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Making Pathologists Ready for the New Artificial Intelligence Era: Changes in Required Competencies

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ABSTRACT

In recent years, there has been an increasing interest in developing and using artificial intelligence (AI) models in pathology. Although pathologists generally have a positive attitude toward AI, they report a lack of knowledge and skills regarding how to use it in practice. Furthermore, it remains unclear what skills pathologists would require to use AI adequately and responsibly. However, adequate training of (future) pathologists is essential for successful AI use in pathology. In this paper, we assess which entrustable professional activities (EPAs) and associated competencies pathologists should acquire in order to use AI in their daily practice. We make use of the available academic literature, including literature in radiology, another image-based discipline, which is currently more advanced in terms of AI development and implementation. Although microscopy evaluation and reporting could be transferrable to AI in the future, most of the current pathologist EPAs and competencies will likely remain relevant when using AI techniques and interpreting and communicating results for individual patient cases. In addition, new competencies related to technology evaluation and implementation will likely be necessary, along with knowing one's own strengths and limitations in human-AI interactions. Because current EPAs do not sufficiently address the need to train pathologists in developing expertise related to technology evaluation and implementation, we propose a new EPA to enable pathology training programs to make pathologists fit for the new AI era "using AI in diagnostic pathology practice" and outline its associated competencies.

Introduction

In the past few years, there has been an increasing interest in developing and using artificial intelligence (AI) models in pathology. Recent developments have increased the likelihood of AI being deployed in the field, as a growing number of pathology laboratories have now digitized their workflow. Advances in digital picture processing and pattern recognition have also paved the way for the introduction of AI tools for automated image analysis.[1-5] The interest in implementing AI in pathology is driven by the benefits it might offer to pathology practices. In the era of precision or personalized medicine, several prognostic and predictive categorizations for multiple diseases have been developed, using histopathology parameters. AI models can, for instance, not only help in disease detection[6] or diagnosis generation[7,8] but also help in grading, prognostication, and therapy response prediction using quantitative measurements.[8-12] The application of these AI tools could make pathology diagnoses more accurate by

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decreasing interobserver variability.[5,13] In addition, AI could help reduce pathologists' workloads, which could be useful in resolving the global shortage of trained pathologists.[14,15] For instance, AI could improve pathologists' effectiveness by prescreening slides for the detection of (micro)metastases or microorganisms, filtering out negative biopsies, and quantifying immunohistochemical staining or mitotic activity.[16-19] The use of AI for routine, simple diagnostic tasks could also free up time for pathologists to focus on challenging cases, education, or research tasks.

International survey studies showed that pathologists generally have a positive attitude toward the use of AI, and the majority of pathologists believe that AI will become integrated into the pathology workflow during the next decade.[20-23] However, in the study by Sarwar et al,[20] the respondents showed mixed responses on how the use of AI would impact clinical skills: 34% thought that AI would not affect clinical skills. Some respondents thought that AI would enhance clinical skills (21%), whereas others thought that the use of AI would erode pathologists' skills (26%). Important concerns referred to potential AI model errors and medicolegal responsibility, and the perceived lack of knowledge and skills required for the use of AI in pathology practice. Similarly, an interview study by Coulter et al[24] on digital pathology showed a perceived lack of confidence and understanding of key issues, such as consent, legislation, and ethical guidelines that would require specific training.

The skills that pathologists need in order to make adequate and responsible use of AI technologies in practice are still unclear and so are the risks associated with their introduction, which are rarely studied, according to our survey.[25] Which competencies need to be maintained by pathologists, which competencies may be newly required, and which tasks may be delegated to AI technology?[25-27] These topics have received scant attention so far in publications of (inter)national pathology societies or associations. For example, competency-based medical education based on entrustable professional activities (EPAs) is becoming more common in many medical residency programs, including pathology, but EPAs do not yet cover competencies specifically related to technological advances such as AI.[28-30]

