The future of Artificial Intelligence (AI) in the NHS

Context

The UK Government has recognised the significance of robotics and artificial intelligence (AI) via its Industrial Strategy published in November 2017, and the Industrial Strategy Challenge Fund; created to strengthen UK science and business innovation. As part of this work, the Prime Minister announced in May 2018 a goal to make the UK a world leader in the use of data, AI and innovation to transform the prevention, early diagnosis and treatment of chronic diseases by 2030.

Following this, a Lords Select Committee on AI published their evidence in April 2018 on the future of AI, and an independent Technology Review, known as The Topol Review, was published in February 2019 and centred on AI and robotics, genomics and digital medicine.

What is AI?

In essence, AI is a set of sophisticated technologies that allow machines to do highly complex tasks resembling the processes associated with human intelligence such as reasoning, learning, adaptation, sensory understanding and interaction. At this point in time, AI applications are specific to a particular task or problem.

Our position in brief

Bowel Cancer UK believes that AI has the potential to:

- **Improve prevention of bowel cancer** by utilising and analysing patient data and test results to find patterns that could inform a patient's risk of developing the disease. AI can help to identify high risk groups that should receive regular colonoscopy to detect and remove pre-cancerous polyps.
- **Improve earlier diagnosis of bowel cancer** by optimising tissue and image recognition to support automation and enhance accuracy in pathology and radiology; and by streamlining administrative processes, such as the call and recall functionality of the Bowel Cancer Screening Programme.
- **Develop and deliver effective bowel cancer treatment** by reducing human error during surgery which could improve patient outcomes; utilising patient data more comprehensively and with greater accuracy to target treatment and increase personalisation; and streamlining medical research processes.

However, in order for AI to improve these key areas, a number of policy considerations need to be addressed:

- **The NHS workforce and its role as AI systems evolve:** Despite AI systems automising and streamlining certain human tasks, often with greater accuracy, very few systems at this point in time are able to operate independently of human direction. AI systems should be aiding NHS staff, rather than replacing them, particularly when it comes to decision-making. This is especially important considering the current 'black-box' nature of AI technologies, whereby it's difficult to validate the conclusions and decisions these systems come to when analysing data.
- **Data quality, data storage and its accessibility:** given the nature of algorithms used in AI systems to find complex patterns through analysing large quantities of data from various sources, it's vital that there is significant investment into improving data quality and ensuring the data is stored securely.
- **Public engagement and ethical considerations:** Because the effectiveness of AI will be dependent on data quality and accessibility, patient consent around how their data is used and stored needs to be considered. Furthermore, upholding public trust in new technologies as they develop will be necessary to ensure the successful introduction of AI into the NHS.

Therefore, in order for AI to provide benefit to bowel cancer patients, investment into re-training and capacitating the NHS workforce, particularly in pathology and radiology, will be imperative. In addition, AI can enhance decision-making, learning, reasoning and assist in finding solutions to challenging problems, but this can only be maximised if investment into data systems and quality is prioritised. Lastly, transparency must be encouraged through regular public engagement with new AI technologies, especially as regulations around AI technologies change and develop.

Types of Artificial Intelligence

Machine learning – Machine learning is possibly the most successful type of AI and involves computers learning directly from data, experience and examples. As computer processing powers continue to progress, machine learning is now able to outperform humans on specific tasks including predicting, preventing, screening and diagnosing disease.

Vision perception, speech recognition and language processing – this involves image recognition technologies, and the ability to interpret human language and convert speech to text and text back to speech.

Robotics – this entails machines with the ability to replicate human behaviour and to a large extent with greater accuracy and efficiency.

Automated planning and scheduling – in the near future, AI systems will be able to complete administrative tasks, which could provide the NHS with large-scale workforce productivity gains.

Expert systems – this involves emulating the decision-making ability of a human expert. They are designed to solve complex problems by sifting through bodies of knowledge and data. A significant shortcoming of this is knowledge acquisition and difficulty in validating the conclusions and decision making process of AI systems.

Predicted impact of AI – What we know so far

AI and productivity gains

Current research suggests that AI algorithms will enhance NHS productivity through large-scale process optimisation, clinical pathway streamlining and public health applications.

