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# Significance of machine learning in healthcare: Features, pillars and applications

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ABSTRACT

Machine Learning (ML) applications are making a considerable impact on healthcare. ML is a subtype of Artificial Intelligence (AI) technology that aims to improve the speed and accuracy of physicians' work. Countries are currently dealing with an overburdened healthcare system with a shortage of skilled physicians, where AI provides a big hope. The healthcare data can be used gainfully to identify the optimal trial sample, collect more data points, assess ongoing data from trial participants, and eliminate data-based errors. ML-based techniques assist in detecting early indicators of an epidemic or pandemic. This algorithm examines satellite data, news and social media reports, and even video sources to determine whether the sickness will become out of control. Using ML for healthcare can open up a world of possibilities in this field. It frees up healthcare providers' time to focus on patient care rather than searching or entering information. This paper studies ML and its need in healthcare, and then it discusses the associated features and appropriate pillars of ML for healthcare structure. Finally, it identified and discussed the significant applications of ML for healthcare. The applications of this technology in healthcare operations can be tremendously advantageous to the organisation. ML-based tools are used to provide various treatment alternatives and individualised treatments and improve the overall efficiency of hospitals and healthcare systems while lowering the cost of care. Shortly, ML will impact both physicians and hospitals. It will be crucial in developing clinical decision support, illness detection, and personalised treatment approaches to provide the best potential outcomes.

## 1. Introduction

The term "Machine Learning (ML)" refers to various statistical techniques that allow computers to learn from experience without being explicitly programmed. This learning usually takes the form of changes to how an algorithm works. An ML system may recognise faces by studying a collection of photographs depicting various people. Unsupervised learning and supervised learning are the two major branches of ML. Healthcare is one of the world's largest industries that can benefit from this technology [1–3]. The average life expectancy has increased substantially during the last century with technological developments. While technology has improved significantly since the past, emerging technologies such as Artificial Intelligence (AI) and ML promise a renaissance in healthcare. Using computing, of course, even the most minute and most negligible parts of any operation can be simplified to near perfection. ML is already present in healthcare, but it offers much potential for future implementation [4,5].

The healthcare industry has always been a strong supporter of cutting-edge technologies. AI and ML have found several applications in the healthcare industry, just as they have in business and e-commerce. There are virtually limitless possibilities with this technology. ML is assisting in transforming the healthcare industry for the better with its cutting-edge applications. Healthcare systems have already used Big Data tools for next-generation data analytics because of mandatory procedures like Electronic Medical Records (EMR). ML tools are set to offer even more value to this process. These improve the quality of automation and intelligent decision-making in primary/tertiary patient care and public healthcare systems. This could be the most significant impact of ML tools, as it can improve the quality of life for billions of people worldwide [6–8].

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ML technologies have a wide range of uses for improving clinical trial research. By applying sophisticated predictive analytics to clinical trial applicants, medical professionals could evaluate a broader range of data, reducing the expenses and time required for medical tests. There are a variety of ML applications that can further improve clinical trial efficiency, such as assisting in determining optimal sample sizes for greater efficacy and reducing the possibility of data errors through the use of EHRs. This method addresses a significant issue in the healthcare field, as well-trained radiologists are becoming increasingly scarce worldwide. Another benefit of ML in the healthcare business is giving individualised therapies that are more dynamic and efficient by combining personal health with predictive analytics [9–11].

ML has many potential applications for research and clinical trials. Using ML-based predictive research to identify latent clinical trial participants can help researchers move with a supply from many data points, such as previous doctor visits, social media, etc. It also ensures that data is accessed in real-time and manages the trial associates, thereby supporting the most appropriate sample size to be investigated and utilising the energy of electronics work, which aids in the reduction of data-based errors [12,13]. Electronically recorded medical imaging data is abundant these days, and various algorithms may be used to find and discover patterns and anomalies using this dataset. ML algorithms can analyse imaging data in the same way a highly-skilled radiologist can, detecting abnormal skin patches, lesions, tumours, and brain bleeding. As a result, the use of these platforms to aid radiologists is expected to skyrocket [14,15].

The field of research is another area that looks to profit significantly from ML. Clinical studies are prohibitively expensive and can take years to complete. Researchers can reduce their pool of possible clinical trial participants by using ML-based predictive analytics to find them from various data points such as social media, previous doctor visits, and others. Another technique to utilise ML in this situation is to observe trial participants in real-time. Such technologies can also assist researchers in determining the optimal sample size to test and utilising electronic records to eliminate database errors [16,17]. The main aim of this paper is to discuss the significant potential of ML in healthcare.

## 2. Need for machine learning in healthcare

The quality of healthcare services and the ability to treat complex diseases constantly improve. Nonetheless, many challenges remain, notably the dosage and duration of therapies based on individual characteristics or for patient groups with few clinical studies, such as children [18]. So, in recent years, ML has been successfully integrated into paediatric care to predict the best and most individualised treatments for children. ML has been thrust into the spotlight since the outbreak of the COVID-19 pandemic. Organisations have turned to ML to stay competitive and gain an advantage, from streamlining operations to driving R&D in a sometimes volatile and uncertain work environment. ML has helped hospitals and health systems deal with unique challenges [19,20].

ML technology is one of the most exciting areas of AI, and many companies are attempting to leverage it for their purposes. ML is becoming increasingly popular. It uses algorithms to facilitate data-driven learning and can be used in scenarios ranging from business to healthcare. Healthcare is constantly changing due to the constant development of new technology and ideas. ML could assist medical professionals in some of these new scenarios. Today's technology can elicit insights from unstructured text previously challenging to generate and deploy on a large scale. With this new wealth of ML-derived intelligence, physicians and administrators can make timely, informed decisions about patient care and operational programmes that affect millions of lives [21–23].

## 3. Research objectives

As advanced technology gains traction in the healthcare sector, it produces high-performance computing that is fast, dependable, and capable of handling large and complex data silos. Automated ML helps medical professionals to provide high-quality patient care and healthcare facilities. This technology provides novel methods and efficient programming interfaces for harnessing data in real-time, allowing healthcare professionals to make the most of it. This enables healthcare professionals and other staff to work more efficiently and provide better patient care. ML applications in healthcare are currently primarily used to analyse large amounts of data to assist doctors and other medical professionals in making more informed decisions. This technology can assist doctors in identifying anomalies, patterns, and trends while also assisting in the reduction of human error. Data science, which includes ML models, has enabled accurate and efficient healthcare operations and fast computing capabilities [24–26]. The primary research objectives of this paper are as under:

RO1: To study ML and its need in healthcare;

RO2: To explore the associate features of ML for strengthening the structure of healthcare;

RO3: To study the appropriate pillars of ML for healthcare;

RO4: To identify and discuss the significant applications of ML in healthcare.

