Deep Science Publishing
https://doi.org/10.70593/978-81-988918-5-3_12

DeepScience
Open Access Books

Chapter 12: Exploring the future of artificial intelligence, cloud, and data-driven innovation in healthcare delivery

12.1. Introduction to Healthcare Innovation

Innovations in healthcare can enable better quality care at lower costs, decrease medical errors, decrease geographic disparities in healthcare access and economic disparities in healthcare quality, and increase biomedical research productivity. The fundamental economic and organizational characteristics of the healthcare delivery system create a complex environment for developing, disseminating, and implementing innovations. Distinguishing characteristics of this environment include health as a major driver of well-being, the major role that regulation plays in the delivery system, favoring patient safety and equity of access to quality care; the private and public financial coverage systems that pay for most healthcare services; and the distinct clinical and operational strategies for patient populations or types of medical services and procedures. There are also substantial differences among the stakeholders in developing and adopting innovations. The relative risk and risk aversion of the users and the developers affect the extent and rate at which innovations are adopted and adapted. Misalignment of the incentives for adoption of innovations can delay, impede, or reverse what could be widespread dissemination of promising innovations (Kuo, 2011; Jiang et al., 2017; Reddy et al., 2019).

This paper focuses on innovations that result from applying information technologies to managing data. In particular, we analyze several promising innovations that utilize information innovations to create enhanced cloud-based Electronic Health Record Systems that permit active clinical analytic behavior of practitioners. The first innovation is the development of active clinical data collection systems for clinicians and patients. These jointly-created and curated sources of current data on patient medical and behavioral histories, clinical processes, and treatment responses become knowledge

resources for providers, payors, and regulators. We advocate the expanding use of these resources for creating universal, actionable intelligence of how medical care processes and outcomes vary across patients, specialties, and regions as the guide for improving the quality of medical care and decreasing its costs (Ristevski & Chen, 2018; Wang et al., 2018).

Fig 12.1: Exploring the Future of AI, Cloud, and Data-Driven Innovation in Healthcare Delivery

12.1.1. Background and Significance

The historical context of AI, cloud, and data innovation in healthcare dates back to the early developments to enhance computer-based medical decision-making in the 1970s. Advancements in machine learning and AI, in accordance with the ever-expanding use of big data in healthcare, coupled with the industrialization of high-speed affordable computing power for algorithm processing and increases for healthcare operations efficiencies have reignited the promise of using AI to enhance and/or automate human decision-making in healthcare. As examples, the purpose of certain AI systems was to enhance medical decision-making by humans, assisting oncologists in offering the

optimal treatments based on patient profiles, risk factors, disease stage, etc. Other companies have sprung up to address other medical decisions, accelerating eye disease detection. Coupled with the advent of open-source software, making sophisticated AI algorithm implementation easier, these developments have helped usher in a new wave of AI implementations for healthcare delivery improvement and innovation. AI boasts the potential to make the healthcare delivery system more efficient with better outcome quality.

In brief, the convergence of AI, cloud, data, and associated systems innovation offer a unique opportunity to accelerate and improve healthcare delivery innovation. While it's certainly not a silver bullet to all challenges faced, it can: Reduce point-of-care disruption; Rationalize better-supported clinician decision-making; Streamline leading-edge clinical protocol adherence; Leverage machine-generated insights to improve chronic disease management; Shorten diagnostic windows; Propagate patient-doctor virtual engagement; Drive new patient-centric delivery models; etc.

12.2. The Role of Artificial Intelligence in Healthcare

The application of AI technologies in the healthcare domain is ubiquitous, ranging from clinical support systems to workflow and working environment optimization, from advanced patient management solutions to predicting health outcomes for early treatment intervention, from hospital administration systems to tools handling big patient data and/or clinical information. Among the different types of AI technologies, the most advanced examples are based on deep learning, reinforcement learning, advanced natural language processing, and AI solutions integrated within robots, for instance, autonomous robots, autonomous exoskeletons, and teleoperated robots for surgical assistance. Closely related to AI utilization in clinical applications and workflows is the overall social mood on the benefits, risks, and restrictions of AI applications. It is different in different countries, but is changing. Among the AI clinical applications, the most developed and ready to be widely utilized are based on medical images analysis, electronic health records mining, and accelerating biomedical research breakthroughs.

