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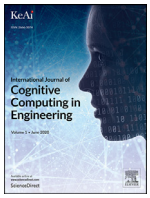

Evolutionary trends in progressive cloud computing based healthcare: Ideas, enablers, and barriers

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ABSTRACT

Cloud computing is one of the significant facilitators of the health information revolution in the healthcare business. The global exchange of records in the health sector through electronic media is facilitated by cloud computing. In healthcare, this technology increases safety and creates innovation. Communication with the health matrix throughout the world makes feasible by the application of this technology. Cloud computing has been utilised in health care for many years and has evolved in conjunction with developments in business. This technology establishes standard accessible hardware for diverse healthcare applications via a network connection. Cloud computing and processing ensure safe communication, and the cloud servers secure all essential data. Doctors can counsel their individuals on their health and broadcast their patient's daily health regimes, typically keeping their minds and bodies healthy. Psychologists and psychiatrists can use videoconferencing that makes patients comfortable with their patients. This paper discusses cloud computing and its need for healthcare. Major key advantages, barriers, and challenges of Cloud computing for the healthcare industry are identified. Finally, it discusses the significant applications of cloud computing for healthcare. Today more and more healthcare suppliers are providing Internet of Things (IoT) enabled gadgets to patients, and patient data are instantly communicated to their doctors by linking such devices to the cloud system of hospitals. As a result, cloud computing, in conjunction with fast-expanding technologies such as Big Data analytics, artificial intelligence, and the internet of medical things, improves efficiencies and expands the number of ways to streamline healthcare delivery. It improves resource availability, improves interoperability, and reduces costs.

1. Introduction

Cloud computing is the next turning point, despite all the concerns, in the digital transformation of the healthcare business. Hospitals and other non-IT-specific enterprises take full advantage of this technology. In healthcare, this technology is helpful for a digital medical component that captures data from hospitals, other institutions, and patient records and reports on the diagnosis. The global health cloud computing market will increase rapidly over the next few years with favourable signals from the healthcare industry (Liao and Qiu, 2016, Roy et al., 2018, Sultan, 2014). A comprehensive list of functions is supplied for various cloud computing providers' healthcare industry-related demands and requirements. Thus, health practices quickly deactivate, extend, and contract new capabilities (Ahuja et al., 2012, Griebel et al., 2015).

The health organisation's objective is to enhance clinical results and people's quality of life. The flow of improvement in a person's health improves the general population's health, reducing the financial expenses of maintaining a healthcare system. Many healthcare organisations still have traditional IT systems or technologies that cannot interact (Doukas & Maglogiannis, 2012, Dang et al., 2019). This limits clinicians' capacity to acquire information promptly and accurately, helping them make better educated clinical judgments. The extensive use of cloud-based patient care documentation facilitates sharing of information among doctors, the outcomes of interactions between other doctors and patients,

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and treatment. Cloud computing outlines how remote servers to store, save, manage, and process data over the internet, rather than constructing an on-site data centre, using servers, or hosting the information on a computer (Calabrese & Cannataro, 2015, Sobhy et al., 2012, Chauhan & Kumar, 2013).

A health service would need to spend considerably on the infrastructure and maintenance to handle all the internal operations connected to storage, data processing, transfer, and cooperation. Things have altered substantially with the introduction of cloud computing, even though much growth is already taking place in healthcare institutions. This has aided in the development of facilities and infrastructure and has also opened up new paths in medical research, making it multidisciplinary for the benefit of humanity. Cloud computing has found its way through technological breakthroughs to allow medicine in various ways. There are certain evident instances where cloud computing has aided inpatient treatment, such as offering medical facilities virtual consultation even in the most remote places (Darwish et al., 2019, Hanen et al., 2016, Mehraeen et al., 2017, Ma et al., 2015).

Cloud-based infrastructures have contributed to the discovery of various vaccines by clinical scientists and health professionals worldwide, supporting specialists to provide the necessary information to produce a potent antigen. Cloud-based services provide colossal support and strengthen the health infrastructure by enhancing the accessibility and interoperability of information. The cloud brings value to the organisation with various methods to save costs, simple data access, enhanced security, and efficiency. Efficiency and productivity improvements are typically far more than cloud and safety. Healthcare companies can improve productivity and deliver better services to their clients, which are essential because they can consider their business (Kumar & Nirmalkumar, 2019, Hu et al., 2012, Cimler et al., 2014). This paper discusses the significant potential of cloud computing for healthcare.

2. What is cloud computing?

In its most basic form, Cloud computing entails storing and accessing data and programs over the internet rather than on the computer's hard drive. Customers who use cloud computing do not own the infrastructure; instead, they rent it from a third-party supplier. On-demand self-service, broad network access, resource pooling, and rapid elasticity are essential properties of cloud computing and cloud services. Cloud computing's popularity is growing because of its multiple advantages. One element that allows organisations to deliver cloud services is avoiding high software license expenses. They rely on the internet. Cloud resources are accessible across the network at any time and through a standard method that encourages the usage of various platforms (Cho et al., 2014, Fong & Chung, 2013, Rallapalli et al., 2016).

Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS) are the three basic categories of cloud computing. IaaS is the foundation for cloud computing. It usually gives users access to networking capabilities, computers, and data storage. IaaS allows one to have the most flexibility and control over the IT resources. It is comparable to existing IT resources that many IT departments and developers are already familiar with. The second type, PaaS, eliminates the need to manage the underlying infrastructure, allowing one to focus on application deployment and management. This allows one to be more productive because one will not have to worry about resource procurement, capacity planning, software maintenance, patching, or any other undifferentiated heavy lifting that comes with running an application. The third type, SaaS, gives a fully functional product managed and maintained by the service provider. Most of the time, when people talk about SaaS, they are talking about end-user applications (such as web-based email). The service is well maintained, along the underlying infrastructure is managed (Stantchev et al., 2014, He et al., 2012, Lubamba & Bagula, 2017, Singh et al., 2021).

3. Need for cloud computing for healthcare

Much data is produced daily in the healthcare business. The time is necessary for providers and patients to make these data securely available remotely. Health cloud computing allows organisations to get rid of limits while providing better results for patients. Cloud computing reduces operational expenses and provides individualised treatment for healthcare providers. In addition, the adoption of cloud solutions contributes to efficient workflows and improves service. At the same time, patients obtain faster health industry replies. Cloud solutions provide access to healthcare information. It allows individuals better to monitor their health (Doukas et al., 2010, Elmogazy & Bamasak, 2013, Gao & Sunyaev, 2019, Masrom & Rahimli, 2014).

Doctors and health professionals deliver world-class solutions with cloud computing services. It is processed fast and quickly using user-friendly cloud tools to generate concisely, easy-to-refer information that enables analysts to evaluate and deliver guided therapies. The need to save time for both patients and healthcare professionals helps boost online health consultation and seamless support for remote health care (Haleem & Javaid, 2020, Skondras et al., 2018). Healthcare has worked on traditional systems for a long time but has recently seen several needs for digital transformation. Wearables and virtual medicine have enabled patients to receive personalised care at times necessary. The increase and the demand for interoperability across electronic health record technology platforms have given birth to a demand for cloud-based technology, which provides secure, fast, and cost-effective solutions for many applications (Lee et al., 2015, Muhammad et al., 2019).

4. Research objectives

Health cloud computing can contribute to improving resource sharing. It provides a very effective medical monitoring and management system while reducing enormous operating expenses. Cloud-based radio-frequency identification technology enables safe, effective, and high-quality monitoring and administration of medical data. It can assist in offering state-of-the-art outcomes in transmission, smart health monitoring, and accurate placement. IoT Cloud is the newest innovation combining several internet-connected technologies to offer real-time solutions in numerous locations and settings. The rise of IoT finds its application in any way, from chronic illness management to the avoidance of different health issues, has benefited immensely from health care. Cloud and internet integration in healthcare offers several advantages, including high dependability, high efficiency, virtualisation, and scalability (Salih & Lilien, 2015, Ratnam & Dominic, 2014, Akrivopoulos et al., 2017). The four major objectives of this paper are as under:

RQ1: - To study cloud computing and its need for healthcare and technologies assisting cloud computing for healthcare;

RQ2: - To discuss the key advantages of cloud computing for the healthcare industry;

RQ3: - To study the barriers and challenges in adopting cloud computing for healthcare;

RQ4: - To identify and discuss significant applications of cloud computing for healthcare;

5. Key advantages of Cloud computing for healthcare

In today's world, cloud computing is constantly revolutionising healthcare. According to Global Markets Insights Inc, the healthcare cloud computing market will be worth $55 billion by 2025. In addition to scalability and storage, today's healthcare businesses are increasingly turning to cloud technology for its impressive capabilities such as collaboration, accessibility, efficiency, and security, to name a few. First, as a Software as a Service (SaaS), the cloud may provide on-demand hosted services to healthcare businesses, allowing instant access to business applications and customer relationship management (CRM). Infrastructure

Fig. 1. Key advantages of cloud-based technologies in the healthcare system.

as a Service (IaaS) can provide medical facilities with on-demand computing and massive storage. Finally, as a Platform as a Service (PaaS), the cloud can provide a secure environment for web-based services and cloud application deployment (Alzoubaidi, 2016, Goli-Malekabadi et al., 2016, Padhy et al., 2012).

More than just delivering medical information from many computers, anywhere, and any mobile device is at the heart of cloud-based healthcare transformation. It is also about the advantages of linking medical centres and cloud users to share patient health data through the Internet. Cloud computing in healthcare is cost-effective and easy to install, with many other benefits that can be put to good use. As a result, cloud-based services provide invaluable assistance and help improve the health infrastructure by making data more accessible and interoperable. There are several advantages of cloud-based technologies used in healthcare systems (Devadass et al., 2017, Aceto et al., 2020, Javaid et al., 2020, Kumar et al., 2018). Fig. 1 shows some of the key advantages of these technologies.

Sophisticated security technologies and protocols are available for additional security levels in cloud computing. In order to prevent sensitive information, cloud providers are needed to adhere to regulatory obligations relating to electronic medical records. Cloud technology can provide feedback on medical information, analyse it in real-time, and ultimately enhance patient-centred and data-driven healthcare. Cloud-based data analytics may help generate accurate and focused marketing campaigns and promotions utilising business info from several sources (Alharbi et al., 2016, Kuo et al., 2011). This makes it much easier for physicians to work with patients. Doctors have been able to keep a separate medical file for each patient they treat. Cloud technology synchronises and distributes this information in real-time across offices. This technology helps with trouble-free data storage and backup scalability and cuts back during congested daylight periods. In addition, social distancing tactics necessitate remote consultation with patients with minor symptoms (Ali et al., 2018, Bamiah et al., 2012, Rajabion et al., 2019).

Cloud deployment and upgrades are faster than hosting software onsite. The management of cloud services is relatively less expensive and does not cause consumers to stop their service. Health care providers and their patients encounter services with the highest bandwidth and speed with speedier services. Cloud platforms include ML and AI, which help companies handle large volumes of customer data and do data analysis across numerous contact points of healthcare services (Tyagi et al., 2016, Abdelaziz et al., 2018, Seddon & Currie, 2013). The general use of cloud-based data storage technologies in healthcare has generated the potential to enhance patient care outcomes. Researchers may use the cloud in their own time and at a fraction of the cost to utilise supercomputer-like analysis capabilities. All data previously unavailable in the filing cases are searchable and analysed by employing the most complicated available computer algorithms with the arrival of cloud computing (Gavrilov & Trajkovik, 2012, Hoang & Chen, 2010).

