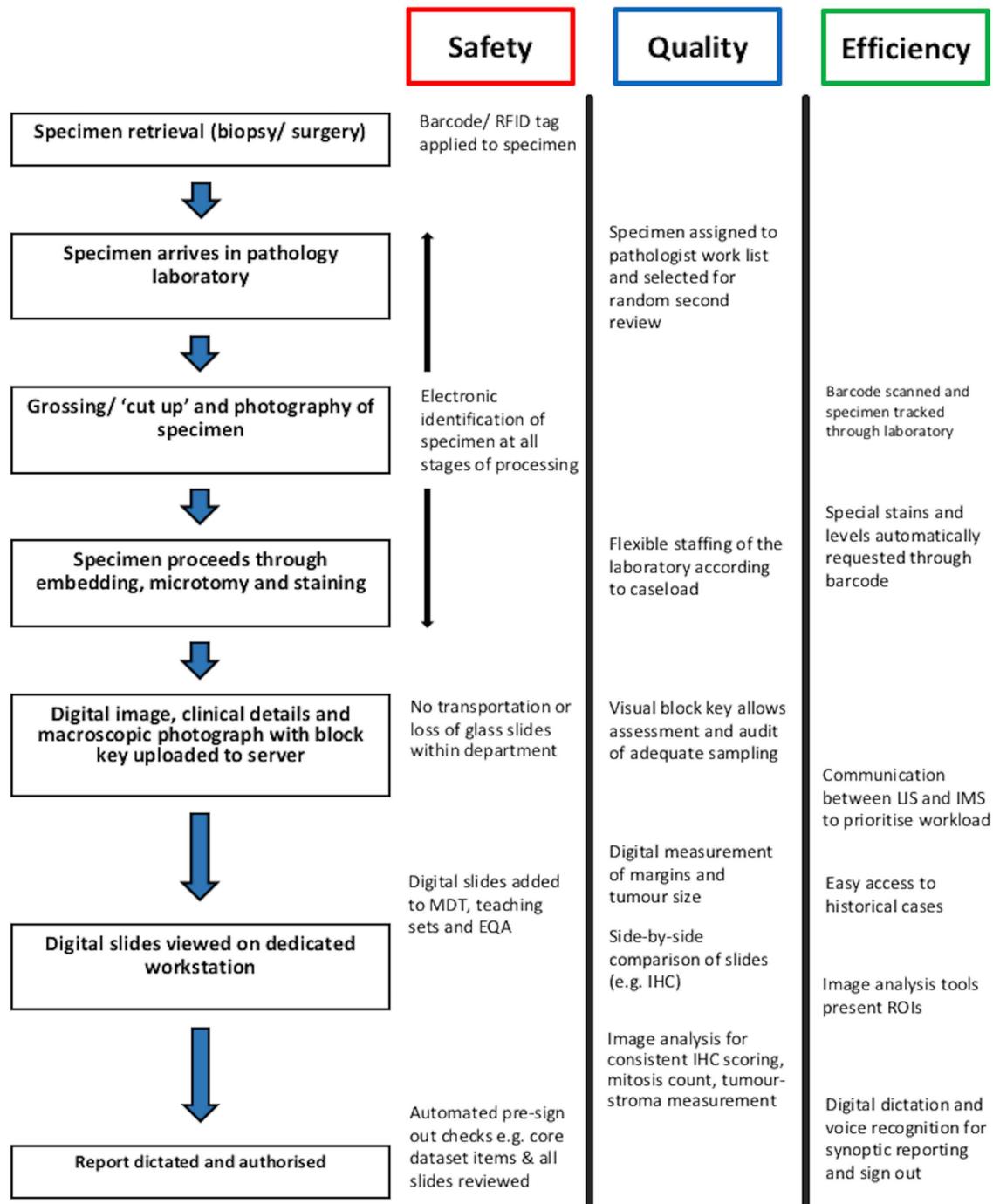
Figure 2. Benefits of a digital pathology workflow

Quality, safety and efficiency benefits are present throughout the journey of a specimen from the clinical request through to report sign-out (EQA: external quality assurance scheme, MDT: multidisciplinary team meeting, IHC: immunohistochemistry, LIS: laboratory information system, IMS: image management system, ROI: regions of interest)