## 4. Associate features of machine learning for healthcare structure

Fig. 1 reflects the variety of smart and caring features associated with the ML culture for its extensive services in healthcare perspectives. It includes support from the various intelligent and digital tools like AI and cloud data performances belonging to healthcare services. Even at a reasonable cost, the generation of electronic medical records further impressively assists the healthcare domain. The smart prepared reports, digital notes, records maintaining, etc., are several other impactful zones where ML principles explore its quality services in the healthcare domain [27,28].

Healthcare institutions are using ML systems to monitor and anticipate potential epidemic outbreaks in various parts of the world. This

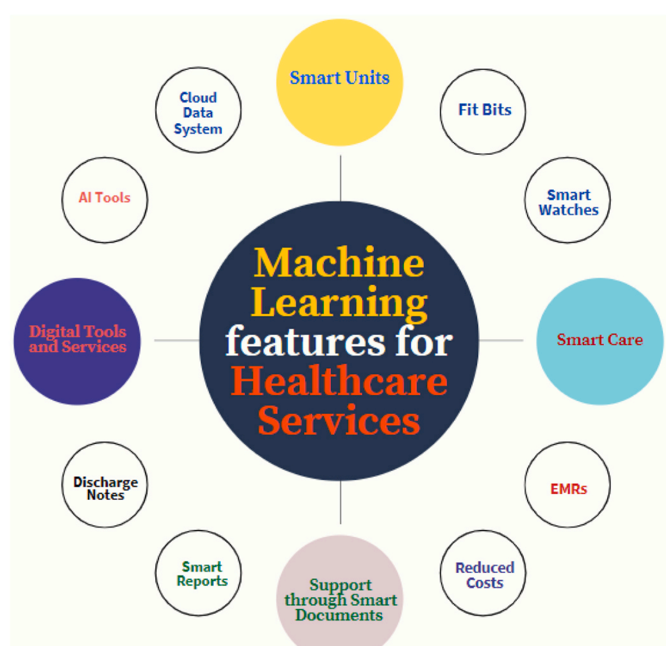


**Fig. 1.** Smart features of machine learning for healthcare domain.

digital system can forecast disease outbreaks by gathering data from satellites, real-time updates on social media, and other crucial information from the web. It has the potential to be a boon, particularly for third-world countries that lack adequate healthcare facilities. ML and related data-driven techniques address some of the core causes highlighted by long lines, fear of exorbitant bills, a drawn-out and too complex appointment process, and a lack of access to the correct healthcare provider. Similar challenges have plagued traditional organisations for decades, and ML techniques are already part of the solution. This is because vast databases and intelligent search algorithms, the strength of ML systems, excel at pattern matching or optimisation challenges [29–31].

Powerful ML technologies for hospital operations management must differentiate from traditional systems by combining empathy with a profit-generating purpose. Finding accurate therapy alternatives for an individual based on specific medical history, lifestyle choices, genetic data, and constantly changing pathological testing is the goal here, which is exceedingly complex and demanding. We must naturally employ the most potent AI approaches, deep neural networks, AI-driven search algorithms/advanced reinforcement learning, probabilistic graphical models, and semi-supervised learning to handle the challenge. ML in healthcare enables them to extract insights from historical data such as diseases, family history, and genetic diseases, among other things, and make swift judgments [32–35].

In recent years, the widespread availability of hardware and cloud computing has resulted in a more extensive use of ML in several domains of human life, ranging from utilising it for social media recommendations to adopting it for process automation in factories. Healthcare is another industry that keeps up with the times. ML algorithms in healthcare have a lot of potential because of the volume of data gathered for each patient [36,37]. On the other hand, they can plan ahead of time, recommending a complete treatment to the patient, resulting in fewer expenses and a better patient experience. ML is a blessing in disguise for the healthcare industry. There is a lot of unstructured data in patient records, previous therapies, and the patient's family's medical history. ML assists clinicians in predicting real health issues by evaluating patients' history data [38,39].

The advancement of this technology has hastened the transition to information-based healthcare delivery and administration. Today's multidisciplinary approach to improving healthcare outcomes, combined with improved imaging and genetic-based personalised therapy models, relies on ML-powered information systems. Furthermore, while a healthcare professional and an ML algorithm will almost certainly reach the same conclusion based on the same data set, ML will yield results considerably faster, allowing treatment to begin sooner. Another advantage of employing ML techniques in healthcare is that it decreases the likelihood of human error by removing some human participation. This is especially true for process automation activities, as tiresome, repetitive work is where humans make the most mistakes [40–42].

Clinical decision support technologies aid in analysing vast amounts of data to detect a condition, decide on the next stage of treatment, identify any potential difficulties, and improve overall patient care efficiency. ML is a powerful technique that assists physicians in doing their duties more efficiently and promptly and reduces the likelihood of making an incorrect diagnosis or prescribing ineffective treatment and its growing popularity in recent years. The cause for this is the increased acceptance of electronic health records and the digitisation of numerous data points, including medical photographs. Medical images, such as X-rays, were analogue for the longest time. This has hampered technology for anomaly detection, case grouping, and illness research in general. Fortunately, the digitalisation of the industry has resulted in more significant opportunities for these forms of data analysis, including ML [43–45].

Healthcare data for ML must be prepared so that the computer can detect patterns and conclusions more quickly. It is done by humans who tag components of the dataset, a process known as annotation over the input. Clinical specialists also analyse data, write new rules, and improve machine performance. However, for ML systems in healthcare to learn rapidly and successfully, the annotation done on the data must be correct and relevant to extracting essential concepts with appropriate context. Surgical operations necessitate extreme precision, adaptability to changing situations, and a consistent approach over an extended period [46–48]. While trained surgeons possess all of these characteristics, one of the prospects in ML for healthcare is for robots to perform these duties. ML algorithms can simulate an active component that would function on another similar condition based on previously gathered data on active components in medications and how they influence the organism [49,50].