For healthcare professionals, who currently spend between 15 and 70% of their time conducting administrative tasks[1], AI systems will be capable of ordering tests, compiling medical notes, and completing administrative tasks in the near future. This is expected to provide the NHS with the biggest workforce productivity gain and will allow health professionals across primary and secondary care to focus their time on clinical tasks and patient-clinical interaction. Moreover, AI is expected to improve systems efficiency and productivity for the wider health system.

Prevention

Machine learning algorithms are already helping clinicians predict those at higher risk of cancer, which in turn means there's a better opportunity to prevent disease[2]. By scanning patient health records as well as examining patterns of behaviour and lifestyle, AI can find 'clusters' of patients with similar health conditions and determine the likelihood of them developing certain health complications based on new patterns of comorbidity that would otherwise not have been realised. These clusters are useful as they can provide new correlations in data that allow for preventative interventions before it's too late, and support clinicians with taking a more comprehensive approach to managing the disease[3]. With regards to bowel cancer, this could be particularly beneficial for people with genetic conditions, such as Lynch syndrome, who are more likely to develop bowel cancer as a result of their genetic predisposition.

In addition, AI has the potential to better validate conclusions in colonoscopy. Colonoscopy can prevent the incidence of bowel cancer by identifying and removing precancerous polyps[4]. However, it has been found that the miss rate for polyps of any size is approximately 22%, and this has been attributed to two factors; blind spots and human error[5]. While blind spots can be

[1] Topol Review Interim report, Jun 2018
[2] https://reform.uk/research/thinking-its-own-ai-nhs, Accessed September 2018
[3] Ibid.
[4] Paggi, S et al. (2018). Linked colour imaging reduces the miss rate of neoplastic lesions in the right colon: a randomized tandem colonoscopy study. Endoscopy 50: 1 - 7
[5] Misawa, M et al. (2018) Artificial Intelligence-Assisted Polyp Detection for Colonoscopy: Initial Experience. Gastroenterology 154(8): 2027 – 2029

overcome using a wide-angle scope, human error is more challenging. This is particularly important considering the increasing gap in endoscopy experience and skills as a result of the current Accelerated Clinical Endoscopist Training Programme[6] to increase workforce capacity. AI has the potential to bridge this gap by providing automated detection of polyps. However, at this point in time, further machine learning and prospective evaluation will be required[7].

AI and cancer diagnostics

AI has the potential to transform cancer diagnostics. While AI can utilise patient data more extensively and with greater accuracy than humans, its use in healthcare will focus on improving human decision-making rather replacing it. So far, advances have shown the potential of AI to reduce human medical errors and inaccurate diagnoses, while lowering the cost of diagnostic services[8]. Progress in healthcare diagnostics will most notably be noticed through data analytics across all aspects of a patient's life and in medical imaging, including pathology and radiology[9].

Data analytics

Currently, existing data is too complex and disparate for clinicians to be able to utilise its full potential and improve cancer diagnostics. There is an opportunity for machine learning algorithms to use these data sets and combine them with other cancer risk factors to facilitate earlier detection of cancer and improve cancer diagnostics. Cancer Research UK's Grand Challenge programme currently seeks to explore how machine learning can be used to examine patterns of symptoms and behaviours within accessible datasets, both medical and non-medical (e.g. social media activity, shopping history, online search history) that could indicate the presence of cancer[10]. Similarly, Microsoft is researching the use of AI to interpret online search engine behaviours, such as someone searching their symptoms online long before they see their GP[11]. Where there is a lack of awareness of bowel cancer symptoms, this could prevent delays to seeing a GP and receiving a diagnosis. In addition, the ability of AI to improve research processes and access to relevant guidance may provide benefits particularly to younger bowel cancer patients who are more likely to experience delays in

[6] https://www.hee.nhs.uk/our-work/endoscopy/clinical-endoscopist-training-programme Accessed October 2018

[7] Misawa, M et al. (2018) Artificial Intelligence-Assisted Polyp Detection for Colonoscopy: Initial Experience. Gastroenterology 154(8): 2027 – 2029

[8] https://www.pwc.at/de/publikationen/branchen-und-wirtschaftsstudien/healthcare-ai-new-health.pdf, Accessed February 2019

[9] http://data.parliament.uk/writtenevidence/committeeevidence.svc/evidencedocument/artificial-intelligence-committee/artificial-intelligence/written/69680.pdf, Accessed 05 September 2017

[10] http://data.parliament.uk/writtenevidence/committeeevidence.svc/evidencedocument/artificial-intelligence-committee/artificial-intelligence/written/70515.pdf, Accessed 13 September 2017

[11] https://www.pwc.at/de/publikationen/branchen-und-wirtschaftsstudien/healthcare-ai-new-health.pdf

diagnosis because of the assumption that bowel cancer isn't a disease younger people can develop.

