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Quantum computing led innovation for achieving a more sustainable Covid-19 healthcare industry

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ABSTRACT

Involvement of multiple stakeholders in healthcare industry, even the simple healthcare problems become complex due to classical approach to treatment. In the Covid-19 era where quick and accurate solutions in healthcare are needed along with quick collaboration of stakeholders such as patients, insurance agents, healthcare providers and medicine supplier etc., a classical computing approach is not enough. Therefore, this study aims to identify the role of quantum computing in disrupting the healthcare sector with the lens of organizational information processing theory (OIPT), creating a more sustainable (less strained) healthcare system. A semi-structured interview approach is adopted to gauge the expectations of professionals from healthcare industry regarding quantum computing. A structured approach of coding, using open, axial and selective approach is adopted to map the themes under quantum computing for healthcare industry. The findings indicate the potential applications of quantum computing for pharmaceutical, hospital, health insurance organizations along with patients to have precise and quick solutions to the problems, where greater accuracy and speed can be achieved. Existing research focuses on the technological background of quantum computing, whereas this study makes an effort to mark the beginning of quantum computing research with respect to organizational management theory.

1. Introduction

The quintessence of societal development has shifted towards the technology, giving rise to a plethora of terms for current societal age, namely: information era, digital era, new media era, industry 4.0 era, to name a few (Ivanov et al., 2019; Jabbour et al., 2018; Radanliev et al., 2019; Xu et al., 2018). The basic thread of connectivity is information and communication technology (ICT) that offer innovative solutions to society and organizations those have unexpectedly become highly dependent upon technology (Azadegan et al., 2020). From layman to organizations to technological giants, every stakeholder of the technological landscape is constantly trying to upgrade their expertise in the space of technology and innovation (Gong and Ribiere, 2020; Tan et al., 2020). Organizations thrive to upgrade their prevailing expertise as well as infrastructure to attain supremacy in the marketplace. Disruptive technologies act as a medium to bring disruptive advances and innovation (Martínez-Vergara and Valls-Pasola, 2020), which are continuously transforming the business models and putting organizational performance on a nonstop swivel (Craighead et al., 2007; Kull and Closs, 2008). The quest for technological innovation has led organizations to explore completely new possibilities of technological landscape, making way for a future i.e. post-digital/binary era. However, the extensive research on quantum computing will challenge the existence of classical computers and provide a futuristic vision for wave-based technology rather than binary one that exists currently. In a quantum world, information can be encoded as 0, 1 or both 0 and 1 simultaneously; where

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two particles can be viewed as both separated and yet tangled (Mehring, 2007; Voss, 2002). Companies like Google and IBM have claimed the application of quantum computing for digital innovation (Cho, 2018; Malina and Woerner, 2019). To achieve technological supremacy the innovation and new technological developments definitely address the uncertainty and complexity in an organization (Cuijpers et al., 2011). The new unknowns in the quantum leap are foreign for processing the information for all functions of any firm.

Furthermore, last two decades witnessed the penetration of information technology (IT) in every business sector and every business tries to utilize their best of innovation capabilities. Healthcare sector has also been revolutionized by IT applications and inventions as well, due to their potential for minimizing cost and improving quality of services via breakthrough innovations (Alrahbi et al., 2021; Hansen et al., 2019; Singh and Varshney, 2020). The adoption of a quantum computing led information system (IS) in healthcare is crucial since it includes human lives at stake and has potential for offering innovative solutions to many challenges. The unstoppable pandemic situation has created a lot of disarray worldwide and scientists and organizations are all into the race in combating with its alarming situation alike. Huge amount of data is being generated everyday based on Covid-19 and the business eco-system need fastest machine possible to crunch these data and as well as serve the patients across geographies (Biancone et al., 2021). Data is being generated right from number of cases to the various clinical trials to develop drug and advanced vaccines (Madhavan et al., 2021). While quantum computing is just emerging as a viable technology, it stands in practice on the shoulders of many scientists who spent years (Chae, 2019; Dahlmann and Roehrich, 2019) to solve complex problems with high-performance computing (HPC). Disruptive technologies have created a wave of change and offering unexpected novel capabilities, also termed as DARQ (Distributed Ledger Technology (DLT), Artificial Intelligence (AI), Extended Reality (XR) and Quantum Computing (Q). However, all other components of DARQ have been researched and established reasonably in the mainstream except Quantum Computing (Accenture, 2019).

Existing research focuses on the technological expertise of quantum computing, but this domain is yet to be explored from the perspective of managing a complex industry such as healthcare that is directly linked to the lives of humans and animals. Therefore, this study aims to explore, "*what are the areas of healthcare industry, where quantum computing can play a disruptive role in near future?"* More specifically, "*where quantum technology is to have innovative solutions for more advanced healthcare system?"* Healthcare organizations are among the first in queue to adopt evolving and innovative technological infrastructure and hence become most vulnerable to the near future disruptions. This study adopted a qualitative approach to answer the research question and it contributes to the body of knowledge by expecting the near term disruptive changes those can give a permanent shape to healthcare industry, how different players/stakeholder including suppliers, patients, healthcare providers and supporting agencies such as health insurance are going to act under the influence of quantum computing. This research highlights a futuristic approach towards the possibilities of quantum computing in healthcare system, grounded in the organizational information processing theory (OIPT) to provide a way forward for organizations to adopt disruptive technologies. The remaining paper is structured in five sections. Section 2, presents the literature review followed by related theories. Section 3 indicates the research design followed by findings in section 4. Section 5 indicates the discussion of findings and study being concluded in section 6.

2. Literature review

A plethora of literature has developed based on the technical know how's of quantum computing; however, a limited literature is available with the management and information system perspective of this disruptive technology (Madhavan et al., 2021). The spread of Covid-19 questions ability of healthcare industry to address the healthcare challenges posed to entire world population (Drago et al., 2021). This study aims to connect the literature of quantum computing technology and healthcare organizations to the organizational information processing theory with respect to the current pandemic situation worldwide that can possibly be utilized for innovative solutions in healthcare setting.

2.1. Quantum technology: a challenge for existing technological infrastructure

Presently there is a unique opportunity to take a lead in new generation technologies that can offer many societal and economic benefits as early as possible. Emerging technologies such as industry 4.0 have evolved to lead us towards a post-digital era (Accenture, 2019). The quantum world is not binary. Particles in a quantum space behave like a wave, where electron is supposed to spin in two different directions at one point of time, where one can assign either 1 or 0; or both 1 or 0 to the information simultaneously, that gives rise to their being separate yet entangled at the same time (Arute et al., 2019; Hewitt-Horsman, 2009; Jiang et al., 2019). Quantum computing is a concept driven from Physics where the behavior of atoms and fundamental particles like electrons and photons is used to develop the computing prowess (Georgescu, 2014). A classical computer deals with bits, which can take the state of 0 or 1, whereas a quantum computer measures the performance in qubits which can simultaneously take 0, 1 and anything in-between. This ability to be in different state at the same time is called *superposition*. There exists another quantum mechanical phenomenon known as *entanglement* that occurs when a pair or a group of particles is generated, interact, or share spatial proximity in a way such that the quantum state of each particle of the pair or group cannot be described independently of the state of others, even when the particles are spatially separated (Bub, 2010; Preskill, 2012). Superposition, along with entanglement, is the secret sauce that gives immense computing prowess to a computing device so that parallel processing can take place. This makes the outcome to be based on probability rather than having a deterministic solution (Mihara, 2011). Three components used by computers in quantum landscape are: Quantum superposition, tunneling and annealing to process the information (Singh and Singh, 2017). *Quantum Superposition* can be defined as building block of the quantum mechanics, where two quantum states can add together to get another quantum state, which will be valid or vice versa. Superposition reflects the wave like status and follows Schrodinger Wave Equation. *Quantum Entanglement* is a state when two or more particles are generated so that the quantum state of single particle cannot be destroyed independently. No matter how far the particles are, but they can reflect same quantum state. Hence, any change at one end in the quantum state will be responsible for the change in the other particle.