Competencies and EPAs are related but refer to different aspects of a professional's training. EPAs were first described in 2005 by Ten Cate as "units of professional practice, defined as tasks or responsibilities to be entrusted to the unsupervised execution by a trainee once he or she has attained sufficient specific competence," therefore representing work descriptions.[31-33] In contrast, competencies are person descriptors (eg, knowledge, skills, attitudes, and values).[31-33] EPAs usually require multiple competencies. For example, the EPA "compose a diagnostic report for surgical pathology specimens" includes competencies such as diagnostic knowledge and ancillary test utilization.[28]

It is argued that adequate training of pathologists is essential for successful and responsible AI use in pathology.[14,22,34] With this paper, we aimed to identify and evaluate the EPAs and underlying competencies of pathologists required in the AI era. As there is more experience with digitalization, AI development, and implementation in radiology, including the required competencies, we will use the literature from this other image-driven medical specialty as a backdrop for our analysis. We conclude by presenting a new EPA specifically related to AI that we propose to incorporate into pathology training.

Status Quo: Limited Attention to Artificial Intelligence Education in Pathology Training

Gaining extensive knowledge about disease patterns, macroscopically, microscopically, and molecularly, is the essence of pathology training. These areas are well covered in pathology residency programs. For example, the current "critical professional competencies" (a term comparable to EPAs) listed in the Dutch national pathology residency program are as follows: (1) performing and reporting autopsies, (2) macroscopic examination and reporting, (3) microscopic examination and reporting, (4) cytologic examination and reporting, (5) frozen sections examination and reporting, (6) active participation in multidisciplinary patient meetings, and (7) scientific education in favor of clinical practice (eg, translation of new scientific insights into clinical practice; see also Table 1).[29] Limited attention is currently being paid to AI in pathology training programs, according to our literature survey.[28,29,35-38] For example, in the Dutch national pathology residency program, AI is only briefly mentioned as a new development together with molecular pathology and digital pathology. The program document states that training programs should be adjusted to these new developments but does not mention how and to what extent.[29]

In a proposal for EPAs in pathology training from the College of American Pathologists (CAP) in 2017, based on the Accreditation Council for Graduate Medical Education (ACGME) pathology milestones or core competencies,[30] AI is not specifically mentioned, although competencies related to technological innovation, implementation, and quality control, which are also relevant for AI deployment, are described. These EPAs provide guidance for the resolution of preanalytical testing issues, optimize test utilization, improve quality and patient safety, evaluate and choose a new test or instrument, and implement a new assay or test system (see also Table 1 for a comparison with the Dutch pathology training program).[28] The Dutch Federation of Medical Specialists published a teaching document on technological innovation in 2018, applicable to all medical residency programs.[39] In this document, technology-related competencies are more specifically described, such as technology implementation, critical evaluation, knowing one's own limits, collaboration, and entrepreneurship (see Table 2).[39] However, how and to what extent this set of competencies is also applicable to pathology has not yet been evaluated.

Competencies for Working With Artificial Intelligence: Learning From Radiology, Another Image-Based Medical Specialty

The field of radiology is, to some extent, comparable with pathology, as both are image-based diagnostic medical specialties.[26] In radiology, the development of automated image analysis models is well underway, with several AI tools on the market and in use in daily radiology practice (https://radiology.healthairegister.com). Perhaps unsurprisingly, discussions about AI education in radiology (residency) have already begun.[27,40-42] A white paper from the European Society of Radiology in 2019 states that "the implementation of AI in radiology requires that trainees learn how to best integrate AI in radiologic practice, and therefore, a specific AI and informatics module should be included in the future radiology training curricula."[43] Forney and McBright[40] similarly propose that residents must learn the following: (1) the basic concepts of AI, that is, understand how AI models are created and work, (2) how AI can be applied in radiology, that is, supportive or replacement tools for radiologists, applications for scanning protocols or automated image analysis, and (3) understand how to assess AI tools in radiology, that is, analytical validity, clinical need/utility, cost efficiency, knowledge, and awareness on potential limitations or risks (for the patient).

