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Balancing act: the complex role of artificial intelligence in addressing burnout and healthcare workforce dynamics

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ABSTRACT

Burnout and workforce attrition present pressing global challenges in healthcare, severely impacting the quality of patient care and the sustainability of health systems worldwide. Artificial intelligence (AI) has immense potential to reduce the administrative and cognitive burdens that contribute to burnout through innovative solutions such as digital scribes, automated billing and advanced data management systems. However, these innovations also carry significant risks, including potential job displacement, increased complexity of medical information and cases, and the danger of diminishing clinical skills. To fully leverage AI's potential in healthcare, it is essential to prioritise AI technologies that align with stakeholder values and emphasise efforts to re-humanise medical practice. By doing so, AI can contribute to restoring a sense of purpose, fulfilment and efficacy among healthcare workers, reinforcing their essential role as caregivers, rather than distancing them from these core professional attributes.

INTRODUCTION

The WHO classifies burnout as an 'occupational phenomenon', with the 11th Revision of the International Classification of Disease (ICD-11) defining it as a 'syndrome conceptualized as resulting from chronic workplace stress that has not been successfully managed. It is characterized by three dimensions: feelings of energy depletion or exhaustion; increased mental distance from one's job, or feelings of negativism or cynicism related to one's job; and reduced professional efficacy …'.[1] It can manifest as a sense of detachment from patients, a depletion of emotional resources and a diminished sense of personal fulfilment. Such a state compromises the quality of patient care, precipitating medical errors[2] and a decline in physician productivity and career satisfaction.[3] Burnout has become so ubiquitous among physicians, nurses and staff workers that it is now markedly impairing the healthcare workforce. In McKinsey's most recent nursing survey, 31% of nurses indicated their intent to leave direct patient care jobs[4] and a report from Mercer's US healthcare labour market projects that 1.1 million registered nurses will be needed by 2026.[5] In 2021, the Association of American Medical College estimated that the USA could see a shortage of 37 800 and 124 000 physicians by 2034.[6] Overall, the Mercer report projects a shortage of more than 3 million healthcare workers (HCWs) by 2026.[5] Health systems have yet to adapt to this large-scale workforce attrition, leading to disruptions in care delivery, worsening access to care issues and prolonging wait times.

The rapid evolution of artificial intelligence (AI) in healthcare presents an unparalleled opportunity to address burnout workforce shortages among HCWs.[7] In recent years, the capabilities of AI in healthcare have seen exponential growth, spurred by significant advances in machine learning (ML) algorithms, the proliferation of generative AI and the widespread application of deep neural networks.[8] These technological advances have resulted in the creation of more accurate predictive models, sophisticated data analysis tools and advanced systems for automating clinical and administrative tasks. Innovations in natural language processing (NLP) are transforming electronic health records (EHRs), making them more intuitive and efficient, while AI-driven diagnostic tools are significantly enhancing the accuracy and speed of patient care. Moreover, the use of generative AI to synthesise medical literature and aid in decision-making is adding a new layer of depth to personalised patient treatment plans. However, these advancements are not without significant risks. The integration of AI could lead to potential job displacement as tasks once performed by humans are automated.[9] There is also an increased complexity in medical information and cases, which could overwhelm providers who are not adequately