It is critical to delve into quantum supremacy (Boixo et al., 2018) that primarily draws a demarcation between quantum computing and classical computing. Quantum supremacy as a concept (Preskill, 2012) indicates that a quantum computing based device can provide a solution that no classical computer (even a present-day supercomputer) can feasibly solve in comparison with computational speed, image processing, simulation and modeling, telecommunications and any technological domain that exists, thus affecting every business domain. Industries those are estimated to get affected foremost by quantum technology led innovation include healthcare sector, telecom sector, FinTech, defense sector and engineering etc. Though, initial application of quantum technology has already been phased out, but it is still far from being commercialized.

According to Boixo et al. (2018), one of the biggest constraints for the algorithm to be executed is the random-access memory where the wave function is stored. This memory is characterized by $2n \times 2 \times 4$ bytes. For $n = 48$ qubits, this would require at least 2.25 petabytes (1petabyte = 1000 terabyte = 1000000 gigabyte), which is approximately the limit of what can be done on one of the largest supercomputers present today.

For example, in Table 1, Trinity, the seventh fastest supercomputer in TOP 500 has around two petabytes of primary memory, which is one of the largest. For computers having less than approximately 48 qubits, direct simulation is viable on a classical computing machine. Google has developed a quantum computer named Sycamore whose chip is composed of 54 qubits, each made of superconducting loops (Arute et al., 2019; Gibney, 2019). IBM has also developed a commercial quantum computer and it is named IBM Q System One (Malina and Woerner, 2019).

The processing power and speed of quantum computers is greatly higher than the supercomputers, which further can pave ways for solving most complex problems and answer the unknowns (Timpson, 2019). Quantum computing can be employed to solve some of the persisting complex problems revolving around our life, health, environment, engineering and business to have disruptive and innovative solutions.

2.2. Healthcare ecosystem and pandemics: opportunities for disruptive technologies

Healthcare industry has witnessed a fundamental shift by radical innovations and the technological changes sprouted from industry 4.0. Technologies such as Blockchain, Artificial Intelligence, Augmented Reality, Cyber Physical Systems, Cloud Computing, to name a few, have already been implemented widely in the healthcare applications (Ahram et al., 2017; Boonstra et al., 2018; Goh and Arenas, 2020; Massaro, 2021; Nchinda et al., 2019; Urbinati et al., 2019) resulting a continuous whirlwind of technological upgradation for the industry (Wimelius et al., 2021). The Covid-19 has witnessed the rise of telemedicine as safe and sustainable solution that can serve mass consumers with basic needs and advice in healthcare (Biancone et al., 2021; Drago et al., 2021).

Future may be predicted by assumptions and simulations, but the unexpected scenarios such as pandemics may not be predicted beforehand. However, quantum computing technology is supposed to offer healthcare solutions to the problems impossible for computers today, such as genome sequencing, discovering new drugs and materials, creating vaccines and medicines much faster than today, to name a few (Abduljalil and Abduljalil, 2020; Aftab et al., 2020; Hashemzadeh et al., 2020; Loeppky, 1999; Sneha and Priya Doss, 2016; Szefler, 2018; Vinod and Prabaharan, 2020; Wang et al., 2018a). Furthermore, huge amount of data is generated by healthcare systems having complex information management and clinical operations (Basile et al., 2022; Massaro, 2021; Nchinda et al., 2019; Ozercan et al., 2018; Wang et al., 2018b; Zheng et al., 2019) giving rise to technological innovations in the healthcare industry. Research (Accenture, 2019) suggests that extensive experiments have already been conducted by healthcare executives with respect to DARQ technologies, which are considered to have extensive transformational impact on the industry in coming years. One state-of-the-art quantum enabled molecular comparison application is being developed by Biogen in collaboration with Accenture and 1QBIT, with an aim to improve advanced molecular design to speed up drug discovered for complex neurological disorders such as multiple sclerosis, Alzheimer's, Parkinson's and Lou Gehrig's Disease (Accenture, 2019). Healthcare data is flowing through patient records, medical instruments, service applications, experiments, etc. and traditional technological systems fail to analyze and leverage the results from such data (Malik et al., 2018; Plachkinova et al., 2018; Rajabion et al., 2019). Quantum computing appears to be a promising and disruptive technology to leverage the extensive data and processes of healthcare industry.

Healthcare industry, in general, encompasses numerous heterogenous systems (Thune and Mina, 2016) performing discreet but related operations. New theories and knowledge is usually generated from a multifaceted interplay between scientific, clinical as well as commercial units altogether. Dai and Tayur (2020) term healthcare ecosystem a bundle of four major components, namely, Delivery, Financing, Policymaking and Innovation. Furthermore, World Health Organization (WHO, 2010) enumerates primary components of healthcare ecosystem as "Leadership and governance, Health information systems, Health financing, Essential medical products and technologies, Human resources for health and Service delivery". Bearing in mind the big picture, healthcare industry has four key stakeholders, viz., the policy makers (government), payer, service provider and the patients (Mantzana et al., 2007; Martínez-Román et al., 2020). Existing research (Thune and Mina, 2016) indicates the role of institutional regulation and policymaking as crucial in terms of innovation and dissemination of new technological base in healthcare industry. Studies also highlight the e-health and growth of telemedicine (Biancone et al., 2021; Drago et al., 2021) in recent past, however studies lack in presenting an integrative view of all stakeholders involved in healthcare sector. The entire healthcare technological innovation process is considered to be iterating between the innovation development to implementation and the healthcare ecosystem components from technology, healthcare delivery, financing to policymaking (see Fig. 1).

World Health Organization (WHO, 2019) estimates the overall spending on healthcare being increased 2.2 times in economies witnessing fast growth. In general sense, technological innovation models are developed most often by private sectors, however, in terms of medical innovation, several agents are involved and more often it heavily depends upon the policymakers, user feedback, and scientific testing (Martínez-Vergara and Valls-Pasola, 2020; Thune and Mina, 2016). This development further depends upon the respective governmental policies of each country. For instance, studies highlight the

Table 1
List of top 10 supercomputers in the world.

Rank	Supercomputer Name	Location	Country	Cores	Rmax (TFlop/s)	Rpeak (TFlop/s)	Power (kW)
1	Summit	DOE/SC/Oak Ridge National Laboratory	United States	2,414,592	148,600	200,795	10,096
2	Sierra	DOE/NNSA/LLNL	United States	1,572,480	94,640	125,712	7,438
3	Sunway TaihuLight	National Supercomputing Center in Wuxi	China	10,649,600	93,015	125,436	15,371
4	Tianhe-2A	National Supercomputer Center in Guangzhou	China	4,981,760	61,445	100,679	18,482
5	Frontera	Texas Advanced Computing Center/Univ. of Texas	United States	448,448	23,516	38,746	No Data
6	Piz Daint	Swiss National Supercomputing Center (CSCS)	Switzerland	387,872	21,230	27,154	2,384
7	Trinity	DOE/NNSA/LANL/SNL	United States	979,072	20,159	41,461	7,578
8	AI Bridging Cloud Infrastructure (ABCI)	National Institute of Advanced Industrial Science and Technology (AIST)	Japan	391,680	19,880	32,577	1,649
9	SuperMUC-NG	Leibniz Rechenzentrum	Germany	305,856	19,477	26,874	No Data
10	Lassen	DOE/NNSA/LLNL	United States	288,288	18,200	23,047	No Data

(Source: 54th edition of the TOP500 published in November 2019; Top 500 (2019)).

