ijlpr 2023; doi 10.22376/ijlpr.2023.13.2.P135-P143

International Journal of Life science and Pharma Research

ISSN 2250-0480

Research Article

Technological Implementation in Health Industry

A Novel 4A Framework for Measuring Outcomes of Technological Implementation in The Healthcare Industry

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Abstract: The healthcare industry is ever-evolving, and advancements in this industry are happening on multiple fronts, i.e. scientific, medical, regulatory etc. This industry has witnessed significant changes concerning technology usage, which has changed the overall complexion. The advent of advanced computing tools, such as AI, ML etc., has significantly augmented the capabilities within the industry and is making this industry future ready. The healthcare industry has been reactive, i.e. it treats individuals after they get the disease; however, with the application of the latest tools, the healthcare industry is becoming more predictive, i.e. it can predict the risk profile. This is the most significant impact advanced tools have brought to this industry. Advanced computing tools are being applied to multiple functions across the industry, such as drug development, patient treatment, diagnosis, insurance reimbursement etc. As there are multitudes of applications projecting different kinds of benefits, it becomes essential that we have a tool or framework which can measure the impact. This study aimed to develop a framework to evaluate the benefits of implementing these advanced computing tools. The primary objective of this technology application should be to impact the primary outcomes, i.e. accessibility, speed and accuracy, patient compliance and affordability. We must have a framework that objectively assesses the impact and provides guidance to all the stakeholders. This paper proposes a novel 4A framework to help all stakeholders assess the effects. The central idea in healthcare is to improve a patient's life. One can do that by making medicines more productive, reducing adverse effects, improving predictability, reducing cost, improving access etc. This paper provides a strategic framework to assess the impact on the suitable parameters. Novel 4A framework measures the effect on these critical parameters, i.e. access, accuracy, affordability and adherence. As this industry touches patient's life, there are multiple concerns and the primary amongst them, especially for the technology applications, are the ones related to legal and ethical. The overall archetype proposed in this research paper takes into account and provides a framework for the impact assessment. The novel 4A framework presented in this article will serve as a tool to evaluate the impact advanced computing tools will have on the healthcare industry.

Key Words: artificial intelligence, outcome assessment, framework, healthcare

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Received On 7 December, 2022

Revised On 2 February, 2023

Accepted On 7 February, 2023

Published On 1 March, 2023

Funding This research did not receive any specific grant from any funding agencies in the public, commercial or not for profit sectors.

Citation Rajaram, Amit Kumar Pandey, Sanjay Saproo and Sanjeev Bansal , A Novel 4A Framework for Measuring Outcomes of Technological Implementation in The Healthcare Industry.(2023).Int. J. Life Sci. Pharma Res.13(2), P135-P143 http://dx.doi.org/10.22376/ijlpr.2023.13.2.P135-P143