Table 1
Comparison of entrustable professional activities (EPAs) mentioned in the Dutch and USA (CAP) national pathology residency programs, and ACGME pathology milestones

EPAs/critical professional competencies	Dutch program	USA (CAP) program	ACGME pathology milestones
Autopsies	Performing and reporting autopsies	Perform a medical autopsy	Patient care 1: reporting, Patient care 4: interpretation and diagnosis Patient care 6: autopsies Medical knowledge 1: diagnostic knowledge Medical knowledge 2: clinical reasoning
Macroscopic examination	Macroscopic examination and reporting	Perform gross dissection of simple and complex specimens	Patient care 1: reporting Patient care 2: grossing
Microscopic examination	Microscopic examination and reporting	Compose a diagnostic report for surgical pathology specimens	Microscopy not specifically mentioned. Patient care 1: reporting Patient care 4: interpretation and diagnosis Medical knowledge 1: diagnostic knowledge Medical knowledge 2: clinical reasoning
Cytology	Cytologic examination and reporting	Compose a diagnostic report for cytology specimens Perform adequacy assessment/rapid interpretation for cytology specimens Perform fine needle aspiration	Cytology not specifically mentioned. Patient care 1: reporting Patient care 4: interpretation and diagnosis Medical knowledge 1: diagnostic knowledge Medical knowledge 2: clinical reasoning
Frozen sections	Frozen sections examination and reporting	Perform intraoperative consultations and frozen sections	Patient care 5: intraoperative consultation, including frozen sections
Multidisciplinary meetings	Active participation in multidisciplinary meetings	Provide pathology support for interdisciplinary conferences	Patient care 3: clinical consultation Interpersonal and communication skills 2: interprofessional and team communication
Scientific education	Scientific education in favor of clinical practice		Practice-based learning and improvement 3: evidence-based and informed practice Practice-based learning and improvement 3: scholarship
Quality control		Provide guidance for the resolution of preanalytical testing issues Optimize test utilization Improve quality and patient safety Evaluate and choose a new test or instrument Implement a new assay or test system Perform a laboratory accreditation inspection	Systems-based practice 1: patient safety and quality improvement System-based practice 2: system navigation for patient-centered care Systems-based practice 3: physician role in health care systems System-based practice 5: accreditation, compliance, and quality
Informatics			System-based practice 4: informatics
Professionalism			Practice-based learning and improvement 2: reflective practice and commitment to personal growth Professionalism 1: professional behavior and ethical principles Professionalism 2: accountability/conscientiousness Professionalism 3: self-awareness and help-seeking
Communication			Patient care 3: clinical consultation Interpersonal and communication skills 1: patient and family-centered communication Interpersonal and communication skills 2: interprofessional and team communication Interpersonal and communication skills 3: communication with health care systems

Of note, the discipline(s) of pathology in the USA differs to some extent from the Dutch situation. With respect to the system in the USA: we focus on surgical pathology. The USA (CAP) program is based on the ACGME pathology milestones. Text obtained from References.[28-30]
CAP, College of American Pathologists.

Furthermore, other scholars have stated that radiologists should be familiar with regulatory frameworks and the ethical implications of using AI tools, including responsibility or liability issues.[42] For example, it could be a risk when radiologists are held ultimately responsible for the diagnoses when using AI support tools which they do not (completely) understand.[44-47] Other scholars have warned about the risk of automation bias and undermining confidence, which is the idea that AI is more correct or accurate than humans and that humans tend to believe machine-generated data easily, making human doctors less confident about their own skills.[48,49] It is important to take into account those risks related to AI introduction and ensure the taking of forward-looking or prospective responsibilities. Throughout this paper, we refer to responsibilities mainly in a forward-looking dimension. Forward-looking responsibilities are, for example, a responsibility to call in sick when you cannot go to work. This can be understood as a duty to do something. It is attributed to prevent damage and help organize collective endeavors. If such tasks or duties remain unfulfilled, backward-looking responsibilities can arise, eg, one is blamed or punished.[50] Professional associations, such as the American College of Radiology (Data Science Institute) and the Radiology Society of North America, have set up frameworks or pathways for adequate implementation of AI and provide learning tools for radiologists (in training).[51,52] To summarize, radiology literature on AI education has shown that knowledge of basic AI concepts and