6. Potential drivers of cloud computing for the healthcare industry

Fig. 2 exemplifies the various critical and potential drivers-sum-enablers of cloud computing to enhance the healthcare domain's overall performance. There are two advantages to moving to the cloud for healthcare. Both healthcare practitioners and patients have benefited from it. On the commercial side, cloud computing has been shown to help lower operating costs while allowing providers to provide high-quality, tailored treatment. Patients who have become accustomed to receiving treatments can now receive the same level of care from the health sector. The major observed drivers' areas are big data concepts, Artificial and machine learning concepts, telehealth techniques, high powered analytics, etc. Cloud computing has further improved patient outcomes by increasing patient participation in their health plans by providing access to their healthcare data (Jindal et al., 2018, Singh et al., 2017, Jemal et al., 2015, Mohammed et al., 2014).

Cloud computing provides the best solutions to healthcare demands that are cheaper, quicker, and more personalised. It can significantly contribute to medical and epidemiological research, illness prediction, and clinical trials. Cloud analytics support hospitals through cloud analytics, predictive analyses, AI-based tools, and resources in evidence-based decisions. Cloud analytics can continuously monitor the results by analysing them from different linked medical equipment. Healthcare providers should strategise which cloud-based solutions they can use to meet their goals: marketing, analysis/diagnostics, patient monitoring, prevention, and management (Liu et al., 2018, Nur & Moon, 2012).

A firm with a remote employee needs to expand up to manage people remotely swiftly. It also required reduced costs, continuing operating expenses, and compliance with stringent safety and privacy rules. There was no flexibility to grow the existing local infrastructure fast and effectively, nor could additional users be incorporated within an acceptable period. Strategic work included creating an IT operating model, assessing cloud platforms and tools, and developing strong proof. The cloud architecture enables developers to swiftly deploy resources and work remotely, including virtual workstations in the cloud. This also removes the difficulty of managing hardware inventory, fixes and virtual desktop infrastructure (Guo et al., 2012, Alshammari et al., 2020, Dzombeta et al., 2014).

Providers of health care do not have to worry about their cloud data management. Health care practitioners may focus on the essential areas of healthcare with the help of competent IT specialists monitoring and controlling the system. Cloud computing facilitates the monitoring of

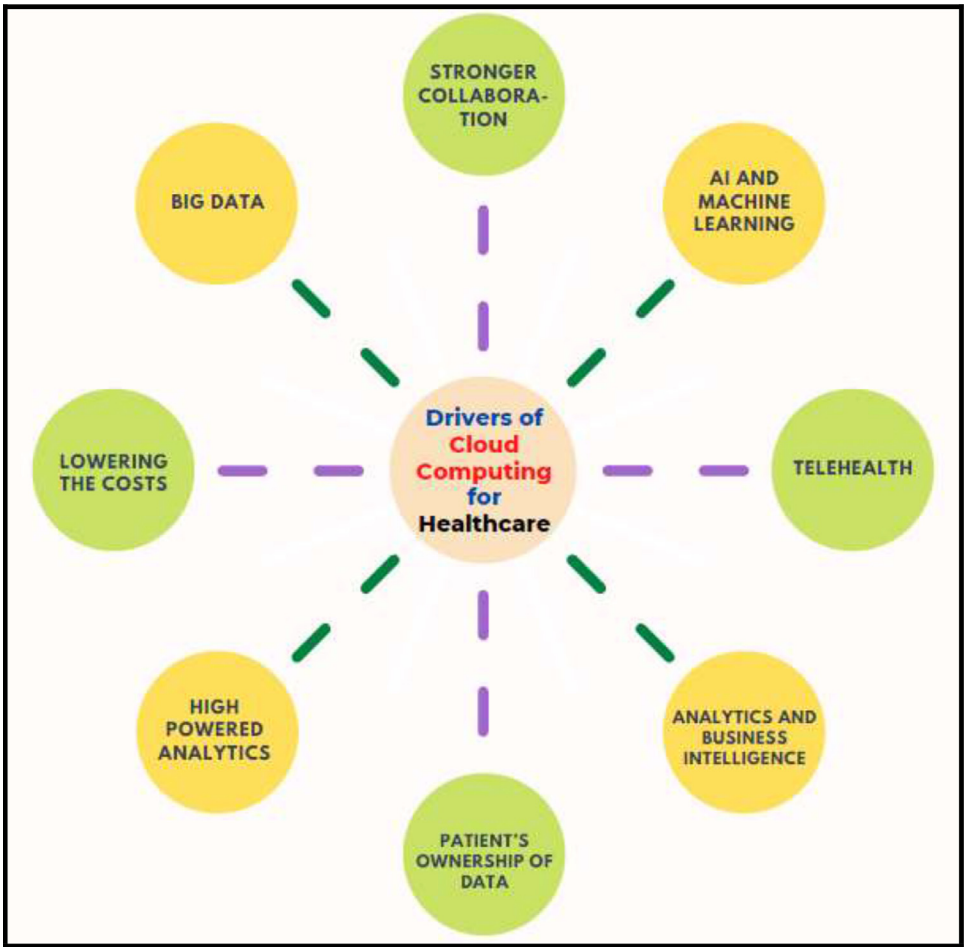

Fig. 2. Impactful Enablers of Cloud Computing for Healthcare.

payments by healthcare providers. Moreover, investments in significant and costly infrastructure are not necessary. Choosing a cloud solution can be far more cost-effective than building physical systems by personalising a plan which corresponds to their demands. Cloud servers can upload, exchange and retrieve information faster so that healthcare professionals, hospitals, research, and financing agencies can collaborate better (Alphonsa & Amudhavalli, 2018, Agarwal & Sebastian, 2016, John & Shenoy, 2014).

The large amount of data created in the healthcare business may be successfully stored and accessed on virtual drives. Cloud computing is utilised to provide services and platforms that aid in managing client data. As a result, many healthcare firms or organisations are offering cloud computing services to their clients in the software, platforms, and infrastructure. These allow for improved information exchange, record administration, and resource allocation in healthcare institutions. The cloud speeds up processes and makes it simple for medical professionals to work together and give treatment as a team via mobile devices, video conferencing, and software designed for health care companies. The capacity of doctors to give high-level treatment to patients has been increased by keeping them in contact with patients and colleagues (Casola et al., 2016, Bamiah et al., 2012, Ijaz et al., 2021).

7. Barriers and challenges in adopting cloud computing for healthcare

The security and system downtimes have always been seen as barriers and limitations for the cloud computing concept when serving the healthcare industry. Fig. 3 explores the numerous concerns and challenges to be undertaken while planning to implement cloud computing practices for the healthcare sector. Furthermore, the switching between the cloud providers and fulfilling the overall security norms have also been coined as the additional barriers and through process concerns for cloud plantation for healthcare. The effects of cyber-attacks, nature sensitively of data, use of smart keys, the flexibility of the overall system, following the regulations and laws, etc. have further given an edge to the entire interactive and impressive implementation of cloud computing tools and technology for the healthcare units (He et al., 2017, Mvelase et al., 2015, Masrom & Rahimli, 2015).

The major limitation of cloud computing is that it provides lesser control of its infrastructure. This is a major problem for enterprises, but the service providers take care of this, giving assurances and signing several contracts. Several customers are managed simultaneously as cloud providers, which can occasionally provide difficulties and support concerns. There are also opportunities for service providers to confront some outages that eventually affect the operations and business of healthcare organisations. Cloud has a trend in many fields and is rapidly embraced by many branches, particularly healthcare, which has been relatively hesitant to upgrade to the cloud solution (Ratnam & Dominic, 2014, Zhou et al., 2014, Kabachinski, 2011).

8. Cloud computing applications for healthcare

Electronic medical records, mobile apps, patient portals, IoT devices, and big data analysis are all supported by cloud computing. Cloud solutions provide easy streamlining and updating appointments and monitoring, financial administration/planning, and preserving patient records and clinical/non-clinical data. In addition, cloud-based smart routing systems can easily handle patient assistance (An et al., 2015, Somula et al., 2019, Javaid & Khan, 2021). Medical imaging may be kept on cloud platforms safely since they can manage and acquire knowl-

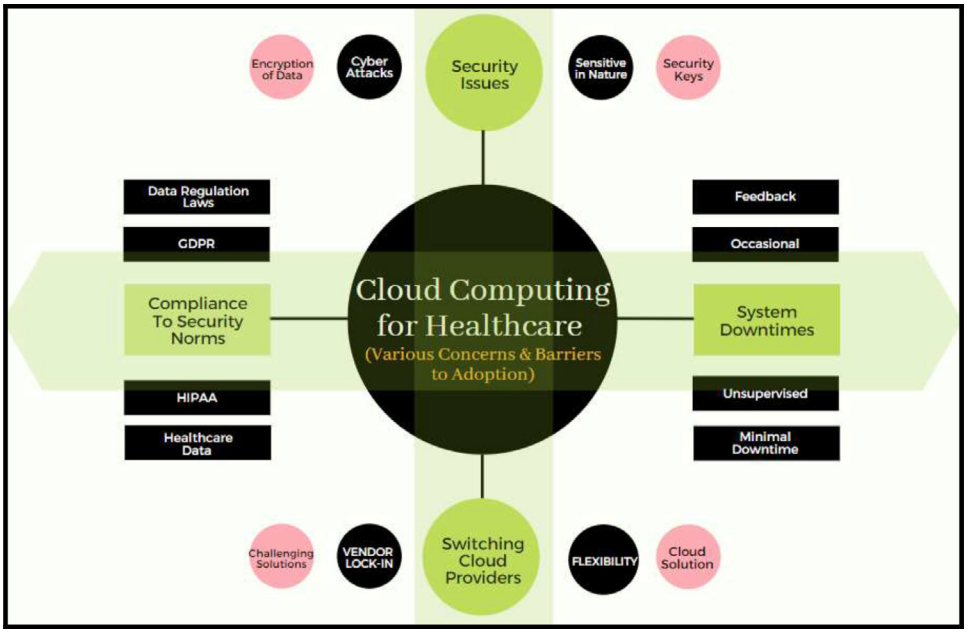

Fig. 3. Barriers and Challenges in adopting Cloud Computing for Healthcare.

edge from enormous data sets that can aid diagnostic support and speed up medical and predictive health research when used with big data analytics. Cloud-based health solutions operate on a subscription basis, which means healthcare organisations. The benefit of a full-service system is a predictable cost model which improves the visibility of monthly operational expenses (Liu & Park, 2013, Youssef, 2014, Brohi, 2014, Bhatia et al., 2020). Table 1 discusses the significant applications of cloud computing for healthcare services.