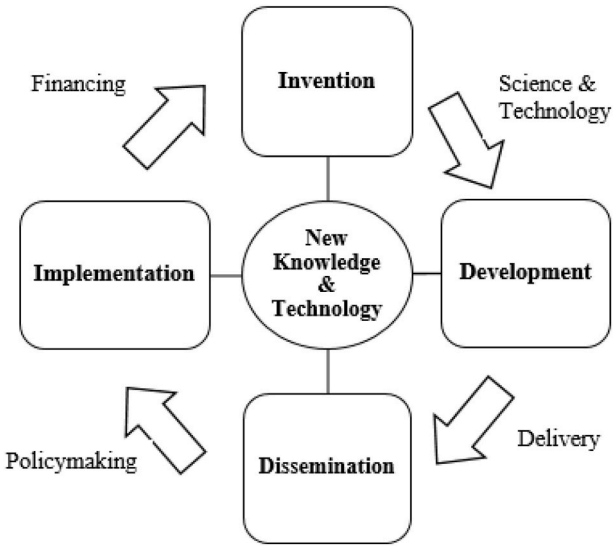

Fig. 1. Healthcare Innovation & Ecosystem Process cycle
Adapted from (Dai and Tayur, 2020; Thune and Mina, 2016; WHO, 2010).

blockchain usage to preserve and exchange data across healthcare stakeholders ranging from hospitals, healthcare research centers, laboratories to pharmacy and insurance companies to offer value to customer (Massaro, 2021; Shaygan and Daim, 2021; Spanò et al., 2021). Further a study by Chakraborty and Paul (2022) indicates the intention of purchasing the healthcare applications and involvement to consume the services to drive the value. Existing literature has focused upon the various aspects of interactions between the healthcare components. Due to complexity, uncertainty of healthcare sector and intricate structure of human body, there is need of a care system that is quick and precise. Therefore, healthcare industry is chosen and interwoven healthcare ecosystem thus puts forth a discussion for the role of technological integration.

2.3. *Organizational information processing theory (OIPT): disruptive innovation and information processing*

Technological uncertainty is one of the critical factors an organization deals within current era of digitization and disruptive innovation (Ahmad et al., 2013). Startups disrupt incumbents' stand in the market with new technological innovation and implementation capabilities (Barlow et al., 2006; Martínez-Román et al., 2020) in the marketplace, which leads to dealing with uncertain factors with respect to technology implementation quite frequently (Tatikonda and Montoya-Weiss, 2001). Organizations have to streamline processes with numerous uncertain factors, viz., internal information processing structure (Winkler et al., 2015), inter-departmental collaboration (Cuijpers et al., 2011), end user demand (Arifiani and Arifiani, 2019), infrastructure demand (Gupta et al., 2018a,b), etc. End user satisfaction in healthcare is the resultant of internal information processing structure, inter-departmental collaboration and utilization of infrastructure and technology. To bring into line these factors, one significant approach is to re-align the organizational design thereby increasing their information processing capacity (Cuijpers et al., 2011). Organizational Information Processing Theory (OIPT) given by Galbraith (1973) paves way for a strategic alignment within firms. The major focus of OIPT is organizational design structure and how innovative changes can be brought; a firm must develop to deal with numerous uncertainties arise time and again. The organizational structure should reflect the information processing needs in order to make effective decisions when high level of uncertainties or risk arise (Gupta et al., 2019). OIPT advocate the concept of information processing needs, developing capability of information processing and their fit to address any uncertainties. Organizations adopt different ways to survive uncertainty and increasing information needs either to have buffers to decrease the impact of an uncertain event or adopt a structural mechanism that influence the information processing capability to address uncertain environment. Therefore, OIPT implementation is considered as a connection between the information and its management by organizations to attain competitive advantage through continuous innovation (Fairbank et al., 2006). Organizations, therefore, must exploit the information efficiently as well as effectively for driving innovation in complex uncertainties (Srinivasan and Swink, 2018). Implementation of OIPT in healthcare sector has also been studied extensively, but the emphasis mainly remains upon the integration of computerized operations (Queenan et al., 2016), decision making based on uncertainties in context with health insurance (Winkler et al., 2015), supply chain disruptions (Azadegan et al., 2020). However, now, when big incumbents like Google and IBM are trying to penetrate the market with their Quantum computing capabilities (Cho, 2018; Flother et al., 2020; Gibney, 2019; Soenksen and Yazdi, 2017), and offering cloud infrastructure for the same, it puts a tremendous pressure over healthcare industry to keep up with the pace. Thus, OIPT turns out to be most suitable approach to understand the information needs and information management by organizations while implementing much disruptive technologies such as quantum computing, which not only needs a whole new technological infrastructure, but will put decision makers and their teams at a tough position to redefine policies.

2.4. *Quantum computing possibilities in healthcare industry*

Healthcare industry is often bounded in uncertainties from all fronts, be it disruptive technological innovation, or unpredictable health hazards, or discoveries of new diseases or drugs. Previous research (Ng and Bezak, 2020; Swan, 2015) highlights the challenges and barriers faced by healthcare stakeholders due to emergence of disruptive technologies. Few studies highlight the increase in adoption of telemedicine as an alternative to physical visits that have indirect influence on pharmaceutical e-commerce platforms (Biancone et al., 2021; Drago et al., 2021). Technological advancements not only disrupt the system applications' implementations, but also organizational workflow design, project management aspects, administrative processes, and decision support etc. (Adamuthe and Thampi, 2019; Woodson et al., 2019).

Digital healthcare ecosystem is a multifaceted synthesis of medical informetric and business models, which further involves both personalized and general healthcare information and services disseminated via varied technologies (Drago et al., 2021). Stephanie and Sharma (2020) emphasize three paradigms for practice-oriented healthcare ecosystem, viz., digitization, viability and connectedness. Digital ecosystem enables real-time big-data collection to analyze healthcare trends, models as well as predictive analytics. It has led to convergence of industry 4.0 technologies with healthcare industry to offer better, personalized as well as precise healthcare services. However, disruptive technological changes often create uncertainty and equivocality in the organizational information process (Fixson et al., 2017; Mikalef and Pateli, 2017; Yang and Hsiao, 2009), since the organizational processes rotate around the information flows. In purview of information processing theory, Fairbank et al. (2006) highlight the significant factor of an organizational performance as the direct link across the information, i.e. the resource and the management of that information, more specifically the ability of an organization to process the correct amount required and type of information. Unpredicted health hazards often prove to be greater source for uncertainty and equivocality, specifically for healthcare industry. Additionally, Covid-19 has been a great stressor for the healthcare industry (Cobianchi et al., 2020b) such as, the need to address and control the pandemic, to provide diagnostic as well as preventive care, and further to develop new drug or vaccine and check their efficacy against variants, that too as swiftly as possible. Unpredicted scenarios give rise to uncertainty and equivocality demanding quick knowledge transfer

and technology enabled solutions (Cobianchi et al., 2021; Secundo et al., 2019). Furthermore, such scenarios have an enormous capability for producing big data and thus offering opportunity for better data analytics (Sestino et al., 2020), not just patient care data, but data related to virus type and gene mutations, ecological and geographical data, etc., which could be leveraged for forecasting and predictive capabilities by both technology and healthcare industry (Sousa et al., 2019). In the context of introducing quantum technology capabilities to cope with unpredicted health hazards, healthcare industry will be required to process and access its existing organizational structure to provide better decision support and to decide whether this disruptive innovation can be leveraged with existing ones (Au-Yong-Oliveira et al., 2021).