1. INTRODUCTION

Advanced computer and software technologies have brought about unfathomable feats in medical sciences that have revolutionized the healthcare ecosystem. Advanced technologies such as Artificial Intelligence (AI), Machine Learning (ML), Block chain, Predictive Analytical tools, etc., have significantly affected various aspects of the healthcare ecosystems [1]. As a result, technology usage in the healthcare industry has advanced tremendously [2]. During the early years (before the 1980s), technology had limited use and was mainly employed to increase pharmaceutical production. During this time, pharmaceutical companies were the primary target for enhancing research productivity, while technology had a relatively minor role to play in organizations involved in healthcare delivery, such as hospitals, medical devices etc. [3]. During the 1990s, technology began significantly influencing healthcare, including EHRs (electronic health records) and cutting-edge diagnostic and analytical tools. During the 2000s, the Internet of Things (IOT) [4] enabled linked devices [5] began to gain attention, and most recently, the USFDA (United States Food and Drug Administration) authorized medicine that is contained in a Bluetooth-enabled gadget that can send signals straight to smartphones and physicians. A lot has changed in the last five years, from the mainstreaming of IOT to the rise of artificial intelligence (AI) and machine learning (ML)[6]. The fundamental shift these advanced computing tools have brought to the industry is to make it more predictive rather than reactive [7]. Healthcare has been a reactive industry [8], i.e. one goes to the physician or hospital only after becoming sick or having disease symptoms. Once the ill person goes to the physician, the required treatment is provided. With technology, many diseases/events can be predicted early; hence, the healthcare industry can save lives [9,10]. Machine learning, a part of artificial intelligence, uses vast datasets and indicates interrelationships among various variables. Machine learning uses different algorithms which help in drawing interrelationships between multiple variables. These techniques can uncover many previously unknown associations [11,12]. They can also help in generating newer hypotheses [2, 13]. This will also help draw inferences from multiple datasets of different people, and one can open up many new interrelationships. This will help in making the healthcare system more predictive [8,9,14]. The success of Health information technology, a term widely used for the usage of technology in healthcare, depends upon proper data collection of every individual. Data collection is the basis of this application and determines the accuracy and reliability of prediction [15, 16]. Multiple factors drive technology adoption in the healthcare industry [17, 18]. The overall spending on healthcare is increasing, and the world is looking for ways to reduce this [19,20]. Apart from the ageing global population [21,22], the healthcare industry also needs a skilled workforce. One can make the industry more efficient by addressing these aspects using advanced computer tools [23]. There is a growing need to make the healthcare industry more efficient, and based on the initial usage of technology, it can make a meaningful impact. While many technology tools are being implemented, it is essential to notice the critical objective: to make healthcare more affordable, improve accuracy, and improve adherence or access. This article examines how technology is used in the healthcare sector, paying particular attention to the results that may be obtained by utilizing already existing and emerging technologies [24].

2. RELATED WORK

There has been research work which has been done to understand the role of technology in the healthcare setting. Most of the work has been focused on understanding one aspect, i.e. either concentrate on the pharmaceutical industry or hospital industry etc. In a paper written by Thimbleby et al. [1], they focused on how the future will look like. Similarly, Alain et al. [2] have focused on factors which will make the technology more acceptable in the healthcare setting. Gossink et al. [3] have focused on how the future of medicine will look if advanced technological tools are applied. Al-Jaroodi et al. [4] have presented a qualitative view of key industry trends. There has been some work on the predictive abilities of these advanced technologies; for instance, Lopez et al. [7], Waldman et al. [8] and Kumar [9] have studied how these tools can make healthcare more predictive. Work has also been done on understanding how these tools can impact healthcare services [10]. Work has been done to understand the role of technology in improving diagnostics [12] and drug discovery [13]. Work has also been done to understand the general trends this will bring to the industry [14,15,16]. Though there has been work done on different aspects regarding the use of technology in the healthcare industry, work still needs to be done which takes a holistic approach and understands the actual outcome of the usage of technology. The patient is the central theme of this industry, and any intervention has to benefit the patient. Through this research work, we have tried to understand the outcomes of this intervention. Outcome measurement is an essential aspect of any new initiative. Through this work, we have tried to understand the actual outcomes technology usage will bring about in this industry. Also, a novel framework has been proposed for measuring these outcomes.

3. OBJECTIVE

The healthcare ecosystem has many players, including pharmaceutical companies, patients, physicians, hospitals, medical device companies, and insurance companies, and technological advancements are impacting all aspects of this ecosystem. Table 1 presents a matrix of industry v/s application areas witnessing a lot of activity. For instance, within the pharmaceutical industry, the spectrum of technological applications covers diverse domains from improving productivity in drug discovery to supporting effective commercialization. Similarly, medical device companies are using technology to make devices that can interact with several other systems and provide meaningful insights. Also, wearables such as smartwatches use technology to measure various health parameters and predict abnormal health patterns.