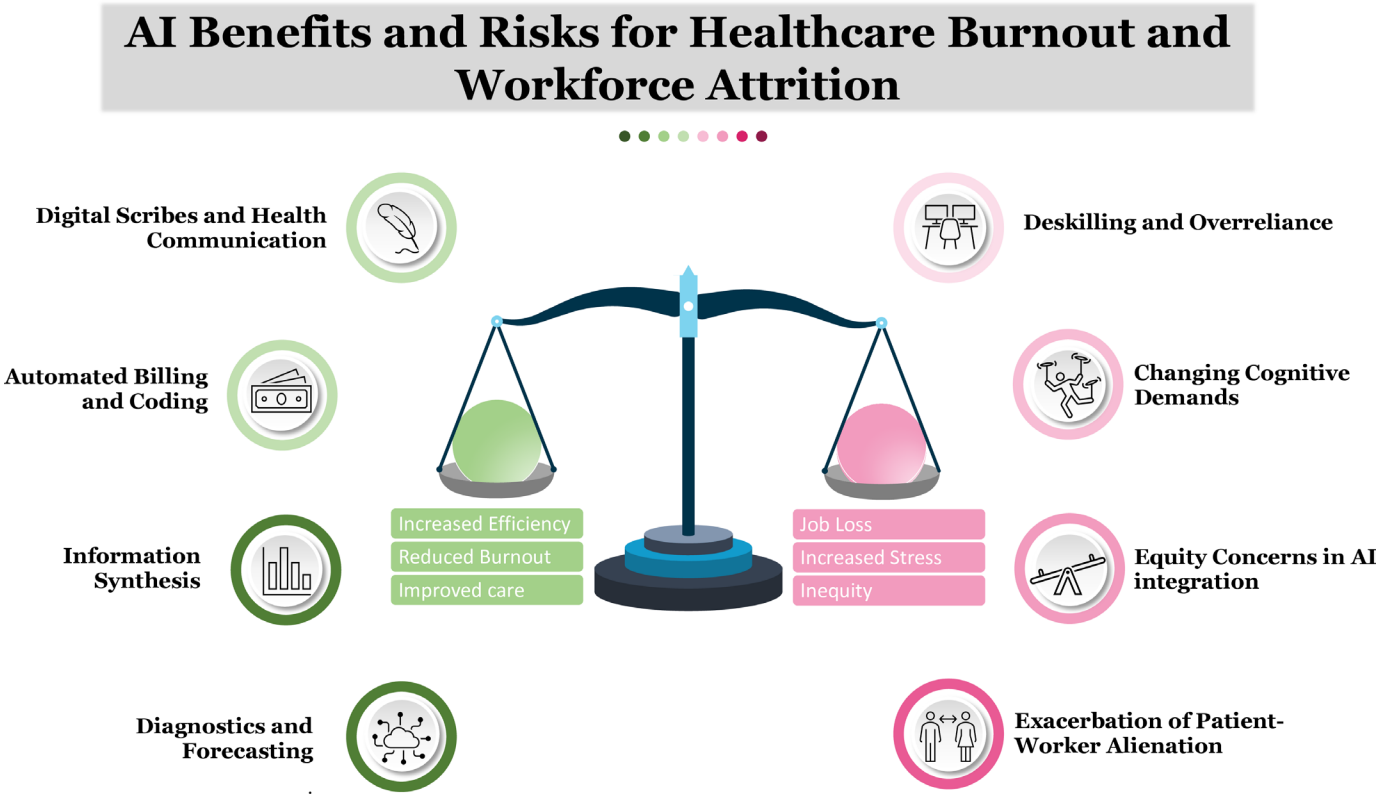

Figure 1 Balancing the Impact of artificial intelligence (AI) on healthcare workforce dynamics. This figure illustrates the dual nature of AI integration in healthcare, highlighting both the benefits and potential risks.

trained to leverage these new tools[10] Additionally, there is a risk that the reliance on AI may diminish clinical skills,[11] as continuous practice and hands-on experience are crucial for maintaining proficiency. Below, we explore the various challenges and potential AI innovations that could prove beneficial in addressing the critical issue of burnout among healthcare professionals. This discussion aims to strike a balance between leveraging the advantages of AI and mitigating its potential risks to ensure that it serves as a supportive tool rather than a disruptive force in healthcare (see figure 1).

ENHANCING WORKFLOW WITH AI: STREAMLINING ADMINISTRATIVE AND DOCUMENTATION PROCESSES

In the effort to leverage AI technologies for enhancing workplace efficiency and mitigating clinician burnout, the burden of administrative tasks and clinical documentation in EHRs must be a central focus. In the current era of EHRs and heightened regulatory demands, clinicians now allocate almost half of their workday to documentation and other administrative responsibilities.[12] This significant burden of administrative and clerical time diminishes the time available for direct patient interaction, establishing trust, imparting patient education and attending to the comprehensive physical, emotional and psychological needs of patients. Such a shift can lead to a disconnection from the core mission of healthcare and create misaligned incentives, thereby heightening the likelihood of burnout among medical professionals. To realign healthcare with its foundational goals and alleviate the strain on medical professionals, AI presents several innovative opportunities. These include digital scribes for easing documentation load, chatbots and AI tools for enhancing healthcare communication, and automated systems for streamlining billing processes.