Furthermore, countries are investing greatly in healthcare technology innovations (Cresswell and Sheikh, 2013), and other industries have started to invest in quantum technology research (Pérez-Castillo et al., 2021), which provides an opportunity for this disruptive technology to penetrate the most useable sector, i.e., healthcare. Quantum computing seems to have significant potential in pharmaceutical industry with various incumbents and startups working on quantum technology possibilities in drug discoveries, vaccine development and various other applications. Quantum technology integrated with industry 4.0 technologies provides opportunities for accelerated innovation and discoveries in any domain of knowledge that might be out of our vision in current times. It is estimated that quantum technology market will be worth $1.9bn by year 2023 and increasing up to $8bn by year 2027 (Vernacchia, 2019). Quantum computing fits seamlessly in the right space and it can be utilized in broadly, six possible ways in the healthcare domain to provide solution for problems which in general are vast, complex, unknown, and time consuming, shown in Fig. 2. However, uncertainty, complexity and dynamism in disruptive innovations levy compromises among organization's resource distribution and policy structure (Tushman and Anderson, 1986).

3. Research design

To examine the potential of quantum computing led innovation in Covid-19 strained healthcare industry, we have undertaken a qualitative approach in the present study. A semi-structured questionnaire (shown in Appendix A) is developed with the view of organizational information processing theory (OIPT). The Professionals from healthcare sector, representing pharmaceutical industry employees, hospital staff, clinicians, nurses and information technology consultants in healthcare having considerable experience of a minimum 3 years have been approached for sharing their views. Therefore, the present study offers understanding the potential and address to the problems of healthcare industry to address the dynamic situation such as Covid-19.

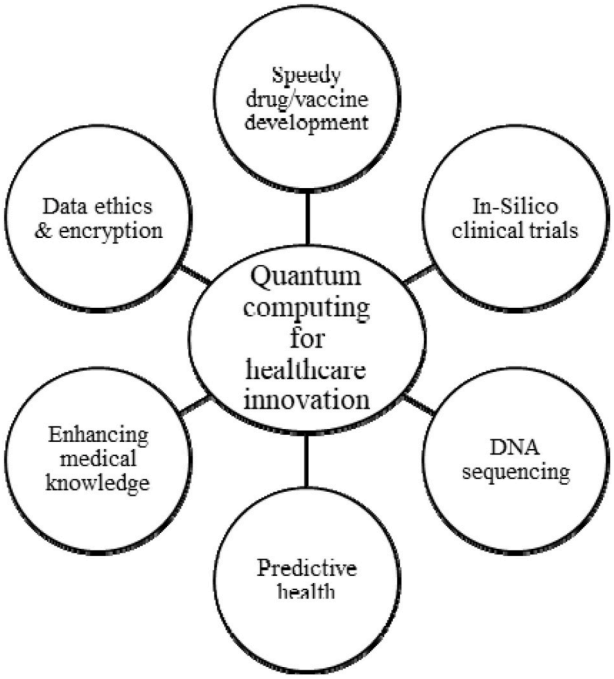

Fig. 2. Quantum computing possibilities in healthcare innovation.

3.1. Data collection

A qualitative study is appropriate, when the field of study is new and its significance in a particular field is not known or very few informants are available (Strauss and Corbin, 1990). In this study, the professionals of healthcare industry have indicated their concerns and expectations from the quantum computing that will offer advantage to the eco-system even beyond Covid-19. Since quantum computing in healthcare is at very nascent stage and due to non-availability of established scale as a starting point, qualitative study was planned (Strauss and Corbin, 1990). The subjective questionnaire was developed on the basis of McCracken (1988) guidelines from his book *"The Long Interview"*. The semi-structured questionnaire consisting six questions was designed, where potential applications of quantum computing from healthcare professionals were asked and discussed.

Around 250 professionals were approached from all the categories those directly related to healthcare industry, but only 31 who have an idea about the potential of quantum computing have been considered for further interviews. Further, interview schedule has been shared and after close follow-up during June and July 2021, one on one interviews were conducted. First purpose of the interview is described followed by 25–30 min to have their detailed opinion to each question posed. Out of 31 only 21 have shared their expectations and innovation that can change the healthcare industry forever employing quantum computing. After careful consideration, only 20 responses are found useable. Table 2 shows the profile of respondents and for anonymity, they are masked from R1 to R20. The data is collected from India, since it has witnessed considerable disruption and strain on healthcare system due to Covid-19 in past years.

Table 2
Details of respondents.

Interviewee Profile No.	Interviewee Code	Job Title	Years of Experience
1	R1	Manager/Sr. Manager	More than 10 years
2	R2	Manager/Sr. Manager	5–10 years
3	R3	Associate Professor	More than 10 years
4	R4	Medical Doctor	3–5 years
5	R5	Dentist	5–10 years
6	R6	Medical Doctor	5–10 years
7	R7	Medical Doctor	1–3 years
8	R8	Medical Doctor	3–5 years
9	R9	Hospital Staff	3–5 years
10	R10	Medical Doctor	5–10 years
11	R11	Medical Doctor	5–10 years
12	R12	IT Consultant	More than 10 years
13	R13	Hospital Staff	5–10 years
14	R14	Nurse	5–10 years
15	R15	Hospital Staff	3–5 years
16	R16	Manager/Sr. Manager	5–10 years
17	R17	Nurse	5–10 years
18	R18	Nurse	5–10 years
19	R19	Medical Doctor	5–10 years
20	R20	Director/CXO/ Founder	More than 10 years

3.2. Data analysis

Employing transcription and verbatim, study developed a thematic analysis to present the themes and sub-themes. The research design of the study is presented in Fig. 3. By employing coding to transcript, study has ensured the internal consistency. Study compared the emerging themes with secondary data for triangulation purpose. For this, study developed first the open codes from the interview data. Secondly, it converged and extracted axial codes corresponding to open codes. At last, it mapped the extracted axial codes to selective codes. Through triangulation approach study assessed the research questions from different views for having validity and in-depth analysis. Table 3 showcases the three-layered approach that shows the convergence with gathered data, reports from industry and research articles.

4. Findings

Major findings representing the themes and sub-themes indicating four sectors: (i) Hospitals (ii) Pharmaceutical Organizations (iii) Insurance Organizations and (iv) Patient are presented that those can be key stakeholders witnessing the quantum computing led innovation in their operations.

