Revolutionizing Healthcare: Augmenting AI to Enhance Diagnostic Precision and Clinical Integration

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Abstract:

Achieving an accurate and timely diagnosis is critical to effective healthcare delivery and positive patient outcomes, yet has remained a significant problem throughout the history of medicine. This research paper will delve into how AI can fix this issue, marking the beginning of the evolution of healthcare. Analysis of previous data demonstrated that the use of machine learning and large language models in healthcare was associated with more accurate diagnostic results, as intended. The results indicate that with the aid of AI, the efficiency, accuracy, and overall quality of healthcare delivery can be significantly elevated. Moreover, the adoption of AI-driven diagnostics could reduce the burden on healthcare professionals, streamline clinical workflows, and enable more personalized treatment plans, ultimately transforming patient care and fostering innovation in medical practices.

Introduction:

In April of 2009, Kurtis “Trey” Newbern lay in the hospital bed, burning up with a 105-degree fever (13). His head throbbed as he fought off blurry vision and waves of nausea. He had been at work earlier that day when he first started experiencing alarming symptoms. Trey called his mother, who rushed him to the emergency room to receive a diagnosis and treatment. A nurse checked on Trey and quickly concluded that he suffered from sinusitis (13). Despite his mother’s pleas, the nurse did not perform tests or check-ups, instead opting to use her intuition. She sent him home with Tylenol and directions to drink plenty of fluids. Hours later, Trey awoke in excruciating pain. His mother rushed him to another hospital, where he was diagnosed with bacterial meningitis (13). Trey quickly fell into a coma; within two days, he was dead. The doctors said that if he had been diagnosed twelve hours earlier, he would have survived.

Although an extreme case, Trey’s story illustrates the importance of accurate and swift diagnostics. Trey’s life was taken by the inefficiency and inaccuracy in his doctor’s manual diagnosis. The stakes in healthcare are incredibly high: a correct initial diagnosis can be the difference between life and death. While Trey’s initial nurse meant no harm, humans were fallible, and her mistake was fatal. Machines are capable of performing routine tasks without fear of fatigue or error in judgment. Specifically, artificial intelligence (AI) has immense transformative potential in medicine. AI algorithms could provide the timely and accurate diagnoses that human judgment lacks, ensuring that tragedies like Trey’s death are avoided in the future.

Ancient Medical Diagnostics

Before looking at the effects of AI, it’s helpful to understand the trajectory of the historical diagnostic process. To correctly prescribe treatments, it has always been crucial to identify the correct illness. Long before the recent medical implementation of AI, ancient medical methods and diagnostics had a rich history, dating back thousands of years. The first recorded attempts at medical diagnosis were found in Ancient Egypt and Babylonia, in the Edwin Smith Papyrus (14). Written by Imhotep around 2630-2611 BC, this document was one of the first texts that applied early diagnostic techniques to a variety of medical situations (14). The Edwin Smith Papyrus was first designed as a surgical textbook and started with clinical cases of head injuries and methodically progressed through the body. It showcased the ancient Egyptians' understanding of the connection between the pulse and the heart, as well as the functions of the stomach, bowels, and major blood vessels. The Papyrus, one of the first known medical texts, offers an intriguing perspective on how ancient Egyptian physicians treated disease through observation and logical reasoning.

Around 1069-1046 BC, a Babylonian named Esagil-kin-apli wrote an ancient medical textbook called the Diagnostic Handbook (14). The Diagnostic Handbook marked the introduction of empiricism, logic, and rationality to diagnose sickness or disease. By documenting the symptoms of many different types of diseases, he used logical rules to combine a patient's observable symptoms with their diagnosis and outcomes. The Diagnostic Handbook was a landmark event in the history of medicine, laying the foundations of modern medicine (14).

Ancient Methods of Diagnostics

The lack of proper modern tools and equipment forced ancient physicians to resort to other ways of diagnosis. Through their observation techniques, they were able to find subtle differences and identify diseases in their patients. One physician from Greece by the name of Hippocrates, developed the fundamental use of observation, sparking the development of perceptive techniques (15). For example, over two thousand years ago in ancient Greece, with no other way to diagnose his patients, "[Hippocrates] was the first who believed that [observation] helps recognize the symptoms of each disease" (15). Hippocrates concluded that the diagnosis and treatment of a physical or mental diagnosis was solely based on methods of observation. Hippocrates contributed to modern medicine by establishing the base form of diagnosis. His detailed observations paved the way for centuries to come.