Patient identification errors occur in up to five per cent of all cases processed in the pathology laboratory (4,5). Many of these errors occur at accession or during copying of patient details between request forms, cassettes and slides. A laboratory system employing end to end digital identification (for example with barcodes or radio frequency identification tags) would remove these manual steps to a single identification, ideally at specimen retrieval (i.e. at the time of biopsy or surgery). In one large study where bar coding was implemented for the throughput of an entire laboratory, misidentification errors were reduced by 62% and there was an increase in the efficiency of the pathology laboratory (6). Barcoding allows full laboratory tracking and provides real time information about specimens, assets and processes in the laboratory (7). Barcodes can also store information about specimen type and this data can be used to route the resulting digital slide to a certain pathologist or add instructions for special stains or additional levels automatically.

In a totally digital pathology department the journey of a glass slide would finish in the laboratory after scanning. Digital slides are then available to view at any workstations. This saves time spent by pathologists organising, searching for and moving slides, processes that place demands on a pathologist's time and attention (8). One time and motion study of a digital workflow claimed opportunities to improve pathologist workflow releasing up to 13% of every pathologist's time (9). This study also identified potential savings in laboratory technician time by removing the need to assemble and distribute trays of glass slides though it remains unproven if all of this time could be recouped as improved productivity in a real world setting.

A digital workflow also creates opportunities for better management of a pathologist's workload. Digital dashboards can provide information such as the number of cases to be reported, the progress of immunohistochemistry and special stains, and the assignment of specific cases to trainees. In addition the pathologist could assign cases to work lists such as teaching sets or multi disciplinary team meetings. These are areas where efficiency

improvements are cited in digital radiology (10) but similar improvements have not yet been quantified in pathology. One published example of a digital pathology dashboard was in a haematopathology setting (11). The authors reported a subjective improvement in workflow and efficiency after the implementation of a dashboard to track, triage and direct specimens within the pathology department. No studies have objectively assessed the effect of such systems on turn around time and efficiency.

The digital pathology workstation offers benefits in quality and efficiency. Digital slides can easily be annotated and regions of interest identified and linked to the written report. The report itself can be constructed using voice recognition software, a technology that has improved both turn around time and report accuracy in radiology (10,12). Similar results were seen in one analysis of this technology when implemented at a large academic pathology centre (13). This study showed a threefold increase in the number of reports signed out within 24 hours of report dictation and a reduction in transcription errors. Finally most slide viewing software allows the calibrated measurement of important features such as distance to a surgical margin and tumour dimensions. In one comparison of digital versus glass slide review of prostate cancer core biopsies, a greater inter-observer agreement in length of affected core was found when pathologists used digital measurement (14).

For the digital workflow to be beneficial to the pathology department, tight integration must exist between the slide scanner, IMS, LIS and the additional modules described above. Most WSI systems comprise a slide scanner, IMS and viewer but usually not a LIS (15). In the transition to a fully digital department the evaluation and costing of a suitable LIS is necessary to create the aforementioned integration. Additionally, the whole pathology laboratory system must communicate effectively with other hospital systems such as electronic specimen labelling and the electronic patient record. Proprietary image formats, LIS and IMS database design, and software for digital dictation and report creation may not be interchangeable between vendors and this could have an impact on the smooth

functioning of laboratory informatics as a whole. This in turn could affect the efficiency and quality benefits of a fully digital workflow.

Second opinion practice, collaboration and new ways of working

Digital pathology already provides significant benefits in remote and frozen section diagnosis, and in second opinion practice (16–18). The use of digital pathology is particularly prevalent in regions such a Scandinavia and Canada where patient populations are dispersed over large geographical areas and specialist reporting expertise may be concentrated in large centres. The Eastern Quebec Telepathology Network provides the largest documented exposition of how digital pathology can improve healthcare provision in areas of dispersed populations (19,20). By providing remote macroscopic supervision, remote intra operative consultation, and access to expert opinions both in the primary diagnostic and review setting, this network reduced unnecessary two stage surgery, provided support for lone pathologists working in provincial hospitals and facilitated the recruitment and retention of both surgeons and pathologists. Transplantation histopathology has also benefitted from international collaboration made possible by digital pathology. A 2012 study reported over 3000 transplant biopsies performed in Italy and reviewed as digital slides in the USA (21). This approach allows international expertise to be accessed in an 'on call' system where urgent results are required to decide if an organ is suitable for transplantation. Establishment of supra regional reporting networks of this nature has the potential to increase the available organ donor pool by improving access to specialist review (22,23).