Digital scribes

Digital scribes are rapidly evolving as a potential solution to reduce the burden of clinical documentation. Digital scribe is an AI technology that integrates speech recognition with NLP to synthesise provider–patient interaction, summarise it in the EHR,[13] populate diagnostic fields and create billing codes. There has been an increase in private healthcare-informational technology companies that are developing and perfecting this technology.[14] Early studies have shown the promise of digital scribes in improving documentation efficiency by almost 2.7-fold,[15] but the clinical validity and usability of this AI-based technology is still in its infancy.

This automation not only streamlines the record-keeping process but also enhances data accuracy and accessibility. In a retrospective analysis of documented notes, Steinkamp *et al* showed that 50.1% of total text in patients' notes was copied forward from prior notes.[16] The redundancy in clinical documentation inundates clinicians with copious amounts of duplicated data, leading to wasted time in chart review and contributing to burnout.

Further comprehensive research is required to evaluate the impact of AI-based documentation technologies

on clinician burnout reduction over the long term. For example, Nguyen *et al* conducted a study where digital scribes were implemented in a cancer centre. The findings indicated that the adoption of digital scribes was deemed marginally acceptable and appropriate, as well as marginally usable by oncologists. However, the study did not demonstrate a reduction in clinician burnout. Moreover, the study was constrained by a small participant pool, and it did not investigate the long-term effects of digital scribes on clinician burnout.[17] As healthcare institutions grapple with increasing workplace efficiency, the impact of these technologies on reducing HCWs burnout must be a central focus. Additionally, increased workplace efficiency may have a perverse and unintentionally effect on morale as health systems push HCWs to see more patients to optimise profit margins. Developing a regulatory framework that monitors efficiency measures with HCWs well-being and patients' outcomes will be necessary to mitigate this potential downstream effect.

Inbox management and digital health communication

Another facet of the administrative burden is the time clinicians spend responding to inbox messages and other digital forms of healthcare-related communication. The electronic inbox has become an overwhelming aspect of medical practice. Historically, managing administrative tasks was an implicit part of the job for physicians, interacting with regulators, payors and vendors. However, the shift to a digital platform has led to an unchecked increase in volume. Several factors contribute to this surge:

1. Federal regulations, such as the mandate from the Department of Health and Human Services for immediate release of test results, have doubled patient inquiries via patient portals, often about sensitive information.
2. The financial structures of healthcare, including the preference for copays during in-person visits over patient portal interactions, have encouraged more portal use for patients. The bureaucracy of prior authorisations and equipment renewals adds to the workload without additional pay.
3. Healthcare delivery organisations have shifted tasks previously handled by support staff to physicians, under the guise of 'free' physician time. This results in physicians burdened by tasks inconsistent with their qualification level, such as clerical work and minor clinical queries.
4. Commercial pharmacies, through automated systems designed to reduce their costs, flood inboxes with unnecessary prescription renewal requests.

Prepandemic data showed that family physicians spend 1.5 hours daily on inbox management.[12] US clinicians receive almost triple the inbox messages compared with their international counterparts, with over a third being system-generated and of low value. Patient messages, while constituting only 3% of the total, demand more time and careful handling. These have increased by 157% since the pandemic's onset and have remained high. Patients now expect immediate, real-time access to their physicians for non-urgent matters, a service that some institutions promote as a competitive advantage. Yet, the healthcare system lacks the supportive care teams and compensation models to effectively provide this service. Additionally, with increasing patient portal registrations, patients are messaging clinicians more often, thus increasing the time clinicians spend in EHRs dramatically.[18]