4.1. Diagnostics

It is critical to have accurate and early diagnoses that can lower the cost of treatment and result in better outcome. For instance, the survival rate increases multifold and treatment cost decreases significantly when disease like Covid-19 and Cancer can be diagnosed early. Parallel to this, the current diagnostic techniques are difficult, complex and costly. It has

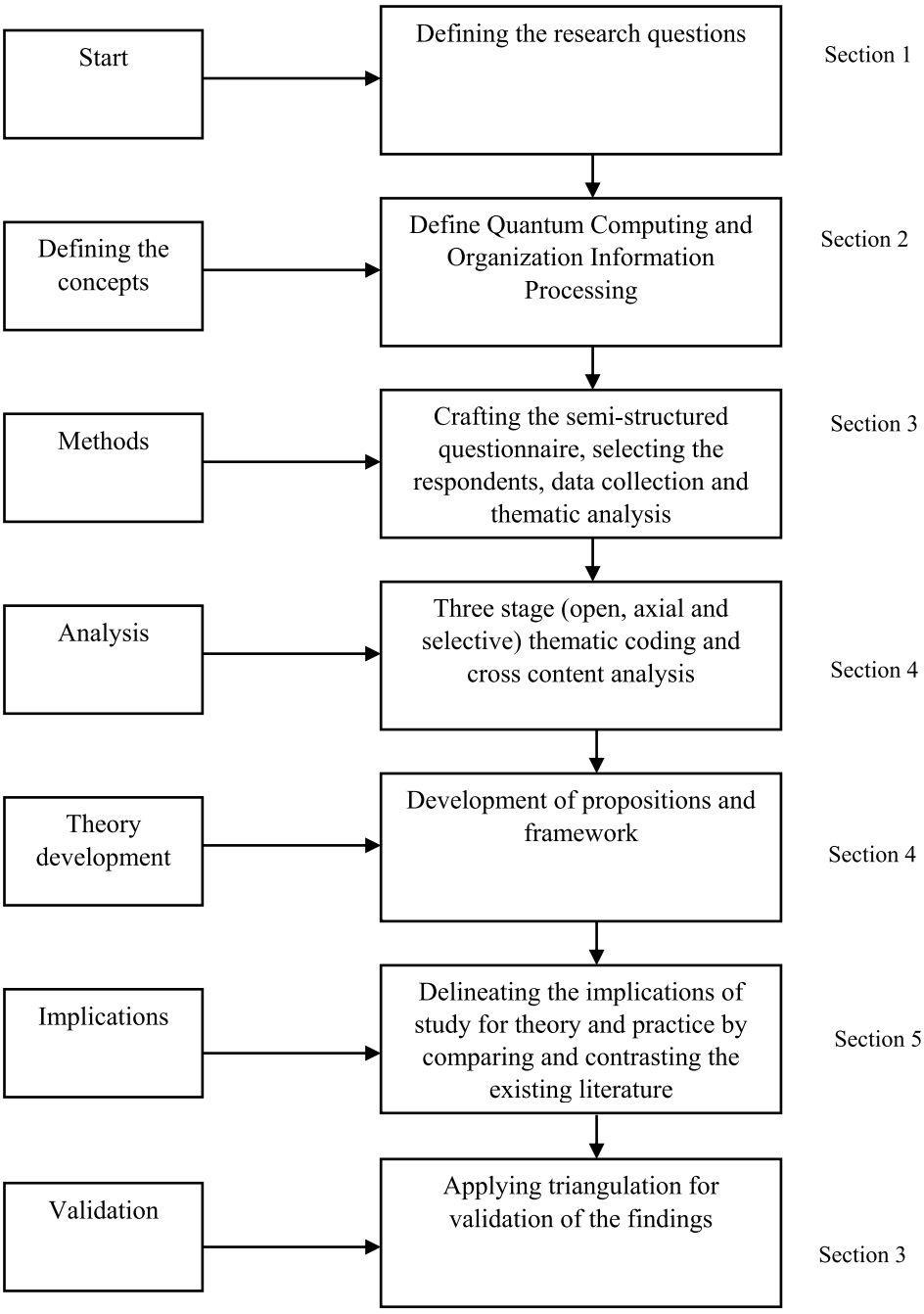

Fig. 3. Research design.

Table 3
Triangulation approach.

Industry Reports	Data Gathered	Research Articles	Emerging Themes
McKinsey and Company (2020)- Quantum computing have potential and offer innovative solutions, where simulation for larger and complex molecules can be achieved. The application of quantum techniques can help in finding the target and a precise disease understanding	R11- The quantum computing can facilitate in deciding on quickly, about dosage for a particular disease and age and can help in optimizing the properties of a particular drug. This can further help in identifying causality and side effects if any along with mass customization.	Cao et al. (2018) - The existing methods of drug development is not capable of addressing the complex mechanism. By employing the machine learning principles quantum computing can influence the drug discovery.	- Smart contracts - Drug design - Point of care - Disease treatment - Decision support system
Strategyand.pwc (2020) - Quantum computing hold most promise for healthcare in terms of less invasive diagnosis and speedy clinical trials on the basis of number of combinations.	R9 – How much radiation, what kind of tissue to be treated in critical patients is always a concern in clinical setting, quantum computers can be very helpful in that case.	Solenov et al. (2018) - The imaging and other dispersed information is difficult for human beings to analyze and predict the state of possible action that can be achieved through quantum computing.	- Clinical trials - Imaging - Diagnosis - Radiotherapy
Accenture (2020) - As the quantum computers will be becoming readily available, that will open the doors for pharmaceutical organizations and therapies for range of diseases along with security of data.	R14 – In health insurance usually it is difficult to identify and model the risk profile of prospective patient, who may require funds in future. The technology of quantum sort can address this problem.	Zinner et al. (2021) – Quantum computing can facilitate drug design and appropriate pricing not only in pharmaceutical products, but also in designing and pricing the healthcare insurance.	- Pricing - Risk identification - Secured data

been observed that even after establishing the diagnosis; it suggests that around 20% cases are victim of wrong diagnosis. The techniques such as CT (computed tomography); MRI (magnetic resonance imaging) and scanning through X-rays are common diagnostic tools for practitioners across the world (Yuan et al., 2020). The quantum computing has the potential to address the problems faced in healthcare due to Covid-19. In the words of R5, "*Believing the claims of Google and IBM, quantum computing has a potential to utilize the emerging technologies to address the Zoonotic diseases such as Ebola, Covid-19 and SARS, that otherwise place the major implications in terms of economic and health disruption*". Therefore, quantum computing is having very high potential in saving human lives and possibly preventing the loss of human lives.

4.2. Imaging

In medical field from last 3 decades, the imaging has revolutionized healthcare in many ways. It allows the clinicians and nurses to identify the disease in advance and facilitate the patients for their faster recovery (Strategyand.pwc, 2020). By history, imaging is one of the key developments in past 1000 years. As on today, medical imaging facilitates healthcare providers, insurers and patients. Medical imaging procedures are usually painless and non-invasive. The technologies like Ultrasound of medical imaging facilitate the clinician to understand the body structure and take certain decisions. When it comes to complex parameters of body, then typical medical imaging may require another boost. According to R16, *"In the existing image processing facilities, to achieve segmentation, registration, compression, retrieval and recognition requires multiple operations as pre-processing on the basis of original images to extract the key features"*. The quantum computing may facilitate by employing the technologies such as machine learning or artificial intelligence to multiple power of medical imaging.

4.3. Radiotherapy

Radiation therapy has been used from quite some time to treat the cancer and other tumors based surgeries in medical field. The main goal of the radiation therapy is to shrink the undesirable tumor or cancer cells (Zheng et al., 2019). The non-optimal attack on non-cancerous tissues causes blistering, dryness and itching kind of problems to the patients along with other side effects such as mouth or joint problems. Therefore, there is a requirement of technology that can precisely focus on a particular cell that needs to be shrunk and damaged. Over and above, it's been witnessed that many cancer patients had a difficult time during Covid-19, due to the shift in focus towards Covid-19. In the words of R9, "*During Covid-19, the cancer patients are the most sufferers, due to the engagement of hospitals to only Covid-19. Quantum computing shows potential to the complicated optimization where thousands of variables are present. Multiple simulations can be achieved in fraction of seconds through quantum computing, that offer's optimal solution"*. Quantum computing can be helpful in uncertain situations where one has to monitor the patient remotely and have to consider multiple parameters. Table 4 indicates the open, axial and selective codes under Hospitals.