Mandatory second pathologist review prior to the issuing of a report is recommended by the Royal College of Pathologists in a number of situations including high grade dysplasia in Barrett's Oesophagus and pT1 cancers detected in the UK bowel cancer screening program (24). Individual departments also have local policies for double reporting of other specimens (25). The time required for dual reporting can add significantly to specimen turnaround time.

A digital pathology platform allows instant sharing of WSI in review cases as multiple pathologists can review the same case in parallel. With a fully digital workflow this process can be automated thus creating real-time quality assurance through randomly selected mandatory review of a proportion of all cases. Kamat et al described a system of automatic pre sign out second pathologist review that resulted in a decrease in the number of major errors in reports and empowered pathologists to proactively ask for second opinions (26).
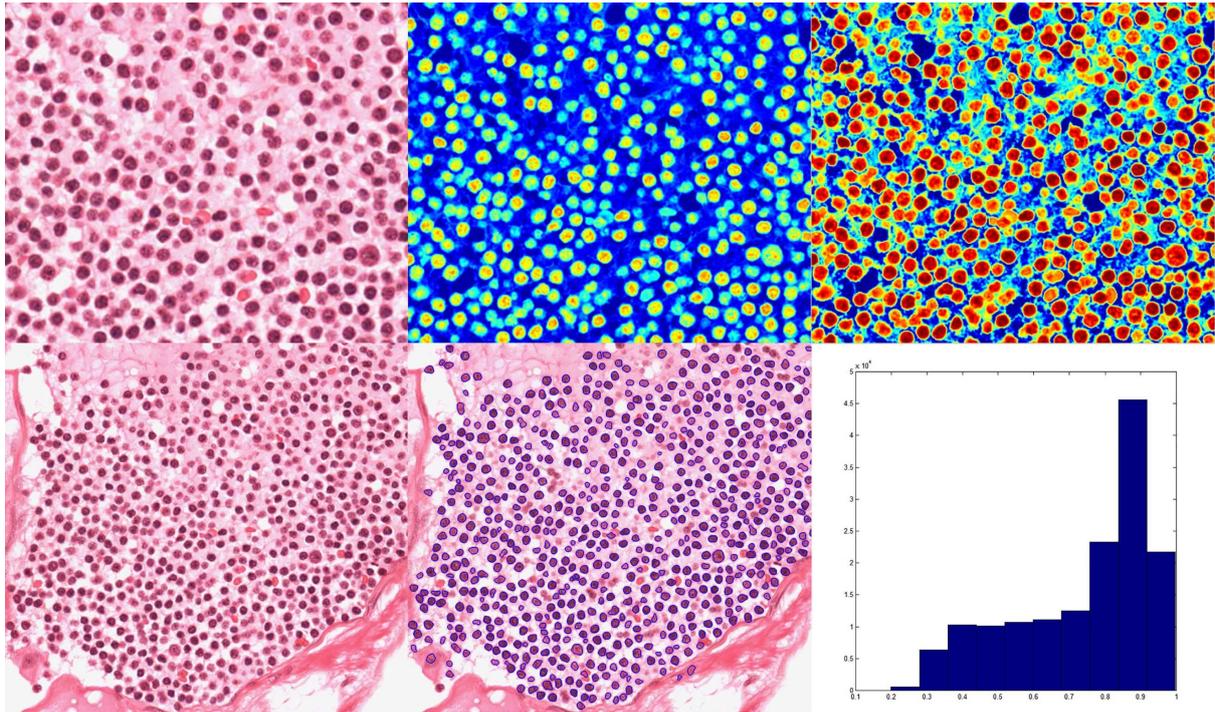
Image analysis (figure 3)