Services such as Generative AI and Co-Pilot offer promising avenues to address the issues of inbox management and digital healthcare communication. Autocompletion of text while typing or templating/drafting responses to the deluge of messages has the potential to accelerate response times and inbox clearance.[19] These advanced tools leverage NLP and ML algorithms to categorise, prioritise and respond to a high volume of patient inquiries, appointment requests and other routine communications. By automating repetitive tasks, healthcare professionals can focus more on patient care, reducing response times and improving the overall efficiency of healthcare services. Furthermore, these AI systems can be trained to recognise urgent requests, ensuring critical health issues are addressed promptly, thereby enhancing patient safety and satisfaction. While the research on this subject is still emerging, a study by Ayers *et al* demonstrated that AI chatbot responses to patient questions are a possible solution. Ayers *et al* performed a cross-sectional study with 195 randomly selected patient questions from a social media forum and showed that chatbots can generate higher quality and more empathetic responses to patient questions than physicians could.[20]

Automated billing and coding

Implementing AI in medical billing and coding could substantially lighten the administrative burden on doctors. Medical professionals currently dedicate a significant amount of their time to billing tasks, which takes away from patient-focused activities.[21] This process is multifaceted, encompassing coding, insurance claims and addressing denials, all within a tightly regulated industry. Keeping pace with regulatory changes demands ongoing education and adaptability, adding to the stress of the job. Accurate and prompt billing is critical to a practice's revenue, and mistakes can result in significant financial repercussions. Interactions with insurers can be complex and contentious, often leading to extra work and tension. Despite the intention behind EHRs and billing systems to make the process smoother, they can at times be unwieldy and error prone.

By ensuring accuracy of billing codes and congruency between physician and nursing notes, AI can reduce chart errors, improving billing revenue cycle and the time physicians spend correcting charts. In a retrospective cohort study, Kim *et al* showed that NLP in combination with ML predictive modelling using Random Forest, had an 87% accuracy with the CPT billing codes generated by their billing department for elective spine surgeries.[22] Emerging AI technologies like Iodine's AwareCDI Suite

have shown that they can help hospitals with better utilisation management, optimise coding and improve revenue.[23] Though we are in the infancy of automation for billing practices, a potential exists for large-scale administrative savings lies ahead and health systems must balance the cost of buying AI venture-based medical coding software with the potential long-term administrative cost savings. As healthcare institutions grapple with workplace efficiency, they must invest in research and prioritisation of AI technologies that aid in reducing clinicians' documentation, medical coding burdens and bring the HCWs back-to-the bedside.

AI TO REDUCE COGNITIVE LOAD

AI presents a transformative approach to mitigating the complex, decision-based cognitive load on healthcare providers, which is a significant factor contributing to workplace stress. The implementation of EHRs has led to a massive data deluge and fragmented landscape of data sources, creating inefficiencies,[24] consuming resources and leading to care delays that inflate healthcare costs. Despite industry efforts to streamline data ecosystems, health information remains chaotic and HCWs are burdened with sifting through massive quantities of data to find relevant information for a particular encounter. As digital data proliferates, there is a pressing need for integrated AI and human intelligence solutions to effectively organise medical data, which would substantially decrease the time clinicians invest in compiling medical histories, reduce healthcare costs, enhance patient care efficiency and address access to care issues.

Reducing cognitive load through information synthesis

AI excels in synthesising vast amounts of healthcare data into coherent summaries and intuitive visualisations, enhancing comprehension and decision-making for healthcare providers. It can aggregate and interpret complex medical information from various sources, presenting it in a simplified format that highlights key insights. While preliminary studies show promise, research by Ando *et al* brings to light the current gaps—particularly, AI's struggle to emulate the nuanced, tacit knowledge that physicians possess, often leading to summaries that may lack the depth of human-infused clinical reasoning.[25] Though the authors note that AI output editing by a clinician can bridge this gap, discharge summaries independent of this factor would be far more advantageous.