Table 1: Spectrum of technological applications in the healthcare industry

Pharmaceuticals		Patient	Healthcare Delivery	Device	
Drug Discovery	Clinical Trials		Hospitals	Wearables	Non-Wearables
New Target discovery	Reducing patient recruitment timelines	Compliance/adherence	Health records	Personal health data	Intelligent sensors in equipment for online monitoring (ventilators, Bipaps)
Identifying new diseases from existing targets	Identifying new target diseases	Longitudinal tracking of health data and getting early warning signal	Radiology - machine learning application to improve diagnosis	Early detection	
Making medicines more personal	Identifying new targets	Availability of medicines	Initial diagnosis using chatbots		
			Early diagnosis of diseases (e.g. Diabetic retinopathy using scan)		
			Focus from treatment to prevention.		

Advanced technologies, such as Artificial Intelligence, machine learning etc., are being applied within various segments of the healthcare industry, and table-1 provides a summary of broad application areas. All the elements within the industry, i.e. pharmaceutical industry (responsible for developing medicines), hospitals (accountable for treating patients), diagnostics (responsible for accurate diagnosis), medical devices (responsible for devices), are witnessing multifold changes due to these. Application of these technologies is likely to make this industry more efficient; as many applications are being tried using various technologies, it becomes important that we have a framework to analyze and understand the real impact this would have on the healthcare ecosystem.

4. RESULTS

The claim of technology application varies from improving disease outcomes, improving adherence, improving convenience, making medicines more targeted etc., so we must have a framework to understand the accurate impact technology will have. [25] This review focuses on creating a framework which can measure the impact in terms of actual outcomes; figure 1 below presents the overall architecture of the technology intervention. There are three broad sections, i.e. input, intervention and output. The input parameters are the various technological tools such as artificial intelligence (AI), machine learning, blockchain, etc. Using these input tools, intervention in the form of either improved access, accuracy, affordability, or adherence will be observed, eventually leading to better disease outcomes.

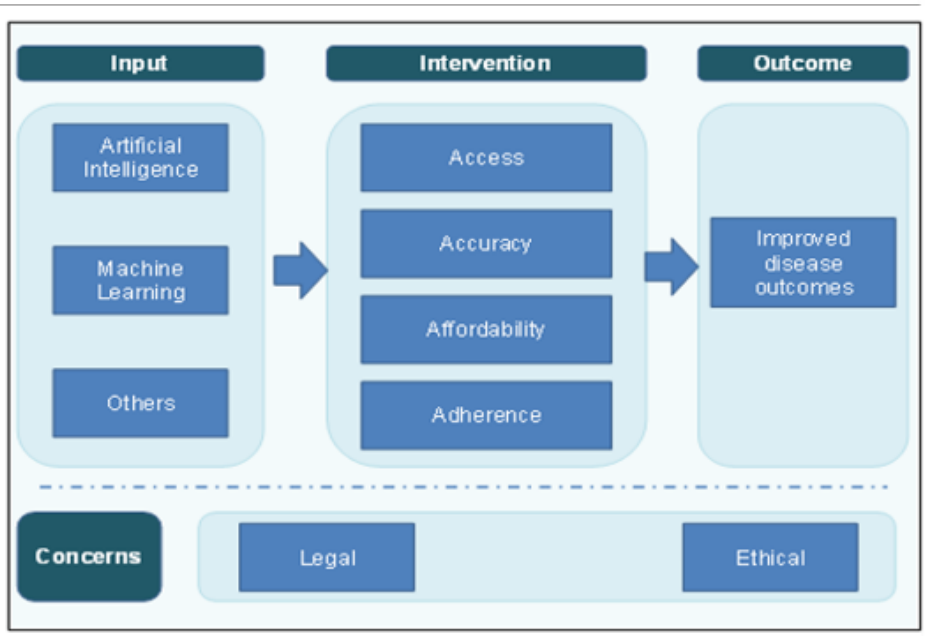

Fig 1: framework of technology applications.