Clinical trials and research take a significant amount of time, effort, and money. Predictive analytics based on ML assists save the time and money invested in clinical trials while also delivering accurate findings. Furthermore, ML technologies can discover potential clinical trial applicants, access their medical history records, monitor the candidates throughout the trial process, choose the best testing samples, eliminate data-based errors, and do a variety of other things. Healthcare workers can apply ML to better their industry, streamline several operations, and ultimately save lives. Aside from its direct involvement in the medical sector, ML serves a critical preventive function. This technology improves monitoring by allowing specialists to identify possible flaws that are not currently visible but have the potential to harm our lives. Some of these include emerging diseases and pandemics, general pollution, and other factors that may impact our overall health [51–53].

Using ML, healthcare facilities can predict concerns that have not yet afflicted the patient at the global level. This enables doctors to suggest treatments that either eradicate the problem before it occurs or significantly reduce its severity. It is especially important in cancer treatment, where early detection is critical. Smart imaging is one of the most interesting new healthcare technologies, made possible only by ML. Patient records are one of the things on which healthcare relies heavily [54,55]. Improving and simplifying patient records can assist medical workers in anticipating potential issues, resolving present ones, and assessing specific situations. Patient records contain their previous diagnoses, health conditions, and physical and emotional health insight. Smart patient records are becoming a reality due to ML, and they are widely used in the medical field. Smart patient records simplify and streamline patient records, making them more valuable to medical professionals in nearly every manner [56,57].

## 5. Pillars of machine learning for healthcare

The concept of ML and its versatile capabilities have been reported to serve the healthcare domain in various ways. Fig. 2 explores the different enablers and quality pillars for helping and caring for healthcare units. The outbreak prediction capability, medical imaging diagnosis, behavioural modifications, records of patient data, etc., are some of the majorly elaborated quality pillars of the renowned ML concept, which further extends its services for the benefit of society through healthcare services. These ML attributes' effectiveness and undoubtfully performance provide all the essential foundations while there is a need for these services in healthcare practices [58,59].

ML is the process of teaching computers to recognise patterns by supplying them with data and an algorithm to work with. It is difficult to detect diseases manually; ML plays a significant part in diagnosing the patient's ailment, monitoring his health, and recommending required steps to prevent it. It can range from minor illnesses to severe diseases such as cancer, which are difficult to detect early. Learning and predicting mental health concerns globally or among specific demographic sectors is one of the ML use cases in healthcare. This assists mental healthcare clinicians in identifying demographic segments that are most sensitive to stressors such as pandemics or natural catastrophes. It can assess biological activity, absorption, distribution, metabolism, and excretion features and choose molecules with desirable biological

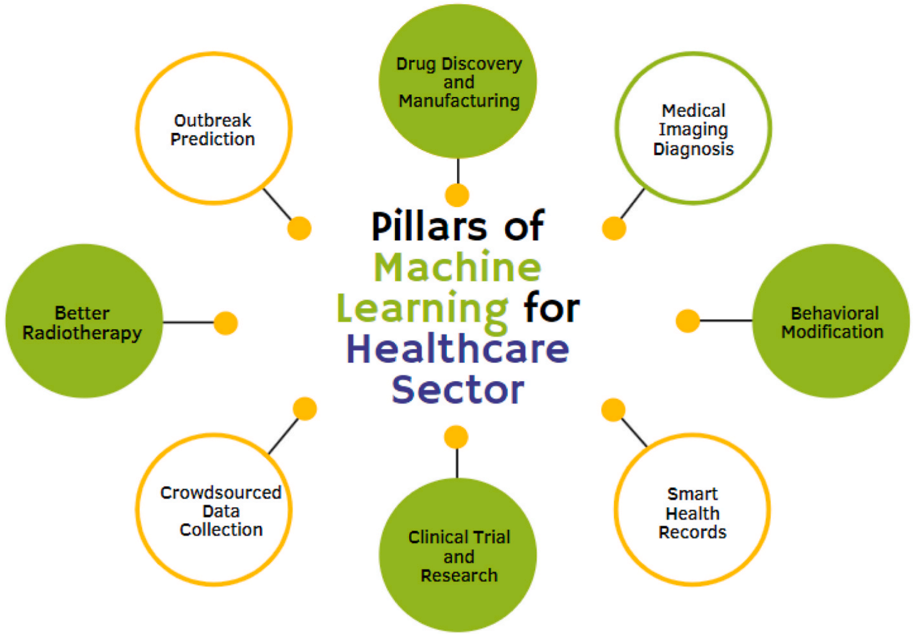


**Fig. 2.** Pillars of machine learning for healthcare services.

activity and physicochemical attributes [60–62].

Crowdsourcing was recently found in the medical area, and today academics and practitioners use the approach to access vast volumes of data that people contribute with their permission. Such real-time health data has far-reaching consequences for how medicine will function in the future. This technology can analyse vast amounts of data gathered from real-time social media feeds, satellites, website information, and institutional records. Networks can assist in making sense of this data and forecasting anything from malaria outbreaks to serious infectious diseases. Updating and maintaining health data is a time-consuming and costly procedure. This technology has played an essential part in easing the data entering procedure. However, most processes still take a long time to complete because they must be done manually. This is where ML enters the picture. It claims to save time, money, and effort [63,64].

By delivering individualised treatment recommendations, ML can assist in shifting the focus of healthcare from a reactive to a preventive approach. In healthcare applications, it can assist clinicians in providing highly tailored therapy based on unique patient traits and symptoms. As a result, the likelihood of patients experiencing side effects from prescription medication will be reduced. The application of ML algorithms in healthcare can aid in predicting and tracking disease outbreaks. ML can also reduce poor epidemic outcomes [65,66]. ML can improve and simplify the drug discovery process and simplify clinical trials. There are numerous problems that pharmaceutical companies encounter in this field. Organising clinical trials has always been a time-consuming and labour-intensive procedure with numerous factors to consider. Thus, to produce accurate results, potential clinical trial applicants must be rigorously vetted based on several criteria. This constantly monitors and evaluates a massive amount of data to guarantee that the medications are safe and effective by using this technology [67,68].