4.4. Drug design

When it comes to disease types and its variants, these can be in thousands. According to an estimate, there are around 10000 diseases and we have only 500 cures, those may be effective or not. With the increasing rate of diseases, the global spend on healthcare is expected to rise to approx. $18 trillion worldwide by 2040 (Zinner et al., 2021). In the words of R20, "*The molecule design is the very first stage in any drug design and discovery. The existing system of drug development, do hundreds of millions of comparisons with the help of classical computers up to a certain molecule size"*. Through quantum computers it can be possible to compare large molecules that can further advance the pharmaceutical products for range of diseases.

4.5. Clinical trials

Clinical research in coronavirus and its variants along with others such as AIDS, tuberculosis can further facilitate to identify the machines and tools to develop the countermeasures against chronic and other complex diseases. Coronavirus is known as part of SARS virus, which is a major threat for human beings today (Abduljalil and Abduljalil, 2020). The pharmaceutical companies have developed few vaccines, but companies are yet to develop the vaccines for kids from age of 0–18. In the words of R13, "*The quantum computing can be helpful to run a multiple combination therapy in research and development laboratories to identify the suitable vaccine for children. With the help of Qubits, the precise and accurate vaccine and drug development can be achieved while dealing with complexities"*. Clinical trials are one of the ways to verify and strengthen the reliability of a therapy or vaccine. In most of the clinical trials, we consider either animals or humans as a testing carrier that can be avoided with silico trials, where quantum computing can simulate human beings (Pappalardo et al., 2019).

Table 4
Open, axial and selective codes for Hospitals.

Selective Code	Axial code	Symbolic Quotations from Interviews and Open Code
Hospitals	Diagnostic	Adoption of quantum computing can facilitate the hospital and healthcare eco-system to improve their efforts and eliminate the requirement of repetitive testing. This can further health care providers to benefit patients with reduced cost of treatment (R17). (Open Code: Avoid repetitive testing and reduce cost) In the case of complex disease symptoms like cancer, it is necessary to find out a suitable radiation therapy that could be least harmful to human and can target only cancerous cells. The quantum computing can possibly simulate this at best (R11). (Open Code: Precise target for radiation)
	Imaging	Image processing is one of the ways to collect the information from different departments to arrive on a conclusion. To evaluate the image from multiple viewpoints is difficult with naked eyes. Hence, quantum computing can bring out the information which is not possible otherwise through classical methods (R 7). (Open Code: Improved insights from quantum computing enabled imaging) In the big healthcare system like ours, where thousands of patients are processed on daily basis, it becomes extremely painful and inefficient for existing system to offer meaningful clues to the clinicians. Quantum computing can be helpful to enhance the speed and accuracy of imaging operations (R18). (Open Code: Speed and accuracy of imaging)
	Radiotherapy	Quantum computing can offer large-scale optimization that can be solved within the clinically possible framework. The quantum computing can offer improved convergence rates and potentially offer effective treatment (R5). (Open Code: Effective treatment through radiations) In most of the surgeries, the radiation therapy acts as a primary modality. In most of the cases, the question remains the degree of radiations needed. Quantum computing advances the accuracy and power of computer that promises a change of game for healthcare due to high precision evaluation of the condition and treatment (R15). (Open Code: Appropriate degree of radiations)

4.6. Decision support

Quantum computing is expected to disrupt the pharmaceutical industry and change its fortune, where industry usually spends billions of dollars to develop a molecule. In the words of R4, "*The dynamic situations like Covid*-19 has *challenged the industry in terms of data and its utilization, what, why and how to use the data of end users (patients), records of pharmacies (selling and buying records) and records with hospitals (electronic health records) of billions of people*". That can further dictate the opportunities for quantum computing in life sciences to shorten the time in days to discover, develop and commercialize a therapy as compared to the existing one of years (Flother et al., 2020). With the help of unparalleled decision support offered by quantum computing, it can help in being innovative to avoid human and animal trials and still provide the groundbreaking medicines to the world. Table 5 indicates the open, axial and selective codes under Pharmaceutical Organizations.

4.7. Risk identification

The quantum computing as a service (QCaaS) can facilitate the health insurers proactively with solutions those are customer/patient centric. The cloud based QCaaS can offer precise applications that can fit the bill best in terms of having the health insurance that best suits to a patient on the basis of lifestyle and environment they are living in

Table 5
Open, axial and selective codes for pharmaceutical organizations.

Selective Code	Axial code	Symbolic Quotations from Interviews and Open Code
Pharmaceutical Organizations	Drug Design	Quantum computing techniques have the potential in the drug discovery, design and vaccine development in short span of time as compared to classical approaches that take years otherwise and save billions of dollars with adequate and accurate discovery (R13). (Open Code: Structured drug discovery) It is also important to monitor the molecular interactions especially at atomic level while developing a drug. There are more than 20000 proteins in a human genome those need to be simulated to understand the interactions among existing and new drugs that is yet to be invented. Hence, quantum computing can lead the innovation in healthcare (R19). (Open Code: Quantum computing led interactions with other drugs)
	Clinical Trials	The reliability of a drug or vaccine correspond to potential of the computing system that can identify the useful information from noisy datasets, that can be further helpful design a response or develop the therapeutic relationship (R5). (Open Code: Faster and minimum trials with high accuracy) To fasten the clinical trials through technology, one needs to advance computational power of classical system through both technology and mathematics to process the data of masses and avoid the usage of human and animals through powerful simulations (R13). (Open Code: Use of technology and mathematics to identify number of combinations for clinical trials).
	Decision Support	In today's time, there is huge data that is published and known by healthcare professional's right from molecule development to the product use in the case of disease. But from the development to the use by patients, there are number of processes, where large data needs to be compiled to take certain decisions in drug research (R6). (Open Code: Utilization of published and professional experience for decision making. The deployment of quantum computing will offer special skills in the drug and vaccine development not only in the current pandemic, but also for future, where such computer networks can facilitate the combined decision of hospitals and pharmaceutical companies to identify the precise correlation and causations those are difficult for classical systems (R18). (Open Code: The decisions in different stages on the basis of multi-stakeholder data).

(Fairbank et al., 2006). According to R15, "*The risk profiling with traditional systems is very time consuming and very costly. By employing quantum computing with the help of simulations one can access the different scenarios quickly and drive down the cost of risk profiling matching it to the legal framework*". This can help health insurers in the process of risk aggregation along with underwriting function.

4.8. Pricing

For insurance companies the risk modeling and design of different plans is critical to cater the need of masses. In the classical system, due to

limited computing power, one has to run multiple interactions and still may not have the adequate solution that best suits to a healthcare insurance buyer needs (Cuijpers et al., 2011). With the help of big data and external factors, a simulation through quantum computing can be employed to cater to volume and speed to identify the risk pools and offer pricing that is precise to the needs and health conditions of an individual. In the words of R5, "*The pricing of healthcare insurance and plan can be further simulated on the basis of location, lifestyle and facilities required by a patient, hence quantum computing can offer customized pricing solutions to the patients on the basis of their risk and willingness*". The optimal pricing can help the healthcare insurance suppliers as well as the patients to fulfill their healthcare needs from time to time.

