J R Coll Physicians Edinb 2020; 50: 262–8 | doi: 10.4997/JRCPE.2020.309 REVIEW

Electronic health records: a critical appraisal of strengths and limitations

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Abstract

Electronic health record (EHR) was hailed as a major step towards making healthcare more transparent and accountable. All the developed nations digitised their health records which were meant to be safe, secure and could be accessed on demand. This was intended to benefit all stakeholders. However, the jury is still out if the EHR has been worth it.

There have been incidences of data breaches despite cybersecurity checks and of manipulation compromising clinicians' integrity and patients' safety. EHRs have also been blamed for doctor burnout in overloading them with a largely avoidable administrative burden. The lack of interoperability amongst various EHR software systems is creating obstacles in seamless workflow. Artificial intelligence is now being used to overcome deficiencies of the EHR. Emerging data from real-world usage of EHR is providing useful inputs which would be helpful in making it a better system.

This review critically appraises the current status and issues with the EHR and provides an overview of the key innovations which are being implemented to make the system more efficient for health care providers leading to a reduction in their administrative burden.

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Keywords: electronic medical records (EMR), digital patient records, patient data, artificial intelligence (AI), administrative burden, clinician burnout, voice-to-text technology, voice recognition technology, digital scribe, data aggregation, interoperability

Financial and Competing Interests: Suchitra Kataria declares no conflicts of interest. Vinod Ravindran is the Editor-in-Chief of the *Journal of the Royal College of Physicians of Edinburgh*. This paper has undergone peer review in accordance with *JRCPE's* policies.

Introduction

Digital health technologies have rapidly progressed in the last five to ten years, and digitising medical records was one of the logical steps in the pursuit to modernise the healthcare system.[1,2] Huge resources in various forms have been deployed worldwide to overhaul the system and maximise efficiency. The promise and intended benefits of electronic health records (EHR) were many at the outset, for instance, elevating the levels of care, enhancing patient safety, streamlining chaotic processes and cutting costs. The portability and advantages of having digitised records which could be accessed and utilised anywhere during the clinical decision-making process promised to herald a new era in patient care. In this narrative review we have analysed if the EHR has lived up to its promise or fallen short of lofty expectations. We have also discussed some recent advances which have the potential to overcome its current inefficiencies and turn it into an efficient system.

Implementation of EHR in different countries worldwide

In the USA, prompted by the evidence that EHRs can substantially enhance the quality and efficiency of care, the Health Information Technology for Economic and Clinical Health (HITECH) Act of 2009 came into effect to fast-track the process.[3] Since then, more than $30 billion of investments have been made by American federal government and almost 96% of hospitals have adopted EHRs, compared to only 9% in 2008.[4] The HITECH is an incentivisation program which pays the hospitals and the clinicians for implementing the EHRs.

The adoption of EHR in the National Health Services (NHS) in the UK was mooted as a harbinger of change in 1998, geared to enhance the quality of care. The key benefits identified then were: 1. Greater convenience through structured information access, 2. Better communication to improve the patient-related outcomes, 3. Quicker evidence-based decision making during care delivery and 4. Optimisation of resources by effective utilisation and productivity at all levels.[5] As a result the UK achieved 100% EHR adoption in all general

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practices (GP).[6] The GP record systems are more valuable as these are longitudinal and lifelong electronic records of the patients as opposed to hospital EHRs residing within each hospital which are episodic in nature. On the other hand, although the hospital covers a shorter duration of care, the spectrum of data is quite wide and intense given the battery of investigations and outcomes all plugged in together.

Vietnam implemented EHR nationwide in 2019. With the objective of having at least 90% of the population access to satisfactory health care by 2025, Vietnam also intends to apply information technology (IT) in all commune and ward health stations by 2020.[7] Malaysia intends to achieve the goal of digitising health records in all of its 145 government hospitals in the next four to five years. Out of these 145 hospitals, 35 (25%) are currently wired to Hospital Information System (HIS) and 118 (7%) out of 1,703 government clinics have deployed Clinical Information System (CIS).[8]