While much has been achieved with AI applications, the promises of AI applications have not yet been fulfilled. Saying that AI is capable of doing miracles and taking the lead in healthcare delivery would be a hyperbole. AI is anticipated to improve how healthcare is delivered, improve healthcare services, and realize anticipatory healthcare processes. AI will be an enabling advanced technology to provide healthcare services in a timely, accurate, effective, equitable, and financially viable manner, entailing enhanced decisions by physicians, accelerated patient treatment and recovery, and thus lowering hospitalization and treatment costs.

12.2.1. AI Applications in Diagnostics

Machine learning algorithms are currently used in a variety of medical applications. Most notably in the areas of disease diagnostics and prognostics. AI has also made significant inroads into the enhancement of medical images in order to assist radiologists. These capabilities are derived primarily from advances in computer vision and natural language processing. Because computer vision finds its ultimate impact by emulating human sensitivity to visual stimuli, ML-based algorithms have been used to detect anomalies in images of the lungs, skin, eyes, breast, and colon, among others. Machine vision systems have achieved sensitivity and specificity comparable to or exceeding those of trained radiologists in detecting breast cancer from mammograms, diagnosing certain skin cancers from images, and interpreting arrays of retinal fundus photographs. ML algorithms trained on datasets of chest X rays have also provided diagnostic support for detecting pneumonia and used to look for signs of tuberculosis. Furthermore, deep learning algorithms have achieved state-of-the-art accuracy in detecting lung disorders using a large public dataset of chest X rays.

Pretrained computer vision and natural language processing algorithms increasingly leverage continuous learning to enhance their diagnostic accuracy. A skin cancer patient who has a tumor removed provides an augmentation to the image dataset for the tumor type. If the image shows a skin texture or color specific to the type of skin cancer, it becomes a highly accurate mask to delineate the tumor area. The radiologist and patients are also providing additional data points for precise radiation treatment delivery through video communications instead of in-person consultations. Furthermore, early detection of a number of serious, highly morbid diseases and pathophysiology of disease through accurate computerized image analysis has made the greatest inroads in radiology.

12.2.2. AI in Patient Management

Artificial Intelligence (AI) is laying the groundwork for new paradigms in patient management and support, specifically through early detection, risk prediction, supportive symptom management, and guidance. Out of the variety of functions, enabling active human support and remote monitoring of patients are the most important by opening new economic opportunities of patient management. AI can enable remote management and optimization for huge populations with the investment of a small resource input on the patient side, and it can enable other non-physician actors to do the heavy lifting of managing relationships with patients and normalizing patient data before clinical interpretation becomes necessary.

Various current functions and projects are proof-of-concept for the prospect of a new level of patient support. In this case, a physical robot has conversational abilities and a

variable emotional guest design to hold conversations with elderly people, increasing cognitive performance. Others are centered on creating chatbots with the purpose of addressing the needs of specific patients. The training data, thereby, derives from written communication samples to help inform the AI. Prominent areas of research within chatbots for patient management lead efforts in diabetes management, whereon specialized chatbots give support in the area of dietary compliance, or weight management, where virtual coaching provided by chatbots develops into additional training during clinical trials.