ML enables machines to learn concepts, interpret data, and provide desired outputs independently. ML models learn to interpret data through conditions and clauses using various learning approaches such as unsupervised, supervised, and more. As a result, they are suitable for producing prescriptive and predictive insights. Furthermore, ML aids in optimising patient involvement and recovery by sending out timely alerts and notifications to patients regarding their visits, report collection, and other activities. One of the most critical ML applications in healthcare is disease identification and diagnosis. Concerns such as hereditary and genetic problems and certain types of cancer are difficult to detect in the early stages, but they can be precisely recognised using properly-trained ML solutions [69,70].

ML is being used to solve a variety of problems in healthcare. The ability to get the proper therapy improves patients' quality of life, and the health care system can assure efficient use of resources by offering suitable therapies to patients. ML may assist a value-based approach to cancer care and the importance of access to linkable health data and collaboration among various public and commercial players to make this a reality. This technology is hugely beneficial in healthcare delivery's organisational and administrative aspects, such as patient and bed management, remote monitoring, appointment administration, duty roster compilation, and other tasks. Daily, healthcare workers spend their time on duplicate chores like record administration and upkeep and claims processing, which stops them from providing the necessary treatment. The use of ML models may result in automation and the elimination of human intervention in locations [71–73].

An illness like diabetes is that many people carry it for a long time without having any symptoms. As a result, by the time people notice the symptoms and effects of diabetes for the first time, it is too late. However, cases like these could be avoided with the help of ML models. Models based on ML can now assist us in identifying such subconscious and involuntary actions and making essential lifestyle modifications. This might be as basic as wearable is that prompt us to move our body after long periods of inactivity or apps that prompt us to adjust our body postures [74,75]. Only data-driven development methodologies allowed for the rapid creation of COVID-19 vaccines. The integration of image recognition algorithms for minimal abnormality identification, such as cancer metastasis, improved the quality of radiology diagnosis. Various data are utilised to forecast health issues and diseases, ranging from social media posts to wearable medical records. False positives must be reduced in various applications, such as sensor alarms. A false positive occurs when a test result wrongly classifies a condition, such as a disease, as being present when it is not. Technologies are applied to diagnosis data to improve false positives and false negatives [76,77].

ML has become an inseparable part of industries, bringing significant advancements such as telemedicine, self-driving cars, hyper-targeted ads, and many other valuable solutions that benefit entrepreneurs by making their businesses more profitable and customer-centric. ML helps healthcare professionals with various tools and techniques that significantly impact health outcomes. ML software, equipped with intelligent predictive algorithms, can provide immediate benefits to disciplines with large datasets [78,79]. Physical inactivity increases the risk of diabetes, cardiovascular disease, cancer, hypertension, obesity, and mental disorders significantly. Regular physical activities of more than 1 h per week, on the other hand, can prevent these diseases and cut mortality rates in half. An important aspect is that the recommendation is tailored to the individual. ML is a critical tool for providing ongoing and real-time individualised coaching and incentive systems in which recommendations are made based on daily activity performance. People who want to start doing activities but need an extrinsic nudge are already doing small amounts of activity but need to be motivated to do more, and so on [80,81].

ML extracts learn, predicts, and foresees from massive medical data while providing professional support and assistance. ML tools, cardiovascular disease, and nervous system disorders are among the most frequently researched diseases. Self-trained systems can learn through supervised and unsupervised methods, greatly facilitating early detection and diagnosis. Self-trained systems must constantly interact with clinical study data to perform well, implying that human activity is inextricably linked to ML [82,83]. Only a few industries have as much structured data as finance and banking, making it an ideal field for applying AI and ML. Many years ago, investment banks were the first to use AI innovation. Since then, the industry has advanced to unprecedented levels, enhancing practitioners' and clients' experiences. ML is a relatively new scientific field in which computers are taught to do more than simply follow the rules. They can learn from others' mistakes. It is used for predictive analysis and improves patient care quality. The use of information and data to forecast the possible future is known as predictive analysis [84,85].

## 6. Significant applications of machine learning for healthcare

Healthcare organisations can also use machine learning to improve risk adjustment. These technologies use algorithms that can extract information from clinical charts faster and more accurately than manual review processes, and they become smarter as more documents are processed. ML allows plans and providers to identify hidden risk factors and healthcare gaps and improve risk score accuracy. ML provides the healthcare profession with the information they need to manage risk better and improve patient care quality by identifying gaps in care. This technology integrates and explores larger data sets and facilitates decision-making. It is based on an algorithmic mechanism that gathers a set of instructions to perform specific tasks. This allows medical professionals to learn relevant data without human intervention. The dependability and efficacy of data analysis using ML tools in healthcare have increased. As a result, there are expectations for evolving healthcare services with faster diagnosis and patient recovery [86–88]. Significant applications of Machine Learning for Healthcare are discussed in Table 1.

ML in healthcare delivers algorithms with self-learning neural networks that can improve treatment quality by assessing external data on a patient's condition, X-rays, CT scans, and numerous tests and screenings.

The application of ML improves the industry's organisational side [225–227]. These regulate the processes, such as claims processing and revenue cycle management, and this technology might easily automate clinical documentation and records administration. There are more and more corporate use cases in the headlines every day. When it comes to AI in the medical field, this must recognise the enormous potential and advances that ML may bring to the healthcare industry. Algorithms outperform radiologists in detecting malignant tumours [228,229].

ML has several potential applications in medical research and development. As anyone in the pharmaceutical industry, clinical trials are expensive in terms of both time and money and can take years to complete in many cases. Using ML-based predictive analytics to identify potential clinical trials can assist researchers in creating a pool from a