Cloud platforms operate on the principle of interoperability to gather, analyse and share data from various IoT devices, pharmacies, insurance companies, hospitals, clinics, and healthcare. Using cloud technologies, centralised and decentralised base data may be connected smoothly. Since the electronic health record implementation, collaborative healthcare has been a new standard (Doukas & Maglogiannis, 2011, Mehrtak et al., 2021, Rajini & Beulah, 2016). In order to achieve incredible customised solutions that also help the stakeholders in minimising mistakes and delays in the exchanges of important information, this technology is beneficial. This technology assists healthcare through IoT for efficient information systems (Sun et al., 2021, Bao et al., 2021, Bao et al., 2021). Now a days, technologies play an essential role in healthcare and other areas (Khan and Javaid, 2021, Haleem et al., 2021, Haleem et al., 2020, Javaid & Haleem, 2021, Gupta et al., 2021, Javaid et al., 2021). The cloud delivers on-demand computing, quickly becoming a tool to help, particularly when healthcare institutes and hospitals want network information to be deployed, accessed, and handled. Given the necessity to seek improved storage, cooperation, and data sharing strategies under the health standards, data losses must be prevented (Bhattacharya et al., 2012, Akinsanya et al., 2019, Sandhu et al., 2018).

9. Discussion

The cloud computing solution is incredibly trustworthy for healthcare to exploit their network remotely. Every hospital is now beginning to embrace the solution to safeguard patient records. It enables medical professionals to maintain patient records electronically. This type of method can undoubtedly enhance the safe storing capacity of information. Nowadays, doctors make it easy for patients to cooperate with mobile, video, and application technologies. Cloud computing makes it possible for patients to receive better treatment and communication. Cloud-based IoT services can transform a comprehensive system of healthcare. IoT cloud may also be utilised to create databases, combining the cloud with intelligent information systems for hospitals. The IoT-associated integration enables the data collection from different sensor devices in real-time sensor systems. These gadgets are linked through various methods and locations to the hospital system. A cloud with IoT may be used in hospitals to electronically store all patient records, including photographs, documents, and videos.

Authorised users may access critical information for both the delivery of services and research purposes. In addition, this cutting-edge connection would also allow real-time and low-cost data transmission between hospitals and service providers. It is thus time to use cloud-based IoT technologies to provide efficient services for the healthcare industry. The supplier can mix a wide range of technologies with valuable data sharing to produce a vast data pool. With the backing of a more complicated system, this data collection can make it more significant. The use of cloud computing technologies can enhance the convenience and cost-efficiency of health care activities. The cloud offers the newest technologies for deploying, accessing, and utilising networked information, applications and resources in on-demand computing. The healthcare structure faces several new problems due to the growing needs and expectations. Now health companies may scale millions of electronic patient records with the help of cloud computing. It also combines health information and facilitates hospital, surgical and clinical journeys. Cloud-based healthcare solutions decrease the gap between specialists, enabling them to analyse cases and offer views independently of geographical limits. Cloud computing empowers and enables patients to manage their well-being through the democratisation of data.

10. Future scope

The applications of cloud computing in healthcare have a promising future. This technology will enable physicians to create best-in-class patient journeys supported by tech-enabled care delivery areas such as telehealth and remote monitoring. Cloud computing advancements are critical to improving future healthcare with an ageing population. Many health care clinicians and administrators realise that advances in health care delivery via the use of technology to improve treatment, administration, and efficiency are now urgently needed as a priority. Health care opportunities are already expanding on market advances. Clinical trial researchers strive to determine which medicines perform best for particular patient subgroups. The vital information about surgery and

Table 1
Cloud computing applications for healthcare.

S No	Applications	Description	References
1	Save vast amount of data	Cloud storage solutions can save vast quantities of data at prices that match small, medium, and large healthcare organisations' budgets. If hospitals, laboratories, and physicians switch to cloud storage with pay-by-usage and subscription models, they do not need to invest in sophisticated IT infrastructures. Cloud computing can change the healthcare business with the aid of virtual medicine. Doctors and therapists can provide patients with high-quality personalised therapy online using cloud-based apps and software. Cloud-based devices such as biomass sensors, home care devices, and wearables can give continuous care to patients and quickly detect symptoms of distress and decay by remote monitoring of the heart rate, blood pressure, motion, and other body processes.	(Louk et al., 2014, Glasberg et al., 2014, Abrar et al., 2018, Glaser, 2011)
2	Increase access to the patient	Cloud computing is to give new ways to ensure the information in the healthcare sector. It can also increase access to patients with only a secure internet connection using a device of their choosing from anywhere in the globe. The demands of health care professionals alter with changing times. Cloud technology allows healthcare providers to scale up or down to suit their present demands quickly and cost-effectively. As technology evolves, a cloud-based system allows data and applications to be quickly upgraded. Healthcare providers can track, monitor, and improve cloud computing financial and administrative procedures. It improves the productivity of office management by automating everyday chores. With a mix of fast-growing technologies such as Big Data Analytics, Artificial Intelligence & IoMT, numerous ways to simplify and enhance efficiency may be explored. Cloud computing enhances the availability of resources and interoperability and decreases expenses.	(Khattak et al., 2015, Nirabi & Hameed, 2018, Abawajy & Hassan, 2017)
3	Enhance experience	Working with colleagues in the health care sector can improve patient care and give people affordable care services in conjunction with financing choices. The usage of cloud computing in healthcare provides each stakeholder with a seamless experience to connect and make a difference. Real-time access to patient data is provided through cloud computing. It provides means of finding less efficient locations, highlighting problems with data quality, and more. New capabilities such as machine learning solutions are offered by cloud computing. Collaboration across doctors, departments, and institutions is vital, with healthcare companies migrating to value-driven care payment mechanisms. Medical suppliers can share data via the cloud computing server and enhance cooperation in improving therapy.	(Yang et al., 2020, Narkhede et al., 2020, Lupşe et al., 2012, Karaca et al., 2019)
4	Handle electronic medical record	Healthcare providers must handle electronic medical records, patient portals, mobile applications, and big data analytics. Cloud computing enables health institutions to store all of these data while eliminating additional physical server maintenance expenditures. Healthcare organisations can save money as cloud computing works according to the subscription model. Furthermore, healthcare institutions can use the cloud provider's capabilities to minimise expenses by employing the cloud server. Cloud servers assist in making healthcare providers more secure.	(Singh et al., 2020, Wooten et al., 2012, Marwan et al., 2018, Parane et al., 2014)
5	Security	Cloud computing provides security services to prevent unauthorised access and infringement of risk management and monitoring to their users. It all concerns the analysis of and what the cloud service offers. Before using the cloud, the healthcare area suffered from operating costs, infrastructure costs, and trouble-free communication. Cloud usage gives the healthcare environment a chance to improve patient services. This exchange of information conveniently increases operating efficiency and simplifies expenses. It facilitates and makes medical record exchange safer, automates back-end processes, and makes it easier to develop and maintain telehealth apps.	(Al Nuaimi et al., 2015, Mourya & Idrees, 2020, Haleem et al., 2022, Sun et al., 2012)
6	High-quality treatment	The cloud helps patients obtain high-quality treatment without ever going to a hospital using innovative mobile gadgets to monitor the state of the patient and smartphone applications to keep their doctor informed or get remote moral and medical support. Health organisations are now moving towards payment mechanisms for value-based treatment. Therefore coordination of doctors, divisions, and even institutions is vital. Before the cloud was launched, it was a slow and challenging process to get full copies of medical information. However, all the record data are consolidated using solid cloud architecture to provide immediate access to data everywhere and anywhere.	(Wang & Alexander, 2013, Alharbi et al., 2016, Zickau et al., 2014, Ehwerhemuepha et al., 2020, Lin et al., 2014)
7	Optimum treatment decision	Maintaining patient data changes cloud computing and extensive data analysis, supporting healthcare practitioners to make optimal treatment decisions, decreasing operating expenses, and much more due to its infinite and elastic scalability, high data availability and accessibility, and the desired budgetary shift from equipment to operational cost. Cloud computing provides several benefits for a large spectrum of healthcare stakeholders. The cloud computer allows medical organisations to cope with electronic health records, mobile applications, and extensive data analytics while avoiding the added expense of sustaining physical servers.	(Zhiqiang et al., 2015, Huang et al., 2018, Singh et al., 2019, Javaid et al., 2020)
8	Reduced operating expenses	Cloud computing helps to reduce operating expenses and facilitates high-speed electronic recording systems, patient portals, and mobile apps. With increased data cooperation and clinical trial administration, the cloud has also revolutionised the face of medical research. Now, health workers find it simpler to trace their health records and make informed judgments with the data uploaded to the cloud. The storage and maintenance of large data volumes require more support workers, software, and higher costs. Cloud solutions enable healthcare firms, from inside a centrepiece, to store all rich data and save the unnecessary expense of maintaining physical networks and servers, considerably decreasing overhead hardware expenditures. Health organisations struggle consistently with low funds, pushing them to engage in daily operations that limit their innovativeness. A major benefit of the cloud is decreasing the overall ownership costs for its customers to healthcare organisations.	(Ermakova et al., 2020, Chang et al., 2009, Luarasi et al., 2013)
9	Quick backup	The cloud has the advantage of quick backups and recovery alternatives, reducing significant data loss risks. Cloud enhances the ability to rapidly recognise, differentiate, forecast, and respond to data demands through smarter data solutions like big data and machine learning. The advantages of interoperability in healthcare have been shown to include wearable devices, IoT-enabled gadgets, and online health tracking apps on the cloud. Health organisations struggle to save, use and analyse the growing amount and quantity of data sets they gather and link to from many sources every day. The emergence of cloud computing allows health organisations to use their health data to tackle major healthcare problems today. Instant access to information everywhere and at any time is enhanced by central, real-time access to clinical information and cooperation to improve decision-making in clinics.	(Doheir et al., 2019, Ahn et al., 2013, Alexandru et al., 2016, Hameed et al., 2015)

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Table 1 (*continued*)