The trajectory of medicine has evolved from early Greek observational practices focused on diagnosing through physical examination to a highly advanced field leveraging technology and data-driven insights for precise diagnostics and personalized treatment. The foundation and framework that ancient diagnostic methods provided helped structure and make modern medicine systematic and effective. This revolution has jointly enhanced the accuracy, efficiency, and accessibility of medical care, leading to improved patient outcomes and a deeper understanding of human health as a whole.

The Importance of Accurate and Timely Diagnosis

Doctors have always understood that an accurate diagnosis can be the difference between life and death. An accurate and timely diagnosis is necessary in healthcare, as it directly impacts patient outcomes. In an experiment conducted in the 20th century, doctors were only accurate with their diagnostics around 71.4% of the time (16). Frequent inaccuracies endangered millions of lives, often increasing the fatality rates of otherwise treatable diseases; inaccurate diagnoses often led to delays in treatment and caused the risks of complications to skyrocket.

Persistent and significant challenges in medicine

One of the major issues in the 20th century was the overwhelming amount of patient data and work that each physician had to complete. Each year, hospitals from around the world generate

vast amounts of data from their health records, medical imaging, and other sources (18). After arranging their patient's data, doctors have to analyze and interpret the information to make accurate diagnoses and make the correct treatment plans. From there, doctors then have to synthesize their data from various sources, including lab results, imaging studies, and their patient's history, in order to form a comprehensive understanding of the disease. Each physician must also stay updated on the latest medical research and protocols, consider the side effects of each medicine that they prescribe, and effectively communicate with other healthcare professionals. Finally, they also have to make separate documentation and reports, describing their findings. Overall, doctors and physicians spent 15.5 hours per week on documentation (23). Doing each step of this process manually, was much slower than viable, often leading to human fatigue, health effects, and a slowdown in processing abilities.

In addition to efficiency, accuracy, and human error were also major drawbacks of manual diagnosis (18). Despite their training, healthcare professionals still cause errors, biases, and diagnostic inaccuracies, which can lead to negative and improper patient outcomes (1). No human is perfect, and even healthcare experts still perform hundreds of misdiagnoses year-round. Physician-led diagnostics further had many systematic limitations. Miscommunication between healthcare providers and patients frequently leads to misunderstandings and diagnostic errors. For example, the effects of miscommunication in healthcare are extensive and can result in "inadequate informed consent, which can lead to malpractice lawsuits" (12). Miscommunication between a clinician and a patient can cause several issues, including misunderstandings about treatment plans, medication errors, decreased patient satisfaction, reduced adherence to prescribed therapies, and ultimately, poorer health outcomes. The surrounding environment, including interruptions and workload, also affected human performance and led to an inconsistent workflow (18).

The Impact of Misdiagnosis on Patient Outcomes

These challenges were further aggravated by the consequences of misdiagnoses, which resulted in false patient outcomes. Without access to modern medical treatments, patients had no means to address a misdiagnosis on their own and had to rely completely on their physician's judgment. When a misdiagnosis occurs, the unsure treatment and delay in appropriate care for the patient could result in severe injuries and even death. While significant advancements had been made since ancient times, there was still room for improvement in ensuring accurate and timely diagnoses to prevent such tragic outcomes.

Since the beginning of 2012, diagnostic accuracies have skyrocketed to 95% (17). This vast increase in accuracy can largely be attributed to the implementation of AI into the healthcare industry (17). As discussed before, one of the major issues of manual diagnostics was physician overload. Computers don't experience fatigue, and their ability to identify patterns allows for a more consistent and accurate analysis of complex data, causing the process to be more efficient

(18). In turn, eliminating the need for breaks would significantly speed the process up, causing it to almost be instantaneous, further assisting and easing the workload. Through pre-trained models, AI can enhance diagnostic accuracy and cause a decline in sub-optimal human errors. AI can further facilitate better communication by providing clear, data-driven insights and recommendations, reducing the risk of misunderstandings.