4.9. Auto payment

In the corporate world, merger and acquisition are common practices and the same is with health insurance organizations, where organizations need the smooth transition and acquire the data of insurer for getting the benefits and best services of the company (Schulte and Lee, 2019). The health insurance companies have to do quick payments not only to patient's in requirement, but also to other stakeholders all under a legal framework. The automation and verified transfers from insurer to insurance company to hospital for the medical treatment can be designed on the quantum computing principles for hassle-free experience. In the words of R7, "*Employing quantum computing can help even if there is any error in the payments and can prevent the breach of large scale data available with health insurance organizations. Apart from quick payment, quantum computing will also facilitate the security of data stored at different locations and at different treatment centers in case of patients*". The auto-payment will help companies to get their due premium on time as well as patient in dire need of funds for treatment will be savior and big relief in the time of disease. Table 6 indicates the open, axial and selective codes under healthcare insurance organizations.

4.10. Point of care

Data is being produced in every industry and healthcare is not an exception, where data is getting produced at different stages. For instance, laboratory conducts different medical tests, at hospital in outpatient department (OPD), at pharmacies and medical stores, where patients procure the required medicines and healthcare insurance organization, those are receiving the diverse data on daily basis across the globe (Secundo et al., 2019). Increasing digitization and connected sensory system may disrupt the existing hospital industry and can diminish the requirement of physical hospitals and can only focus on the patients. According to R6, "*Through employing quantum computing approaches one can facilitate the prediction of life style required for patients. For instance, the Covid*-19 has *infected different patients in different way, it will be great to see that how quantum computing can advise and predict the health plan, diet according to biological parameters of a patient*". Potentially, quantum computers can utilize numerous health parameters, genetic facts, data collected from sensors and personal health information that can predict the future of a person's health.

4.11. Secure data

In many developing countries, the counterfeit products are witnessed in pharmaceutical industry, which is a key industry in healthcare. The presence of counterfeit products in any economy is a threat to safety and health of its citizens (Sestino et al., 2020; Sousa et al., 2019). According to an estimate more than half a million people die in a year due to the consumption of spurious medicines across the globe. In an e-commerce environment, it is difficult to trace the quality of medicines, which is one of the key channels for most of patients due to the consequences Covid-19 has posed on us. Therefore, an innovative system of encryption can be devised that can prevent the violation of intellectual property rights (IPR). In the words of R3, "*The quantum computing shows the potential of utilizing quantum uncertainty for encryption, where it can be used for making private keys that can encrypt the information which is available online and can prevent the copy paste issue to generate the spurious pharmaceutical products.* Additionally, the same can be applied in securing the data of patients.

Table 6
Open, axial and selective codes for healthcare insurance organizations.

Selective Code	Axial code	Symbolic Quotations from Interviews and Open Code
Insurance	Risk Identification	The insurance companies can benefit from the quantum computers ability by simulating the weather conditions and manage the related losses. The risk aggregation capabilities can facilitate and enhance to underwriting function of insurance companies (R9). (Open Code: Identify the risk while offer a healthcare plan by an insurance company) Quantum computing will impact the healthcare insurance, where the risk of product reliability, third party involvement and transfer of ownership can offer clear vision not only to insurance organization, but also the users (R2). (Open Code: The risk of insurance provider to fulfill their commitment)
	Pricing	Large amount of data is flowing through different environments in the form of volume, velocity, variety, veracity and value. Quantum computing can improve the risk understanding and improve the pricing in healthcare insurance models (R5). (Open Code: Optimizing the price according to customer requirement) The cost of health insurance is on the rise and Covid-19 have given it a catalytic advancement, however by simulating the market scenario and harnessing natural language processing capabilities, the process of pricing, reservations and policies can be modeled (R20). (Open Code: The pricing can be predicted through market scenario and policies in healthcare)
	Auto payment	We have witnessed many patients struggling to get the funds from their insurance companies, while they need it most at the time of treatment. It will be helpful to deploy quantum computing that can facilitate the real-time payment to care provider rather than doing manual verification at multiple points and multiple times (R11). (Open Code: Real-time payment when required). The real-time payment is necessary in paying the premium as well as availing the benefits or rewards if the policy benefits are not availed for certain period. This non-availing the healthcare policy may recommend the better plans as well those can be purchased simultaneously (R19). (Open Code: Flexibility to patient to divert the payment to other parties)

4.12. Disease treatment

The quantum computing has many potential applications, since it has moved from experiments to enterprise wide deployment in few industries. Few industries in recent past have witnessed the exciting results. Following the principles and features of quantum theory such as entanglement and superposition, it can allow the guess and practice based approach in disease treatment with quick solutions (Yuan et al., 2020). By enhancing the capability of precision medicine, the quantum computing adoption in healthcare is set to change the field of diagnosis, treatment and inhibit disease. According to R16, "*The application of quantum computing can cater the personalized market demand and mass customization by driving the knowledge from pandemics. The aim of community and public health can be achieved with the help of genomics*". Apart from maintaining public health, quantum computing can also help in

offering the insights for businesses that otherwise lie in the medical records in hospitals and scientific research in the form of patents and articles published in journals. Table 7 indicates the open, axial and selective codes for patient.

4.13. Quantum computing led innovation in healthcare sector beyond Covid-19

Emerging technologies have revolutionized healthcare industry and aiding the clinicians, nurses, hospital staff and other stakeholders to serve the patients with utmost care and safety (Yuan et al., 2020; Yang and Hsiao, 2009). Right from laboratories to teaching and practice hospitals utilize imaging and diagnostic techniques to early identify the symptoms of a disease. However, the existing techniques of imaging and diagnosis are having the scope to enhance its utilization of big data and precise insights from medical doctors, nurses and others. At present, the radiation therapies is most common for many diseases and before conducting any surgery to kill the harmful tissues, but the current techniques are not optimal to the greatest extent. Hence, we propose:

P1. *The quantum computing techniques can bring innovation in most common activities in hospitals such as medical imaging, diagnostics and radiation therapy to achieve the objective of mass customization every time with high precision.*

Table 7
Open, axial and selective codes for patient.

Selective Code	Axial code	Symbolic Quotations from Interviews and Open Code
Patient	Point of care	At present a patient normally comes to hospital for different type of treatment and large amount of data about the disease and health plan of individuals is created and produced, which is only in the preview of hospital with their limited experience (R17). (Open Code: Experienced based treatment) If quantum computing can measure the big data with the help of sensors, wearables and other medical devices and store in cloud to be monitored regularly. This continuous monitoring can open an innovation space in healthcare that will influence the existing hospital system in making the patients' point of care (R8). (Open Code: The point of care will be patient rather than hospital).
	Secure Data	Quantum computing enabled healthcare system requires hacker to break the law of quantum physics; of they want to steal some information such as genomic, genetic or electronic health record data. (R1) (Open Code: Secured and encrypted information system). The healthcare systems need to be smarter to integrate the infrastructure, employees, patients, operational tasks and clinical activities with emerging technologies. The data generated by these systems needs to be safe, reliable and should enhance the patient experience (R20). (Open Code: Alignment of all resources through quantum computing towards secured data).
	Disease Treatment	Precise medical treatment in healthcare sector is the need of hour, whether it is Covid-19 or post pandemic situation. We need a technological innovation that can improve the analysis of medical imaging that can enhance image-aided diagnostics (R3). (Open Code: Precise medicine/ surgery for the disease treatment). Healthcare industry is one, which often requires quick solution due to emergency situations posed by patients, be it an accident or be it cancer kind of incident. Potentially, quantum computing can analyze the stage of a patient and best suitable therapy to get the patient to better state or at least in the earlier state of body and mind (R15). (Open Code: Adequate disease treatment even in complex and challenging situation).