S No	Applications	Description	References
10	Minimise medical mistakes	When used in cloud computing, analytics can operate with massive data volumes, including dynamic and extensible settings. Enhanced cloud computing analytics collecting and processing skills can considerably minimise the number of medical mistakes. Cloud computing has demonstrated its capacity to adapt quickly and correctly to the demands of the industry from its inception. Cloud computing is widely applied, facilitating decision-making and communication at many levels in various healthcare facilities. Cloud computing is much more than the leading choice for futuristic health practitioners. The whole healthcare field has been changed by cloud computing, with its on-demand accessibility, internet services, and high-data accessibility.	(Giniat, 2011, Kagadis et al., 2013, Alassafi, 2021, Meri et al., 2017)
11	Easy data sharing procedure	The data sharing procedure is more straightforward with cloud computing. Since information on health care is intended to remain anonymous in the cloud, the data may also be securely shared in real-time with all the appropriate health workers such as physicians, nurses, and carers. Besides sharing, medical reports and information may also be accessed from any place else on a remote basis. Cloud also made remote conferences, rapid health care updates, and patients' circumstances more accessible and suitable for healthcare workers. The cloud can hold vast quantities of information at a relatively small cost. With minimum interaction, cloud-based solutions may update and improve their capabilities at a respectable rate and update all necessary information in real-time. Faster accessing information includes the benefits of cloud computing for healthcare, which may overcome obstacles facing industry stakeholders and patients.	(Ou et al., 2013, Mohan & Aramudhan, 2015, Doheir et al., 2018)
12	Virtual session	The cloud enables doctors and patients to begin virtual sessions that increase patient care services. Users may share, examine and save data on the cloud, and clinicians may access and archive them from afar. Different healthcare centres can use a button to get patient details by posting papers on the cloud without worrying about tedious paperwork and delayed treatment. It may provide excellent service quality in scheduling, referrals, procurement, inventory management, and other background tasks. The fact that an electronic health record is stored and backed up by a cloud enables the decrease in storage cost. It was a slow and challenging process to access complete copies of patient records before the cloud. All records are consolidated, giving fast access to information anywhere and anytime using cloud computing technology.	(Dutta et al., 2021, Zafar et al., 2014, Shi et al., 2015, Wang & Jin, 2019)
13	Excellent healthcare service for patients	Healthcare firms may resort to various options, ranging from managed data centre solutions with built-in security components to real-time network monitoring that aids in the prevention of cyber security assaults. The use of cloud computing in the healthcare business has altered the way of doctors, hospitals, research clinics, and private organisations that provide excellent and inexpensive healthcare services to their patients. Cloud computing technologies offer some of the most outstanding options for providing better medical services by allowing healthcare suppliers to simply and securely store and exchange medical information to increase operational efficiency and save expenses.	(Alharbi et al., 2015, Elhoseny et al., 2018, Nigam & Bhatia, 2016, Daman et al., 2016)
14	Healthcare information	Cloud technology is employed in various Internet of Things or linked devices to offer clients healthcare information. This will give important insights into health monitoring, healthcare plan creation, and improved monitoring and treatment of patients. Cloud computing has grown in the technological environment through time, becoming an emergent force that has aided many businesses over the previous several decades. Healthcare is one industry that has seen significant improvements in terms of facilities due to cloud computing. Cloud computing allows data to be stored centrally in the cloud. This data may be retrieved from the central data centre from several places simultaneously, avoiding flaws in data transmission operations.	(Deng et al., 2011, Abdelaziz et al., 2017, Esposito et al., 2018)
15	Remote consultation	Using the healthcare cloud, many problems are solved by owning patients' confidential medical data. It allows doctors to undertake consultations in remote places and access their medical history. Health facilities employ systems to keep updated records of all patients admitted, diagnosis, treatment, and medical history. This patient profile includes problems and dangers also. Cloud computing supports handling service data that anybody with adequate credentials may access. Patients may also be part of the network and have exclusive access to their records. Health institutions are now developing mobile applications that enable patients to work with hospitals on their healthcare. This issue is addressed by digital platforms linking patients to doctors who make virtual consultations or visit patients at home.	(Altowaijri, 2020, Ratnam et al., 2014, Jemal et al., 2015, Marcu et al., 2015)
16	Increase efficiency of the medical system	Doctors have found cloud computing to be highly beneficial in increasing the efficiency of the medical system by many times at a fraction of the expense. Furthermore, cloud computing has aided medical practitioners in reaching out to a larger population, which was previously difficult owing to a shortage of medical workers. The healthcare business deals with unstructured data that originates from various sources. Medical cloud computing can handle the various problems by preserving a patient record in the centre where it may be conveniently accessible. The health cloud system promotes and plays an essential role in delivering intelligent therapy.	(Abatal et al., 2018, Xu et al., 2017, Chang et al., 2021)
17	Home healthcare	Home healthcare is another emerging market for healthcare cloud computing technologies. Because of the flexibility that cloud computing provides, a rising number of home healthcare users will be able to access better and more efficient healthcare services without physically visiting the hospital. Many healthcare organisations are also creating cloud-based healthcare apps, such as clinical telemedicine software with monitoring devices for chronic patient care at home. Healthcare organisations are collaborating to perform studies in order to address human healthcare challenges promptly and efficiently. Deploying cloud computing gives enterprises cost and infrastructure flexibility since IT resources are bought and employed based on demand and needs. As a result, cloud adoption allows for more effective collaboration among diverse stakeholders in the healthcare business. Cloud computing allows for storing client data on virtualised cloud storage systems.	(Bhatia et al., 2013, Al-Sheikh & Ameen, 2020, Mutlag et al., 2021)
18	Optimal management and preservation of data	The Healthcare cloud aids in the optimal management and preservation of data, allowing institutions to deal with it conveniently and correctly. Healthcare providers who frequently use antiquated data management solutions have speed concerns. These include the system's inability to handle a large volume of data in a short period. Healthcare cloud computing is well-known for its speed and accuracy of data. The suppliers of health care services enable their workers to access information anywhere and anytime by storing cloud data and computer resources. The health care agency and clinicians do not have to invest in hardware infrastructure because the cloud computing providers already deal with these difficulties.	(Nassoura, 2020, Hendrick et al., 2013, Li et al., 2021, Molo et al., 2021)

(*continued on next page*)

Table 1 (*continued*)

S No	Applications	Description	References
19	Keep inventory up to date	It is critical for medical institutions to keep their inventory up to date. However, at numerous multi-speciality hospitals where inventory data is massive, the possibility of losing track of a specific product's inventory is high. This may result in the inability to get necessary medical equipment and medications during medical emergencies. Healthcare cloud computing may transfer the information to the attendant available through cloud systems and provide them with instructions on treating the hurt or distressed person. They retain large amounts of data in large hospitals that have to be handled correctly. New physicians or practitioners may learn from them and execute the previously established theory without wasting time. It helps to get therapy started immediately and to decide fast. The health cloud can analyse such vast data and be presented as needed.	(Lee, 2016, Ekonomou et al., 2011, Kumari et al., 2018, Ali et al., 2020)
20	Exchange healthcare information	Cloud computing improves the health care environment, conveniently exchanges information, increases operational efficiency, and saves expenses. In many circumstances, information from multiple health service providers may be required simultaneously. Cloud-based products can enhance their functionality more quickly, cheaper, and with minimum or no service disruption. Furthermore, cloud services allow healthcare practitioners and their patients to quickly access vital information. The healthcare environment is evolving more quickly than ever before by using cloud computing technology. This provides better medical services for lesser money and makes healthcare providers more competitive. Hospitals, research clinics, private medical institutes, and physicians seek ways to improve day-to-day work and effectiveness and save expenses.	(Kundalwal et al., 2018, Alharbi et al., 2017, AbuKhousa et al., 2012)
21	Remotely accessible servers	Cloud computing is a flexible option that allows hospitals to use a network of remotely accessible servers to store massive amounts of data for an IT professional's safe environment. The requirement demands that hospitals and health care institutions utilise electronic medical records in a meaningful way to save patient interaction information. This improves medical services in terms of quality, security, and efficiency, involving patients and families, enhancing the coordination of care, and ensuring the privacy and safety of patients.	(Yan et al., 2020, Jangade & Chauhan, 2016, Hucíková & Babic, 2016)
22	Maintenance of data storage service	Cloud solutions include management, design, and maintenance of data storage services, enabling health providers to lower their costs in advance. In the past, the danger of theft or destruction has been substantial in physicians using registering offices to keep reams of the patient records. Paper documents are readily lost or stolen and obliterated by a flood, fire, or natural disaster. There was a considerable risk to patient safety given the absence of protection around these materials. All data previously unavailable in the filing cases are searchable and analysed by employing the most complicated available computer algorithms with the arrival of cloud computing. This will allow providers of health care to detect and act on hazards to public health that was previously unseen until far later in their life cycle. Cloud storage solutions providers utilise economical solutions for reducing their clients' data management costs, hospitals and healthcare organisations.	(Vaishya et al., 2020, Kocabas & Soyata, 2020, Oh et al., 2015, Althebyan et al., 2016)
23	Reduce time-consuming procedures	All medical facilities collect daily amounts of information throughout the medical industry. Cloud storage reduces the burden and time-consuming procedures connected with data entry and storage. Cloud security computing services make it easy for licensed personnel to get into a database, obtain relevant information, enter innovative information, and extract different files in seconds. Patient data can be stored in a cloud storage system within seconds for future recovery. Cloud computing enables them to access a universe of information about symptoms, therapies, and drugs in any particular area. If a patient presents an unusual number of symptoms that are difficult to discover first, all available information on the particular symptoms may easily be digitally retrieved.	(Ahmed et al., 2017, Ochian et al., 2014, Chen and Hoang, 2011)
24	Enable communication and collaboration	Cloud computing enables communication and collaboration easier for medical professionals across large distances. If a new patient previously has a long-time association with another hospital in a remote town, we can contact that facility immediately to get the essential medical background information. As healthcare cloud computing advances across the medical sector, patients' lives are improved, and the hospitals are better cared for since information is available to those in need. Patients may also be able to communicate from home to physicians using cloud computing technologies. If a patient needs constant monitoring, they can submit information from the home area to the medical institution. Cloud solutions in the healthcare business are easy and safe for both doctors and patients.	(ul Amin et al., 2017, Alexandru et al., 2019, Priyadarshini et al., 2019)
25	Improve medical institutions	Cloud connectivity will also improve interactions among different medical institutions with the common objective of identifying and containing the problem when an epidemic arises and physicians are hurried. Healthcare professionals can rapidly upgrade tools and software applications in cloud computing without losing time. When a new patch or software generation comes into being, a healthcare development technology will upgrade the system as medical personnel at institutions operate freely. Mobile applications are built into cloud-friendly facilities that make system programs legible and operational on tiny devices. Collaborating personnel can communicate with cloud computing and cooperate from a distance, independent of the server protocols.	(Haleem et al., 2019, Biswas et al., 2014, Thota et al., 2018)
26	Reduce dependency	Health personnel should always be able to communicate information about patient cases. If another doctor has to inform the system, the data from any device should be accessible. Cloud reduces the dependency on a specific device to use patient records independently from their location. Health information is very significant for medical research and the treatment of subsequent situations. Doctors should always have the opportunity to study records and use insights for new therapy. The software might contribute to informed therapeutic decision-making, medical error checking, and therapy regimens. The fundamental advantage of cloud computing is that it has a real influence on all healthcare professionals. These systems save time and enhance organisation for physicians and employees. User experience and more data openness are enhanced in patients. Stakeholders can receive complete reports on how the institution performs at any time. Cloud computing enables an enterprise to avoid investing in internal server space.	(Kumar et al., 2014, Narayanan & Güneş, 2011, Takeuchi et al., 2013, Muhammad, 2015)
27	Reduce paper documents	Sometimes, losing data is more significant when data is kept in paper documents and the local database. The data has been valuable for many years, and data loss might result in worse difficulties without any backup. Data loss can occur whenever there should be a backup or recovery strategy. Cloud is the ideal solution because the cloud-saved patient data is protected from any form. Data may be stored independently of time and place, making cloud storage more scalable. This helped the healthcare sector better predict illnesses and the potential to spread among individuals. Better quality therapy may be achieved using the information kept in the cloud.	(Zhang & Liu, 2010, Meri et al., 2019, Wan et al., 2013, Rizvi et al., 2018)

therapy will be easily stored. They can investigate and lay them out as a case study for future doctors based on the information they preserve. In addition, the analysis of large data may also aid in improved data separation for suitable usage.