Medical imaging: Pathology and radiology

New AI technologies will change the role of practitioners, as machines take on the more technical aspects of diagnosis[12]. Digitisation and the use of AI for tissue and image recognition could augment other parts of the cancer diagnostic pathway, including pathology[13]. Some tasks in pathology that were previously done manually have already been automated, such as cell counts, and typing and screening of blood. This leaves pathologists to carry out more complex tasks. However, AI can also perform complex tasks and, in some instances, with greater accuracy. This has been seen in a study which showed computers predicting the grade and stage of lung cancer better than a pathologist,[14] although larger-scale validation with more diverse types of tissue is still required.

In addition, AI has the potential to support radiology, which has become significantly more complex and data rich as cross-sectional imaging has progressed to provide greater clarity. The sheer abundance of data has changed how radiologists interpret images, and often requires significant focus to search for patterns that are extremely difficult to find with the human eye alone. Furthermore, the amount of data continues to increase in imaging, some of which is only extractable by software. This is paving the way for the role of computers to extract fine information about tissues invisible to the human eye and process this data quickly and accurately.[15] A study conducted by MIT found that machine learning algorithms could register brain scans and other 3D images more than 1,000 times faster than current analytical techniques.[16] The use of AI in both pathology and radiology can therefore help to improve diagnostic and surgical outcomes.

In the long term, AI systems will have an increasingly prominent role in cancer diagnostics. For bowel cancer, this will be noticed namely in pathology and radiology.

Cancer treatments and surgery

AI technology also has the potential to develop and deliver cancer treatment. The increasing ability of AI to analyse data more comprehensively and with greater accuracy and pace could provide vital improvements to: the personalisation of treatment and care, particularly as genetic data becomes more readily available; streamlining medical research including drug discovery and identifying suitable clinical trials; and robot-assisted surgery.

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[12] http://data.parliament.uk/writtenevidence/committeeevidence.svc/evidencedocument/artificial-intelligence-committee/artificial-intelligence/written/69640.pdf, Accessed 06 September 2017

[13] http://data.parliament.uk/writtenevidence/committeeevidence.svc/evidencedocument/artificial-intelligence-committee/artificial-intelligence/written/70515.pdf, Accessed 13 September 2017

[14] Topol, E. J. (2016). Adapting to Artificial Intelligence: Radiologists and Pathologists as Information Specialists

[15] Topol, E. J. (2016). Adapting to Artificial Intelligence: Radiologists and Pathologists as Information Specialists

[16] http://news.mit.edu/2018/faster-analysis-of-medical-images-0618 Accessed October 2018

Personalisation of treatment and care

The use of machine learning to predict a patient's response to treatment using genetic data is an area of exploration that is being developed[17]. Cancer Research UK has considered this in their Lung Matrix Trial group, whereby patient groups are stratified based on gene changes identified in cancer cells. This is known as stratified medicine, whereby treatment is matched to patients based on genetic changes in their cancer cells, and allows doctors to target specific cancer cells[18]. These different patient groups could then evolve throughout the trial as more potentially effective drugs are identified.[19]

For bowel cancer patients, particularly those at advanced stages and those with a genetic condition like Lynch syndrome, a more comprehensive understanding of the genetic makeup and staging of a patient's tumour could enable more targeted treatments. Targeted treatments are more likely to work and can maximise outcomes for patients by ensuring they don't unnecessarily undergo the gruelling side-effects of treatment that may not even work. An example of this has been noticed in the use of a machine learning software called TEXLab that can forecast survival rates and response to treatments of patients with ovarian cancer[20]. TEXLab examines specific biological characteristics, including genetic makeup, that influence a patient's survival rate. It can provide clinicians with more detailed and accurate information around patient response to different treatments, enabling them to administer better and more targeted treatments quickly[21]. This could particularly benefit advanced bowel cancer patients, where accessing personalised and more targeted therapies is a key challenge and impacts quality of life and survival[22]. Finally, this approach allows for more personalised care plans to be coordinated, and supports patients better with managing their treatment programmes[23].