12.3. Cloud Computing in Healthcare

Modern Healthcare is moving toward the digital ecosystem that offers a better user experience to consumers as well as enables organizations to leverage data effectively. Stakeholders are in search of an efficient technology platform that enables them to share and use data effectively to identify new services, methodologies, clinical insights, devices, etc. Cloud computing is one of the enabler technologies. Nowadays, it is becoming necessary to build a cloud-enabled architecture to be ready for creating and delivering new products and services based on the intelligent use of data. The cloud provides a flexible way to enhance data management, storage, sharing, and processing among different partners involved in the delivery of services as well as new service providers entering the healthcare ecosystem. Innovators are creating applications in the biotechnology, physical, and life sciences that accelerate the development, testing, adoption, and use of biopharma, hospitals, and payers. Healthcare is an ecosystem among different stakeholders that include consumers, hospitals, physicians, device manufacturers, insurance, and pharmacies. Solution providers are rethinking problems of healthcare from an ecosystem point of view. These involve solving issues like wellness, care, diagnosis, and patient commitment, coordination, and sharing. For this innovative capability, stakeholders are creating a cloud-based architecture that provides a more granular data sharing and analysis capability. The importance of the cloud as a tool for creating an effective data management and sharing capability has been seen in the implementation of the HITECH Act in the U.S. With changes in requirements and use cases, the cloud is becoming an important enabler of the healthcare ecosystem. On the other hand, healthcare organizations are concerned about the risks and costs that may be incurred with its implementation to manage patient data. Even with the differences in opinion about cloud technology, CIOs are considering using cloud-enabled architecture. The data flow and business processes for different stakeholders are evolving to identify innovative services and solutions delivered to consumers in a more effective and efficient manner. Thus, we find the importance of studying the impact of the cloud in enabling the change in the data-enabled architecture of the healthcare ecosystem.

Cloud Infrastructure performs some functions that have controlled the cost and a valuable evolution for ameliorating structural time and Cost Pressure. The Problems of Overheating of Servers, Space Constraints, IT Support, Capital Outlay Can Be Handled using Cloud as it Completely Removes Hospital Concerns. The Application Authorisation Process is Simplified with the role changes thereby removing logistical problems inherent in the Adoption of On-Premises Applications. All activities with regard to Security and Redundancy are taken care of Customer, Application Setup Becomes Easier as they are Located at One Facility, Used with Different Systems and upgraded dynamically. Additional Resources can Be Called on Easily and Quickly and also can be Shut off Implicitly. Cloud Computing as a Service Model brings Quiet Advantages as Compared to In-House Hosting: Reliability, Scalability, Cost, Security, Simplicity, Accessible from Anywhere and Backup and Recovery are taken care of.

Fig 12.2: Cloud Computing in Healthcare

12.3.1. Benefits of Cloud Adoption

Utilization of Cloud Computing in Healthcare provides varied opportunities to enhance institutional working processes and health care delivery. Cloud Computing has opened

new doors for innovation and development in Hospitals, thereby prompting the hospitals to move towards Cloud-based services which are much cheaper and reliable. Cloud offers Healthcare a low-cost option for supporting expansive Data Storage capabilities, with charge-back Incentives for Out-sourcing non-core applications. With Cloud computing Hospitals can reduce maintenance Cost of Hardware equipment, help doctors to access their Informatics remotely, Patients to guide post treatment regimen, a Centralized patient database to retrieve all their historical Fact, and enable Coordination between the Health Care fraternity more interactive. Cloud offers ample opportunities to improve the work environment of professionals, give better decision support to Institutions, and In the end bring about better health care delivery. Cloud-based approaches not only support currently existing medical activities but also pave new pathways into the future of digitally supported health care.

Cloud adoption by Hospitals provides Enhanced Flexibility as Compared to On-Premises set up due to varying Demand.

12.3.2. Challenges in Cloud Implementation

One of the biggest challenges in cloud implementation in healthcare is the security and privacy risk of sensitive health data. There have been cases of data breaches in layers of the healthcare system because of cloud service technical weaknesses or non-technical weaknesses. These have raised concerns about security flaws in the cloud system. The migration of health records to the cloud has changed the risk landscape and added new security network outsourcing risks. The existing security use and risk guidelines for traditional IT infrastructures are insufficient to secure the data in the cloud while abiding by the government rules and regulations.