The Who, Where, When, Why, and How of AI's Introduction

Academic professors from Stanford and MIT first implemented AI systems in healthcare in the 2000s, followed by Microsoft and OpenAI's introduction of the first models for medical diagnostics a few years later (19). AI and the initial machine learning models were implemented at academic medical institutes in the United States and in startups such as DeepMind in the United Kingdom in 2012 (19). In the 1970s and 1980s, AI started to increase its ranges and impacts with new and advanced systems, showed a few developments in machine learning for imaging analysis in the 2010s, and consistent growth onward after 2015, due to the vast advances in machine learning (20). Artificial intelligence was used to lower fatigue and shortages, manage growing volumes of medical data with ease, and improve medicine and treatment planning at a cheaper cost while further enhancing efficiency in the healthcare industry (21). The process of implementing AI in hospitals requires several key steps. First, developers created distinct algorithms by training them with large datasets. This step enables the AI model to learn patterns and make the accurate predictions needed. Next, developers conducted trials and validation studies to prove their model's effectiveness. These studies were crucial for ensuring that their AI systems could sufficiently support or improve upon real diagnostic and treatment methods. Lastly, developers had to introduce their model to healthcare professionals, showing them how to work alongside AI systems (22). As physicians continued to collaborate and get used to AI, new models were constantly developed and refined, improving the accuracy and efficiency of diagnostic and treatment processes.

The Types of Machine Learning Models Used

Integrating AI into the healthcare industry requires many types of models and algorithms. There are hundreds of various AI models in the AI industry, each with different purposes. Some assist with image detection, while others perform categorical evaluation. In the case of improving the healthcare industry by increasing diagnostic accuracy, efficiency, and precision, Large Language Models (LLMs), Natural Language Processors (NLPs), and Generative AI (GenAI) are most practical. Due to their automation, these systems improve disease observation, by analyzing medical images and data more quickly and accurately than human doctors, leading to earlier and more accurate detection rates. LLMs are deep learning models that are pre-trained on vast amounts of data and are also commonly used on large user datasets. An NLP is a machine-learning technology that gives computers the ability to comprehend and act upon human language. NLPs can be used to diagnose a patient with a proper prescription, based on

the patient's needs and concerns. GenAI is an AI system that can generate new ideas, content, and data and thus mimic creativity (20). For example, a partnership between the Mayo Clinic and Google Cloud developed a novel machine-learning platform to support patient care and research in a way that uses the data more effectively and efficiently (20). The project enhanced research outcomes and vastly improved evaluations. As AI models improve further, their integration into healthcare systems will continue to revolutionize diagnostics, improving patient outcomes, and saving countless lives (20).

Initial Problems and Complications

AI's rise in health care was not seamless, contrary to how it's portrayed. Although it took seven years for the FDA to approve the use of advanced AI models in healthcare, the models were still flawed and people misunderstood their cause (24). First off, developing, testing, and integrating AI systems into healthcare infrastructure proved enormously expensive. Due to the limited understanding of AI in the 20th century, the initial reactions were not supportive, and further questioned if the use of AI was needed (25). Additionally, healthcare professionals didn't feel the need to change their work style to accommodate AI (25). Many were accustomed to traditional methods and workflows, which had been honed over years of practice. The introduction of AI was seen as a disruption to these established routines, and there was a general reluctance to alter familiar processes. They felt as if their professions were at risk of being replaced, and the adaption posed new challenges (25). The growing capabilities of AI in diagnosing created a sense of insecurity among healthcare workers, leading to concerns that the unique expertise and judgment they provided might be replaced. This fear of replacement made the adaptation to AI more challenging, as it was not just about learning new tools but also about navigating the uncertainty of their future roles. On the technical side of healthcare, early computers lacked the capabilities and functionalities to process complex AI tasks (26). Without high-end processors, the scope and performance of AI systems were limited and misused (26). AI's initial narrow focus on medical consultation was another leading problem since it was not useful in many specific categories of medicine.