Private tech companies such as DigitalOwl, Wisedocs offer AI-digital solutions to structure medical data and provide summaries with relevant variables such as patient diagnoses, treatments, medications among other significant findings, but large-scale adaptation of these technologies with proven results has yet to be a reality. Once realised, these summaries of medical records can be traded through directed exchange or query-based exchange across health systems.

Medication pop-up alerts for allergies or drug–drug interactions have inundated clinicians with copious, with at times, irrelevant information. Liu *et al* studied that AI techniques could be used to have more relevant medication alerts which can reduce alert volumes by 54%,[26] thus reducing the cognitive burden on clinicians. Remote monitoring devices is another example where clinicians must sift through copious information for relevant data points. AI can help swift through this data to identify relevant data points or changes in patients' clinical status.[7] If these AI-based solutions are realised, it would reduce physician's burden to integrate various data systems, filter through unstructured medical data, reduce time spent writing discharge summaries and decrease pop-up alert fatigue, thus reducing cognitive burden and bring HCWs back to the bedside. More investment to develop and perfect this technology can result in untold gains.

Reduced cognitive burden through AI-enhanced diagnostics

AI's role in diagnostic support also has the potential to reduce cognitive load on HCW in the realm of diagnosis and problem solving. Numerous studies highlight reduced cognitive burden through AI-enhanced diagnostics. In dermatology, AI-based technologies have diagnosed skin pathologies at nearly the same level as dermatologists for some conditions.[27] Early studies in pathology indicate that a synergistic approach with AI-based technologies and human intelligence results in a far more efficient and accurate diagnostics.[28] By leveraging vast datasets to analyse images, lab results and patient histories, AI algorithms can identify patterns and anomalies that may elude human detection. This support not only accelerates the diagnostic process but also elevates diagnostic accuracy, potentially leading to early detection and treatment of conditions. When health systems integrate these AI technologies into clinical workflows, there potential for increased workplace efficiency, clinical accuracy and overall reduced cognitive burden on HCWs and reduction in the stress associated with medical error.

Forecasting

Predictive analytics powered by AI can forecast patient deteriorations and improve hospital operations by being proactive instead of reactive. Winslow *et al*'s study on ML model for early warning for clinical deterioration has shown a decrease in-hospital mortality as it resulted in early recognition and transfer to intensive care units of sick patients.[29] For physicians, the ability to anticipate and mitigate health issues before they escalate can reduce the stress and unpredictability associated with emergency interventions. This prediction goes beyond clinician burnout. In addition, AI has shown promise in anticipating patient utilisation of healthcare resources. Scheduling, registration, transporters are just a few additional examples where workflow optimisation can be found through intelligent scheduling of outpatient appointments, predicting no-shows, allocating transporters in the

hospital, enhancing bed turnover and anticipating emergent use of healthcare resources.

CHALLENGES AND RISKS OF AI IN HEALTHCARE

While the integration of AI in healthcare offers numerous benefits, it is equally important to recognise and address the potential challenges and drawbacks that may emerge. This section presents a counterpoint perspective, highlighting some critical concerns and the necessity of appropriate values alignment.

Deskilling and over-reliance

A crucial issue at the intersection of healthcare and technology is the potential deskilling and overreliance on AI technologies, such as Large Language Models. As clinicians increasingly depend on AI for diagnostics and treatment recommendations, there is a tangible risk that their clinical skills may deteriorate.[30] This dependency could impair physicians' abilities to make independent, critical decisions, especially in situations where AI systems are unavailable, malfunction or yield erroneous results. Moreover, the dynamic nature of healthcare employment, where professionals often transition between diverse clinical settings, exacerbates this risk.[31] This variability across workplaces underscores the urgency of sustaining and enhancing clinical skills in tandem with AI utilisation. The introduction of AI could also hinder the acquisition of essential skills by medical trainees. Overreliance on AI for decision-making might prevent trainees from developing the critical thinking and problem-solving abilities necessary for independent practice.[32] This could result in increased anxiety and cognitive load if AI systems are not available, particularly in emergency situations.