Another challenge is the interoperability issues that arise from adopting multiple cloud services. An organization may adopt different types of cloud services for varied purposes or join a cloud alliance. This creates an increased level of diversification and complexity in healthcare cloud computing. Many healthcare organizations will likely adopt cloud computing in different forms to address varying needs. This diversity of cloud structures creates complications in interoperability and data exchange in subclouds or between clouds. A full potential of cloud in improving patient outcome or in reducing the costs of treatment would only be realized through optimal information sharing across multiple cloud systems. Interoperability is critical to achieving the goal of cloud computing and the future sustainability of the data-driven healthcare model.

Technical support is another major challenge that IT departments face during cloud system implementation. Many healthcare organizations do not have the resources to ensure that cloud computing runs smoothly and efficiently within their organization.

Organizations that have limited internal technical expertise might struggle when implementing cloud-based tools and services that require a higher degree of technical support.

12.4. Data-Driven Decision Making

The current trend in orientation towards knowledge-based economy and increased economic competition is pushing organizations worldwide towards a better use of the data and information they manage. Data is one of the most valuable resources a company may possess; once collected, properly processed and analyzed, data is able to provide valuable knowledge to companies, which can be then used to achieve better organization performance and strategic planning, thanks to better decision making and support in their daily work. Companies usually leverage large volumes of data, mainly entered but then hardly exploited in data repositories, known as data warehouses, or company's operational systems. Many companies in the past years shifted their investment priorities from the implementation of Enterprise Resource Planning systems, aimed at integrating all organizational processes, to the development of large data warehouses, to be fed by operational data coming from these integrated systems, and the use of Business Intelligence techniques and solutions. The goal of this investment shift is the need of exploiting the power of the data a company may leverage. In particular, by means of data mining and data warehousing solutions, a company is able to discover knowledge hidden in its data.

In particular, in the health care sector, companies are investing heavily in large data warehouses and are adopting data-driven decisions. In fact, healthcare provides a critical foundation to the economy and there is an increasing demand for a healthier population. Making informed decisions in the healthcare industry has a significant impact on achieving collectively desired goals. With the advent of cloud technologies, increased broadband speeds, and consequently low-cost data availability, rich data sets surrounding the patient are generated. These data sets can be mined for insights that allow significant healthcare process improvements in the industry through better algorithms enabling faster and more accurate diagnoses as well as predicting relapse and recommending critical care needed for high risk patients.

12.4.1. Importance of Big Data in Healthcare

The creation of watertight data channels and the associated processes has tremendously enhanced the collection, storage, and transmission of data, making it possible to collect enormous amounts of data for research and business across all sectors, including healthcare. The so-called four Vs of Big Data — volume, variety, velocity, and

variability — define its characteristics that foster numerous opportunities and challenges for researchers and business practitioners alike, whether in the private or the public sector. Broadly speaking, Big Data is defined as data that has grown disproportionate to our analytic capabilities, containing other types of data such as structured, semi-structured, and unstructured data. The increase of digitally available healthcare data and additional sources, such as sensor and image data, are anticipated to trigger new data analytics methods and tools capable of handling the unique features of Big Data. And this also applies for the healthcare sector. Data analytics tools and techniques are also vital for capabilities that generate data-driven decisions for innovative digital healthcare products and services.

The increasing electronic generation of data in the healthcare domain and its various sources makes it reasonable to predict that Big Data will be part of the routine managerial experience in the next 3-5 years, not just for private, but also for public healthcare firms. However, several challenges exist. Managers in the healthcare domain have not been trained in the analytical tools needed to create, or at least influence, data-driven decision making in their organization. Furthermore, many of the existing tools and techniques for analyzing Big Data are still being tested or are being experimentally implemented, with researchers unpacking the unique features of Big Data and addressing the lack of a robust, well-tested, theoretically-grounded foundation to achieve accurate and actionable insights for data-driven decision making. Yet, the healthcare industry's increasing dependence on advanced analytics processes, applied by healthcare, medical, and pharmaceutical firms, ultimately requires the use of current, and validated methods and techniques for Big Data analytics.