Besides the EHR implementation there are wider implications of digitising heath records. For example, Australia has rolled out the My Health Record system with an opt-out medical record option for all its citizens as a part of National Digital Health Strategy.[9] My Health Record is designed to share patient information seamlessly between health providers resulting in continuity and better care. Approximately 23.2 million Australians have signed up for the system.[10] The Danish government is creating World-Class Digital Service (WCDS) which is an app-based platform for accessing all publicly held data on Danish citizens.[11] The Finnish government-run Social Insurance Institution has created a set of digital healthcare services called Kanta.[12] This is an amalgam of personal electronic health records, a pharmaceutical database, a patient-data repository, a prescription service, and archives. In My Kanta pages, the citizens can input their personal health information and this serves as a national data repository to monitor everybody's wellbeing.[12]

Impact of EHR

The digital transformation of healthcare has accelerated in recent years and EHR has been an integral component of this process. This has delivered plenty of benefits to all the stakeholders at all levels. For instance, early diagnosis of diseases, prevention of medication mistakes (drug overdose, adverse effects, drug interactions, allergic reactions etc.) by 95% , life-saving measures by ensuring compliance with care adherence, and decreasing the number of duplicate diagnostic tests and lowering costs by 7–11%.[13–15] There are some more specific advantages:

a. Epidemic management in developing countries

An EHR system was implemented in Rwanda to support and improve HIV and TB patient care. Continuous data quality assessment and clinical data use led to creation of multiple interventions in the system. One of the evaluation cycles identified 15 previously undiagnosed paediatric patients with HIV while another cycle led to an EHR intervention which helped to decrease the proportion of completed critical CD4 lab results that did not reach clinicians by 34.2% ($p = .002$). Moreover, an automated data quality improvement system reduced known errors by 92%.[16] The implementation of EHR in sub-Saharan Africa has increased in the past 10–15 years but it is primarily driven by international efforts at controlling the HIV/AIDS epidemic.[17]

b. Better informed decision making

Availability of patient information in a structured and processed format with tracking in real time provides an unmatched decision-making opportunity for a busy clinician in the electronic version as opposed to cumbersome paper-based scribbles. Time-bound alerts and reminders for patients aligned to management, prevention and screening have been proven to improve the quality of care especially in chronic diseases.[18] Access to already available laboratory data prevents unnecessary duplication further bringing down the cost of care.

c. Care coordination

EMR fosters better interactions and coordination within the multifunctional care delivery team. Prescription errors and dosing misinterpretations are easily avoided when information is legible and not left to individual deciphering. Individual task allocation, follow-ups and subsequent scheduling etc. are without any ambiguity. A recent study, entitled Dynamic Electronic Health Record Detection (DETECT), combined the EHR data with machine learning to detect individuals at risk of developing a first episode of psychosis in primary and secondary care settings.[19] In the development and validation datasets, DETECT was found to have positive net benefit (prognostic accuracy) in each scenario in detection of a first episode of psychosis.[19] This ability to predict real-time personalised risk of developing a health issue is of immense clinical utility and enhancing patient outcomes.

d. Patient satisfaction and better outcomes

EMR harnesses point-of-care data and overcomes various human errors resulting in quality of care enhancement, patient compliance and satisfaction with better outcomes. The care gaps can be identified and appropriate corrective, screening or precautionary measures can be undertaken in a timely manner.

e. Care advancement based on real-world evidence

With the increased adoption of EHR, clinicians can access similar data pools transcending institutions and large groups of patients. This could be for a particular age group, gender or disease groups. Large-scale data comparison and benchmarking allows quicker analysis and conclusions. It also allows the hospitals and healthcare systems to have centralised control over prescribing and facilitates clearer focus on value-based care models. For instance, DeepMind has partnered with four large hospital groups in the UK. An app called Streams processes the hospitals' data to generate alerts drawing doctors' attention to the potential deterioration of patients in real time.[20]

The insights generated from EHR provide value and effectiveness of various management approaches besides patient readmission risk evaluation, paving the way for outcomes-based pricing and reimbursement. In the UK, Verily (https://verily.com) is enabling data processing for the NHS Heywood, Middleton and Rochdale Clinical Commissioning Group. Using the anonymised patient records from the hospital, the data processing engine identifies telltale signs of chronic diseases like diabetes and alerts the doctors for timely action. In the USA, Cityblock Health (https://www.cityblock.com), a company focused on urban community health, intends to utilise patients' data pooled from low-income city dwellers to enable better care for individuals covered by Medicaid.