Changing cognitive demands

The integration of AI in healthcare not only alters the types of tasks performed by physicians but also shifts the cognitive demands placed on them.[33] While AI is adept at handling routine tasks efficiently, it often leaves physicians to manage more complex and challenging cases. While this shift has the potential to offer intellectual stimulation by engaging healthcare providers with high-level medical problems, the continual exposure to such high-stress scenarios without the balance of less demanding tasks could inadvertently exacerbate burnout.[34] The constant demand to tackle only complex cases might also diminish job satisfaction and long-term engagement, as the variation in task difficulty—often linked to career longevity—is reduced. In addition, issues around the explainability of AI systems can exacerbate these tendencies, hindering HCWs ability to communicate effectively with patients and make informed decisions.[35]

Exacerbation of feelings of patient-healthcare worker alienation

Widespread integration of AI in healthcare could intensify feelings of alienation between patients and healthcare workers. As AI assumes greater responsibilities, the essential human touch in patient care might become less prevalent, potentially diminishing patient satisfaction and trust.[36] Additionally, healthcare workers may feel marginalised by AI technology, concerned about job displacement or the devaluation of their professional skills. This concern is underscored by developments such as generative AI nurses, which operate at significantly lower costs compared with human nurses.[37] Such cost efficiencies may pressure healthcare systems to view human workers as replaceable elements within AI-driven workflows. This is just one of many concerns that the deployment of AI could lead healthcare providers and institutions to prioritise financial efficiencies at the expense of meaningful improvements in patient care (ie, the pressure to streamline operations, reduce costs, and boost revenues might overshadow the potential of these technologies to enhance care quality or improve patient outcomes).

Equity concerns in AI integration into healthcare

The integration of AI in healthcare surfaces significant equity concerns, as it could perpetuate and even exacerbate existing health inequities on personal, systemic and structural levels. AI systems are typically trained on existing data, which mirrors the biases and disparities found in current healthcare practices.[38] Consequently, AI algorithms might unintentionally reinforce these inequities, resulting in diagnostic and treatment recommendations that could disproportionately disadvantage marginalised populations. Moreover, the adoption and distribution of AI technologies across healthcare systems underscore additional equity issues. Advanced AI systems are more likely to be implemented in financially robust, urban academic hospitals, enhancing their healthcare services and efficiency.[39] In contrast, rural healthcare systems and those serving historically marginalised communities may lack the resources to adopt these technologies, potentially widening the health service quality gap between urban and rural areas.

The commercial nature of AI development further complicates these equity issues. Often, the drive for profitability outweighs social responsibility, leading companies to prioritise marketability and cost-efficiency over the identification and correction of biases in AI models. This approach differs markedly from the motivations of independent researchers focused on ethical considerations and public health outcomes, who are more likely to address these biases.

MITIGATION STRATEGIES

To address the challenges AI introduces to healthcare workforce dynamics, it is crucial for systems to implement continuous education programmes that evolve with technological advancements, emphasising the development of diagnostic and decision-making skills. HCWs must balance the efficiency benefits of

AI with vigilant oversight of its outputs, fostering a culture of critical engagement to enhance capabilities without compromising care standards. Transparency is additionally key and involving healthcare workers in the design and implementation phases can align AI technologies with user needs, improving effectiveness and confidence in clinical settings. Moreover, creating an environment where AI supplements rather than replaces human capabilities is essential, ensuring fair compensation and recognising healthcare workers to help mitigate AI's perceived threats. Finally, stringent regulatory oversight and proactive bias correction in AI applications are necessary to prevent potential inequities, ensuring AI technologies promote health equity and access, enhancing patient care and supporting healthcare workforce dynamics effectively.

In conclusion, while AI has the potential to transform healthcare by reducing administrative burdens and enhancing diagnostic capabilities, it is imperative to remain cautious and address the accompanying risks. Ensuring continuous training, balancing financial considerations and maintaining the human element in patient care are essential steps to mitigate the negative impacts of AI integration. By taking a measured approach, healthcare systems can harness the benefits of AI while safeguarding against its potential drawbacks.