Ethical Dilemmas

The rushed implementation of AI in healthcare introduced unforeseen challenges, particularly regarding patient privacy. Trust in AI to handle a patient's private information became a significant concern, raising questions about the security and ethical implications of using such technology in sensitive medical contexts. The endless consideration and concerns about protecting and ensuring privacy in the hands of AI sparked controversy throughout the field. When AI was first launched, sensitive medical information was not properly protected and was being sold separately. For example, a few genetic testing and bioinformatic companies were reported to have "[sold] customer data to pharmaceutical and biotechnology companies" (2). Such practices were pervasive throughout the industry early on since the low profitability of

small companies incentivized them to sell customer data. Without proper permission from their users, small companies left their users' medical profiles at risk and unaccounted for. Additionally, without a detailed understanding of how AI works, patients didn't fully understand the uses and benefits of AI, sparking disputes for consent. Since the ideology of AI was new and limited, there was widespread skepticism and uncertainty. This lack of understanding made it difficult for patients to fully trust AI-driven decisions in their healthcare, leading to hesitancy and resistance.

One of the more recent debates centers around determining who is responsible when AI makes a mistake. This issue raises questions about accountability, as it is unclear whether the blame should fall on the developers of the AI, the healthcare providers using the technology, or the institutions that implemented it (28). For example, in a research report from UC Berkeley, a machine learning model was shown to "[assign] the same level of risk to Black patients yet sicker than white patients. White patients were given higher risk scores, thus more likely to be selected for extra care" (3). In these studies, an unnecessary bias was placed toward colored patients, compared to white ones. This brings up the concern of racism in AI and another ongoing debate. AI can also reflect racial discrimination and prejudices, as shown in several algorithms used in many hospitals. One of the algorithms was designed to predict which patients needed extra care from their healthcare provider and a larger amount of medicine (27). A 2019 research paper in Science describes how black individuals are more inclined to pay for aggressive hospital visits, such as emergency care while having uncontrolled conditions (27). Due to this concern, Black patients received a lower risk rank compared to their white colleagues and did not qualify for extra treatment as much as white patients with similar conditions (27). To solve these dilemmas and challenges, it is crucial to establish clear ethical guidelines and boundaries. These boundaries must address issues, such as privacy, fairness, transparency, and accountability.

Examples of Current Applications of AI in Healthcare

Despite the several issues in the adoption of AI into medical facilities, the current applications of AI in healthcare are vast and transformative, ranging from medical screening to cancer treatments.AI is already used in cardiac care, to correctly predict which patients might be exposed or suffer from arrhythmias (4). Similarly, in the diagnostic accuracy sector, a landmark study published in Nature showcases "how an AI model outperformed human radiologists in detecting breast cancer from mammograms, showcasing the potential for AI to enhance diagnostic accuracy" (4). AI models can outperform human tasks and manual evaluations. In a timely and efficient manner, these models can easily detect whether a patient has breast cancer using the vast datasets, and training based on their sample data (4). New algorithms are continually being developed, providing crucial support to doctors in their medical tasks and rapidly improving in effectiveness (4).

In addition to this progress, AI is also currently being implemented in various hospitals, one of which is the TidalHealth Peninsula Regional Hospital, located in Maryland. In the past year, TidalHealth faced numerous challenges regarding its Clinical Decision Support, since it had been inefficient and inaccurate (33). To solve this issue, TidalHealth incorporated AI into its processes, as an innovative and cost-efficient solution (33). The AI model that IBM provided them to implement into their clinical decision support involved an "AI solution [that combined] clinical decision support and AI with patients' electronic medical records, making it easier to find relevant and useful information. [...] The hospital cut time per clinical search from 3-4 minutes to less than 1" (33). TidalHealth's largest area for improvement was their response times, and their usage of AI eliminated the need to spend more time than necessary.

Another case study of AI's current implementation in medical facilities is through the Megi Health Platform, a spinoff of the Magdalena Clinic. The main challenge that the organization faced was centered around the optimal use of their highly trained medical staff (34). Instead of burdening their talented employees with repetitive tasks such as gathering medical history and reminding patients to record measurements, the Clinic knew that they had to solve the issue somehow. To do so, they created an AI health platform, called the Megi Health Platform (34). The system could automate the mainstream tasks and could even "facilitate the two-way exchange of valuable data and information" (34). Using an AI-automated database that can store patient information, the Magdalena Clinic was able to leverage AI and solve their recurrent issue. Although there are countless ways in which machine learning algorithms can be used to assist healthcare in current practices, these algorithms could also be used to discover and create new ones.