Table 2
Competency set: technological Innovator

Role definition: Effective use of expertise in the field of technological innovation with the aim to improve accessibility, quality and affordability of health care **Competencies:** the medical resident		
1	Recognizes that medical technological developments can contribute to improvement of patient care	Innovation
2	Is aware that several steps are needed to bring about change	Implementing changes
3	Assesses medical technological developments for their added value in improving patient care	Critical appraisal
4	Knows the limits of one's own knowledge and skills related to medical technology	Knowing one's own limits
5	Recognizes the importance of collaboration with other (health care) professionals and companies in the field of technological innovations	Collaboration
6	Identifies opportunities for existing and new technological innovations, acts accordingly and dares to take responsible risks	Entrepreneurship

Translated from Federation of Medical Specialists Competentieset Technologische innovatie (original in Dutch).[39]

applications, AI critical appraisal skills, and awareness of ethical and legal implications are strongly recommended for adequate, beneficial use of AI in diagnostic image analysis and are already taken into account to some extent in radiology training programs.

Changes in Pathologists' Roles and Responsibilities in Artificial Intelligence-Aided Pathology

We found multiple studies about the potential applications or roles of AI models in pathology, but there are no comprehensive publications yet on how AI would change the roles and responsibilities of pathologists themselves.[5,22,53] It is often stated that AI applications in pathology would take over the simple and repetitive tasks of pathologists, freeing up time for challenging cases.[1,4,5,54] If true, how would that affect pathologists' roles and responsibilities? One could make a distinction based on (1) which roles and responsibilities may be attributed to AI, (2) which roles and responsibilities will remain with pathologists, and (3) which new roles and responsibilities may arise or which ones may become more important or accentuated due to AI implementation.[54] In this section, we will evaluate these distinctions. Very limited literature exists on this topic, but we use the EPAs (or critical professional competencies), mentioned in the Dutch national pathology residence program and the training program of the CAP, as our starting points (see Table 1). We will focus on AI models related to automated image analysis for diagnostic, prognostic, and predictive purposes (eg, tumor detection, tumor grading, and biomarker scoring such as programmed death-ligand 1 for immunotherapy as opposed to, for instance, automatic tissue processing technologies in the laboratory). Although AI's impact on pathology is still speculative, these types of applications are expected to significantly alter the manner in which pathologists execute specific tasks, which tasks they execute, and how they make decisions. As a result, pathologists will most likely require different or additional competencies to adapt to these changes.

Roles and Responsibilities That Can be Expected to be Attributed to Artificial Intelligence

Roles and responsibilities that can be attributed to AI will likely be related to *microscopic evaluation and reporting*. Microscopic evaluation entails microscopy interpretation (identification of abnormalities and artifacts) and generation of a (differential) diagnosis, using clinical reasoning and adequate use of ancillary tests.[28,29] Reporting entails generating a timely report including microscopic description, interpretation of ancillary tests, and (differential) diagnosis, for simple as well as complex cases, expressing ambiguity and uncertainty when needed.[28,29] As proposed by Zarella et al,[55] automated image analysis models can be classified into the following 4 functional categories for microscopy evaluation: (1) detection (including identification of abnormal regions such as cancer cells), (2) characterization (including classification of histopathologic patterns or diagnoses), (3) quantification (including mitotic counts, immunohistochemistry scoring), and (4) prediction (including disease outcome, treatment response). AI reporting models can generate a standardized pathology report. AI models often combine different tasks as well, such as detection, characterization, and reporting.[55] This could mean that pathologists would have to spend less training time on microscopic evaluation and reporting. The "supportive" detection and quantification tasks in particular could help optimize pathologists' efficiency. In contrast, characterization and prediction models will have more impact on pathologists' roles and responsibilities in the long term, as they may, to some extent, even take over pathologists' main task as diagnosticians. This would be especially true when it is unclear upon which (new) features the output of the AI model is based. In order to be able to detect potential model errors and evaluate more complex cases, pathologists would still have to gain experience in the broad scope of pathology, including simple or "bulk" diagnostics, which could be (partially) processed by AI in the future.[56] For example, a pathology laboratory could have an automated AI system that detects basal cell carcinomas in skin biopsies and resections and makes a standardized report, but pathologists in training would still have to know the morphologic spectrum of (simple) basal cell carcinomas as they are part of the differential diagnosis of other lesions such as skin adnexal tumors, melanoma, or Merkel cell carcinoma (diagnoses that could be missed or misclassified by the basal cell carcinoma model).