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REFERENCES

1 World Health Organization. Burn-out an 'occupational phenomenon': international classification of diseases. May 28, 2019.
2 Li CJ, Shah YB, Harness ED, *et al*. Physician Burnout and Medical Errors: Exploring the Relationship, Cost, and Solutions. *Am J Med Qual* 2023;38:196–202.
3 Hodkinson A, Zhou A, Johnson J, *et al*. Associations of physician burnout with career engagement and quality of patient care: systematic review and meta-analysis. *BMJ* 2022;378:e070442.
4 Berlin G, Burns F, Essick C, *et al*. Nursing in 2023: how hospitals are confronting shortages. McKinsey & Company; 2023. Available: https://www.mckinsey.com/industries/healthcare/our-insights/nursing-in-2023
5 Bateman T, Hobaugh S, Pridgen E, *et al*. US healthcare labor market. Mercer; 2021. Available: https://www.mercer.com/content/dam/mercer/assets/content-images/north-america/united-states/us-healthcare-news/us-2021-healthcare-labor-market-whitepaper.pdf
6 The complexities of physician supply and demand: projections from 2019 to 2034. Washington, D.C, USA Association of American Medical Colleges; 2021. Available: https://www.aamc.org/media/54681/download?attachment
7 Gandhi TK, Classen D, Sinsky CA, *et al*. How can artificial intelligence decrease cognitive and work burden for front line practitioners? *JAMIA Open* 2023;6:ooad079.
8 Rajpurkar P, Chen E, Banerjee O, *et al*. AI in health and medicine. *Nat Med* 2022;28:31–8.
9 Obermeyer Z, Emanuel EJ. Predicting the Future - Big Data, Machine Learning, and Clinical Medicine. *N Engl J Med* 2016;375:1216–9.
10 Khan B, Fatima H, Qureshi A, *et al*. Drawbacks of Artificial Intelligence and Their Potential Solutions in the Healthcare Sector. *Biomed Mater Devices* 2023;1:1–8.
11 Aquino YSJ, Rogers WA, Braunack-Mayer A, *et al*. Utopia versus dystopia: professional perspectives on the impact of healthcare artificial intelligence on clinical roles and skills. *Int J Med Inform* 2023;169:104903.
12 Arndt BG, Beasley JW, Watkinson MD, *et al*. Tethered to the EHR: Primary Care Physician Workload Assessment Using EHR Event Log Data and Time-Motion Observations. *Ann Fam Med* 2017;15:419–26.
13 van Buchem MM, Boosman H, Bauer MP, *et al*. The digital scribe in clinical practice: a scoping review and research agenda. *NPJ Digit Med* 2021;4:57.
14 Quiroz JC, Laranjo L, Kocaballi AB, *et al*. Challenges of developing a digital scribe to reduce clinical documentation burden. *NPJ Digit Med* 2019;2:114.
15 Wang J, Lavender M, Hoque E, *et al*. A patient-centered digital scribe for automatic medical documentation. *JAMIA Open* 2021;4:ab003.
16 Steinkamp J, Kantrowitz JJ, Airan-Javia S. Prevalence and Sources of Duplicate Information in the Electronic Medical Record. *JAMA Netw Open* 2022;5:e2233348.
17 Nguyen OT, Turner K, Charles D, *et al*. Implementing Digital Scribes to Reduce Electronic Health Record Documentation Burden Among Cancer Care Clinicians: A Mixed-Methods Pilot Study. *JCO Clin Cancer Inform* 2023;7:e2200166.
18 North F, Luhman KE, Mallmann EA, *et al*. A Retrospective Analysis of Provider-to-Patient Secure Messages: How Much Are They Increasing, Who Is Doing the Work, and Is the Work Happening After Hours? *JMIR Med Inform* 2020;8:e16521.
19 Baxter SL, Longhurst CA, Millen M, *et al*. Generative artificial intelligence responses to patient messages in the electronic health record: early lessons learned. *JAMIA Open* 2024;7:ae028.
20 Ayers JW, Poliak A, Dredze M, *et al*. Comparing Physician and Artificial Intelligence Chatbot Responses to Patient Questions Posted to a Public Social Media Forum. *JAMA Intern Med* 2023;183:589–96.
21 Blanchfield BB, Heffernan JL, Osgood B, *et al*. Saving Billions Of Dollars—And Physicians' Time—By Streamlining Billing Practices. *Health Aff (Millwood)* 2010;29:1248–54.
22 Kim JS, Vivas A, Arvind V, *et al*. Can Natural Language Processing and Artificial Intelligence Automate The Generation of Billing Codes From Operative Note Dictations? *Glob Spine J* 2023;13:1946–55.
23 Landi H. Iodine software rolls out AI solution to tackle a major hospital challenge. Fierce Healthcare; 2024. Available: https://www.fiercehealthcare.com/health-tech/iodine-software-rolls-out-ai-software-tackle-major-hospital-challenge
24 Howe JL, Adams KT, Hettinger AZ, *et al*. Electronic Health Record Usability Issues and Potential Contribution to Patient Harm. *JAMA* 2018;319:1276–8.
25 Ando K, Okumura T, Komachi M, *et al*. Exploring optimal granularity for extractive summarization of unstructured health records: Analysis of the largest multi-institutional archive of health records in Japan. *PLOS Digit Health* 2022;1:e0000099.
26 Liu S, Kawamoto K, Del Fiol G, *et al*. The potential for leveraging machine learning to filter medication alerts. *J Am Med Inform Assoc* 2022;29:891–9.
27 Esteva A, Kuprel B, Novoa RA, *et al*. Dermatologist-level classification of skin cancer with deep neural networks. *Nature New Biol* 2017;542:115–8.
28 Steiner DF, MacDonald R, Liu Y, *et al*. Impact of Deep Learning Assistance on the Histopathologic Review of Lymph Nodes for Metastatic Breast Cancer. *Am J Surg Pathol* 2018;42:1636–46.
29 Winslow CJ, Edelson DP, Churpek MM, *et al*. The Impact of a Machine Learning Early Warning Score on Hospital Mortality: A Multicenter Clinical Intervention Trial. *Crit Care Med* 2022;50:1339–47.