12.4.2. Data Analytics Tools and Techniques

The variety and complexity of data requires sophisticated tools and new ways to look at it in order to draw useful conclusions. This requires the development of new technology which has occurred over the last three decades in order to answer critical business questions. Technology is an extension of the human body and without the proper instruments we cannot progress. We have always improved on the instruments available. Powdered glass and clay lenticular lenses from the 13th century allowed the invention of the eyeglass. Optical telescopes using glass lenses and glass mirrors allowed people to think about the earth orbiting the sun. Microscopes allowed for the discovery of cells. The stronger and lighter steel implements allowed us to build cathedrals. Big Data technology is a new instrument to allow us to take advantage of unprecedented amounts of information. It is nothing but an extension of our brain to help organize and make conclusions out of excessive amounts of numbers.

The advent of systems, blurring the boundaries between research and business intelligence, Big Data around the business at large, a massive increase in computing power and new algorithms and tools have allowed the proper management of complexity in complex adaptive systems such as health care to become a reality. These changes have profound implications on the nature of research and care models and on the type of research needed. With the development of data analytics, health care has come up with ways to make better decisions that improve the lives of real patients. Data at scale is key to develop structural data-driven decisions.

12.5. Integration of AI and Cloud Technologies

The integration of AI and Cloud Technologies can deliver enhanced outcomes for patients. It enables the flexible and accessible development of domain-specific models that exhibit functional expertise within their operational constraints established by the principal health stakeholders. These delegated experts can in turn become the architects of AI-based health solutions far beyond the ability of any centralized laboratory. Specialists can generate and use personalized models that are secure, ethically compliant, and transparent. Models deployed in the cloud can be optimized and regularly curated on a coinvestment basis between the domain experts and the technologists who develop the enabling tools and infrastructures.

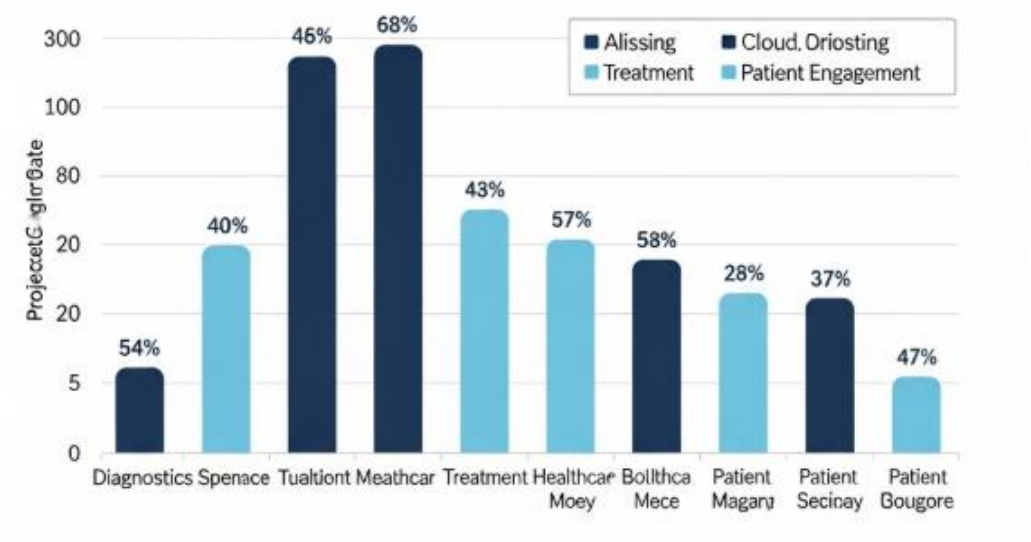

Fig : Exploring the Future of AI, Cloud, and Data-Driven

This partnership can alleviate the cost barriers of AI system development and health resource allocation. It would allow for multiple parallel, federated models to be rented to clinicians across diverse patient populations and health ecosystem environments. This