Figure 1 provides the overall archetype of the technology applications. In the healthcare industry, the most important outcome is improving patients' lives by improving disease outcomes. This can be achieved by targeting multiple accuracies, affordability, adherence or access aspects. Any intervention in this industry- be it technology or otherwise should impact one of these essential dimensions. Apart from looking at the likely positive impact, one should also review the concerns to have a holistic perspective. To measure the outcome of technology usage in the healthcare ecosystem, a novel 4A framework is being proposed that will help measure the impact these new technologies will bring to this ecosystem/industry. Technology or any intervention should

improve one of these A's to have a meaningful impact. These A's deal with the following

- Access
- Affordability
- Accuracy
- Adherence

Technology, if it needs to impact then, must do one of these A's

- **A1 (Access)**

Does it make healthcare more accessible, i.e., it can reach places or people which otherwise would have been difficult or devoid of access?

- **A2 (Affordability)**

Does it reduce the cost of healthcare both for the patients and payors (such as the government, insurance companies etc.)?

- **A3 (Accuracy)**

Does it make the treatment more accurate Currently, there are a lot of medicines which show variable impact on individuals mainly due to various biological systems? With the usage of technology, we can predict the exact target, so we can develop appropriate diagnostics to confirm whether the treatment will work.

- **A4 (Adherence)**

Does it improve treatment adherence? Will patients be more compliant with the treatment?

5. DISCUSSION

A literature review was conducted to understand these points and found that technology will positively impact all these aspects. Technology will have many effects on all the 4 A's, and here are some factors based on the research.

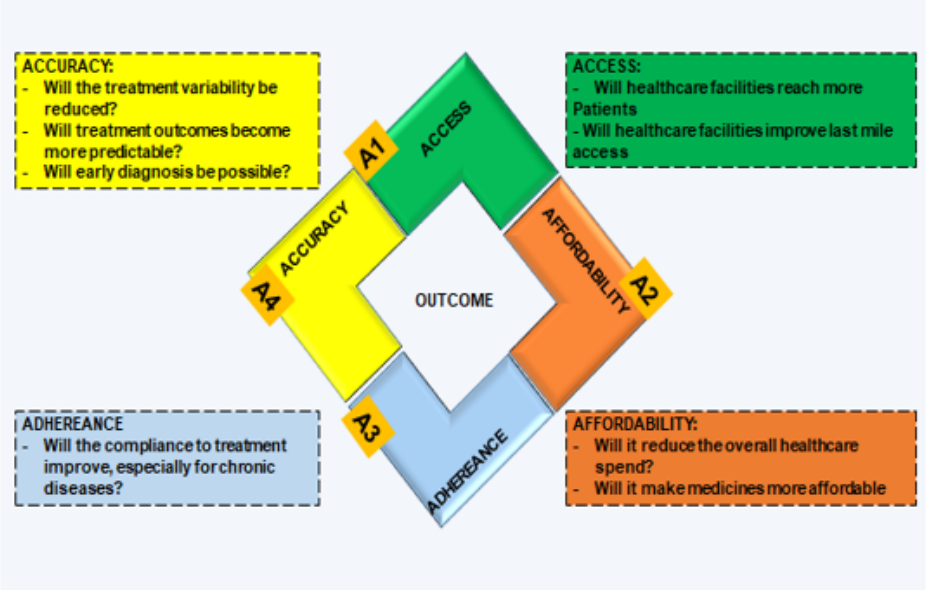

Fig 2: A novel 4A framework

Figure 2 presents the central idea of this research paper. The novel 4A framework is an evaluation tool to understand the impact of technology implementation. Any intervention has to hit the main idea of the healthcare industry, i.e. how it will benefit the patient. Though the four aspects covered under this novel framework are mutually exhaustive, at the same time, they are collectively thorough in understanding the impact.

A1. ACCESS

The healthcare industry's digitization offers significant potential since it will considerably increase access to healthcare. Healthcare is about to undergo a fundamental transformation because of technologies like artificial intelligence (AI), deep learning, and augmented reality (AR). These tools will make it easier to access doctors [26], medical information, and medications while also enhancing diagnosis [27] and treatment [28].