Image analysis has long been promised as a way to remove the subjectivity and variability in pathology diagnosis. A fully digital workflow would mean that image analysis could be performed on any pathology image without the need for specific image preparation. Image analysis software is already widely available, and has FDA regulatory approval in the USA, for the quantification of nuclear markers such as oestrogen receptor or cell membrane markers such as HER2/neu (27). An increasing number of laboratories are incorporating such software into their workflow (28). An analysis of one such system demonstrated that semi-automated HER2 quantification could reduce inter-observer variability but raised concerns over the false positive rate and the potential for over-treatment (29). In this setting image analysis may be best placed in helping resolve equivocal HER2 measurement (30) or in prompting pathologists to submit these specimens for a second opinion or in-situ hybridisation.

Automated image analysis has often been targeted at tasks associated with high inter- and intra- observer variability. Smits et al showed that the estimation of tumour cell percentage in lung cancer was subject to marked inter-observer variability (31). Recent advances in targeted therapies for lung cancer requires accurate measurement of EGFR and ALK mutations in tumour tissue, and the interpretations of these tests can be altered by the estimated tumour cell percentage on a glass slide. Hamilton et al designed and validated an image analysis system that automatically measures tumour area and calculates percentage

of tumour cells and tumour nuclei (32). This system exhibited better concordance than estimation by eye when compared with manually counted tumour cells. Accurate DNA extraction based on this method would enhance molecular testing by reducing false negative rates and therefore give patients access to molecular therapies that may have otherwise been denied. In the study hand counting of tumour cells took an estimated 100 hours per slide compared to 3 minutes using automated image analysis (32) , demonstrating the efficiencies that targeted image analysis techniques can bring to clinical practice. With more molecular therapies becoming available across multiple classes of cancer, accurate analysis of tumour mutation content is essential to ensure patients are correctly stratified to receive these treatments.

Simpler diagnostic tasks such as quantifying fat in the liver, which is prone to significant subjectivity, can easily be performed reliably and accurately by image analysis tools, and it has been asserted that the time for manual evaluation of hepatic steatosis has passed (33). However, the widespread adoption of image analysis in diagnostic pathology faces significant barriers including the need for more robust standards for validation of image analysis, and the development of systems that facilitate pathologist workflow when incorporating image analysis into a clinical case.

Figure 3. Image analysis techniques

A nuclear detection algorithm in use. Segmentation of nuclei and cytoplasm or tumour and stroma allow quantitative analysis of digital slides. Methods to analyse nuclear morphometry, orientation and co-localisation with other features can complement traditional histopathological features in providing diagnostic and prognostic information.

It is unlikely that automated image analysis will completely replace the full diagnostic capabilities of a pathologist in the short term, but this technology could be a useful adjunct in the reporting process. Computer assisted safety checks could ensure that every slide in a case had been reviewed or that all core data items had been completed in a synoptic report. Image analysis techniques could be applied to present regions of interest to a pathologist thereby directing their expertise to specific features of a case (34,35).This could be particularly useful in long cases requiring prolonged periods of concentration or in cases where measurement of multiple foci of tumour is important such as in breast or prostate cancer. It is uncertain whether pathologists would favour such systems, and their use is not common in digital radiology, partially due to difficulties with using the system and professional confidence in their outputs.

Validation studies and examples of routine clinical use

The last decade has seen an abundance of validation studies in digital pathology mostly examining concordance between a diagnosis made on glass and digital images. A recent systematic review showed broad concordance in these studies but noted that study quality and sample size was variable (36). The digital pathology community has recognised the need for robust validation of whole slide imaging in the primary diagnostic setting and professional organisations in many countries have published guidelines for the conduct of validation studies (37). The College of American Pathologists (CAP) (38) and the Digital Pathology Association (DPA) (39) have published guidelines detailing the design and execution of validation studies. Both guidelines agree that studies should evaluate the entire WSI system in the intended practice setting and specify proper training and record keeping of the process. There is, however uncertainty about the optimum time between a pathologist viewing the same case in a glass or digital format, the so-called washout period. A recent study showed that a pathologist can recall 30% of previously seen cases at least 4 weeks after first viewing a case (40) - a timeframe longer than that in either the DPA or CAP guideline. The two guidelines state different minimum case numbers required for a validation study with the DPA requiring at least 100 cases in comparison to the CAP recommendation of 60 cases. These differences highlight the lack of evidence in the design of validation studies. However, the production of these and other guidelines provide a framework that will lead to better standardisation and comparability of validation studies in the future.