Roles and Responsibilities That Will Still Be Expected of Pathologists

Roles and responsibilities that will likely still be expected of or attributed to pathologists in the coming years will be related to areas where less AI research has been conducted: *macroscopic activities and interpretation*, including grossing and autopsies, and *intraoperative examinations* (frozen sections). Although these are relatively small components within pathology, increasingly being performed by trained lab technicians (grossing), and they may be subjected to more subspecialization in the future (autopsies and intraoperative examinations), it will be important to continue to be trained in these disciplines as is currently the case. Moreover, another competency or EPA that will likely still be important for pathologists is active *participation in multidisciplinary meetings*, explaining the pathology results, nuanced explanations, and demonstrating the microscopy where needed. During these

multidisciplinary meetings, pathologists will also be able to correlate their findings and the AI's output with the clinicoradiologic picture. This may, for example, lead to considering a metastasis from a primary tumor somewhere else in the body or a nonrepresentative pathology specimen when the radiologic images indicate a strong possibility of cancer.

Required Roles and Responsibilities of Pathologists in the Light of Artificial Intelligence Implementation

Depending on which residency program is taken as a starting point (Dutch or CAP program, Table 1), competencies related to *scientific self-education and quality control* may be either new or gain more importance.[28,29] This includes scientific education in the form of critical appraisal of publications on AI technologies and quality control skills, such as assessing, implementing, and monitoring AI technologies in the laboratory.[39,57,58] As previously described for radiology,[40] pathologists will need to acquire basic knowledge of the different steps in AI model development as well as potential risks in the design and reporting of AI studies.[58] They will be expected to spend less time diagnosing routine cases but will need to spend more time on and acquire the abovementioned novel competencies.

In a sense, the role of a pathologist as a pure "diagnostician" is expected to partially change to that of a "data integrator or interpreter."[57] Some diagnostic tasks may be partially taken over by AI, but the pathologist will need to have an understanding of what constitutes appropriate input and output values of the AI application to conduce to the solidity of the diagnostic process. Pathologists will also need to be able to provide the right input to the AI application. This may include selecting the right area on the slide to get the mitotic activity index calculated and being aware of the relationship between image quality and accuracy rate.[27] After the AI model has provided an output, the pathologist should be aware of the generic strengths and weaknesses of the AI model they decided to apply, for instance, task specificity and analytical validity, and evaluate the AI-generated data or outcome in light of the individual patient context. This may entail determining whether the output is reasonable and thinking of differential diagnoses or potential pitfalls.[27] We believe that developing the clinical expertise to interpret AI outcomes in the patient context will, therefore, become an important aspect of educating pathologists.

Of note, a basic understanding of informatics is required before being able to use AI models by integrating them into the pathology daily workflow. Informatics is briefly mentioned in the Dutch and CAP training programs ("can deal adequately with automation and information systems" and "can work with information technology staff to integrate new test instrument or system with current laboratory information systems").[28,29] It is described in more detail as a subcompetence in the ACGME pathology milestones.[30] Here, pathologists are expected to demonstrate familiarity with basic technical concepts of hardware, operating systems, and databases, as well as the ability to utilize medical informatics in the direction of operation of the laboratory).[30] To what extent attention is paid to informatics in current residency programs is unclear, but initiatives such as the Pathology Informatics Essentials for Residents curriculum may be very helpful for obtaining adequate informatics knowledge and skills.[59,60]

A competency that will become important in AI-aided pathology is an awareness of one's own professional strengths and weaknesses.[61] Studies in radiology have shown that increased automation of certain activities can lead to automation bias (ie, overreliance on automated systems) and deskilling (ie, a decline of skills due to lack of regular training).[27,48,49] Therefore, there is a risk that pathologists in training may stagnate in their professional development, and pathologists, in general, will lose their diagnostic skills or critical awareness once automated image analysis models are increasingly being used.[56] In order to be able to become adequate data managers or interpreters, pathologists in training should keep themselves exposed to standard diagnostics, address potential AI model errors, and discuss these cases with human colleagues.