would enable the continuous and efficient adaptation and micro functionalization of the base models suitable for specific patient populations either by motivational end user centric UIs or by federated model circuitry built into the core functions. Democratization of AI in the Health tech space makes it easier for motivated individuals to create solutions suitable for culturally diverse, subtle needs. The impact of these ethical, operational changes on the integrity of the health ecosystem dynamics based on trust is expected to be positive, and moreover measurable as a robust rallying point for future donor, institutional, and governmental financial support.

12.5.1. Synergies Between AI and Cloud

Cloud computing and AI are two of the most influential technology trends in recent years. AI research and development now take advantage of the scale, low cost, and theoretical underpinnings of cloud services, while cloud services are being rapidly enhanced with AI services such as augmented analytics, AI-enhanced security, and AI-based cloud automation. AI and cloud services are therefore two elements of an interconnected technology ecosystem that is reshaping economic foundations. Hundreds of technology and service companies are increasingly integrating AI and cloud services, with the offering, delivery, and management of models and AI-enhanced services forming core areas of investment and innovation. Cloud-based AI development will become easier and accelerate as low-code/no-code application development environments are enhanced with AI capabilities, new tools become available, and enterprise and application developers have access to central repositories of reusable AI models, ML pipelines, training datasets, and other elements, integrated with workflow and software development lifecycle tools. We expect to see greater reliance on crowdsourcing for model and dataset development, especially in areas where scarce skills slow progress and where businesses and organizations have the ability to contribute and share their resources, expertise, and capital. Cloud service providers will offer better life cycle management functions, including support for continuous retraining and monitoring of deployed AI models. Enhanced services will make it easier to take advantage of multi-cloud and hybrid cloud infrastructures for enterprise applications. Models, datasets, and pipelines will be better integrated with the functions and elements of popular application development frameworks. Cloud-based services will allow a more diverse set of stakeholders, partners, and collaborators to participate in AI model development. Security, compliance, and regulatory services in these areas will mature.

12.5.2. Future Trends in Technology Integration

In the next several years, AI will be integrated with cloud computing so closely that trying to separate them will not make sense. Consequently, when we address our AI bucket, essentially we are talking about multiple cloud services. Our AI bucket will look more like our cloud service bucket. That change has several massive repercussions. First, clouds will deliver experimentation and MLOps tools that make it easy to use AI. Simulators can replicate or stimulate the situations an AI needs to encounter in the real world, but in a synthetic way, allowing for the rapid parallelized training of different AI. Reinforcement learning takes time to train AI models, but with the right simulation framework, that time can be dramatically reduced. Tool makers are building these frameworks. Cloud providers will deliver these tools as services to make it easy to experiment, test, build, and deploy both traditional, heuristic-based AI as well as models that use RL in a simulated environment. Clouds are already delivering these services across the entire model lifecycle, from pre-training specialists to MLOps tools to infrastructure and tooling specialists. Some of them integrate tightly with clouds. This whole stack will be seamlessly integrated with cloud services to enable self-service experimentation using proprietary and third-party models.

Second, enterprise applications will embed AI more and more deeply. An AI or ML service hosted in the cloud will be able to assist or automate decisions associated with enterprise application processes - for example, scheduling, underwriting, loan approval, KYC, arrest, or career assessment.