Global medical companies around the world are using AI to not only assist their current practices but to also make new ones. For example, Johnson & Johnson partnered with the Mayo Clinic to "[enable] researchers to develop more targeted medicines, driving progress toward precision medicine" (5). Without the aid of artificial intelligence, the process of developing new medicines could take months and even years. The evidence shown by Johnson & Johnson showcases the impact of AI in the process, driving efficiency and accuracy into the workflow. Not only is AI being used to develop new medicines, but to even "help prioritize which locations will be greatly impacted to quickly respond to risk factors that may otherwise affect the ability to deliver products to people who count on them" (5). One of the largest issues worldwide is the issue of product availability and reliability. With the automation of delivery and prioritization, those in marginal communities who experience a higher severity of effects from disease can receive their medications faster.

Future Applications of AI in Healthcare

Given the broad scope of AI today, the future potential appears boundless. AI performs manual tasks at a higher level than humans, leaving little room for manual impact. The automation of

many human tasks raises the issue of whether AI will supplement or replace the current system. The answer to this question lies in the careful integration of AI into the current diagnostic system. While AI can automate many tasks and achieve performance levels that exceed those of most humans, it should be viewed as a tool designed to enhance and support human capabilities rather than replace them entirely. By leveraging AI to handle routine or complex tasks, physicians and healthcare workers can focus on areas that require creativity, critical thinking, and interpersonal skills. This approach allows AI to complement human efforts, leading to more efficient workflows and innovative solutions, while preserving the essential roles that only humans can fulfill (4). As shown through many hybrid AI models, “Utilizing AI-driven virtual reality (VR) simulations, students can practice surgical techniques or patient interactions in a completely safe, controlled environment, gaining confidence and proficiency without the risk of real-world consequences” (4). Students can leverage AI for their benefit, and mutually grow from the collaboration. Using AI as an opportunity to learn and benefit, AI won’t systematically replace jobs but would provide support and reinforce their workflow. While this might be the case for a few sectors, certain medical roles could be in danger due to the upbringing of AI, and at risk for termination (29). Having an AI model as support can go two ways; it can either replace or double-check. In some medical fields such as X-ray scanning, AI can act as a second reviewer, “decreasing the human workload by 44 percent” (6). At the moment, AI can only act as an assistant, but it is certain that in the distant future, a vast range of medical roles will be replaced.

AI in Skilled vs Monotonous Tasks

AI is effective at handling monotonous tasks, but its performance in more skilled or complex tasks is still under evaluation. Currently, medical facilitators around the world use AI in high-risk scenarios, such as, “AI-powered surgical robots ... [assist] surgeons with tasks such as suturing and tissue manipulation” (7). Not only can AI automatically perform routine tasks, but it can also highly perform skilled tasks, including surgical assistance. In contrast, AI is seen to reduce monotonous tasks in many medical jobs by automating their work, and alleviating stress for humans. For example, “AI can automate data entry tasks, extracting information from various documents and inputting it into relevant systems” (8). After learning and processing several datasets, an AI model can increase user productivity, reduce errors, improve customer service, and also optimize cost savings. The range of tasks that AI can automate range from data entry and invoice processing, all the way to financial analysis and risk assessments (29).