30 Choudhury A, Chaudhry Z. Large Language Models and User Trust: Consequence of Self-Referential Learning Loop and the Deskilling of Health Care Professionals. *J Med Internet Res* 2024;26:e56764.
31 Sparrow R, Hatherley JJ. The promise and perils of AI in medicine. *INT J CHIN COMP PHIL* 2019;17.
32 Civaner MM, Uncu Y, Bulut F, *et al*. Artificial intelligence in medical education: a cross-sectional needs assessment. *BMC Med Educ* 2022;22:772.
33 Bjerring JC, Busch J. Artificial Intelligence and Patient-Centered Decision-Making. *Philos Technol* 2021;34:349–71.
34 Nazareno L, Schiff DS. The impact of automation and artificial intelligence on worker well-being. *Technol Soc* 2021;67:101679.
35 Markus AF, Kors JA, Rijnbeek PR. The role of explainability in creating trustworthy artificial intelligence for health care: a comprehensive survey of the terminology, design choices, and evaluation strategies. *J Biomed Inform* 2021;113:103655.
36 Sauerbrei A, Kerasidou A, Lucivero F, *et al*. The impact of artificial intelligence on the person-centred, doctor-patient relationship: some problems and solutions. *BMC Med Inform Decis Mak* 2023;23:73.
37 Cameron D. Nvidia wants to replace nurses with AI. Gizmodo; 2019. Available: https://gizmodo.com/nvidia-wants-replace-nurses-with-ai-1851347917
38 Celi LA, Cellini J, Charpignon M-L, *et al*. Sources of bias in artificial intelligence that perpetuate healthcare disparities-a global review. *PLOS Digit Health* 2022;1:e0000022.
39 Koski E, Scheufele EL, Karunakaram H, *et al*. Understanding disparities in healthcare: implications for health systems and AI applications. In: *Healthcare information management systems: cases, strategies, and solutions*. Cham: Springer International Publishing, 2022: 375–87.