Streamlining medical research processes

The ability of AI to process and find patterns in vast quantities of data is also providing healthcare professionals with new insights and ways of interpreting/understanding health data they have access to, and is driving progress in biomedical and epidemiological research[24]. This includes advancements in drug discovery through machine learning

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[17] http://data.parliament.uk/writtenevidence/committeeevidence.svc/evidencedocument/artificial-intelligence-committee/artificial-intelligence/written/70515.html Accessed 20 February 2019

[18] https://www.cancerresearchuk.org/about-cancer/find-a-clinical-trial/a-trial-looking-at-different-drugs-for-non-small-cell-lung-cancer-national-lung-matrix-trial#undefined Accessed February 2019

[19] http://data.parliament.uk/writtenevidence/committeeevidence.svc/evidencedocument/artificial-intelligence-committee/artificial-intelligence/written/70515.html Accessed September 2018

[20] https://www.imperial.ac.uk/news/190266/artificial-intelligence-predict-survival-ovarian-cancer/ Accessed February 2019

[21] Lu, H., et al. (2019). A mathematical-descriptor of tumour-mesoscopic-structure from computed-tomography images annotates prognostic- and molecular-phenotypes of epithelial ovarian cancer. *Nature Communications 10: 764*

[22] Bowel Cancer UK (2017). Get Personal.

[23] Bowel Cancer UK (2017). Get Personal.

[24] http://data.parliament.uk/writtenevidence/committeeevidence.svc/evidencedocument/artificial-intelligence-committee/artificial-intelligence/written/69659.html Accessed 11 October 2018

algorithms that can analyse large datasets, such as in scientific literature and clinical data[25]. The ability of AI to sift through medical records and patients' genomic data will also enable clinicians to better match patients to suitable clinical trials[26]. This includes finding patients and validating them for biomarker-led clinical trials within minutes, a process that would usually take humans several months. In fact, in an IBM Watson Health study, AI technologies cut the time of assessing the eligibility of patients for a clinical trial by 78%[27].

The ability of AI to sift through large quantities of data and articles can also support clinicians to keep up to date with new medical research. Each year, millions of scientific articles are published in English based journals, making it difficult for clinicians to keep up with all advances. By synthesising current best practice, AI can streamline the process for healthcare professionals to access relevant research and guidance.[28] With more clinicians able to keep up with new research and guidance, the variation in the quality of treatment and care patients receive could be reduced.

Robot-assisted surgery

While AI will have a developing role in new treatments for cancer, its potential has also been seen in improving the effectiveness of cancer treatment, such as in surgery. While this will in part be due to improved diagnostics through AI tools, treatment improvements have also been noticed in robotics. There have been exponential advances in robotic technology since robots first started performing surgery three decades ago[29]. Experimental studies have shown autonomous robots performing better stitching than surgeons, and robotics companies are starting to use AI to help surgeons perform more effective precision surgery with ease[30]. Currently, most robots operate with relatively low AI involvement, but this will change over time with robots becoming the 'hardware' that embeds AI algorithms to perform a task[31].

For example, surgical procedures currently lack real-time information on tumour localisation and patient's anatomy during liver resections, which increases the risk of a tumour not being fully resected[32]. Preliminary findings have shown the use of novel imaging technology, more specifically an electromagnetic surgical navigation system, in providing surgeons with real-time visualization of tumour location and liver anatomy. This is giving accurate localization of

[25] https://www.nature.com/articles/d41586-018-05267-x , Accessed February 2019
[26] https://www.politico.eu/sponsored-content/clinical-trial-matching-ai-matches-patients-with-cancer-research/ Accessed February 2019
[27] https://www.politico.eu/sponsored-content/clinical-trial-matching-ai-matches-patients-with-cancer-research/ Accessed February 2019
[28] http://www.reform.uk/wp-content/uploads/2018/01/AI-in-Healthcare-report_.pdf, Accessed 11 October 2018
[29] https://www.pwc.at/de/publikationen/branchen-und-wirtschaftsstudien/healthcare-ai-new-health.pdf, Accessed 11 October 2018
[30] http://www.reform.uk/wp-content/uploads/2018/01/AI-in-Healthcare-report_.pdf, Accessed 11 October 2018
[31] The Topol Review. (2019). Preparing the healthcare workforce to deliver the digital future
[32] Ruers, T. (2018). Electromagnestic surgical navigation system for open liver surgery: preliminary results. Oral Abstract ESSO38