12.6. Conclusion

Healthcare is a major focus of the 21st century and exposed to great challenges that are solvable with the help of AI, Cloud and Data-Driven Innovations. These have the potential to improve quality of life and increase longevity substantially. However, this technological innovation is not only focused on solving actual problems. Also, the increase in life expectancy leads to aging societies that are already putting a strain on national and social budgets, increasing actual problems of healthcare delivery. This contribution outlined some actual problems in healthcare delivery which have been targeted with innovative solutions that build on Cloud Computing and Data Analytics based AI Innovation. Research efforts to advance these technologies in their technical aspects have to be in focus. However, we have to recognize that these technologies can only result in global healthcare evolution if Cloud- and Data-Driven solutions based on AI are incorporated early and substantially into established and increasingly functioning Digital Health Ecosystems. Such ecosystems are being created from various stakeholders in this area. Starting from Research Institutions and National Health Services, that actually organize and pay for healthcare to provider institutions and

technical solution providers who create the real solutions. In order to be effective and efficient at the same time these Digital Health Ecosystems have to combine in a community and co-creation style. Standards in various fields have to be defined. We hereby emphasize a high degree of flexibility in the defined standards to be able to adjust to each health system ecosystem or local healthcare delivery tasks context-dependent. In our opinion, later individuals cannot wait for Global Standardized Solutions generated by a one size fits all and need already solutions supported with Data- and Cloud-Centric AI Technologies.

12.6.1. Future Trends

New healthcare models such as Telehealth Telemedicine, or Tele-Care, are evolving thanks to the cloud-based Technology Adoption. Offering continuous care, availability, and convenience at affordable prices, the new models are increasingly utilized by patients, healthcare systems and providers, generating massive amounts of patient and clinical data. With the advent of sophisticated AI Services, including Machine Learning and Advanced Analytical, Predictive and Streaming Analytics tools, unprecedented insights about the patient and care processes can now be extracted from the big data. AI is expected to positively influence several trends:

1. Customized and personalized care delivery processes will stem from Continuous Activity and Environmental Monitoring, Smart Sensors and IoT. Personalized care process analytics coupled with Behavioral Genetics and Social Determinants of Health predictive models, will enable healthcare providers to target patients at risk earlier than ever.

2. Healthcare will increasingly be focused on the population and the patient; acute care will represent just the tip of the iceberg. The subclinical phases of chronic diseases, including heart failure, diabetes, chronic obstructive pulmonary disease, and hypertension, currently considered only managements, will eventually be targeted by the healthcare systems for prevention and protocolized interventional therapy. The reduction of costs and the comparative analysis of multiple treatment pathways will demand integrated systems involving the use of experienced organizations in the data mining and pathologic detection.

3. Health Information Exchanges will bloom thanks to a national and coordinated effort envisioned in the new Health IT Exchanges. National HIEs will allow integrated treatment pathway analytics, as well as compliance, and conformance with established protocols. With a growing amount of discriminating data, HIEs will also federate with private datastores and biomedical companies and develop predictive analytics for the most common pathologies.

References

Jiang, F., Jiang, Y., Zhi, H., Dong, Y., Li, H., Ma, S., Wang, Y., Dong, Q., Shen, H., & Wang, Y. (2017). Artificial intelligence in healthcare: Past, present and future. Stroke and Vascular Neurology, 2(4), 230–243. https://doi.org/10.1136/svn-2017-000101

Reddy, S., Fox, J., & Purohit, M. P. (2019). Artificial intelligence-enabled healthcare delivery. Journal of the Royal Society of Medicine, 112(1), 22–28.

Kuo, A. M.-H. (2011). Opportunities and challenges of cloud computing to improve health care services. Journal of Medical Internet Research, 13(3), e67. https://doi.org/10.2196/jmir.1867

Wang, Y., Kung, L., & Byrd, T. A. (2018). Big data analytics: Understanding its capabilities and potential benefits for healthcare organizations. Technological Forecasting and Social Change, 126, 3–13. https://doi.org/10.1016/j.techfore.2015.12.019

Ristevski, B., & Chen, M. (2018). Big data analytics in medicine and healthcare. Journal of Integrative Bioinformatics, 15(3), 20170030. https://doi.org/10.1515/jib-2017-0030