The largest validation study to date involved the glass and digital slide review of over 3000 cases (41). The study was adequately powered and followed the DPA and CAP guidelines on study design. Complete concordance between glass and digital slide diagnosis was seen in 97.7% of cases with less than 1% of non-concordance being clinically significant. A ground truth diagnosis for these cases was established by consensus and interestingly lay with the digital slide diagnosis in nine of twenty-one cases. Many validation studies comment

on the limitations of digital pathology including difficulties viewing small objects, lack of 3 dimensional ("z stack") information, and possible image quality issues in some clinical areas.

Despite many examples of successful digital pathology implementation for frozen section and remote consultation diagnosis there is a paucity of studies that evaluate digital pathology in routine clinical use. Thorstenson et al described a fully digital workflow across two Swedish pathology departments resulting in the digitisation of 500,000 slides (42). Pathologists preferentially used digital slides 38% of the time and users reported satisfaction with the quality of scanned images. Al-Janabi et al documented a success rate of 82% for primary reporting with digital slides (43). The reasons for failed digital diagnoses included poor scan quality, network problems, and slides that required further stains or levels leading to unacceptable diagnostic delay. Concordance with glass slide diagnosis was not cited as a reason for failure. These studies show that while primary diagnosis with digital slides is possible and safe, robust workflow design and reliable scanner procedures are required. Moreover a fully digital department requires a network infrastructure with minimal down time that can allow multiple users to view many different slides simultaneously.

Is the fully digital pathology department cost effective?

Pathology diagnosis with a microscope is rapid, simple and highly cost effective. Compared to radiology, where there are significant capital costs for scanning and viewing equipment, as well as ongoing maintenance and software costs, diagnosis in pathology is inexpensive. Pathology budgets are usually an order of magnitude smaller than radiology budgets for this reason.

Implementing a fully digital pathology workflow would require significant capital outlay on scanners, computer servers, workstations for pathologists, and medical displays. In order to fully digitise the clinical work of the Histopathology (anatomic pathology) Department, an initial outlay of approximately £1.4 million would be required, with ongoing costs of £250,000

per year. Given a departmental budget of approximately £9 million per year, implementing digital pathology would represent a significant initial outlay and ongoing cost. These costs must be set against a background of global economic difficulties and contracting public budgets, requiring pathology departments to justify increased expenditure.

The cost must be justified in terms of its benefits on quality or income. In 2010 Henricks et al. described the factors affecting decisions to implement digital pathology in a laboratory and emphasised the need to show value in digitising slides - whether it is increased efficiency, reduced costs or improved quality (44). A simple cost-benefit analysis (figure 4) performed using data from the senior author's institution shows the time taken for a return on this significant investment. This institution is a large, teaching hospital department comprising 45 full time equivalent consultant pathologists and 120 laboratory and administration staff processing 80000 specimens per year. Smaller departments may require longer timeframes to see the same efficiency and financial benefits.

Using this model, improvements in productivity of 10% or 15% would break even at year 2 or year 1 respectively, leading to a net benefit of introduction of digital pathology. A department half the size of that described above would realise a profit after four years with a productivity improvement of 10%. This cost-benefit analysis makes the assumption that all improvements in efficiency can be recouped as a financial benefit to the department. The validity of this assumption depends on the financial environment of the deployment, being easier to realise in health systems which pay for services on an item-by-item basis or in countries with the financial resources to pay for digital pathology.