liver lesions and critical anatomy surrounding the resection area, even while surgery is taking place[33]. It may eventually be possible for AI to use real-time imaging technology to guide robotic surgery; allowing for more standardised surgical procedures by reducing the variation across surgeons, and improving effectiveness, safety, consistency and accessibility of surgical techniques within the NHS[34].

Policy considerations

In order for AI to drive improvements in prevention, early diagnosis and the treatment of cancer, a number of policy considerations need to be addressed.

AI and the workforce: New areas of required skills will include an understanding of AI algorithms, the ability to analyse big datasets, and a major increase in digital literacy. Policy considerations include:

- **The use of machine learning to reduce the burden on workforce** is welcome, particularly in pathology and radiology, but these should be **seen as an extra diagnostic tool rather than a replacement for a skilled workforce.** Investment into a skilled workforce is therefore required.
- **New areas of required skills will require up-skilling the current workforce**: appropriate education, retraining and ongoing learning resources will be needed. Professionals with a computer science, data science and engineering background will be crucial to reducing the AI and robotics skills gap in the NHS[35].
- **The UK has significant skill gaps for key staff** such as molecular pathologists, radiologists, bioinformaticians, statisticians, clinical geneticists and genetic counsellors. Improving staff retention and career development options must be addressed.
- **Robotics and the workforce:** Recent advances in robotics are likely to support surgeons perform more effective surgery by reducing human error. As robotics progresses, consideration must go into how robotics will complement the NHS workforce, rather than replace it.
- **Streamlining research processes:** As AI will make it easier for health care professionals to keep up with new guidance and scientific papers, as well carry out research using large datasets, consideration should go into how this can be maximised.

Data quality, access and storage considerations: The quality of algorithms is dependent on quality of data, and this could be a significant barrier to AI developments. We can only trust the conclusions of AI if they are based on high quality data. Policy considerations include:

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[33] Ruers, T. (2018). Electromagnestic surgical navigation system for open liver surgery: preliminary results. Oral Abstract ESSO38

[34] https://www.pwc.at/de/publikationen/branchen-und-wirtschaftsstudien/healthcare-ai-new-health.pdf, Accessed September 2018

[35] The Topol Review. (2019). Preparing the healthcare workforce to deliver the digital future

- **Delays in obtaining data:** Progress in research has been limited due to delays in accessing data held by NHS Digital and PHE. Therefore, these organisations need better infrastructure to improve access to relevant and high quality data in the future.
- **Machine learning and data quality:** PHE hold patient level data on chemotherapy and radiotherapy provision, but there are barriers to the application of machine learning on such datasets. To really realise the potential of machine learning in healthcare, investment into improving data quality is vital.
- **A single dataset:** Currently, data organisations collect the same data under separate datasets and there's significant variation between these. Reducing this discrepancy and creating a single dataset should be a priority for ensuring effective use of AI systems.
- **How can conclusions of AI-driven analysis be validated?** Without being able to see each stage of the decision-making (due to the 'black box' nature of AI), it can be difficult to judge two differing conclusions reached by two different algorithms. The extent to which this is a problem varies, e.g. digital pathology can be compared to human analysis, but where datasets become more complex and explorative it becomes difficult to validate conclusions made by AI systems.
- **Data heterogeneity:** Considerations must go into the datasets an algorithm is being trained on. Certain datasets may only be applicable to some populations, so making sure the datasets are diverse for the applicable population is crucial, particularly as the make-up of a disease varies with ethnicity and gender.
- **Algorithms are trained on data that is 'measurable' – so what about data that isn't measurable?** Many healthcare interactions depend on more than just 'measurable' data, such as non-verbal communication and qualitative observations, so considerations into how this will be captured and the impact on patients will need to be made[36].
- **Data governance:** There is a gap in information governance, and a lack of expertise in AI technologies that will need to be addressed[37] in order to accelerate our ability to analyse, interpret and make decisions using AI. However, the Government's recent commitment to create 'Data Trusts' is a step in the right direction to ensure the appropriate infrastructure is in place and that data governance is implemented ethically.