Timeline for AI Development and Implementations

A proper timeline for the implementation of AI can stem from its recent developments. With the proper understanding and usage of machine learning algorithms in healthcare, anything can and will be possible. Short-term advancements would include a wider, more adapted range of AI, in cases such as analyzing medical images like X-rays, CT scans, and MRIs (30). Mid-term

advancements include further integration and broader applications of AI; AI systems will become more advanced and accurate in predicting patient outcomes, disease research, and potential health risks (30). This time range would be most beneficial for the upcoming AI in healthcare since it involves significant advancements and evolutions (30). Long-term advancements, occurring 10 years from now, would include, “Advanced AI-powered brain-computer interfaces could help restore function for patients with neurological conditions or injuries” (9). As technology continues to advance, breakthroughs, the potential for AI seems to be endless. This example with brain-computer interfaces depicts its ability to revolutionize treatment for neurological conditions and injuries (9). Looking toward the future, the impacts of AI in medicine could reshape our understanding of health and diagnostics, allowing for innovations that were once dismissed with the limitations of science (9). The evolution and implementation of AI into healthcare will likely be one of the most significant developments of the coming decades.

Pneumonia and Correlation

AI is used to detect hundreds of diseases, including Pneumonia. Pneumonia is a lung infection that causes inflammation and the buildup of fluid and water in the air sacs in one or both lungs (31). Pneumonia is more common than you think. It causes more than one million hospitalizations and more than 50,000 deaths each year (31). A doctor can often diagnose pneumonia based on symptoms and a chest exam, but it can sometimes take a few days to get results from tests. An AI model can do it in seconds (10). According to research on community-acquired pneumonia, those with weak immune systems, asthma, diabetes, a history of heart failure, or smoking are more likely to experience pneumonia-related problems (11). They also state that pneumonia accounts for a sizeable portion of hospital admissions as well as deaths. It is thus necessary to identify the disease in patients as soon as possible.

Without the use of AI, medical providers use chest X-rays, blood tests, and pulse oximetry (32). A chest X-ray looks for inflammation in the lungs and is one of the most common ways to manually diagnose pneumonia. Blood tests are used to depict whether an immune system is fighting an infection, through the analysis of a patient’s blood health and purity (32). Pulse oximetry is a technique used by doctors to examine a patient’s oxygen level in their blood; low blood pressure would hint at the development of pneumonia (32). Each of these methods of pneumonia detection shares one element, each is inefficient and cost-consuming. With the use of AI, both of these downsides can be addressed. AI models can analyze and go through thousands of chest X-rays with remarkable speed and accuracy, even identifying signs of pneumonia that might be missed by the human eye (32). By reducing the time required for diagnosis and increasing the likelihood of detection, AI algorithms are crucial for the most effective treatment plan. From a blood test, AI can also quickly identify patterns that can indicate infection. After processing and learning from datasets, a machine-learning model can then provide insights that help doctors accurately assess a patient’s needs and medical concerns (32). In the case of pulse oximetry, AI can continuously monitor and analyze levels of oxygen

without any support. Advanced algorithms can detect anomalies and potential complications before the effects take place, allowing for time interference. With these integrations and continuous monitoring, AI can save both time and resources for healthcare facilities, filling in the gaps of manual diagnostics.

Recently, AI experts from around the world have been developing automized pneumonia algorithms and models, one of which is PneumoCare. Pneumocare's AI can integrate data from EHRs, including patient history and symptoms, to provide a more comprehensive view of the patient's health and improve diagnostic accuracy. Based on the diagnosis and patient data, the AI can suggest personalized treatment plans in a mere second, considering factors like age, existing health conditions, and medication interactions. PneumoCare differentiates itself from manual diagnostic methods since its processes can take as little time as 2 seconds, and its accuracy levels are unmatched. In 2024, PneumoCares's accuracy was around 96% whereas manual diagnostic accuracy was around 85%. Another problem that this model addresses is the lack and shortage of radiologists. There is a critical lack of trained radiologists to interpret a large number of chest X-rays or blood tests required for an accurate diagnosis of pneumonia. This shortage can lead to vast delays and incorrect prescriptions (11).

Conclusion

As healthcare continues to evolve and expand, it is necessary to address aspects in which it still underperforms. Integrating AI into diagnostic processes can revolutionize the field of healthcare by enhancing diagnostic accuracy and efficiency, and thus improving patient outcomes. By leveraging and using AI to analyze vast amounts of data and identify patterns, we can mitigate the limitations of traditional diagnostic methods, reduce diagnostic errors, and enhance overall healthcare delivery. Embracing technological advancements in AI offers a path toward a more precise and effective approach to medical diagnostics, benefiting patients and healthcare professionals alike.

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