A final competency mentioned in radiology literature but briefly or not explicitly mentioned in pathology residency programs (Table 1) relates to awareness of *ethical and legal issues*.[42,53] These include issues related to expertise, responsibility, trust, transparency, data stewardship, privacy, and regulatory framework.[44-46,53,56,62-64] Moreover, for a critical evaluation of AI models, an understanding of potential biases is also necessary. Bias can be introduced at every step of AI model development and implementation.[56,65,66] Examples include sampling bias, labeling bias, feature selection bias, and confirmation/automation bias.[56,65,66] Although pathologists do not need to be able to evaluate and solve ethical or legal issues by themselves, they should be able to recognize or identify ethical or legal issues and contact ethicists and legal experts when necessary (eg, when the introduction of a new AI system may have an effect on medicolegal responsibilities).

Proposal for a New Entrusted Professional Activity in Artificial Intelligence-Aided Pathology

Based on the analysis above and by using the recommended EPA description by Ten Cate and Taylor,[33] we propose the following EPA "*using AI in diagnostic pathology practice*" be added to pathology residency programs. This EPA incorporates the aforementioned competencies, knowledge, and attitudes:

- Knowledge about procedures of AI model development
  - o Knowledge about the different steps and techniques in AI model development, including concepts such as machine learning, deep learning, (un)supervised learning, segmentation, detection, classification, and technical and clinical validation[40,58]
- Basic understanding of informatics
  - o As described in ACGME pathology milestones[30] and Pathology Informatics Essentials for Residents curriculum,[59,60] including basic understanding and dealing with laboratory automation and information systems, working together with information technology staff
- Awareness of possible AI applications
  - o Including supportive tools such as automated image analysis for diagnostic purposes, workflow support or quality assessment and quality control in the laboratory, and automatic reporting systems[40]
- Critical assessment of AI tools in pathology
  - o Including potential risks in the application design and reporting, model generalizability, unwanted bias, analytical validity, clinical utility, cost-benefit analysis, impact on the workforce, data protection, and privacy protection[14,40]
  - o Including understanding which application to use and when (not) to use it (eg, more general or very specific AI applications)

  - Knowledge about the validation and implementation of an AI application
- Interpretation of the AI output for an individual patient
  - Including critically assessing AI output data, given the input values and clinical context (eg, determining if the AI output makes sense in the clinical context), understanding input data or preanalytical factors that may influence AI accuracy in an individual case (eg, fixation, sectioning, and staining artifacts), and awareness of task specificity (eg, recognizing that an AI tool developed to detect carcinoma metastasis in the lymph nodes cannot detect other diseases that can cause lymph node enlargement such as lymphoma)[14,27]
- Knowing personal strengths and limits in human-AI interactions
  - Including awareness of the risk of automation bias and deskilling[27,48,49]
- Incorporating AI result(s) in pathology reports
  - Including managing potential uncertainty when there is a disagreement between pathologist(s) and AI and describing the decision-making process in understandable language for the clinician (and patient)
- Recognizing potential ethicolegal issues
  - Including issues related to expertise, responsibility, trust, transparency, data stewardship, privacy, regulatory framework, and knowing when to consult ethics and legal experts[53]

Potential risks in case of failure of this EPA may include patient harm due to wrong diagnosis, which may result in incorrect staging, incorrect or suboptimal treatment, and undue financial costs due to the purchase of an AI model that has insufficient quality or insufficient clinical utility. This AI EPA relates to the following CanMeds core competencies: medical expert, communicator, collaborator, scholar, and professional.[67] During residency, this AI EPA could be assessed by, for example, giving a Critical Appraisal of a Topic presentation on an AI topic, giving a case presentation about a disagreement between pathologist(s) and AI, providing a workplace assessment when using AI in practice, or writing an AI product evaluation or implementation plan. The required supervision level at each stage of residency, and the time period to expiration when not practiced will depend on the extent to which AI will be incorporated in daily pathology practice.