Current issues with the EHRs

Despite the vast expectations and the investment it appears that the EHR has not been entirely successful in what it had set out to rectify. The fundamental problem started at the initial execution stage. Issues in feeding and safeguarding patients' clinical information, hospital inventories, staffing and resources started when the computing devices started to be used extensively.

a. Lack of harmony

The healthcare practitioners and institutions have used the services of numerous vendors who, over the course of time, have continued to add new features and functionalities as the technology and operating systems move to the next levels. With a multitude of software features, inconsistencies abound at various levels. According to a 2018 survey conducted by Black Book Market Research, on average 18% of patient records within organisations are duplicates.[21] Also the match rates between organisations, for example, the hospital and a doctor's clinic, can be extremely low. Even with the same EHR vendor, owing to variable data entry protocols, the match rates could go down to as low as 50%.

b. Problems in patient matching

Matching patients to their medical records accurately is paramount. Any mismatch could potentially compromise patient safety and waste resources on unnecessary procedures or tests. When two patients have similar names, the records of different patients may get combined, resulting even in unnecessary organ removal or unwarranted procedures on a healthy patient. Another common problem is the duplication of patient records. For example, Linda Maria Jones is identified as Linda M. Jones in her primary care provider's EHR; as Maria Jones in her ophthalmologist's record, as Linda M Jones at the endocrinologist's office, and as Linda Jones at the laboratory!

c. Data security and privacy concerns

As of February 2019, more than 2.5 million Australians had opted out of My Health Record.[9, 10] Privacy and cyber security concerns have prevented some of the healthcare providers from uploading patient information to the system. Out of the 22.65 million records which cover almost 90% of the population, only 12.9 million have any data in them.[22] By October 2019 around 90% of GPs and pharmacies as well as 93% of public hospitals registered to utilise the system;[22] however, the Australian Digital Health Agency (ADHA) reported that only 69% of pharmacies and 71% of GPs are using the record system. Only 33% private, 3% care of the elderly healthcare systems, and 41% of pathology and diagnostic imaging services have registered to utilise the records.[22] Having spent $2billion on the project, these results are definitely not in line with initial goals and expectations.[9]

d. Algorithm manipulation in decision-support models

The software is prone to hacking when the cybersecurity is compromised. It is possible to alter the algorithms for illegitimate benefits with *mala fide* intent. Practice Fusion (https://www.practicefusion.com), an EHR vendor based in the USA was fined $145 million for deliberately altering clinical decision support tools at the point of care to benefit an opioid drug company in return for kickbacks.[23] This was a serious breach of the trust clinicians placed in the software and jeopardised patient safety.

e. Contributing to clinician burden

There is evidence to suggest that EHRs may be doing more harm than good during and after the clinical encounter and eventually contributing to clinician's burnout.

The Harris Poll, on behalf of Stanford Medicine, conducted a comprehensive survey of over 500 primary care physicians (PCPs) on EHRs.[24] According to this, EHRs were reported to take away precious time meant for patient–provider communication during a clinical encounter. Almost 62% of every patient interaction was spent using the EHR.[24] For instance, during a 20-minute primary care appointment, the practitioner communicated with the patient for about 12 minutes while 8 minutes were spent documenting the EHR and an additional 11 minutes devoted to documentation after the patient's exit from the doctor's office.

In this survey, 69% of the participants indicated that the EHR sucked up valuable time and has not resulted in strengthening their relationships with patients. 54% of the PCPs were of the opinion that the EHR has detracted them from their clinical effectiveness and 71% attributed technology as a contributor to burnout.[24] Perhaps not unsurprisingly, EHRs were not seen as powerful clinical tools; their primary value, according to PCPs, was data storage (44%).[24]

In the USA, another study, an observational secondary analysis of internal medicine interns at six university-affiliated and community-based programs, revealed that the interns were devoting a disproportionately large proportion of their time to indirect patient care compared to patient interactions or educational activities.[25] More than 43% of the average intern's time was spent on EHR usage during a 24-hour time period.[25]