11. Conclusion

Cloud computing enhances health information technology in healthcare. By using this technology, hospitals can record electronic health records without having to keep physical records. The key advantage of cloud computing is to provide on-demand access with the help of computer resources, such as data storage and computing power. A hospital worker may access the required databases anywhere with all functional features handled effectively at the server's end. This increased facility in the medical sector at a lesser cost and accepts additional patient inflows, expands the workforce and constructs new extensions for hospital facilities. Cloud computing simplifies the delivery of services to inpatient residences by outcall patient care personnel. This technology minimises hardware and software acquisition capital expenditure. These cost reductions might mount up over time if the costs of updating obsolete equipment and acquiring new software and hardware are considered. Because of cloud interoperability, patient data is readily available to assist healthcare planning and delivery for distribution and insight development. In the future, data will be saved and accessed on the cloud whenever needed. Cloud-based technology will drastically change how the health business works by streamlining data access to backup and recovery.

Declaration of Competing Interest

None.

References

Liao, W. H., & Qiu, W. L. (2016). Applying analytic hierarchy process to assess healthcare-oriented cloud computing service systems. *Springer Plus, 5*(1), 1–9.

Roy, S., Das, A. K., Chatterjee, S., Kumar, N., Chattopadhyay, S., & Rodrigues, J. J. (2018). Provably secure fine-grained data access control over multiple cloud servers in mobile cloud computing based healthcare applications. *IEEE Transactions on Industrial Informatics, 15*(1), 457–468.

Sultan, N. (2014). Making use of cloud computing for healthcare provision: Opportunities and challenges. *International Journal of Information Management, 34*(2), 177–184.

Ahuja, S. P., Mani, S., & Zambrano, J. (2012). A survey of the state of cloud computing in healthcare. *Network and Communication Technologies, 1*(2), 12.

Griebel, L., Prokosch, H. U., Köpcke, F., Toddenroth, D., Christoph, J., Leb, I., & Sedlmayr, M. (2015). A scoping review of cloud computing in healthcare. *BMC Medical Informatics and Decision Making, 15*(1), 1–16.

Doukas, C., & Maglogiannis, I. (2012). Bringing IoT and cloud computing towards pervasive healthcare. In *2012 sixth international conference on innovative mobile and internet services in ubiquitous computing* (pp. 922–926). IEEE.

Dang, L. M., Piran, M., Han, D., Min, K., & Moon, H. (2019). A survey on internet of things and cloud computing for healthcare. *Electronics, 8*(7), 768.

Calabrese, B., & Cannataro, M. (2015). Cloud computing in healthcare and biomedicine. *Scalable Computing: Practice and Experience, 16*(1), 1–18.

Sobhy, D., El-Sonbaty, Y., & Abou Elnasr, M. (2012). MagCloud: healthcare cloud computing system. In *2012 international conference for internet technology and secured transactions* (pp. 161–166). IEEE.

Chauhan, R., & Kumar, A. (2013). Cloud computing for improved healthcare: Techniques, potential and challenges. In *2013 E-health and bioengineering conference (EHB)* (pp. 1–4). IEEE.

Darwish, A., Hassanien, A. E., Elhoseny, M., Sangaiah, A. K., & Muhammad, K. (2019). The impact of the hybrid platform of internet of things and cloud computing on healthcare systems: opportunities, challenges, and open problems. *Journal of Ambient Intelligence and Humanized Computing, 10*(10), 4151–4166.

Hanen, J., Kechaou, Z., & Ayed, M. B. (2016). An enhanced healthcare system in mobile cloud computing environment. *Vietnam Journal of Computer Science, 3*(4), 267–277.

Mehraeen, E., Ghazisaeedi, M., Farzi, J., & Mirshekari, S. (2017). Security challenges in healthcare cloud computing: a systematic. *Global Journal of Health Science, 9*(3).

Ma, Y., Zhang, Y., Wan, J., Zhang, D., & Pan, N. (2015). Robot and cloud-assisted multi–modal healthcare system. *Cluster Computing, 18*(3), 1295–1306.

Kumar, N. S., & Nirmalkumar, P. (2019). A novel architecture of smart healthcare system on integration of cloud computing and IoT. In *2019 International Conference on Communication and Signal Processing (ICCSP)* (pp. 0940–0944). IEEE.

Hu, Y., Lu, F., Khan, I., & Bai, G. (2012). A cloud computing solution for sharing healthcare information. In *2012 international conference for internet technology and secured transactions* (pp. 465–470). IEEE.

Cimler, R., Matyska, J., & Sobeslav, V. (2014). Cloud-based solution for mobile healthcare application. In *Proceedings of the 18th international database engineering & applications symposium* (pp. 298–301).

Cho, Y. B., Woo, S. H., & Lee, S. H. (2014). The CloudHIS system for personal healthcare information integration scheme of cloud computing. *Journal of the Korea society of computer and information, 19*(5), 27–35.

Fong, E. M., & Chung, W. Y. (2013). Mobile cloud-computing-based healthcare service by noncontact ECG monitoring. *Sensors, 13*(12), 16451–16473.

Rallapalli, S., Gondkar, R., & Ketavarapu, U. P. K. (2016). Impact of processing and analysing healthcare big data on cloud computing environment by implementing Hadoop cluster. *Procedia Computer Science, 85*, 16–22.

Stantchev, V., Barnawi, A., Ghulam, S., Schubert, J., & Tamm, G. (2014). Smart items, fog and cloud computing as enablers of servitisation in healthcare. *Sensors & Transducers, 185*(2), 121–128.

He, C., Fan, X., & Li, Y. (2012). Toward ubiquitous healthcare services with a novel efficient cloud platform. *IEEE Transactions on Biomedical Engineering, 60*(1), 230–234.

Lubamba, C., & Bagula, A. (2017). Cyber-healthcare cloud computing interoperability using the HL7-CDA standard. In *2017 IEEE Symposium on Computers and Communications (ISCC)* (pp. 105–110). IEEE.

Singh, R. P., Haleem, A., Javaid, M., Kataria, R., & Singhal, S. (2021). Cloud computing in solving problems of COVID-19 pandemic. *Journal of Industrial Integration and Management*.

Doukas, C., Pliakas, T., & Maglogiannis, I. (2010). Mobile healthcare information management utilising Cloud Computing and Android OS. In *2010 Annual international conference of the IEEE engineering in medicine and biology* (pp. 1037–1040). IEEE.

Elmogazy, H., & Bamasak, O. (2013). Towards healthcare data security in cloud computing. In *8th International Conference for Internet Technology and Secured Transactions (ICITST-2013)* (pp. 363–368). IEEE.

Gao, F., & Sunyaev, A. (2019). Context matters: A review of the determinant factors in the decision to adopt cloud computing in healthcare. *International Journal of Information Management, 48*, 120–138.

Masrom, M., & Rahimli, A. (2014). A review of cloud computing technology solution for the healthcare system. *Research Journal of Applied Sciences, Engineering and Technology, 8*(20), 2150–2153.

Haleem, A., & Javaid, M. (2020). Medical 4.0 and its role in healthcare during COVID-19 pandemic: A review. *Journal of Industrial Integration and Management, 5*(04), 531–545.

Skondras, E., Michalas, A., Tsolis, N., & Vergados, D. D. (2018). A VHO scheme for supporting healthcare services in 5G vehicular cloud computing systems. In *2018 Wireless Telecommunications Symposium (WTS)* (pp. 1–6). IEEE.

Lee, Y. S., Bruce, N., Non, T., Alasaarela, E., & Lee, H. (2015). Hybrid cloud service based healthcare solutions. In *2015 IEEE 29th international conference on advanced information networking and applications workshops* (pp. 25–30). IEEE.

Muhammad, G., Alhamid, M. F., & Long, X. (2019). Computing and processing on the edge: Smart pathology detection for connected healthcare. *IEEE Network, 33*(6), 44–49.

Salih, R. M., & Lilien, L. T. (2015). Protecting users' privacy in healthcare cloud computing with APB-TTP. In *2015 IEEE international conference on pervasive computing and communication workshops (PerCom Workshops)* (pp. 236–238). IEEE.

Ratnam, K. A., & Dominic, P. D. D. (2014). Adoption of cloud computing to enhance the healthcare services in Malaysia. In *2014 International Conference on Computer and Information Sciences (ICCOINS)* (pp. 1–6). IEEE.

Akrivopoulos, O., Chatzigiannakis, I., Tselios, C., & Antoniou, A. (2017). On the deployment of healthcare applications over fog computing infrastructure. In *2017 IEEE 41st annual computer software and applications conference (COMPSAC): 2* (pp. 288–293). IEEE.

Alzoubaidi, A. R. (2016). Cloud computing national e-health services: data center solution architecture. *International Journal of Computer Science and Network Security (IJCSNS), 16*(9), 1.

Goli-Malekabadi, Z., Sargolzaei-Javan, M., & Akbari, M. K. (2016). An effective model for store and retrieve big health data in cloud computing. *Computer Methods and Programs in Biomedicine, 132*, 75–82.

Padhy, R. P., Patra, M. R., & Satapathy, S. C. (2012). Design and implementation of a cloud-based rural healthcare information system model. *Universal Journal of Applied Computer Science and Technology, 2*(1), 149–157.

Devadass, L., Sekaran, S. S., & Thinakaran, R. (2017). Cloud computing in healthcare. *International Journal of Students' Research in Technology & Management, 5*(1), 25–31.

Aceto, G., Persico, V., & Pescapé, A. (2020). Industry 4.0 and health: Internet of things, big data, and cloud computing for healthcare 4.0. *Journal of Industrial Information Integration, 18*, Article 100129.

Javaid, M., Haleem, A., Vaishya, R., Bahl, S., Suman, R., & Vaish, A. (2020). Industry 4.0 technologies and their applications in fighting COVID-19 pandemic. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews, 14*(4), 419–422.

Kumar, V., Jangirala, S., & Ahmad, M. (2018). An efficient mutual authentication framework for healthcare system in cloud computing. *Journal of Medical Systems, 42*(8), 1–25.

Alharbi, F., Atkins, A., Stanier, C., & Al-Buti, H. A (2016). Strategic value of cloud computing in healthcare organisations using the balanced scorecard approach: A case study from a Saudi Hospital. *Procedia Computer Science, 98*, 332–339.

Kuo, M. H., Kushniruk, A., & Borycki, E. (2011). Can cloud computing benefit health services?–A SWOT analysis. In *User centred networked health care* (pp. 379–383). IOS Press.

Ali, O., Shrestha, A., Soar, J., & Wamba, S. F. (2018). Cloud computing-enabled healthcare opportunities, issues, and applications: A systematic review. *International Journal of Information Management, 43*, 146–158.

Bamiah, M., Brohi, S., & Chuprat, S. (2012). A study on the significance of adopting cloud computing paradigm in healthcare sector. In *2012 International Conference on Cloud Computing Technologies, Applications and Management (ICCCTAM)* (pp. 65–68). IEEE.

Rajabion, L., Shaltooki, A. A., Taghikhah, M., Ghasemi, A., & Badfar, A. (2019). Healthcare big data processing mechanisms: The role of cloud computing. *International Journal of Information Management, 49*, 271–289.