How Do We Get There in Practice?

In addition to identifying which EPA and competencies are required in the new AI-aided era, it is also important to anticipate *how* pathologists can actually acquire them. It will be necessary to anchor the EPA and competencies in (inter)national residency training programs. As AI can only partially take over some tasks of pathologists at this point, current competencies will remain important in the foreseeable future.[56] Acquiring additional competencies will, therefore, put pressure on the residency programs. The current trend in the Netherlands to reduce the length of the residency program should therefore be reconsidered, or an earlier subspecialization should be promoted; hence, the EPAs and competencies related to technological innovation such as AI can be adequately covered within the general residency programs.

Specific AI training opportunities are urgently needed, such as courses and workshops. Additionally, discussions within and between (inter)national professional pathology associations on how to prepare pathologists for using AI are necessary for determining good practices. Furthermore, interprofessional learning opportunities between, for instance, pathologists, radiologists, AI companies, AI researchers, and ethicists, will be valuable and will help pathologists become bridge builders between AI technologies and clinicians/patients.

It is important to note that training pathologists are one way to contribute to the responsible use of AI technology in pathology and deal with its associated risks, a fact that has so far received little attention.[68] Other strategies to minimize the risks of AI use in medical practice that have gained attention in the academic literature and policy-making have focused on designing responsibility into those systems themselves (eg, value-sensitive design), attributing liability or accountability to AI innovators and companies or mitigating risks to others (such as informing patients about AI use to increase trust and acceptance).[27,50,69,70] However, these approaches are either unjustifiably optimistic about the possibilities of technological design to steer clinical practice, only apply when damage has already occurred or they put cognitive burdens on an already vulnerable group.[27,50,69,70] Adequate training is an additional and prospective way of addressing not only the benefits but also preventing the risks of AI use in pathology. Moreover, increased abilities to responsibly use AI technologies might also increase pathologists' motivation to accept the responsibilities that are tied to the use of medical AI in practice. In general health care and radiology literature, it has been claimed that radiologists should remain responsible for the diagnosis when using AI.[44,46,62,71] In pathology literature, Chauhan et al[53] claim that accountability is a shared transactional concept, involving multiple entities, including the AI model, health care institutions, and health care professionals (eg pathologists). The precise degree to which pathologists can be held accountable for using AI models is not yet clear and will, for example, depend on AI model characteristics, such as transparency and explainability,[45,63] and should be investigated further. We focused on AI training of pathology residents in this paper; however, our findings and recommendations can also be extrapolated to pathologists who have already finished their residency and started to use AI in their daily work.

In this paper, we evaluated what EPAs and competencies pathologists require to make adequate and responsible use of AI technologies in their daily practice, looking at changes in roles and responsibilities due to AI technology introduction. Although microscopy evaluation and reporting can likely be partially replaced by AI in the future, most of the current EPAs or competencies will still be relevant. Moreover, competencies related to technology evaluation and implementation, data interpretation within the clinical context of the individual patient, knowing personal strengths and limits in human-AI interaction, and the ability to recognize potential ethical and legal issues related to technology will become more important. We therefore propose a new EPA for (future) pathologists "using AI in diagnostic pathology practice" and associated competencies. This EPA states that pathologists' clinical expertise to interpret AI outcomes in the individual patient's context is crucial for accurately applying AI techniques and communicating its results for patient care. Pathologists are therefore essential bridge builders or intermediators between AI tools on the one hand and the clinicians and patients on the other hand. We hope that our analysis can serve pathology training programs to make pathologists fit for a future with AI.

Author Contributions

S.V. and K.J. conceived the study and performed the literature study. S.V. wrote the first draft. All authors were involved in

substantially revising and writing the paper and have approved the submitted version.

Data Availability

Not applicable.

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Declaration of Competing Interest

The authors declare no conflict of interests.

Ethics Approval and Consent to Participate

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