Table 1 Issues with EHR and some potential solutions

Key issues	Potential solutions
Unnecessary / out of context documentation	Essential to document only when the information is of clinical value or utility.
Multiple steps and complicated EHR workflows	Process flow simplification and minimising the data entries. Shift some of the data entry responsibility from clinician to support staff.
Need for automation with new technologies	Apply voice recognition, voice assistants, connected devices, digital scribes etc. to reduce human involvement.
Closed EHR software platforms	Third-party app developers need to focus on improving clinician's user experience and create specialty-specific offerings.
Information resting in silos	Standardisation of APIs (Application Programming Interface) across EHR to enable seamless information flow from one to another. Interoperability ensures information availability as per need.
Poor user experience	Simplification of access and mobile optimisation is necessary as the usage is shifting from desktop to mobile devices.

Potential solutions to current problems with the EHRs

The greatest promise of EHRs lies in making the clinical care more predictive, preventive, and precise. Table 1 lists some of the key issues with EHRs and their potential solutions.

At UC Health (https://www.uchealth.com, a large integrated health network based in the USA), researchers have created a team-based intensive intervention model to improve EHR efficiency.[26] Here, Sieja and colleagues devised a two-week 'Sprints' EHR intervention led by a trained 11-member team to reduce clinician EHR burden, alleviate clinician burnout, and improve clinician satisfaction with the EHR, one clinic at a time.[26] The trained team had one project manager, one physician informaticist, one nurse informaticist, four EHR analysts and four trainers who worked in conjunction with the clinic leader. The chief components of the Sprints interventions were: train clinicians to use EHR features more efficiently, realign the clinic's multidisciplinary workflow and create new specialty-specific EHR tools. The duration of Sprints was two weeks and was implemented at six UC Health clinics between January 2016 and July 2017.[26] Clinicians participating in Sprints interventions were surveyed before and after intervention on a net promoter scale ranging from -100 at the worst to +100 with EHR satisfaction.

Clinician satisfaction with the EHR improved from -15 pre-intervention to +12 post-intervention. The percentage of clinicians who reported burnout prior to the intervention witnessed a decline from 39% to 34% after the intervention.[26] The Sprints intervention model can help improve clinicians' EHR use but there were some limitations in this study. For instance, lack of standard parameters to measure EHR user experience and the difference in application at each clinic may have resulted in varying experiences for each physician.

Longhurst et al. analysed extensive feedback from tens of thousands of users, which revealed critical gaps in users' understanding of how EHRs should be optimised.[27] They noted wide variation in EHR experience among all EHR customer bases, and its analysis underscored the lack of appropriate training on EHR usage as the main cause of clinicians' dissatisfaction. Overall, the main conclusion was that if the healthcare organisations provided high quality education for the care providers enabling them to master EHR functionality which they are expected to acquire, this would greatly overcome many issues with the EHRs.[27]

The KLAS research group (https://klasresearch.com) analysed insights shared by over 30,000 physicians which revealed that EHR satisfaction is highly variable across specialties.[28] It concluded that besides investments towards EHR training, standards of such training need to be created in healthcare organisations and the emphasis should be on personalisation of systems.[28] Of note was the potential of physicians to rise above their specialty's EHR limitations by learning effective methods of improving their EHR experience, regardless of their specialty.

Besides training, simple standard practices can help improve EHR functionality by resolving problems in patient matching. For instance, standardising patients' last names and address information in EHRs has been found to be more effective in matching an individual's health records. In a study by Grannis et al. standardising the address was independently associated with improved matching sensitivities for both the public health and HIE (Health Information Exchange) datasets of approximately 0.6% and 4.5%.[29] Standardisation of the last name improved matching sensitivity by 0.6% for the HIE dataset with no change in overall accuracy. Standardisation of other individual fields such as telephone, date of birth, or social security number did not demonstrate any further improvements. The study noted the combined effect of address and last name standardisation showed improved sensitivity from 81.3% to 91.6% for the HIE dataset.[29]

Advances to lessen the EHR-related clinician's burden

a. Voice-to-text and voice-recognition technologies

This technology which can listen to the dialogue between a clinician and patient in the clinic, understand the context,

create a transcription and integrate the matter within the EHR systems without the need for a doctor to type a single letter holds immense potential.