Tyagi, S., Agarwal, A., & Maheshwari, P. (2016). A conceptual framework for IoT-based healthcare system using cloud computing. In *2016 6th international conference-cloud system and big data engineering (Confluence)* (pp. 503–507). IEEE.

Abdelaziz, A., Elhoseny, M., Salama, A. S., & Riad, A. M. (2018). A machine learning model for improving healthcare services on cloud computing environment. *Measurement, 119*, 117–128.

Seddon, J. J., & Currie, W. L. (2013). Cloud computing and trans-border health data: Unpacking US and EU healthcare regulation and compliance. *Health Policy and Technology, 2*(4), 229–241.

Gavrilov, G., & Trajkovik, V. (2012). Security and privacy issues and requirements for healthcare cloud computing. *ICT Innovations*, 143–152.

Hoang, D. B., & Chen, L. (2010). Mobile cloud for assistive healthcare (MoCAsH). In *2010 IEEE Asia-pacific services computing conference* (pp. 325–332). IEEE.

Jindal, A., Dua, A., Kumar, N., Das, A. K., Vasilakos, A. V., & Rodrigues, J. J. (2018). Providing healthcare-as-a-service using fuzzy rule-based big data analytics in cloud computing. *IEEE Journal of Biomedical and Health Informatics, 22*(5), 1605–1618.

Singh, M., Gupta, P. K., & Srivastava, V. M. (2017). Key challenges in implementing cloud computing in the Indian healthcare industry. In *2017 pattern recognition association of South Africa and robotics and mechatronics (PRASA-RobMech)* (pp. 162–167). IEEE.

Jemal, H., Kechaou, Z., Ayed, M. B., & Alimi, A. M. (2015). Cloud computing and mobile devices based system for healthcare application. In *2015 IEEE International Symposium on Technology and Society (ISTAS)* (pp. 1–5). IEEE.

Mohammed, J., Lung, C. H., Ocneanu, A., Thakral, A., Jones, C., & Adler, A. (2014). Internet of Things: Remote patient monitoring using web services and cloud computing. In *2014 IEEE international conference on internet of things (iThings), and IEEE green computing and communications (GreenCom) and IEEE cyber, physical and social computing (CPSCom)* (pp. 256–263). IEEE.

Liu, Y., Zhang, Y., Ling, J., & Liu, Z. (2018). Secure and fine-grained access control on e-healthcare records in mobile cloud computing. *Future Generation Computer Systems, 78*, 1020–1026.

Nur, F. N., & Moon, N. N. (2012). Health care system based on cloud computing. *Asian Transactions on Computers, 2*(5), 9–11.

Guo, Y., Kuo, M. H., & Sahama, T. (2012). Cloud computing for healthcare research information sharing. In *4th IEEE international conference on cloud computing technology and science proceedings* (pp. 889–894). IEEE.

Alshammari, H., El-Ghany, S. A., & Shehab, A. (2020). Big IoT healthcare data analytics framework based on fog and cloud computing. *Journal of Information Processing Systems, 16*(6), 1238–1249.

Dzombeta, S., Stantchev, V., Colomo-Palacios, R., Brandis, K., & Haufe, K. (2014). Governance of cloud computing services for the life sciences. *IT Professional, 16*(4), 30–37.

Alphonsa, M. A., & Amudhavalli, P. (2018). Genetically modified glowworm swarm optimisation based privacy preservation in cloud computing for healthcare sector. *Evolutionary Intelligence, 11*(1), 101–116.

Agarwal, N., & Sebastian, M. P. (2016). Use of cloud computing and smart devices in healthcare. *International Journal of Computer and Information Engineering, 10*(1), 156–159.

John, N., & Shenoy, S. (2014). Health cloud-Healthcare as a service (HaaS). In *2014 International Conference on Advances in Computing, Communications and Informatics (ICACCI)* (pp. 1963–1966). IEEE.

Casola, V., Castiglione, A., Choo, K. K. R., & Esposito, C. (2016). Healthcare-related data in the cloud: Challenges and opportunities. *IEEE Cloud Computing, 3*(6), 10–14.

Bamiah, M., Brohi, S., Chuprat, S., & Brohi, M. N. (2012). Cloud implementation security challenges. In *2012 International Conference on Cloud Computing Technologies, Applications and Management (ICCCTAM)* (pp. 174–178). IEEE.

Ijaz, M., Li, G., Lin, L., Cheikhrouhou, O., Hamam, H., & Noor, A. (2021). Integration and applications of fog computing and cloud computing based on the internet of things for provision of healthcare services at home. *Electronics, 10*(9), 1077.

He, S., Cheng, B., Wang, H., Huang, Y., & Chen, J. (2017). Proactive, personalised services through fog-cloud computing in large-scale IoT-based healthcare application. *China Communications, 14*(11), 1–16.

Mvelase, P., Dlamini, Z., Dludla, A., & Sithole, H. (2015). Integration of smart wearable mobile devices and cloud computing in South African healthcare. In eChallenges e-2015 conference (pp. 1–10). IEEE.

Masrom, M., & Rahimli, A. (2015). Cloud computing adoption in the healthcare sector: A SWOT analysis. *Asian Social Science, 11*(10), 12.

Ratnam, K. A., & Dominic, P. D. D. (2014). The factors associating the adoption of cloud computing: an enhancement of the healthcare ecosystem in Malaysia. *International Journal of Business Information Systems, 16*(4), 462–479.

Zhou, J., Lin, X., Dong, X., & Cao, Z. (2014). PSMPA: Patient self-controllable and multi-level privacy-preserving cooperative authentication in distributed-healthcare cloud computing system. *IEEE Transactions on Parallel and Distributed Systems, 26*(6), 1693–1703.

Kabachinski, J. (2011). What's the forecast for cloud computing in healthcare? *Biomedical Instrumentation & Technology, 45*(2), 146.

An, N. T., Huynh, C. T., Lee, B., Hong, C. S., & Huh, E. N. (2015). An efficient block classification for media healthcare service in mobile cloud computing. *Multimedia Tools and Applications, 74*(14), 5209–5223.

Somula, R., Anilkumar, C., Venkatesh, B., Karrothu, A., Kumar, C. P., & Sasikala, R. (2019). Cloudlet services for healthcare applications in mobile cloud computing. In *Proceedings of the 2nd international conference on data engineering and communication technology* (pp. 535–543). Singapore: Springer.

Javaid, M., & Khan, I. H. (2021). Internet of Things (IoT) enabled healthcare helps to take the challenges of COVID-19 Pandemic. *Journal of Oral Biology and Craniofacial Research, 11*(2), 209–214.

Liu, W., & Park, E. K. (2013). E-Healthcare cloud computing application solutions: Cloud-enabling characteristics, challenges and adaptations. In *2013 International conference on computing, networking and communications (ICNC)* (pp. 437–443). IEEE.

Youssef, A. E. (2014). A framework for secure healthcare systems based on big data analytics in mobile cloud computing environments. *The International Journal of Ambient Systems and Applications, 2*(2), 1–11.

Brohi, M. N. (2014). Trusted cloud computing framework for the healthcare sector. *Journal of Computer Science, 10*(2), 240–250.

Bhatia, T., Verma, A. K., & Sharma, G. (2020). Towards a secure incremental proxy re-encryption for e-healthcare data sharing in mobile cloud computing. *Concurrency and Computation: Practice and Experience, 32*(5), e5520.

Louk, M., Lim, H., & Lee, H. J. (2014). Security system for healthcare data in cloud computing. *International Journal of Security and Its Applications, 8*(3), 241–248.

Glasberg, R., Hartmann, M., Draheim, M., Tamm, G., & Hessel, F. (2014). Risks and crises for healthcare providers: the impact of cloud computing. *The Scientific World Journal 2014*.

Abrar, H., Hussain, S. J., Chaudhry, J., Saleem, K., Orgun, M. A., Al-Muhtadi, J., & Valli, C. (2018). Risk analysis of cloud sourcing in healthcare and public health industry. *IEEE Access, 6*, 19140–19150.

Glaser, J. (2011). Cloud computing can simplify HIT infrastructure management. *Healthcare Financial Management, 65*(8), 52–56.

Khattak, H. A. K., Abbass, H., Naeem, A., Saleem, K., & Iqbal, W. (2015). Security concerns of cloud-based healthcare systems: A perspective of moving from single-cloud to a multi-cloud infrastructure. In *2015 17th international conference on E-health networking, application & services (HealthCom)* (pp. 61–67). IEEE.

Nirabi, A., & Hameed, S. A. (2018). Mobile cloud computing for emergency healthcare model: framework. In *2018 7th International Conference on Computer and Communication Engineering (ICCCE)* (pp. 375–379). IEEE.

Abawajy, J. H., & Hassan, M. M. (2017). Federated internet of things and cloud computing pervasive patient health monitoring system. *IEEE Communications Magazine, 55*(1), 48–53.

Yang, G., Pang, Z., Deen, M. J., Dong, M., Zhang, Y. T., Lovell, N., & Rahmani, A. M. (2020). Homecare robotic systems for healthcare 4.0: visions and enabling technologies. *IEEE Journal of Biomedical and Health Informatics, 24*(9), 2535–2549.

Narkhede, B. E., Raut, R. D., Narwane, V. S., & Gardas, B. B. (2020). Cloud computing in healthcare-a vision, challenges and future directions. *International Journal of Business Information Systems, 34*(1), 1–39.

Lupşe, O. S., Vida, M. M., & Tivadar, L. (2012). Cloud computing and interoperability in healthcare information systems. In *The first international conference on intelligent systems and applications* (pp. 81–85).

Karaca, Y., Moonis, M., Zhang, Y. D., & Gezgez, C. (2019). Mobile cloud computing-based stroke healthcare system. *International Journal of Information Management, 45*, 250–261.

Singh, R. P., Javaid, M., Haleem, A., Vaishya, R., & Bahl, S. (2020). Significance of Health Information Technology (HIT) in context to COVID-19 pandemic: Potential roles and challenges. *Journal of Industrial Integration and Management, 5*(04), 427–440.

Wooten, R., Klink, R., Sinek, F., Bai, Y., & Sharma, M. (2012). Design and implementation of a secure healthcare social cloud system. In *2012 12th IEEE/ACM international symposium on cluster, cloud and grid computing (CC Grid, 2012)* (pp. 805–810). IEEE.

Marwan, M., Kartit, A., & Ouahmane, H. (2018). Security enhancement in healthcare cloud using machine learning. *Procedia Computer Science, 127*, 388–397.

Parane, K. A., Patil, N. C., Poojara, S. R., & Kamble, T. S. (2014). Cloud-based intelligent healthcare monitoring system. In *2014 international conference on issues and challenges in intelligent computing techniques (ICICT)* (pp. 697–701). IEEE.

Al Nuaimi, N., AlShamsi, A., Mohamed, N., & Al-Jaroodi, J (2015). e-Health cloud implementation issues and efforts. In *2015 international conference on Industrial Engineering And Operations Management (IEOM)* (pp. 1–10). IEEE.

Mourya, A. K., & Idrees, S. M. (2020). Cloud computing-based approach for accessing electronic health records for the healthcare sector. In *Microservices in big data analytics* (pp. 179–188). Singapore: Springer.