Ethics and regulations around AI: The 'black box' nature of AI – that is it can only be viewed in terms of inputs and outputs without any knowledge of its internal workings – warrants careful exploration when it comes to medicine. Therefore, at this point in time, it is not appropriate for an algorithm to be the last stage in a decision-making process, i.e. clinician oversight is necessary. Policy considerations include:

- **Patient consent:** The extent to which AI will be effective is dependent on data quality and accessibility, and therefore considerations into how patients are made aware of how their data is being used and how it's stored is paramount.

[36] http://www.reform.uk/wp-content/uploads/2018/01/AI-in-Healthcare-report_.pdf, Accessed September 2018
[37] The Topol Review. (2019). Preparing the healthcare workforce to deliver the digital future

- **Public engagement:** regulating AI systems is going to be an evolving space so transparency and public engagement will be needed to inform how much public trust there is in the 'black-box' nature of AI.
- **Effective governance processes to facilitate the introduction of AI technologies:** new leadership roles with the responsibility of advising NHS Boards on digital technologies will be necessary. The NHS must build skills in data provenance, curation and governance to assess ethical considerations and appraise new technologies[38].

What next?

AI is an emerging theme in healthcare and is still in its early phases of development. Over the next decade, the fusion of genomics, digital medicine and patient data, with AI there to make sense of the overwhelming amount of data, will have an important role in the provision of health and care in the NHS[39].

Bowel Cancer UK will therefore continue to monitor the progress and development of AI systems as new research and evidence becomes available.

Recommendations

- All clinicians and healthcare professionals should be educated in the ethical standards and best practice of working with AI and robotics, and be provided with continuous learning opportunities to grow as AI systems evolve.

- Public engagement in the workings of AI is crucial to ensuring public support and trust is maintained with regards to the changing way that patient data is used. The National Data Guardian and Understanding Patient Data's role in developing frameworks to communicate new and emerging technologies and the use of data to the public is paramount.

- NHS datasets need to be integrated into a secure, high quality data system with data across different health and care settings.

- Investment into data holding organisations, such as NHS Digital and Public Health England in England; NHS National Services Scotland and Information Services Division in Scotland; the Welsh Cancer Intelligence and Surveillance Unit in Wales; and the Northern Ireland Electronic Care Record (NIECR) in Northern Ireland, is crucial to ensuring high quality data input and quality assurance.

[38] The Topol Review. (2019). Preparing the healthcare workforce to deliver the digital future
[39] The Topol Review. (2019). Preparing the healthcare workforce to deliver the digital future2 019

- NHS Digital and the Sustainable Transformation Partnerships (STPs) in England; the Health and Social Care Integration Authorities in Scotland; the Wales Cancer Network; and the Health and Social Care Board in Northern Ireland need to consider how AI can be appropriately and smoothly integrated at the local level, so that outcomes for patients are enhanced.

- Investment into key staff such as molecular pathologists and radiologists will be crucial to ensuring a smooth transition into integrating AI systems in the NHS.

- With AI's ability to target treatments more effectively, increasing the personalisation of the treatment and care pathway for patients, the role of NICE in England and Wales and Northern Ireland, and NHS Scottish Health Technologies Group in Scotland as the responsible organisations for appraising and bringing in new, technologies, innovative medicines and treatments to the NHS will need to be reassessed and maximised.

- Further research into patient views and concerns on AI systems and its growing role in the NHS is necessary. Initial research suggests patients are increasingly willing to engage with AI if it means better access to healthcare, greater accuracy of diagnosis and treatment and improved trust in the technology involved.

- NHS collaboration with academia and industry should be encouraged.[40] This will help to bridge the skills gap and can also provide NHS with opportunities to attract global technical talent and develop a new generation of digital leaders to drive technological transformation in the NHS.

- Effective governance processes should be established to facilitate the introduction of new technologies.[41] This will include setting up a set of ethical principles for those designing and implementing data-driven health and care technologies in the NHS.

[40] The Topol Review. (2019). Preparing the healthcare workforce to deliver the digital future

[41] The Topol Review. (2019). Preparing the healthcare workforce to deliver the digital future2 019