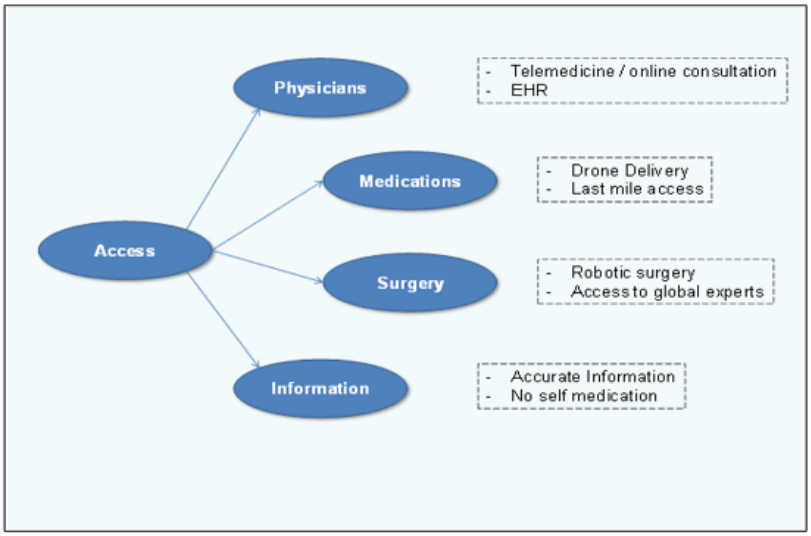

Fig 3: Access Framework

Figure 3 presents the access framework. Healthcare access means improving the ability to access physicians, medicines, or healthcare information. Technology can play vital in enhancing access on multiple fronts, there are different kinds of technology being used to increase healthcare access, and the following are some ways in which it will do so:

- Access to healthcare professionals [26]
- Access to medications [29]
- Access to information
- Access to surgery [30]

5.1. Access to Physician

The interaction between patient and physician is set to change with telemedicine and other online modes of consultation. Telemedicine [31] will become increasingly important in healthcare, allowing patients to interact with their physicians remotely in a virtual environment. Telemedicine will facilitate the interactions seamlessly, and patients will no longer have to go to an office/clinic to meet the physician. These interactions will become even more real with various VR gears under development and provide a live atmosphere [32,33]. During the recent Covid-19 pandemic, telemedicine [32] was of great help as many patient-physician interactions happened online, and routine healthcare was delivered via various online tools. Telemedicine has also helped in storing medical data, as all the data is stored on computers and retrieval, and access is effortless [34].

5.2. Access to Medicines

Technology can potentially improve the healthcare ecosystem by improving access to medicines [27]. However, the availability of drugs could be a challenge, especially in remote areas which need better road connectivity. Recently, drones have been used to deliver medicines to distant places. For example, in Africa, drones were used to deliver drugs. Also, in India, a few states discuss drone usage for supplying vaccines and other essential drugs [29].

5.3. Access to Surgeons

The potential of artificial intelligence in surgical procedures is vast [30]. Using AI, surgeons could perform complex surgeries without being present at the site. Another way by which technology can improve access is the use of robotics to conduct surgeries. Recently in Ahmedabad, India, heart surgery was conducted remotely by Dr Tejas Patel. Both the patient and surgeon were at a different locations, and the surgery was performed remotely using a robotic assembly [34]. If this trend continues, then global experts can conduct surgeries anywhere in the world. This will improve access, as patients will not have to travel to other countries.