Alternatively, digital pathology could be seen as a cost in the context of the wider healthcare environment. A cost-benefit analyses by Ho et al (45) demonstrated a projected $18 million saving over a five-year period in an academic department processing 219,000 cases per year. The majority of these savings were estimated to arise from improvements in laboratory and pathologist efficiency, as a fully digital workflow would consolidate pathology

departments spread over 20 institutions and reduce the number of internal and external

consultations required. The second element of cost savings was attributed to fewer

episodes of under- or over-treatment by the subspecialisation of general pathologists

facilitated by a digital pathology workflow. Both of these studies looked at a hypothetical

implementation of digital pathology and there has yet to be a comprehensive analysis of the

cost effectiveness of a fully digital workflow in routine clinical practice.
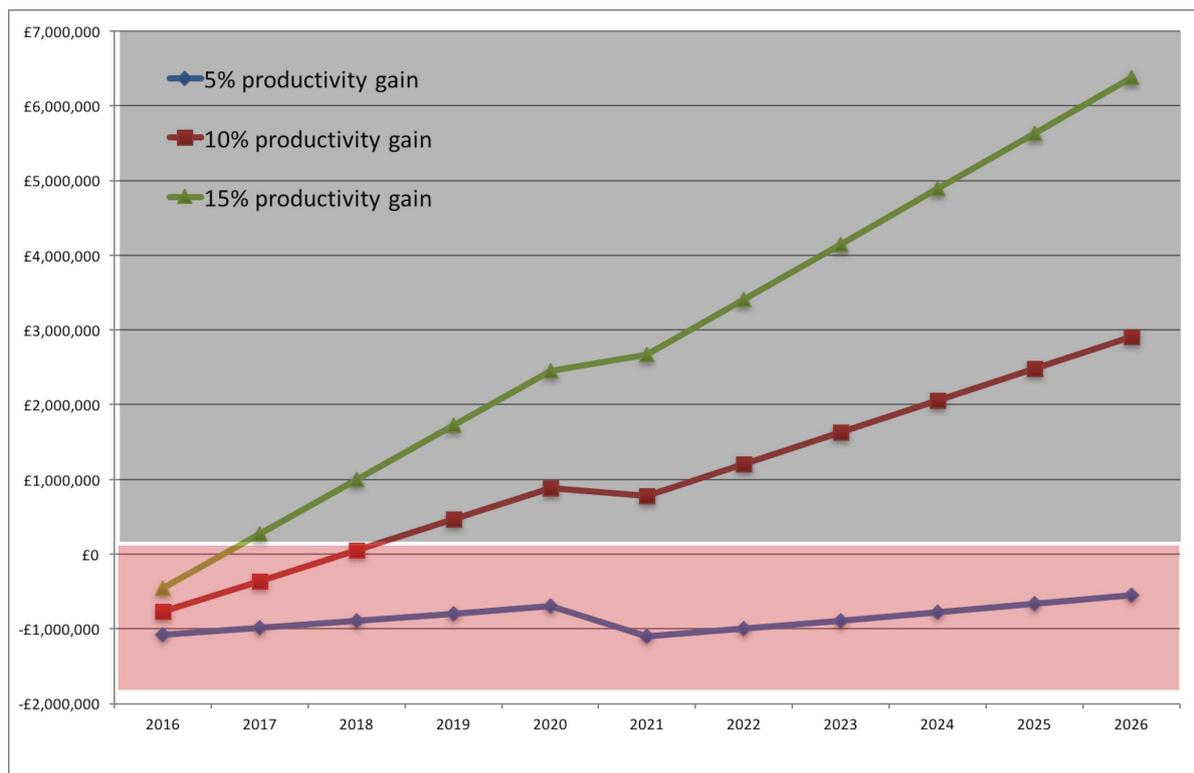
Figure 4. Cost-benefit analysis of digital pathology.

This line graph shows the cumulative cost or benefit over time of a full-scale digital pathology adoption, under varying conditions of productivity improvement. All lines start below zero due to the large initial setup costs of digital pathology. As benefits accumulate over time, the balance of cost and benefit increases toward the positive. The dips in the lines at 2021 indicate the costs of an installation of a scanner upgrade, assuming this happens every 5 years. With a 5% productivity improvement, the costs are never recouped. With a 10% productivity improvement, the costs are recouped by year 2 (2018). With a 15% productivity improvement, the costs are recouped by year 1 (2017). The model assumes all improvements in pathologist efficiency can be recouped as a financial gain.