**Table 1**
Significant applications of Machine learning for healthcare.

| S. No | Applications | Description | References |
|---|---|---|---|
| | Accurately collect the patient's history. | • One of the most crucial roles of a physician is to collect a patient's history accurately. This is frequently difficult because the patient is not a specialist and does not know about the data. Healthcare practitioners can use ML to accurately collect a patient's history and healthcare management to find the most relevant questions to ask a patient based on various factors.<br>• It aids in collecting essential data while also providing a prediction of the most likely conditions.<br>• ML can help people with limited mobility improve their daily lives by providing smart reminders and scheduling assistance, predicting and avoiding potential injuries by identifying common obstacles determining the best paths and obtaining help as soon as possible. | [89–92] |
| | Improve the experience in healthcare services | • The primary goal of ML-assisted platforms aims to improve the experience in healthcare services for the most significant number of people.<br>• In traditional enterprises, the ultimate purpose of already-deployed systems is to maximise profit. Powerful ML technologies for hospital operations management must differentiate from traditional systems by combining empathy with a profit-generating purpose.<br>• The pharmaceutical sector is increasingly turning to ML approaches to solve the infuriatingly complex problem of successful medication discovery.<br>• Many start-up companies also leverage ML systems to evaluate multi-channel data using the most up-to-date reinforcement learning and natural language processing techniques. The main goals are to find patterns and build high-dimensional representations that can be saved in the cloud and used in the drug-discovery process. | [93–97] |
| | Improve treatment process | • ML can improve the treatment process by boosting patient involvement and, as a result, health outcomes and its adoption can significantly improve practically any process in the healthcare business.<br>• Data that is fragmented, duplicated, or missing, combined with hundreds of handwritten document scans, can lead to insufficient insights and incorrect conclusions. Thus, before ML algorithms can efficiently utilise the data, it must first be formatted appropriately and cleaned.<br>• ML algorithms can improve care delivery by giving physicians | [98–101] |

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**Table 1** (*continued*)

| S. No | Applications | Description | References |
|---|---|---|---|
| | | daily recommendations on which patients are most likely to be readmitted and how they might lessen that risk. | |
| | Robotic surgeries and other image-guided therapies | • ML tools bring significant value by enhancing the surgeon's display with information such as cancer location during robotic surgeries and other image-guided therapies.<br>• ML tools/platforms aid radiologists tremendously. Exabytes of medical data are being digitised at various healthcare organisations nowadays. Robust and agile AI-enabled solutions are required to connect to many patient databases and analyse a complicated variety of data kinds, thus aiding robotics procedures.<br>• The developed systems should be able to uncover hidden patterns thoroughly. They should also be able to convert and depict their findings into human-readable forms so that doctors and other healthcare professionals may work on their output with total confidence and transparency, thereby assisting the better implementation of robotic and image-guided processes. | [102–105] |
| | Automatically messaging warning | • ML can provide automated messaging warnings and appropriate targeted material that prompts actions at critical junctures<br>• ML can personalise and improve the treatment process in various ways. A bot system that makes the treatment time considerably easier is one of the top ML for Healthcare applications<br>• A virtual nurse for patients serves as a voice-controlled healthcare assistant, providing information on a wide range of ailments, health conditions, and medications<br>• It facilitates the formation of neural networks and the detection of harmful cells to the organism<br>• In oncology, it seeks cancer-affected cells with the same precision as an expert physician | [106–110] |
| | Detect of diabetes | • Diabetes is one of the most common and deadly diseases as it causes a slew of other significant disorders. Diabetes primarily affects the kidneys, the heart, and nerves. ML could aid in the early detection of diabetes, perhaps saving lives.<br>• The liver is a key player in metabolism and is susceptible to chronic hepatitis, liver cancer, and cirrhosis. Predicting liver illness using massive volumes of medical data is a complex issue, yet, there have already been some notable breakthroughs in this area.<br>• Researchers now have access to massive amounts of data made public by patients themselves. This will be the source of future advancements in ML in Medicine and make near-perfect predictions. It enables healthcare providers to make helpful ideas on time, estimate disease risk, and assign the appropriate treatment resources. | [111–114] |
| | Make timely decision | • One of the most crucial aspects of healthcare is making timely decisions. If physicians and healthcare professionals have additional information, they can reduce risks by making treatment-related decisions ahead of time. ML in healthcare and bioinformatics can process vast amounts of data and provide significant insights to help healthcare workers make timely decisions.<br>• ML enables patients' examinations easy with better access to medical history and forecast results based on treatment and lifestyle.<br>• Besides disease and treatment prediction and modelling, such an ML system can theoretically forecast future patients' likelihood of getting specific diseases based on early screening or routine annual physical exam data. ML can assist in addressing this scarcity.<br>• It can revolutionise medical practice by automating chores and improving human decision-making. Reducing hospital readmissions is a big challenge for healthcare providers. Medicare payments are connected to readmission rates, and ignoring this issue can be costly. | [115–119] |
| | Discover health problem | • Another primary application of ML in healthcare is that clinicians can discover health problems before they become diseases by analysing massive patient data. Clinical institutions can apply ML in health care to detect strokes based on existing health conditions, assess heart health, and detect other issues.<br>• Doctors and clinical experts can diagnose potential much earlier since ML algorithms provide real-time data and analysis. ML in healthcare allows professionals to automate many administrative duties to provide better patient care.<br>• This technology can help in the early stages of medication research. It is already dominated by research and development technologies such as precision medicine and next-generation sequencing, which are utilised to uncover alternative treatment pathways for complex disorders. | [120–124] |
| | | | [125–129] |

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**Table 1** (*continued*)