A2. ACCURACY

Artificial intelligence can significantly improve the accuracy of diagnosis and early detection/prognosis [35,36]. AI has been used to improve the predictability of various diseases. Deep learning algorithms have demonstrated that one can detect diabetic retinopathy using retinal fundus photographs. In a study with 9963 and 1748 images, the algorithm had a high sensitivity and specificity towards detecting referable diabetic retinopathy. In this study, optimization was done for a particular type of neural network which could classify the images and predict diabetic retinopathy. Examples like these validate the promise of technology in improving the speed and accuracy of detecting various diseases [37]. Technology such as deep learning can predict the disease early and make an interconnection between the two conditions. In a study done by google and its subsidiary Verily [38], they demonstrated that deep learning could be used to predict the risk of CV disease using a retinal scan. In disorders related to the cardiovascular system, such as MI (myocardial infarction) and angina, expecting early could be of immense value, as one can take necessary precautions. Currently, to predict CV risk for a patient, one needs to look at risk factors such as high cholesterol, blood pressure, age, smoking history, weight etc [39,40]. Predicting CV risk through an eye scan is a significant advancement in technology. In a study conducted by the Mayo Clinic, AI algorithms were used to identify patients with weak heart pumps. In a study conducted over six months, 125,610 ECGs were analyzed using an AI algorithm and predicted the CV risk [41]

A3. ADHERENCE

Chronic diseases such as diabetes, cardiovascular, cancer and respiratory are increasing globally due to lifestyle and other

factors [42]. Also, life expectancy is increasing due to improved healthcare standards [43]. Multiple studies have shown the importance of medication adherence to improve clinical outcomes. AI tools such as patient reminder systems, health records, and outcome tracking can help enhance disease outcomes. AI-assisted devices can also help improve patient-doctor interaction and disease management [44].

Compliance is an area that is set to witness significant improvement based on the latest technological advancements. Currently, there are many types of non-compliance i.e.

- Failure to take medications on time
- Failure to get diagnostics on time
- Failure to meet physicians etc

Medication adherence is essential, and studies have shown the benefit of adherence, especially in chronic diseases such as diabetes [45,46,47,48].

A4. AFFORDABILITY

Healthcare costs have been increasing globally, and in the last 20 years, the amount spent on healthcare (as a % of GDP) has risen from 8.6% to 9.8% [49]. The global average for health expenditure per capita is ~ $ 1121[50]. If technology can help reduce this, that would be a significant advancement. In the US, the total healthcare expenditure in 2020 was $ 4124 bn. Out of this, ~50% is spent on hospital, physician, and clinical services [51]. If technology can improve the outcomes, that will bring substantial savings and reduce the spending on healthcare. Technology can help in reducing the overall cost of healthcare- directly or indirectly.

5.4. Direct interventions which can reduce healthcare costs include

- Reducing administrative tasks by automation [52]
- Helping Physicians to get predictive analysis from detailed case history [25,53]
- Appointment scheduling [54,55] etc.

5.5. Indirect interventions which can reduce healthcare costs include

- Helping pharmaceutical companies in developing medicines faster and safer [55]
- Identifying new targets for drug discovery
- Predictive analysis of patients' risk profile through longitudinal tracking of data

5.6. Summary of direct technological interventions that can help in reducing the healthcare cost

Tools based on Artificial intelligence and other technology can significantly reduce the time a physician spends on administrative tasks such as filling out various forms and doing other admin activities.

Another important area where technology can support reducing costs is predictive analysis[56,57]. If software can predict the risk profile accurately based on the longitudinal diagnostics data, then physicians can treat and adjust the line of treatment. This will help save treatment costs for complications that could have been prevented through early intervention. An example of this was demonstrated in a study done between 'Centre Hospitalier Universitaire Grenoble-Alpes (CHUGA)' in France and Elsevier[58]; they developed a machine learning algorithm for patient's historical data and created models which can predict the likelihood of getting adverse events. This is a significant insight for the treating physician. Also, if the software can help in making connections, then that would go a long way in reducing the overall healthcare cost

5.7. Summary of indirect technological interventions that can help in reducing the healthcare cost

There are many areas where technology is helping the pharmaceutical industry develop better medicines, which will bring healthcare costs down [59]. AI-based tools can help in target selection [60], as they can scan through multitudes of target and predict with reasonable accuracy the ones which will work. Pharmaceutical drug discovery involves identifying a suitable biological target [61] which can help in disease management if upregulated or downregulated. The next step is to identify the chemical which will help in this up or down-regulation [61]. Both biological target identification and chemical target have vast numbers as it is very time and resource intensive to identify the correct targets. AI can support this by scanning large sets of data and predicting likely targets and chemical compounds[60].