Microsoft and Nuance Communications are collaborating to accelerate the development of a clinical intelligent system.[30] This advanced system intends to combine ambient sensing and conversational AI to create automatic clinical documentation alongside the EHR. Additional components involve ambient listening with patient consent, wake-up word, voice biometrics, signal enhancement, document summarisation, natural language understanding, clinical intelligence and text-to-speech.[30] An amalgamation of speech, natural language processing and AI is expected to be made available to an initial set of clinician specialties within 2020 and will subsequently be expanded to other specialties in the coming years.

Equipped with multi-party speech recognition, computer vision and language understanding, these tools can not only listen and understand the in-clinic interaction but also integrate actionable insights within the document and point-of-care recommendations.[30] The AI-enabled intelligent system can access a patient's history and scan earlier interactions to warn about potential drug interactions or allergy and reduce any errors as well as saving the doctor's time [30]

b. Digital scribes

Digital scribe creates an automated process to generate a document from spoken interactions between the patient and the doctor by deploying speech recognition, natural language processing and AI.[31]

Robin Assistant™ created by Robin Healthcare completes clinical documentation, creates billable notes for all patients, and facilitates simple follow-ups to complex tasks through a plug-in device powered by AI.[32] It has been found that multitasking leads to errors that are overcome by Robin's robust software which documents thorough and accurate information. This can be plugged directly into the EHR automatically.

Augmedix utilises Google Glass to decrease the paper workload by providing a technology-enabled documentation service for doctors and health systems.[33] Physicians wear Google Glass while seeing patients and the visit information is sent to a remote scribe that records all the patient's visit notes. Thus in real time the clinicians are not required to handle their computers during patient interactions. Use of Augmedix smartglasses have been claimed to reduce EHR charting time by 80% and allow providers to see up to 25% more patients (https://augmedix.com).

Vanderbilt University Medical Centre is creating a digital assistant called VEVA (Vanderbilt's EHR Voice Assistant) which can analyse patient data and create patient summaries in real time.[34] The hospital is test-piloting a system where EHRs can talk back to the doctors. The aim is to create focused interactions with the patients and cut down the distraction of feeding the information into software to almost zero.

Recently, the tech giant Amazon has launched Amazon Transcribe Medical, which transcribes doctor-patient interactions and seamlessly inserts the text directly into the medical record.[35] Before making this product available, Amazon had introduced another U.S. Health Insurance Portability and Accountability Act of 1996 (HIPAA)-eligible machine-learning service called Amazon Comprehend Medical in November 2018. Comprehend Medical was created to process unstructured medical text and identify information such as patient diagnosis, treatments, dosages, symptoms and signs, etc. to improve clinical decision support, streamline the revenue cycle and clinical trials management. Also, this addresses data privacy and protected health information (PHI) requirements better.

Fred Hutchinson Cancer Research Centre in Seattle deployed Comprehend Medical which helped evaluate millions of clinical notes to extract and index medical conditions, medications, and choice of cancer therapeutic options.[36] This shortened the time to process each document from hours to seconds.

c. Data aggregation

Google Health is working on an EHR data aggregation tool capable of pulling data from various clinical systems into a unified dashboard for clinicians.[37] Although in development and early clinical pilot stage, the tool intends to provide a single access through which clinicians can obtain a unified view of data that would usually be spread across different systems. All the patient related vitals, laboratory investigations, medications and notes, alongside the scanned documents, etc. will reside in an interoperable platform on the clinician's digital device.[37]

'Search', which is synonymous with and integral to Google, also finds an application here. Doctors can search for keywords and use clinical shorthand to obtain results, for instance, entering 'abx' would make available all the references to antibiotics in the results, including any administered medications.[37]

'Google technologies' such as autocomplete and autocorrect functionalities intend to eliminate the misspelt terms not identical to matches searched for terms showing up in results. All recent and historical trends are displayed in graphs and tables when any value is clicked. Key admission notes can be accessed quicker. No sooner than the clinician types in any terminology the autocomplete common clinical phrases are displayed and difficult-to-spell terms are automatically suggested.[37]

Conclusion

Clearly EHRs have come a long way and are here to stay. Proper utilisation and optimisation of EHR functionality is an ongoing need. Attention to some of the key imperatives would help address the EHRs shortcomings and maximise their utility.