| S. No | Applications | Description | References |
|---|---|---|---|
| | Handle online appointment scheduling | • ML can handle online appointment scheduling by intelligently examining clinician calendars and assigning an appointment date.<br>• ML assists in the handling of billing, appointment rescheduling, appointment record filing, giving advice to patients, setting up reminders, redirecting emergency calls, and much more. Medical imaging and disease diagnosis are likely among the most significant advancements in ML for healthcare.<br>• Furthermore, ML tools may simulate why and under what conditions diseases are more likely to occur, guiding and preparing doctors to intervene even before an individual exhibits symptoms.<br>• Finding accurate therapy alternatives for an individual based on his or her specific medical history, lifestyle choices, genetic data, and constantly changing pathological testing is the goal here, which is exceedingly complex and demanding. | |
| | Analyse patient data | • ML analyses patient data and aids in identifying diseases that may present in the body but are challenging to detect. With ML, medical imaging becomes incredibly effective since the algorithms can process large amounts of radiology and pathology data and make faster choices.<br>• It also aids in the identification of tumours that may develop in size and provides an accurate image of them so that doctors may get a visual representation of the condition.<br>• Researchers frequently encounter difficulties digesting data and determining the next best treatment option. ML models act as a catalyst in analysing this data and determining the optimal paths for researchers to take in order to attain better test outcomes. Wearable smart gadgets have become a key innovation in personal health monitoring, and ML has also grabbed the lead. | [130–133] |
| | Early-stage medication development | • Another application of ML in healthcare is early-stage medication development. During this stage, pharma practitioners can use ML in healthcare for next-generation sequencing.<br>• Precision medicine benefits from ML in healthcare by identifying alternative therapy pathways for complex disorders<br>• ML algorithms enable pharmaceutical companies to blend medication formulations and determine which ones work best. Because they are based on unsupervised learning, ML approaches can be efficient for discovering novel medications and tailoring drug combinations for the individual case | [134–137] |
| | Clinical trials | • ML has a wide range of applications in healthcare, including clinical trials and research; it supports researchers by predicting the best candidates for clinical trials, which reduces the possibility of error. It examines several data points such as medical history, therapies, health and to determine who can participate in clinical trials<br>• For healthcare, businesses can provide real-time data about candidates participating in a study. It is an effective method for making judgments and modifying testing procedures when new predictions emerge.<br>• ML improves personal health by answering patients' common questions via apps. Artificial Intelligence bots can recognise frequent requests, recognise patterns, and transmit them to the appropriate doctors | [138–142] |
| | Assist psychological difficulties | • ML can be used efficiently to assist the elderly and others with psychological difficulties in making health-related decisions. It includes taking the proper drugs, developing healthy habits, and consulting with a specialist as needed. It restricts their prospective range of alternatives to particularly recommended options. As a result, a precise balance between algorithmic instructions and personal flexibility should be provided<br>• The most general ML applications in healthcare include medical billing automation, clinical decision support, and the establishment of clinical care recommendations. | [143–146] |
| | Patient diagnosis and therapy | • ML aids in patient diagnosis and therapy; with its practical applications, it can be used to improve medical care, forecast results, and even aid with procedures, in addition to patient diagnostics and treatment development<br>• While ML has much potential in the healthcare industry, it also has several limitations, such as healthcare data quality, developing physician-friendly products, and assembling a large team of data experts.<br>• Many technology firms worldwide are currently working on systems that provide diagnostics for picture analysis for physicians. As ML algorithms become more common and powerful, there will be an increase in the number of data | [147–150] |

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**Table 1** (*continued*)

| S. No | Applications | Description | References |
|---|---|---|---|
| | | sources derived from various medical imaging. | |
| | Medicine discovery | • ML applications have found their way into the field of medicine discovery, particularly in the introductory stages, from the first screening of a medicine's ingredients to estimating its success rate based on biological parameters.<br>• Pharma businesses employ ML in drug discovery and manufacturing processes. This is confined to utilising unsupervised ML to discover patterns in raw data. The goal here is to create precision medicine powered by unsupervised learning, which will allow doctors to find mechanisms underlying "multifactorial" disorders.<br>• ML technology can assist build tailored treatments and drugs that target specific diseases in individuals by utilising patient medical history. When paired with predictive analytics, this yields even more benefits. So, doctors can rely on ML's predictive powers to diagnose their patients rather than select from a predefined set of diagnoses or evaluate their risk based on their symptomatic history. | [151–155] |
| | Radiology | • In Radiology, ML has proven to be highly beneficial. There are many discrete variables in medical image analysis that can be triggered at any time. Algorithms based on ML are helpful in this situation. Because ML algorithms learn from a wide range of data samples, they can better diagnose and identify the variables of interest.<br>• In medical image analysis, ML is used to categorise items such as lesions into several categories such as normal, abnormal, lesion or non-lesion, benign, malignant, and so on.<br>• ML allows machines and devices to accomplish their task. Robotic surgery is one of the contributions of ML to the healthcare business.<br>• Many experts believe that the application is promising. It is helpful for surgical workflow patterns, surgical skill evaluation, robotic surgical supply advances, and automated suturing. | [156–159] |
| | Development of novel medical procedures | • Today, ML are on its way to becoming a critical component of health care systems, from the development of novel medical procedures to the management of patient data and records.<br>• The rise in ML apps allows us to envision a future in which healthcare professionals will employ data and analytics to optimise operations and automate tasks. AI-based technologies and ML are now being used to monitor and predict epidemics all over the world.<br>• Scientists now have access to massive amounts of data collected from satellites, real-time social media updates, website information, etc. Artificial neural networks aid in collecting data and predicting everything from malaria outbreaks to severe chronic infectious diseases. | [160–163] |
| | Forecast disease | • Healthcare practitioners are now using digital solutions built on ML models to forecast occurrences such as strokes, heart attacks, sepsis, and other critical problems.<br>• These tools collect information from previous patient records, make daily evaluations, and then real-time monitor vital indicators such as heart rate and blood pressure. The technologies can notify personnel of impending patient hazards and allow them to take preventive measures.<br>• One of the most critical uses of ML algorithms in healthcare is detecting and diagnosing difficult-to-diagnose disorders. This can include malignancies that are difficult to detect in their early stages and hereditary illnesses.<br>• Other tools use ML to produce therapeutic treatments in fields such as oncology. The goal here is to create a commercially feasible method of diagnosing and treating clinical diseases by automating the process as much as possible. | [164–169] |
| | Detect minute defects | • It is now possible to detect minute defects in scanned photos of patients using ML techniques such as deep learning, allowing clinicians to make an accurate diagnosis.<br>• Traditionally, procedures such as x-ray and CT scans were sufficient for inspecting minor anomalies, but with the increase in diseases, it was necessary to investigate them thoroughly.<br>• Doctors may now deliver individualised treatment to individual patients based on their needs to the explosion of patient data in genetic information and electronic health records. Their goal is to extract insights from large volumes of data and apply them to make patients healthier individually. These insights can recommend customised combinations and forecast illness risk with ML tools. This results in creating powerful resources for the patient's health improvement. | [170–174] |
| | Helps to treat blood cancer | • ML can now help treat blood cancer and various other ailments. With such renowned | [175–179] |

(continued on next page)