6. CONCERNS

Apart from the positive outcomes of using technology, there are a few concerns which need to be addressed [62]. Broadly they fall into two categories, i.e. Legal and Ethical [63]. Legal considerations are related to the law of the land and are more dependent on the legal framework which governs the technological framework. There are concerns related to data protection and privacy [64,65]. Cyber security is a big concern [65,66], as a lot of medical data will be available which can be misused. Ethical concerns include informed consent and points around safety and transparency [62,67,68].

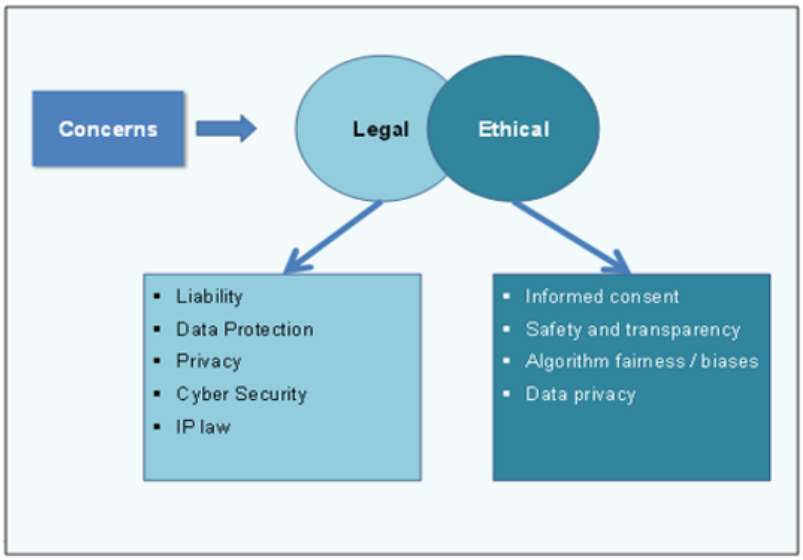

Fig 5: Concerns about using technology in the healthcare ecosystem

Ethical and legal are the two concern areas which will need to be addressed during the process of technology implementation. In addition, as the healthcare industry deals with very personal patient data, it needs to create a framework where this data is not being misused.

7. CONCLUSION

Advancements in computing have brought a lot of new technologies which are rapidly changing the complexion of multiple industries; healthcare is no different and is also being transformed using new-age tools such as AI, machine learning, deep learning etc. Technology usage has just started, and based on initial applications, it is set to make a paradigm change. There are multiple application areas within the healthcare industry (drug discovery, predicting risk profile, outcome assessment etc.) where these tools are being utilized and have started to show real benefits. Technology is set to make healthcare more accessible, affordable, accurate and improve adherence. This research proposes a novel framework to measure impact across these dimensions. Framework assumes significance, providing an objective tool to measure the actual result. There are exciting ways in which technology is being applied to improve healthcare quality; however, there are also a few concerns regarding data security and transparency. In summary, if technology is used as a servant, then it will benefit; however, if it becomes master, then we will reach disaster faster.

8. AUTHOR'S CONTRIBUTION STATEMENT

Dr Sanjeev Bansal proposed the overall framework, while Dr Sanjay Saproo contributed to enhancing the framework. Dr Amit Kumar Pandey was responsible for refining the framework, while the primary author, i.e. Rajaram, was responsible for writing the entire manuscript.

9. CONFLICT OF INTEREST

Conflict of interest declared none.

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