Pathology training in the age of artificial intelligence

Ananya Arora [1], Anmol Arora [2]

[1]Selwyn College, University of Cambridge, Cambridge, UK
[2]School of Clinical Medicine, University of Cambridge, Cambridge, UK

Correspondence to
Anmol Arora, School of Clinical Medicine, University of Cambridge, Cambridge CB2 0SP, UK; aa957@cam.ac.uk

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INTRODUCTION

There are two key emerging technologies which are anticipated to transform healthcare in the next 10 years: artificial intelligence (AI) and robotics. Of the two, AI has attracted particular interest due to scope for generativity and promising results from early studies into its potential implementation. Indeed, a recent study suggested that approximately 80% of pathologists believe that AI will become integrated in diagnostic workflows in the next decade.[1] There is scope for both robotics and AI to transform pathology as a speciality in the near future, though the two innovations are not mutually exclusive. Simple robots which are narrowly programmed to perform some physical actions already exist, but to create advanced robots would require synergies with AI. Before we see robots take over the physical actions of pathologists, we are likely to see AI have significant impact in other ways. This can partly be attributed to Moravec's paradox, an observation by AI researchers that, to program AI which is capable of advanced cognitive processes is often relatively straightforward compared with simple physical tasks.[2] Pathology as a speciality is particularly pertinent to emerging AI research, which currently focusses on image and data analysis, two key elements of a pathologist's role. Early research has begun to explore how AI may begin to affect pathology and improve patient care but the effects on pathology training remain relatively underexamined.

TYPES OF ARTIFICIAL INTELLIGENCE

Most research into AI has focussed on deductive systems. However, there are other types of AI which do not attract as much research or media speculation (table 1). Broadly speaking, there are four categories:

- Deductive AI
- Generative AI
- AI for workflow optimisation
- AI in robotics

Deductive systems function by analysing data sets and finding patterns which would be infeasible for humans to program. Their uses are well recognised in improving diagnoses, notably in fields such as dermatology and radiology. On the other hand, generative AI works by creating new data inspired by existing data sets. One example of this is the use of generative adversarial networks (GANs). GANs comprise of two AI systems: one which learns from an existing data set to create new data and another system which discriminates the data to determine whether it is new or from the old data set. As the systems practise, the quality of data fabrication improves to the point where the synthetic data is indistinguishable from the original data.

AI for workflow optimisation revolves around the use of data analysis in optimising processes and workstreams. Potentially relevant uses include optimising staffing levels and triaging different work. AI in robotics is likely to be one of the last uses of AI to emerge in clinical practice, given that advances in both AI and robotic technologies are required. While simple robotic systems already exist to automate some analyses, these still require human supervision, which can act as a speed-limiting factor at present.

HIGH-LEVEL EFFECTS OF ARTIFICIAL INTELLIGENCE ON PATHOLOGY

Broadly speaking, the career of a pathologist can be outlined by the structure illustrated in figure 1. Following knowledge acquisition in medical school, a pathologist undertakes a combination of several types of work, for example: research, teaching, diagnosis, post-mortem and clinical work.

AI and robotics will exert differential effects on these workstreams and will also have some impact on training. In the short term, technological advancements may first alter the pathologist's role as a diagnostician. The other four job components are relatively resistant, at least in the short term.

Simple forms of robotic technologies may be incorporated in diagnostic systems, enabling automation of analysis. Robotic systems currently exist for analytical purposes, for example, several modern mass spectrometers provide almost fully automated analysis. As such technologies begin to be incorporated, the role of the pathologist will turn towards supervising the diagnostic systems. This can be illustrated with the example of histopathology, where simple robotic technology may be able to automate many of the steps involved with sample preparation. This would initially be in a very limited manner until AI can bring some more flexibility and responsiveness into the systems. In the future, we may also see AI assisting with interpretation of images, analogous to image analysis being developed for use in dermatology and radiology. This is perhaps the most active area of AI research in pathology, given that it has the opportunity to directly improve patient outcomes through improving diagnostic accuracy. Such systems would still require human supervision and the emergence of these technologies may likely follow a prolonged, phasic approach rather than a sudden overhaul of existing systems.