First and foremost would be interoperability. This implies that, for example, a doctor using an Epic system should be easily able to send patient information to a doctor using a Cerner system, or to one from Athena health. For this, combinations of technical and operational solutions are required. A common technical framework to exchange data seamlessly and standardisation of the data is currently needed.

Secondly, EHRs must be redesigned and adopted to suit the clinicians' specific needs. Some of the aforementioned advances in digital technologies, along with dedicated training in EHR usage, will prove to be useful in this regard irrespective of the clinician's specialty.

Thirdly, as discussed earlier, building an EHR system suited to clinical needs should make AI an integral component to enable synthesis of anonymised patient records, combining them with the medical literature and provide decision support with predictive analytics capabilities at the point of care.

References

1 Howarth A, Quesada J, Silva J et al. The impact of digital health interventions on health-related outcomes in the workplace: A systematic review. *Digit Health* 2018; 4: 2055207618770861.
2 Kataria S, Ravindran V. Digital health: a new dimension in rheumatology patient care. *Rheumatol Int* 2018; 38: 1949–57.
3 Blumenthal D. Stimulating the adoption of health information technology. *N Engl J Med* 2009; 360: 1477– 9.
4 Centers for Medicare and Medicaid Services. EHR incentive programs: data and program reports. Baltimore (MD) https://www.cms.gov/regulations-and-guidance/legislation/ehrincentiveprograms/dataandreports.html. (accessed 31/1/20).
5 NHS Executive. Information for health: an information strategy for the modern NHS 1998-2005. 1998. https://webarchive.nationalarchives.gov.uk/20120503231618/http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/@dh/@en/documents/digitalasset/dh_4014469.pdf (accessed 31/1/20).
6 Payne TH, Detmer DE, Wyatt JC et al. National-scale clinical information exchange in the United Kingdom: lessons for the United States. *J Am Med Inform Assoc* 2011; 18: 91–8.
7 HealthcareITNews. Vietnam to deploy EHR nationwide in July. https://www.healthcareitnews.com/news/asia-pacific/vietnam-deploy-ehr-nationwide-july (accessed 25/01/20).
8 HealthcareITNews. EMR implementation for public hospitals and clinics. https://www.healthcareitnews.com/news/asia-pacific/emr-implementation-public-hospitals-and-clinics-cost-rm15b-says-malaysian-health (accessed 25/01/20).
9 Australian Digital Health Agency. My Health Record. https://www.healthdirect.gov.au/my-health-record. (accessed 26/01/20).
10 The Guardian. More than 2.5 million people have opted out of My Health Record. 20th February 2019. https://www.theguardian.com/australia-news/2019/feb/20/more-than-25-million-people-have-opted-out-of-my-health-record (accessed 06/04/20).
11 Computer Weekly. O'Dwyer G. Danish government launches wide-ranging digital services project. November 29, 2018. https://www.computerweekly.com/news/252453418/Danish-government-launches-wide-ranging-digital-services-project (accessed 10/02/20).
12 Kanta. www.kanta.fi/. (accessed 30/01/20).
13 Kataria S, Ravindran V. Emerging role of e-Health in the identification of very early inflammatory rheumatic diseases. Best Practice & Research Clinical Rheumatology 2019; 33: 101429. doi.org/ 10.1016/j.berh.2019.101429
14 Australian Digital Health Agency. Australia's National Digital Health Strategy. www.conversation.digitalhealth.gov.au. (accessed 30/01/20).
15 Ancker JS, Kern LM, Edwards A et al. Associations between healthcare quality and use of electronic health record functions in ambulatory care. *J Am Med Inform Assoc* 2015; 22: 864–71.
16 Amoroso CL, Akimana B, Wise B et al. Using electronic medical records for HIV care in rural Rwanda. *Stud Health Technol Inform* 2010; 160: 337–41.
17 Akanbi MO, Ocheke AN, Agaba PA et al. Use of Electronic Health Records in sub-Saharan Africa: Progress and challenges. *J Med Trop* 2012; 14: 1–6.
18 Kern LM, Barrón Y, Dhopeshwarkar RV, Edwards A et al. Electronic health records and ambulatory quality of care. *J Gen Intern Med* 2013; 28: 496–503.
19 Raket LL, Jaskolowski J, Kinon BJ et al. Dynamic ElecTronic hEalth reCord deTection (DETECT) of individuals at risk of a first episode of psychosis: a case-control development and validation study. *Lancet Digital Health* 2020; 2: 1–11. https://doi.org/10.1016/S2589-7500(20)30024-8
20 Connell, A., Montgomery, H., Martin, P. et al. Evaluation of a digitally-enabled care pathway for acute kidney injury management in hospital emergency admissions. *NPJ Digi Med* 2019; 2: 67.
21 PRNewswire. Improving Provider Interoperability Congruently Increasing Patient Record Error Rates, Black Book Survey. https://www.prnewswire.com/news-releases/improving-provider-interoperability-congruently-increasing-patient-record-error-rates-black-book-survey-300626596.html (accessed 30/01/20).
22 The Guardian. My Health Record: almost $2bn spent but half the 23m records created are empty www.theguardian.com/australia-news/2020/jan/23/my-health-record-almost-2bn-spent-but-half-the-23m-records-created-are-empty (accessed 06/04/20).
23 Medscape. EHR Vendor Practice Fusion Settles Opioid Kickback Case for $145M. https://www.medscape.com/viewarticle/924533 (accessed 12/04/20).
24 Stanford Medicine. How Doctors Feel About Electronic Health Records. National Physician Poll by The Harris Poll 2018. https://med.stanford.edu/content/dam/sm/ehr/documents/EHR-Poll-Presentation.pdf (accessed 15/2/20).
25 Chaiyachati KH, Shea JA, Asch DA et al. Assessment of Inpatient Time Allocation among First-Year Internal Medicine Residents Using Time-Motion Observations. *JAMA Intern Med* 2019; 179: 760–7.
26 Sieja A, Markley K, Pell J et al. Optimization Sprints: Improving Clinician Satisfaction and Teamwork by Rapidly Reducing Electronic Health Record Burden. *Mayo Clin Proc* 2019; 94: 793–802.
27 Longhurst CA, Davis T, Maneker A et al. Local Investment in Training Drives Electronic Health Record User Satisfaction. *Appl Clin Inform* 2019; 10: 331–5.