**Table 1** (*continued*)

| S. No | Applications | Description | References |
|---|---|---|---|
| | | cancer expertise, every patient has access to the best possible treatment decision<br>• While technology has made data entry more accessible, some operations still take long. Daily maintaining up-to-date health data is both tiring and time-consuming.<br>• ML has entered to save time, effort, and money by maintaining health records. Around the world, various ML methods are being used to monitor and anticipate outbreaks. This can access the vast amounts of data collected from satellites, social media platforms, and websites, among other sources. Artificial neural networks enable us to interact with knowledge and anticipate everything from minor ailments to chronic severe infectious diseases. | |
| | Enhance healthcare system | • ML has the potential to enhance the healthcare system significantly. It has already demonstrated encouraging results in assisting clinicians in diagnosing cancer, tumours, uncommon disorders, and pathologies.<br>• In some cases, ML-based systems can even surpass humans. One of the most impressive ML applications in healthcare is disease prediction.<br>• ML can aid in the discovery of links between various patient symptoms and an assumed disease by using patient health information. This can disrupt the medical business by introducing new approaches to healthcare data management, improving patient care, and reducing administrative operations<br>• Medical records that previously required human interpretation can now be used as input data for ML in healthcare initiatives. ML focuses on employing algorithms to learn from data without additional programming. | [180–184] |
| | Enhance the accuracy of clinical studies | • ML can help speed up and enhance the accuracy of clinical studies at every level<br>• ML algorithms can assist scientists in selecting ideal candidates for trials, analysing the information they offer throughout a trial in real-time, detecting data problems, and identifying unexpected trends and resulting in massive cost savings<br>• The most important benefit, though, is that those who require the drugs being studied will be able to receive them sooner. The use of ML intense learning in healthcare applications for medical imaging, disease detection, and drug development is projected to take the lead and drive market expansion.<br>• Another significant motivator of widespread ML implementation is the potential cost benefits to the healthcare sector | [185–188] |
| | Improve the accuracy of results | • Electronic medical devices are becoming more familiar with the advancement of technology and more sophisticated ML and AI applications that vastly improve the accuracy of results<br>• Diagnostic equipment such as computer tomography scanners, ventilators, pacemakers, heart-lung machines, diabetes monitoring tools, or infant incubators are examples of medical devices. These devices provide vital information about the patient's condition, and medical professionals must rely on accurate operation and measurement.<br>• ML is drastically shortening the time it takes for humans to go to the next stage of evolution. In the following years, when more use cases, tests, and apps are developed, the healthcare professional may discuss how cancer has been cured or a deadly pandemic avoided because of a simple smartphone app | [189–193] |
| | Risk management | • Risk management, trading, automation, and performance analysis continue to be the most popular ML applications used by businesses to improve results, drive sales, and increase market share<br>• This technology can replace a significant amount of manual labour and drive greater automation. As a result, businesses can significantly improve their performance and gain a competitive advantage<br>• ML models can be trained to analyse medical records to detect anomalies or areas that require attention, thereby providing new insights into patients' well-being<br>• The potential of ML in retail is exciting, and many companies use ML to create personalised recommendation systems, define pricing strategies and source analytics, and encourage visual search | [194–198] |
| | Healthcare informatics and record digitisation | • ML plays a critical role in streamlining healthcare informatics. Record digitisation aids in proper patient care by optimising operations and reducing administrative costs<br>• ML also aids in the elimination of gaps in data algorithms and clinical predictions. Many health informatics professionals contribute to data integrity by collecting, analysing, categorising, and removing data. Patients benefit greatly from integrating health informatics | [199–204] |

(*continued on next page*)

**Table 1** (*continued*)

| S. No | Applications | Description | References |
|---|---|---|---|
| | | and ML to improve healthcare processes<br>• ML assists pathologists and radiologists in obtaining intricate details in MRIs, CAT Scans, and other imaging technologies with high-level megapixels. Enhanced imaging is beneficial in all scenarios, whether for cardiovascular abnormalities or musculoskeletal injuries<br>• ML also enhances our understanding of the dreadful viruses and bacterial infections that threaten people's lives | |
| | Improve healthcare quality | • ML is also used to improve healthcare quality. Healthcare providers can use ML to create programmes that predict a person's risk for a disease or a patient's likelihood of survival<br>• In medicine, ML is used to automate the diagnostic process. ML has grown at an exponential rate over the last few decades. It is now used to improve the quality of life in almost every field and application<br>• Artificial Intelligence and ML are the technologies of the future. Not only has it permeated almost all industries, but it also has the potential to solve some of humanity's most pressing problems, such as disease detection | [205–210] |
| | Improve operational efficiency | • ML is a promising emerging technology in healthcare. Implementing ML allows healthcare organisations to accelerate processes, increase operational efficiency, and ultimately provide more effective patient care<br>• ML is now being used in healthcare to improve the processing of large amounts of data. Since the development of computing power, it has become more cost-effective and affordable. Since evidence-based medicine has become the gold standard, ML is widely appreciated<br>• Provides access to technology-enabled healthcare, which improves treatments, R&D efficiency, and the development of new tools | [211–215] |
| | Helpful to provide a family history | • ML algorithms can also help doctors by providing vital statistics, real-time data, and advanced analytics about family history, patient's disease, lab test results, blood pressure, clinical trial data, etc.<br>• The modern approach to healthcare is to prevent disease through early intervention rather than treat it after being diagnosed. In healthcare, ML helps analyse thousands of different data points, suggest outcomes, and provide timely risk scores and precise resource allocation, among many other applications<br>• Personalised treatments are not only more effective when individual health is combined with predictive analytics, but they are also ripe for further research and better disease assessment. | [216–219] |
| | Improve diagnostic accuracy | • ML is expected to improve diagnostic accuracy, resulting in fewer instances of over-testing as the ML algorithm learns to send patients only for high-value tests<br>• Medical imaging recognition-based ML systems will significantly assist radiologists and anatomical pathologists in their work. Many of the tasks currently performed by anesthesiologists and critical care personnel are likely to be automated using ML models applied to streaming data.<br>• With ML technology advances, new solutions and ecosystems such as augmented reality and the Internet of Things are making inroads into the healthcare and life sciences<br>• White box testing is more critical than functional testing because ML involves complex algorithms. With the rise of ML, several companies attempt to make a name for themselves in healthcare. | [220–224] |

wide range of data points, such as previous doctor visits, social media, etc. ML has also been used to ensure real-time monitoring and data access for trial participants, determine the best sample size to be tested and leverage the power of electronic records to reduce data-based errors. An ML-based approach to identifying a toxic compound that may cause side effects can save much money before going into clinical trials [230–233].