Haleem, A., Javaid, M., Singh, R. P., & Suman, R. (2022). Medical 4.0 technologies for healthcare: Features, capabilities, and applications. *Internet of Things and Cyber-Physical Systems, 2*, 12–30.

Sun, L., Wang, H., Yong, J., & Wu, G. (2012). Semantic access control for cloud computing based on e-Healthcare. In *Proceedings of the 2012 IEEE 16th international conference on computer supported cooperative work in design (CSCWD)* (pp. 512–518). IEEE.

Wang, L., & Alexander, C. A. (2013). Medical applications and healthcare based on cloud computing. *International Journal of Cloud Computing and Services Science, 2*(4), 217.

Alharbi, F., Atkins, A., & Stanier, C. (2016). Understanding the determinants of Cloud Computing adoption in Saudi healthcare organisations. *Complex & Intelligent Systems, 2*(3), 155–171.

Zickau, S., Thatmann, D., Ermakova, T., Repschläger, J., Zarnekow, R., & Küpper, A. (2014). Enabling location-based policies in a healthcare cloud computing environment. In *2014 IEEE 3rd international conference on cloud networking (Cloudnet)* (pp. 333–338). IEEE.

Ehwerhemuepha, L., Gasperino, G., Bischoff, N., Taraman, S., Chang, A., & Feaster, W. (2020). HealtheDataLab–a cloud computing solution for data science and advanced analytics in healthcare with application to predicting multi-center pediatric readmissions. *BMC Medical Informatics and Decision Making, 20*(1), 1–12.

Lin, C. W., Abdul, S. S., Clinciu, D. L., Scholl, J., Jin, X., Lu, H., & Li, Y. C. (2014). Empowering village doctors and enhancing rural healthcare using cloud computing in a

rural area of mainland China. *Computer Methods and Programs in Biomedicine, 113*(2), 585–592.
Zhiqiang, G., Lingsong, H., Hang, T., & Cong, L. (2015). A cloud computing-based mobile healthcare service system. In *2015 IEEE 3rd International Conference on Smart Instrumentation, Measurement and Applications (ICSIMA)* (pp. 1–6). IEEE.
Huang, Q., Yue, W., He, Y., & Yang, Y. (2018). Secure identity-based data sharing and profile matching for mobile healthcare social networks in cloud computing. *IEEE Access, 6*, 36584–36594.
Singh, I., Kumar, D., & Khatri, S. K. (2019). Improving the efficiency of e-healthcare system based on cloud. In *2019 Amity International Conference on Artificial Intelligence (AICAI)* (pp. 930–933). IEEE.
Javaid, M., Haleem, A., Singh, R. P., Haq, M. I. U., Raina, A., & Suman, R. (2020). Industry 5.0: Potential applications in COVID-19. *Journal of Industrial Integration and Management, 5*(04), 507–530.
Ermakova, T., Fabian, B., Kornacka, M., Thiebes, S., & Sunyaev, A. (2020). Security and privacy requirements for cloud computing in healthcare: Elicitation and prioritisation from a Patient Perspective. *ACM Transactions on Management Information Systems (TMIS), 11*(2), 1–29.
Chang, H. H., Chou, P. B., & Ramakrishnan, S. (2009). An ecosystem approach for healthcare services cloud. In *2009 IEEE international conference on e-business engineering* (pp. 608–612). IEEE.
Luarasi, T., Durresi, M., & Durresi, A. (2013). Healthcare based on cloud computing. In *2013 16th international conference on network-based information systems* (pp. 113–118). IEEE.
Doheir, M., Basari, A. S. H., Hussin, B., Yaacob, N. M., & Al-Shami, S. S. A (2019). The new conceptual cloud computing modelling for improving healthcare management in health organizations. *International Journal of Advanced Science and Technology, 28*(1), 351–362 *351-362*.
Ahn, Y. W., Cheng, A. M., Baek, J., Jo, M., & Chen, H. H. (2013). An auto-scaling mechanism for virtual resources to support mobile, pervasive, real-time healthcare applications in cloud computing. *IEEE Network, 27*(5), 62–68.
Alexandru, A., Alexandru, C., Coardos, D., & Tudora, E. (2016). Healthcare, big data and cloud computing. *Management, 1*, 2.
Hameed, R. T., Mohamad, O. A., Hamid, O. T., & Tapus, N. (2015). Design of e-Healthcare management system based on cloud and service-oriented architecture. In *2015 E-Health and Bioengineering Conference (EHB)* (pp. 1–4). IEEE.
Giniat, E. J. (2011). Cloud computing: innovating the business of health care: healthcare finance executives can lead their organisations in exploring ways to use cloud computing for operational success. *Healthcare Financial Management, 65*(5), 130–132.
Kagadis, G. C., Kloukinas, C., Moore, K., Philbin, J., Papadimitroulas, P., Alexakos, C., & Hendee, W. R. (2013). Cloud computing in medical imaging. *Medical Physics, 40*(7), Article 070901.
Alassafi, M. O. (2021). Success Indicators for an Efficient Utilisation of Cloud Computing in Healthcare Organizations: Saudi Healthcare as Case Study. *Computer Methods and Programs in Biomedicine*, Article 106466.
Meri, A., Hasan, M. K., & Safie, N. (2017). Success factors affecting the healthcare professionals to utilise cloud computing services. *Asia-Pacific Journal of Information Technology and Multimedia, 6*(2), 31–42.
Ou, Y. Y., Shih, P. Y., Chin, Y. H., Kuan, T. W., Wang, J. F., & Shih, S. H. (2013). Framework of ubiquitous healthcare system based on cloud computing for elderly living. In *2013 Asia-pacific signal and information processing association annual summit and conference* (pp. 1–4). IEEE.
Mohan, K., & Aramudhan, M. (2015). Ontology-based access control model for healthcare system in cloud computing. *Indian Journal of Science and Technology, 8*, 213.
Doheir, M., Hussin, B., Basari, A. S., & Elzamly, A. (2018). Identifying critical cloud computing technology issues for improving healthcare management. *Journal of Advance Research in Dynamical & Control Systems, 10*(7), 732–743.
Dutta, A., Misra, C., Barik, R. K., & Mishra, S. (2021). Enhancing mist assisted cloud computing toward secure and scalable architecture for smart healthcare. In *Advances in communication and computational technology* (pp. 1515–1526). Singapore: Springer.
Zafar, Z., Islam, S., Aslam, M. S., & Sohaib, M. (2014). Cloud computing services for the healthcare industry. *International Journal of Multidisciplinary Sciences and Engineering., 5*, 25–29.
Shi, Y., Ding, G., Wang, H., Roman, H. E., & Lu, S. (2015). The fog computing service for healthcare. In *2015 2nd international symposium on future information and communication technologies for ubiquitous healthcare (Ubi-HealthTech)* (pp. 1–5). IEEE.
Wang, X., & Jin, Z. (2019). An overview of mobile cloud computing for pervasive healthcare. *IEEE Access, 7*, 66774–66791.
Alharbi, F., Atkins, A., & Stanier, C. (2015). Strategic framework for cloud computing decision-making in the healthcare sector in Saudi Arabia. *The Seventh International Conference on Health, Telemedicine, and Social Medicine, 1*, 138–144.
Elhoseny, M., Abdelaziz, A., Salama, A. S., Riad, A. M., Muhammad, K., & Sangaiah, A. K. (2018). A hybrid model of the internet of things and cloud computing to manage big data in health services applications. *Future Generation Computer Systems, 86*, 1383–1394.
Nigam, V. K., & Bhatia, S. (2016). Impact of cloud computing on health care. *International Research Journal of Engineering and Technology, 3*(5), 2804–2810.
Daman, R., Tripathi, M. M., & Mishra, S. K. (2016). Security issues in cloud computing for healthcare. In *2016 3rd international conference on computing for sustainable global development (INDIACom)* (pp. 1231–1236). IEEE.
Deng, M., Petkovic, M., Nalin, M., & Baroni, I. (2011). A home healthcare system in the cloud–Addressing security and privacy challenges. In *2011 IEEE 4th International conference on cloud computing* (pp. 549–556). IEEE.
Abdelaziz, A., Elhoseny, M., Salama, A. S., Riad, A. M., & Hassanien, A. E. (2017). Intelligent algorithms for optimal selection of virtual machine in cloud environment, towards enhance healthcare services. In *International conference on advanced intelligent systems and informatics* (pp. 289–298). Cham: Springer.
Esposito, C., De Santis, A., Tortora, G., Chang, H., & Choo, K. K. R. (2018). Blockchain: A panacea for healthcare cloud-based data security and privacy? *IEEE Cloud Computing, 5*(1), 31–37.
Altowaijri, S. M. (2020). An architecture to improve the security of cloud computing in the healthcare sector. In *Smart infrastructure and applications* (pp. 249–266). Cham: Springer.
Ratnam, K. A., Dominic, P. D. D., & Ramayah, T. (2014). A structural equation modeling approach for the adoption of cloud computing to enhance the Malaysian healthcare sector. *Journal of Medical Systems, 38*(8), 1–14.
Jemal, H., Kechaou, Z., Ayed, M. B., & Alimi, A. M. (2015). Mobile cloud computing in the healthcare system. In *Computational collective intelligence* (pp. 408–417). Cham: Springer.
Marcu, R., Popescu, D., & Danila, I. (2015). Healthcare integration based on cloud computing. *UPB Science Bulletin, 77*(2), 31–42.
Abatal, A., Khallouki, H., & Bahaj, M. (2018). A semantic smart interconnected healthcare system using ontology and cloud computing. In *2018 4th International Conference on Optimisation and Applications (ICOA)* (pp. 1–5). IEEE.
Xu, B., Xu, L., Cai, H., Jiang, L., Luo, Y., & Gu, Y. (2017). The design of an m-Health monitoring system based on a cloud computing platform. *Enterprise Information Systems, 11*(1), 17–36.
Chang, S. C., Lu, M. T., Pan, T. H., & Chen, C. S. (2021). Evaluating the E-health cloud computing systems adoption in Taiwan's healthcare industry. *Life, 11*(4), 310.
Bhatia, G., Lala, A., Chaurasia, A., & Rajpal, R. (2013). Implementation of Cloud computing technology for the improvement of entire healthcare services in India. In *2013 International Conference on Advances in Technology and Engineering (ICATE)* (pp. 1–5). IEEE.
Al-Sheikh, M. A., & Ameen, I. A. (2020). Design of mobile healthcare monitoring system using IoT technology and cloud computing. *IOP Conference Series: Materials Science and Engineering, 881*(1), Article 012113 IOP Publishing.
Mutlag, A. A., Ghani, M. K. A., Mohammed, M. A., Lakhan, A., Mohd, O., Abdulkareem, K. H., & Garcia-Zapirain, B. (2021). Multi-agent systems in fog–cloud computing for Critical Healthcare Task Management Model (CHTM) used for ECG monitoring. *Sensors, 21*(20), 6923.
Nassoura, A. B. (2020). Critical success factors for adoption of cloud computing in jordanian healthcare organizations. *International Journal of Scientific & Technology Research, 9*(4), 2798–2803.
Hendrick, E., Schooley, B., & Gao, C. (2013). CloudHealth: Developing a reliable cloud platform for healthcare applications. In *2013 IEEE 10th Consumer Communications and Networking Conference (CCNC)* (pp. 887–891). IEEE.
Li, X., Lu, Y., Fu, X., & Qi, Y. (2021). Building the Internet of Things platform for smart maternal healthcare services with wearable devices and cloud computing. *Future Generation Computer Systems, 118*, 282–296.
Molo, M. J., Badejo, J. A., Adetiba, E., Nzanzu, V. P., Noma-Osaghae, E., Oguntosin, V., & Adebiyi, E. F. (2021). A Review of Evolutionary Trends in Cloud Computing and Applications to the Healthcare Ecosystem. *Applied Computational Intelligence and Soft Computing*, 2021.
Lee, T. G. (2016). *Mobile healthcare computing in the cloud.* Mobile computing and wireless networks: Concepts, methodologies, tools, and applications (pp. 1412–1432). IGI Global.
Ekonomou, E., Fan, L., Buchanan, W., & Thuemmler, C. (2011). An integrated cloud-based healthcare infrastructure. In *2011 IEEE third international conference on cloud computing technology and science* (pp. 532–536). IEEE.
Kumari, A., Tanwar, S., Tyagi, S., & Kumar, N. (2018). Fog computing for Healthcare 4.0 environment: Opportunities and challenges. *Computers & Electrical Engineering, 72*, 1–13.
Ali, S., Singh, R. P., Javaid, M., Haleem, A., Pasricha, H., Suman, R., & Karloopia, J. (2020). A review of the role of smart wireless medical sensor network in COVID-19. *Journal of Industrial Integration and Management, 5*(04), 413–425.
Kundalwal, M. K., Singh, A., & Chatterjee, K. (2018). A privacy framework in cloud computing for healthcare data. In *2018 International Conference on Advances in Computing, Communication Control and Networking (ICACCCN)* (pp. 58–63). IEEE.
Alharbi, F., Atkins, A., & Stanier, C. (2017). Decision-makers views of factors affecting cloud computing adoption in Saudi healthcare organisations. In *2017 International Conference on Informatics, Health & Technology (ICIHT)* (pp. 1–8). IEEE.
AbuKhousa, E., Mohamed, N., & Al-Jaroodi, J. (2012). e-Health cloud: opportunities and challenges. *Future Internet, 4*(3), 621–645.
Yan, S., He, L., Seo, J., & Lin, M. (2020). Concurrent healthcare data processing and storage framework using deep-learning in distributed cloud computing environment. *IEEE Transactions on Industrial Informatics, 17*(4), 2794–2801.
Jangade, R., & Chauhan, R. (2016). Big data with integrated cloud computing for healthcare analytics. In *2016 3rd international conference on computing for sustainable global development (INDIACom)* (pp. 4068–4071). IEEE.
Hucíková, A., & Babic, A. (2016). Cloud computing in healthcare: a space of opportunities and challenges. *Transforming Healthcare Internet Things, 221*, 122.
Vaishya, R., Haleem, A., Vaish, A., & Javaid, M. (2020). Emerging technologies to combat the COVID-19 pandemic. *Journal of Clinical and Experimental Hepatology, 10*(4), 409–411.
Kocabas, O., & Soyata, T. (2020). *Towards privacy-preserving medical cloud computing using homomorphic encryption.* Virtual and Mobile Healthcare: Breakthroughs in Research and Practice (pp. 93–125). IGI Global.
Oh, S., Cha, J., Ji, M., Kang, H., Kim, S., Heo, E., & Yoo, S. (2015). Architecture design of healthcare software-as-a-service platform for cloud-based clinical decision support service. *Healthcare Informatics Research, 21*(2), 102–110.