The regulatory environment

Several federal or governmental bodies worldwide regulate the production and sale of medical devices. The US Food and Drug Administration, arguably the most influential regulator in the world, has previously considered digital slide scanners a class III medical device. These are considered to be a new technology, meaning that a rigorous clinical trial of validity must be submitted to obtain approval (so-called "pre-market approval" (PMA)), implying that full scale clinical trials to prove their safety are required (46). The FDA has proposed requirements for any trial of a whole slide imaging device (47). For example, rather than a standard comparison of glass and digital slides, the FDA has suggested that every slide in a trial also be reviewed by a third party, to validate the glass slide diagnosis itself (so correcting for inter- observer differences). This significantly increases the complexity and cost of a clinical trial. An initial lack of guidance from the FDA as to how digital slide scanners should be evaluated has recently been ameliorated by the publication of draft guidelines for technical assessment of this technology (48).

Lack of regulatory approval is a very significant barrier in the USA (46), because without FDA approval digital slide scanners cannot be marketed or described as a medical diagnostic device. Whilst the FDA considers slide scanners to be a class III device, they have never been formally classified as such. Recent negotiations between the Digital Pathology Association and the FDA have resulted in advice that de novo applications are made for slide scanners to be used for primary diagnosis, and therefore classified as class II devices if the applications are successful (49). This pathway to approval is less complicated and more cost effective than the PMA route, and should a manufacturer be successful in obtaining a class II classification a precedent may be set for the use of digital slides in routine primary diagnostic practice.   Although the FDA (and MHRA in the UK) do not directly instruct doctors which technologies to use, without explicit regulatory approval doctors are likely to be reluctant to adopt digital pathology. In contrast, the granting of Health Canada class II licenses (50), and of a European CE mark (51) to certain digital pathology vendors

has led to both of these regions starting to use digital slides for primary diagnosis. Although this in itself will not convince pathologists of the diagnostic validity of digital slides it is a step towards establishing validity on a worldwide scale.

Acceptance by pathologists

A pathologist viewing digital slides may defer to a glass slide for a number of reasons including unfamiliarity with the viewing software, network latency, a perceived inefficiency of digital diagnosis and a higher level of confidence with light microscope (LM) diagnosis. Deferral has been identified as a significant issue in some studies (52,53) and many pathologists feel that digital slides are too slow for routine diagnostic work. The design of a digital workstation is therefore of paramount importance in matching or surpassing the efficiency of LM diagnosis.

Our group's previous experimental comparison of the microscope and a conventional digital slide system found that digital slides were 67% less efficient than the microscope (54). Although these results were based on a small study (n = 4 pathologists) using a simple digital pathology workstation with a very small display (17 inches, 1024x768 pixels), they indicate that caution should be exercised in assuming that a digital slide viewer will be as fast as a microscope. It was concluded that most of the observed inefficiency was due to a combination of several factors including: (i) the smaller field of view afforded by the digital slide system (ii) issues with the design of the software used for viewing the slides, and (iii) a lack of experience and training using digital slides with the participants. The first two of these issues were addressed in our subsequent work which found that using higher resolution displays and moving the image pixels more quickly could improve pathologist efficiency with digital slides to the point that time to diagnosis could be equivalent with the appropriate

systems (55–57). Subsequent commercial digital pathology systems have placed greater emphasis on performance and usability.

Practicing pathologists will be familiar with the variation in staining quality and intensity between laboratories and within their own institution. The digitisation of slides adds further potential variation in colour contrast and intensity, as each slide scanner will apply different image processing algorithms to the scanned slide. To address this, research groups have calibrated slide scanners using a phantom slide to represent a standardised spectrum of colour (58–60). One study (59) demonstrated an improvement in quantitative colour variation between multiple scanners from a single manufacturer when these scanners were calibrated with a phantom. However the calibration profile that gave the least quantitative variation in colour resulted in unrealistic production of colour when applied to tissue slides. More recently our group has evaluated a phantom calibration slide composed of a colour spectrum representative of H&E stained slides. Pathologists reported a higher diagnostic confidence when using calibrated slides (60). The growing interest in medical colour reproduction and standardisation has resulted in the establishment of a Medical Imaging Working Group by the International Consortium on Colour. A consensus statement in 2014 identified the development of colour calibration slides and work on colour calibration of medical image monitors as key priorities (61).