OBSTACLES TO ARTIFICIAL INTELLIGENCE IMPLEMENTATION

Innovation, as a process, generally consists of invention, development and implementation of a new service or product.[3] The invention and

Table 1 Comparison of different types of AI

Type of system	Working principle	Example
Deductive	System can find patterns in data which humans cannot	An AI-based system which was able to outperform human radiologists in interpreting mammograms[12]
Generative	System can produce synthetic data resembling real data	StyleGAN2 which produces realistic images of human faces when refreshed: www.thispersondoesnotexist.com[13]
Workflow optimisation	System can dynamically plan processes with higher efficiency	AI optimising triage of patients in emergency departments[14]
AI in robotics	System works synergistically with robotic technologies to improve their function, responsiveness and flexibility. This involves deductive systems	Automated anaesthesia delivery systems[15]

AI, artificial intelligence; GAN, generative adversarial networks.

development of algorithms for image and data analysis have received much attention, but it is also pertinent to consider the implementation stage of the innovation and potential barriers to adoption. Notably, AI requires homogenisation of data and large data sets on which to train. It is important that AI systems train on high quality, clean data which is representative of the data set it will ultimately serve. In this way, it is not enough for data sets to simply be large, they must also encompass diversity; otherwise the algorithms will be inherently flawed since they are not adequately trained to analyse rare pathologies or pathologies in under-represented patient groups.

To incorporate AI in an effective manner may require considerable reconfiguration of computer systems, extending beyond individual trusts given the scale of data required for training algorithms.[4] Historically, attracting funding towards back-end and computer systems has been difficult for healthcare systems given that these continually compete against investments which directly improve patient care, for example, increasing staffing capacity.

EFFECTS OF ARTIFICIAL INTELLIGENCE ON CONVENTIONAL TRAINING MODELS

There will always be a need for senior pathologists to supervise technologies and maintain control over the systems. However, we may, in the future, see a reduced demand for junior pathologists since much of the 'grunt work' and basic analyses will be more efficiently delegated to AI and robots. Some reform to the traditional pathology training programme may therefore be required to prevent long-term shortages of senior staff and over-dependence on technology.[5] It could be argued that emerging technologies may automate training opportunities for junior pathologists who would usually learn by experience, especially experience from encountering rare pathologies which tend to generate mistakes. Generative AI, such as the use of GANs as described earlier, offers a solution to this.[6] As deductive AI systems streamline a pathologist's role in diagnostic pathology, generative AI may streamline a pathologist's training.

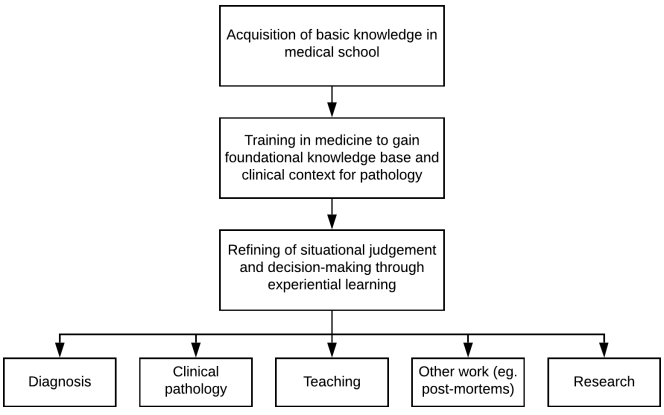

Figure 1 Abstract overview of pathology training model.

Doctors progress in their career training by experiential learning and continual refinement of decision-making, with the limiting factor being practice with difficult cases which test their judgement. Generative systems which are capable of producing synthetic images, cases and simulations can enhance this experiential learning. They can be programmed to produce relevant training material and intelligently adapt to the learning needs of the individual using the learning software. While a junior pathologist may currently go through thousands of cases a year, of which only a fraction may offer substantial learning opportunity, this can be streamlined in the future using relevant emerging technologies. The ability of GANs to produce fake stained images has been explored in the context of pathology, with one study finding that the accuracy of experts (three pathologists and two image analysts) in determining whether images were computer generated or real was only 47.3%.[7] A value of 50% would indicate perfectly realistic data as it would be equivalent to tossing a coin to decide; this is the value conventionally aimed for by developers.[8] Using such technologies to generate training material may help to overcome patient data concerns since the fake images are synthetic and are not attributable to any individual patient.

CONCLUDING REMARKS

The emerging potential of AI to transform healthcare has elicited a range of responses, ranging from scepticism to overexcitement. There are commentators who suggest that, given a long enough time frame, AI and robotics will be able to outperform humans at any task given that the technologies tend to improve exponentially. The premise behind this argument is that when AI reaches the point at which it is able to outperform human programmers at coding AI, it will be used to do so. At that point, we may witness a burst of rapid improvement cycles where each successive iteration improves the technology and the improvement process itself.[9 10] Others argue that this is impractical and distracting from today's applications of such technology.[11] While AI and robotics may change the work that a pathologist undertakes, they also offer new directions for the speciality. The timescales are certainly uncertain, but we should not simply assume that they must be far away.

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Twitter Anmol Arora @AnmolArora_98

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ORCID iDs
Ananya Arora http://orcid.org/0000-0002-0650-3966
Anmol Arora http://orcid.org/0000-0003-4881-8293

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