28 KLAS. Achieving EHR Satisfaction in Any Specialty Impact Report. https://klasresearch.com/archcollaborative/report/achieving-ehr-satisfaction-in-any-specialty/310 (accessed 28/01/20).
29 Grannis SJ, Xu H, Vest JR et al. Evaluating the effect of data standardization and validation on patient matching accuracy. *J Am Med Inform Assoc* 2019; 26: 447–56.
30 Microsoft. The AI Blog. Microsoft and Nuance join forces in quest to help doctors turn their focus back to patients. https://blogs.microsoft.com/ai/nuance-exam-room-of-the-future (accessed 21/01/20).
31 Coiera E, Kocaballi B, Halamka J et al. The digital scribe. *NPJ Digit Med* 2018; 1: 58.
32 Mobihealthnews. Robin Healthcare. https://www.mobihealthnews.com/content/doctors-assistant-robin-healthcare-emerges-stealth-mode (accessed 30/01/20)
33 Digital Innovationand Transformation. Augmedix: Humanizing Healthcare Through Google Glass. Updated on April 26 2017. https://digital.hbs.edu/platform-digit/submission/augmedix-humanizing-healthcare-through-google-glass/ (accessed 30/01/20).
34 Vanderbilt University. Project seeks to help people interact with medical records. Updated on 4th January 2018. https://news.vumc.org/2018/01/04/project-seeks-to-help-patients-interact-with-medical-records/ (accessed 31/01/20).
35 Amazon. Amazon Transcribe Medical. https://aws.amazon.com/transcribe/medical/ (accessed 31/01/20).
36 Taha A. Kass-Hout, Matt Wood. Introducing medical language processing with Amazon Comprehend Medical. https://aws.amazon.com/blogs/machine-learning/introducing-medical-language-processing-with-amazon-comprehend-medical (accessed 21/01/20).
37 American Hospital Association. Google Broadens Focus to Providers and Outcomes with EHR Analytics System. https://www.aha.org/aha-center-health-innovation-market-scan/2019-02-11-google-broadens-focus-providers-and-outcomes (accessed 31/01/20).