## 7. Discussion

Today it seems as if the world is being taken over by ML. This technology is creating a significant impact on the world, from enabling self-driving cars and speech recognition to medical research and treatment. ML algorithms are being developed by researchers for the early detection of cancer. This is accomplished by detecting biomarkers in the blood linked to cancers. Today, ML algorithms, systems, and tools are indispensable for lab diagnosis, image and cycle management, intelligent clinical data analysis, and computer-aided medical procedures such as organ recognition and tissue characterisation. AI has been integrated into smartphone apps to aid inpatient treatment and diagnosis. Machines are now learning to read CT scans and other imaging diagnostic tools to detect any visible abnormalities. ML will have an impact on consumer health applications as well. ML will be further integrated into applications that affect patients' health experiences outside hospitals. This technology could also be used to identify high-risk patients in a population.

ML advances are now being used to develop accurate predictions, effective asset management, and in-depth market analysis. Businesses also create smart chatbots that help them manage responses more efficiently and provide better customer service. This technology could be an ideal fit for marketing firms. They are generally aware of their competitors, and if they have a strong marketing team in place, they have some knowledge of clients and their purchasing habits. ML differs from traditional programming paradigms in that ML systems are trained rather than explicitly programmed. Traditional programming combines rules and data. Some ML for healthcare and research will either use personal data to train the model or process personal data as part of the model's function.

ML has advanced significantly in recent years, and it is now used by a diverse range of businesses and industries. The healthcare industry is no exception, and it is already benefiting from ML. This technology is poised to improve the quality of care and patients' lives in areas ranging from diagnostics to drug discovery. ML is already resolving essential healthcare issues. The increased reliance has resulted in massive amounts of data that necessitate ML automation for effective processing. Health records, clinical trials, claims processing, billing records, and other data available in the medical sector can provide a wealth of information that can assist professionals in making sound decisions.

ML transforms patient care strategies and plays a critical role in healthcare delivery systems. Natural language processing, computer vision, and reinforcement learning are the most well-known deep learning techniques for healthcare. Deep learning algorithms establish accurate and efficient automated diagnostic suggestions. This can help reduce care costs, reduce the administrative load of healthcare professionals, allow them to focus on other complex diagnostics, and prevent delays in reporting urgent cases. Prescriptions help reduce errors and improve diagnostic speed by utilising diagnostic results and auditing.

By understanding ML opportunities, healthcare professionals can collaborate to improve clinical outcomes and the hospital experience. This technology automates computer systems operations by recognising patterns in unstructured data and converting them to structured data. This will benefit practitioners by giving them access to real-time data making critical decisions.

ML will impact hospitals and physicians by playing an essential role in medical decision support, allowing for earlier disease documentation and customised treatment plans for optimal outcomes. AI can also demonstrate and educate patients on key outcomes and disease pathways for various types of treatment. It can improve health systems and hospital management by increasing efficiency while simultaneously lowering care costs. Object detection and image recognition are used in computed tomography and magnetic resonance imaging to detect and predict disease. Deep learning models can generate practical interpretations such as tissue shape, size, and volume with imaging data. ML advancements have resulted in better handling of patients' data and records, development of novel medical procedures, and better treating chronic diseases.

In recent years, the amount of data available has rapidly increased. ML will become more integrated with data and analytics as it advances, influencing how data is stored, shared, and used in various healthcare applications. However, hospitals must have good, reliable, and timely data for AI and ML to be effective. The ML system is based on enormous datasets comprising raw photos of these diseases; it is typically more reliable than detecting them. They should improve the quality of automation and intelligent decision-making in primary/tertiary patient care and public healthcare systems, and this could be the most significant impact of AI tools, as it improves the quality of life for billions of people worldwide.

There are various roadblocks to rapid ML incorporation in healthcare today. One of the most difficult challenges is obtaining patient data sets with the amount and quality of samples required to train cutting-edge ML models. Patient data is challenging to obtain, exchange, and disseminate because it is safeguarded by strong privacy and security restrictions. Furthermore, data format and quality issues necessitate a large amount of effort to clean and prepare for ML analysis.

## 8. Future scope

As smart medical devices grow common, technology-enabled healthcare is becoming a reality. Because the healthcare business encourages innovation, the future of ML in healthcare is quite promising. This technology is in charge of digesting hundreds of distinct data points, accurately anticipating risks and outcomes, and performing various other duties. This can be utilised to create a personalised prescription for people who have a unique set of particular needs. This ML tool could be utilised in the future in conjunction with nanotechnology to improve medicine delivery. ML helps with the current issue and predicts future difficulties. ML can anticipate outbreaks all across the world. The expert must get a massive amount of data controlled from website data, real-time social media updates, and other sources in today's world. This technology will aid in verifying this data and the prediction of everything from sickness outbreaks to serious infectious diseases.

The use of ML in scientific research is becoming more common. Its application has grown in importance, from processing vast volumes of data to creating accurate predictions and assisting scientists in their research endeavours to help them produce discoveries more effectively. ML is used as an innovative technique for epidemiological studies, which has promise for the future of precision medicine. When treatments are paired with individual health considerations, they are most successful. This is why ML and its predictive analytics component can play an essential role in individualised treatments. Clinicians can choose from a restricted number of diagnoses or estimate the risk to their patients based on their clinical history and genetic information. ML techniques will generate several therapy alternatives in the future by leveraging patient medical history. Further, medical schools should explore incorporating coursework on ML and its applications in their curricula. ML and data science should be taught to medical students, residents, and fellows during their training.

## 9. Conclusion

ML can be a powerful tool in the hands of any doctor, scientist, or researcher. Every day, it seems, there is a breakthrough in ML. With each breakthrough, a new ML application emerges that can solve a genuine problem in healthcare. The advancement of ML is continually increasing, and the medical industry is keeping a close eye on this trend. ML concepts are assisting doctors and surgeons in saving precious lives, detecting diseases and concerns even before they occur, managing patients better, engaging patients more effectively in their recovery process, and much more. Worldwide organisations improve healthcare delivery by leveraging AI-driven solutions and ML models. This technology assists organisations and drug makers develop treatments for critical ailments faster and more effectively. Companies can now accelerate their testing and observation processes by using virtual clinical trials, sequencing, and pattern identification. Health behaviours and socioeconomic factors like income, social support networks, and education are more significant predictors of overall health. To improve overall health, health organisations recognise that they must address the whole person, including lifestyle and environment. ML models can identify patients at a higher risk of developing preventable chronic diseases like heart disease, diabetes, etc.

## Declaration of competing interest

None.

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