Althebyan, Q., Yaseen, Q., Jararweh, Y., & Al-Ayyoub, M. (2016). Cloud support for large scale e-healthcare systems. *Annals of Telecommunications, 71*(9), 503–515.

Ahmed, S., Saqib, M., Adil, M., Ali, T., & Ishtiaq, A. (2017). Integration of cloud computing with internet of things and wireless body area network for effective healthcare. In *2017 International Symposium on Wireless Systems and Networks (ISWSN)* (pp. 1–6). IEEE.

Ochian, A., Suciu, G., Fratu, O., Voicu, C., & Suciu, V. (2014). An overview of cloud middleware services for interconnection of healthcare platforms. In *2014 10th international Conference on Communications (COMM)* (pp. 1–4). IEEE.

Chen, L., & Hoang, D. B. (2011). Novel data protection model in healthcare cloud. In *2011 IEEE international conference on high-performance computing and communications* (pp. 550–555). IEEE.

ul Amin, R., Inayat, I., Shahzad, B., Saleem, K., & Aijun, L. (2017). An empirical study on acceptance of secure healthcare service in Malaysia, Pakistan, and Saudi Arabia: a mobile cloud computing perspective. *Annals of Telecommunications, 72*(5), 253–264.

Alexandru, A., Coardos, D., & Tudora, E. (2019). IoT-Based Healthcare Remote Monitoring Platform for Elderly with Fog and Cloud Computing. In *2019 22nd international conference on Control Systems and Computer Science (CSCS)* (pp. 154–161). IEEE.

Priyadarshini, R., Panda, M. R., & Mishra, B. K. (2019). Security in healthcare applications based on fog and cloud computing. In *Cyber security in parallel and distributed computing: Concepts, techniques, applications and case studies* (pp. 231–243).

Haleem, A., Javaid, M., & Vaishya, R. (2019). Industry 4.0 and its applications in orthopaedics. *Journal of Clinical Orthopaedics and Trauma, 10*(3), 615.

Biswas, S., Akhter, T., Kaiser, M. S., & Mamun, S. A. (2014). Cloud-based healthcare application architecture and electronic medical record mining: an integrated approach to improve healthcare system. In *2014 17th International Conference on Computer and Information Technology (ICCIT)* (pp. 286–291). IEEE.

Thota, C., Sundarasekar, R., Manogaran, G., Varatharajan, R., & Priyan, M. K. (2018). Centralised fog computing security platform for IoT and cloud in healthcare system. In *Fog computing: Breakthroughs in research and practice* (pp. 365–378). IGI global.

Kumar, A., Bhattacharya, I., Bhattacharya, J., Ramachandran, A., Maskara, S., Kung, W. M., & Chiang, I. J. (2014). Deploying cloud computing to implement electronic health record in Indian healthcare settings. *Open Journal of Mobile Computing and Cloud Computing, 1*(1), 35–47.

Narayanan, H. A. J., & Güneş, M. H. (2011). Ensuring access control in cloud provisioned healthcare systems. In *2011 IEEE Consumer Communications and Networking Conference (CCNC)* (pp. 247–251). IEEE.

Takeuchi, H., Mayuzumi, Y., Kodama, N., & Sato, K. (2013). Personal healthcare system using cloud computing. *Studies in health technology and informatics, 192*, 936 936.

Muhammad, G. (2015). Automatic speech recognition using interlaced derivative pattern for cloud-based healthcare system. *Cluster Computing, 18*(2), 795–802.

Zhang, R., & Liu, L. (2010). Security models and requirements for healthcare application clouds. In *2010 IEEE 3rd international conference on cloud computing* (pp. 268–275). IEEE.

Meri, A., Hasan, M. K., Danaee, M., Jaber, M., Safei, N., Dauwed, M., & Al-bsheish, M. (2019). Modelling the utilisation of cloud health information systems in the Iraqi public healthcare sector. *Telematics and Informatics, 36*, 132–146.

Wan, J., Zou, C., Ullah, S., Lai, C. F., Zhou, M., & Wang, X. (2013). Cloud-enabled wireless body area networks for pervasive healthcare. *IEEE Network, 27*(5), 56–61.

Rizvi, S. Q. A., Wang, G., & Chen, J. (2018). A service-oriented healthcare architecture (SOHA-CC) based on cloud computing. In *International conference on security, privacy and anonymity in computation, communication and storage* (pp. 84–97). Cham: Springer.

Doukas, C., & Maglogiannis, I. (2011). Managing wearable sensor data through cloud computing. In *2011 IEEE third international conference on cloud computing technology and science* (pp. 440–445). IEEE.

Mehrtak, M., SeyedAlinaghi, S., MohsseniPour, M., Noori, T., Karimi, A., Shamsabadi, A., & Dadras, O. (2021). Security challenges and solutions using healthcare cloud computing. *Journal of Medicine and Life, 14*(4), 448.

Rajini, S. N. S., & Beulah, E. M. (2016). Cloud-based architecture for healthcare system. *Asian Journal of Microbiology, Biotechnology and Environmental Sciences, 18*(4), 1017–1018.

Sun, J., Yuan, Y., Tang, M., Cheng, X., Nie, X., & Aftab, M. U. (2021). Privacy-preserving Bilateral Fine-grained Access Control for Cloud-enabled Industrial IoT Healthcare. *IEEE Transactions on Industrial Informatics* DOI: 10.1109/TII.2021.3133345.

Bao, Y., Qiu, W., Tang, P., & Cheng, X. (2021). Efficient, revocable and privacy-preserving fine-grained data sharing with keyword search for the cloud-assisted medical IoT system. *IEEE Journal of Biomedical and Health Informatics* DOI: 10.1109/JBHI.2021.3100871.

Bao, Y., Qiu, W., & Cheng, X. (2021). Secure and lightweight fine-grained searchable data sharing for IoT-oriented and cloud-assisted smart healthcare system. *IEEE Internet of Things Journal* DOI: 10.1109/JIOT.2021.3063846.

Khan, I. H., & Javaid, M. (2021). Big data applications in medical field: A literature review. *Journal of Industrial Integration and Management, 6*(01), 53–69.

Haleem, A., Javaid, M., Singh, R. P., & Suman, R. (2021). Applications of Artificial Intelligence (AI) for cardiology during COVID-19 pandemic. *Sustainable Operations and Computers, 2*, 71–78.

Haleem, A., Javaid, M., & Khan, I. H. (2020). Holography applications toward medical field: An overview. *Indian Journal of Radiology and Imaging, 30*(03), 354–361.

Javaid, M., & Haleem, A. (2021). 3D bioprinting applications for the printing of skin: A brief study. *Sensors International, 2*, Article 100123.

Gupta, N., Bahl, S., Bagha, A. K., Vaid, S., Javaid, M., & Haleem, A. (2021). Nanomedicine technology and COVID-19 outbreak: applications and challenges. *Journal of Industrial Integration and Management, 6*(02), 161–174.

Javaid, M., Haleem, A., Singh, R. P., Rab, S., & Suman, R. (2021). Upgrading the manufacturing sector via applications of industrial internet of things (IIoT). *Sensors International, 2*, Article 100129.

Bhattacharya, I., Ramachandran, A., & Jha, B. K. (2012). Healthcare data analytics on the cloud. *Online Journal of Health and Allied Sciences, 11* 1 (1).

Akinsanya, O. O., Papadaki, M., & Sun, L. (2019). Current cybersecurity maturity models: How effective in healthcare cloud? In *CERC* (pp. 211–222).

Sandhu, R., Kaur, N., Sood, S. K., & Buyya, R. (2018). TDRM: Tensor-based data representation and mining for healthcare data in cloud computing environments. *The Journal of Supercomputing, 74*(2), 592–614.