The computer display on which slides are viewed is another important element of a digital pathology system. Two issues that arise when considering the performance of displays: colour calibration and screen resolution. Krupinski et al (62) showed no change in diagnostic accuracy when pathologists viewed snapshots breast cores on calibrated versus un-calibrated displays but did note a faster time to diagnosis. Multiple groups have studied the effect of screen resolution with conflicting results. Intuitively one might expect that a large screen with greater resolution made digital diagnosis easier however Cucoranu et al (63) showed that a smaller, lower resolution monitor was associated with a greater confidence in identifying morphological features. Our work (64) showed no difference in time to diagnosis

with increased monitor resolution. A higher resolution did result in a faster time to target, in this case identification of micrometastases in an axillary lymph node. Time to diagnosis was significantly faster using a light microscope than with either of the evaluated monitor configurations. These two studies compared different endpoints and studied three and nine pathologists respectively. It is unlikely that there is one screen resolution, configuration and calibration approach that will be best for all users and all specimens however further work is needed to identify the range of these parameters that offer the optimum experience of a digital pathology system.

Only a few studies have directly addressed the issue of the acceptability of the technology to pathologists as a whole. In an early study, Dennis et al. surveyed 237 UK pathologists about their attitudes to telepathology (not digital slides). While there was broad approval for the use of telepathology for collaboration and case review at multidisciplinary team meetings, only a small minority reported that they would use telepathology for routine diagnosis of remote or local cases (11% and 9% respectively) (65). Furness et al. offered the option to view digital slides to 96 members of the UK renal quality assurance scheme. Only 26 of the members opted to view the digital slides. Those that did reported difficulties with using the slides, and with image quality (66). Other quality assurance schemes have subsequently mandated the use of digital slides with apparent success, for example the UK Bowel Cancer Screening Program (67).

The transition from a glass slide to a fully digital department presents a considerable logistic and organisational challenge. Clearly this change can not happen instantaneously and a period of crossover would occur where a hybrid glass-digital system was in place. Many research groups have published their experience of and valuable lessons learned from this transition (19,42,68,69). Most recently Cheng et al detailed seven principles for implementation of a digital pathology department (68), namely: involvement of all laboratory staff, integration of IMS and LIS, workflow evaluation prior to implementation, proper training of all staff, rigorous validations studies, and robust governance processes. Critically the

authors emphasize that these principles must be applied throughout and beyond the implementation process. The process took eight months, excluding an undefined pre-project to help plan the implementation timeline.

Future directions and challenges

Digital pathology has followed a classic early adoption curve with use primarily in niche applications such as second opinion or frozen section diagnosis, MDT meetings and education. Following large scale validation studies and the development of efficient viewing systems, many more departments are investing in slide scanners and infrastructure to support digital pathology in routine clinical use. Future innovations may include integration of radiology and histopathology images or the application of multi-stain imaging where multiple immunohistochemistry images can be over laid simultaneously. This would lead to a more efficient analysis of complex cases. Image analysis is beginning to generate useful prognostic data from H&E stained slides by analyzing metrics such as lymphocyte density, tumour stroma composition and nuclear morphometry and textural analysis. These approaches have been used in breast (70,71), colorectal (72) and ovarian (73) cancer case series. The routine use of molecular testing for mutation-specific treatments will add another layer of information to be integrated into a pathology report. It is uncertain how this information will be organized, integrated and visualized alongside traditional morphological and immunohistochemical data. The volume of data generated, and the relationships between these data present unique bioinformatics challenges. Being modular and flexible, the digital pathology workflow is well suited to rise to this challenge (74).

Conclusions

The digital slide is the most visible part of a digital pathology system. While this contains all the data needed for diagnosis to take place, a larger more comprehensive system is needed

to ensure every step of the process runs smoothly and safely. Digital technologies can

improve each stage of the diagnostic process, from accessioning of specimens and progress

through the grossing/ cut up room to efficient viewing and software for annotation and report

creation, and the ability to share slides inter- and intra- departmentally. Digital pathology

offers the potential for improvements in quality, efficiency and safety that are compelling

reasons for widespread implementation.

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