With the event of Covid-19, world have witnessed the importance of pharmaceutical industry in saving human lives in terms of speedy vaccine development and other drugs those are used in Covid-19 therapy. The responsibility of faster and target medicine and therapy development depends on several environmental, internal and legal factors (Wang et al., 2018a). The process and molecule level factors are more critical in drug development. Therefore, drug research and development is a very critical part for any pharmaceutical organization, where large number of interactions to be studied among different compounds and to identify best suitable. To finalize a drug design, it is necessary to run parallel clinical trials. The present ratio of conducting clinical trials is on the basis of principles of population spread, but it does not indicate the minimum number of clinical trials that should be sufficient to finalize a drug. Therefore, there is a need of an innovative system that can help in faster research and development and conduct clinical trials and offer robust decision support in the process of developing a drug. Therefore, we propose:

P2. *The precise dosage and compounds of drug or vaccine can be identified within days and can help in identifying the population required for conducting the clinical trials those ensures reliability of any drug. Quantum computing can facilitate decision making at different stages in development, production and distribution of emergency drug with short span of time.*

Disease is one of event, everyone in the world want to keep a distance. Since the events in life are unpredictable, so is the disease at present. It is very painful for many to shell out the funds from their pockets and many die due to the shortage of funds for treatment. Hence, the concept of health insurance has emerged in the past and now well accepted worldwide. However, there are certain challenges for healthcare insurance organizations while designing a healthcare plan for individuals. The biggest challenge is developing a risk profile and pricing (Schulte and Lee, 2019). The healthcare companies at present develop the risk profile on the basis of available techniques that can consider few parameters that further decide the pricing which is vague in most of the cases. Another concern for patients is that they have to do multiple formalities in insurance offices, when actually they need funds in the case of treatment to a disease. Hence, we propose:

P3. *The modeling of all-round risk parameters on the basis of bodily and genetic conditions can be facilitated through quantum computing techniques that can offer optimal pricing to customers. The auto-payment at the time it is required can designed in a way to benefit the patient in dire need.*

In the present healthcare set-up, the focus is on organizing the healthcare facility, rather than focusing on the patient. If we examine critically, the administration staff and other facilities may not be required and those may be adding extra cost to the system, while the key objective is to treat the patient (Accenture, 2020; McKinsey and Company, 2020). The exact point of care needs to be the patient and that can be treated at home and not necessarily in hospital for most of the cases. Many a times it happens, that patient has entered the healthcare facility and after spending certain time, the patient is out with another disease. Therefore, the focus needs to be on identifying the hygienic conditions required for a patient, so he/she does not contract any other disease. Hence, we propose:

P4. *For patient oriented healthcare industry, quantum computing can be helpful in designing the services and reducing/eliminating activities those are unnecessary. Further, employing quantum computing the security of data can be ensured and precise treatment of disease is possible.*

Following the four propositions, a framework (Fig. 4) represents the potential areas of healthcare industry where quantum computing technology can lead the innovation, and hence answers the research question.

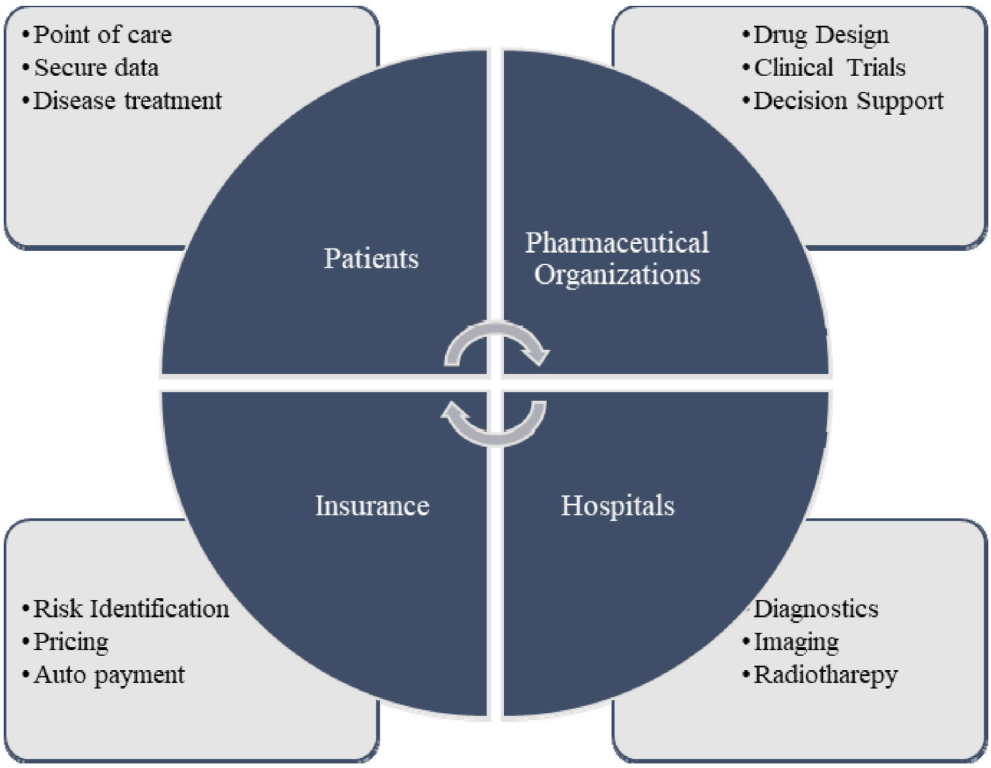

Fig. 4. Potential areas of application for quantum computing in healthcare industry.

5. Discussion

Technological innovation places a radical shift to the economic and social status as well as affirms the competitive edge among economies and organizations (Arthur, 2017; Coccia, 2020; Coccia et al., 2018). Technology led innovation point towards the changes in interoperability among existing and new technological operations and devices, as well as their acceptance and adaption across competitive marketplace (Montes and Goertzel, 2019). We are now progressing towards post-digital era (Accenture, 2019), where industry 4.0 technology will converge and new unimagined applications of such convergence can be witnessed, quantum technology holds the promise of radical innovation and revolutionizing the use of industry 4.0 technologies that will further act as base for industry 5.0. Researchers seek to excavate the use of fundamental quantum laws into technological landscape. Recently, Fintech and blockchain were considered innovative and disruptive technologies revolutionizing the basic operational expertise in organizations. Quantum computing in future will prove to be most disruptive of technologies once it enters the marketplace. It is not some enhanced version of existing industry 4.0 technology, rather it is entirely new, with completely different working and basic principles, rather than binary bits of 0s and 1s, it works in qubits and probabilistic fundamentals (Mihara, 2011). Organizations, such as IBM, Google, IonQ, Honeywell, etc., that have claimed to build quantum computers and algorithms are already set to provide cloud services for commercial access for the technology using online web services by Amazon Web Services (AWS) or Microsoft. Although, the vision of quantum computers replacing our personal desktops is a distant dream, however, start-ups leveraging the cloud-based quantum computing services offering innovative solutions to major problems more specifically of healthcare.

5.1. Implications for theory

It is significant for organizations across industries to realize the quantum information processing capabilities. More importantly, healthcare industry is at the acme of being influenced by the disruptive technology such as quantum computing. The recent pandemic started in 2019 (Covid-19) brought the world to a standstill and there was a big wave of uncertainty with regards to the health of people, economic conditions, business viability, supply chain disruption, and much more (Cobianchi et al., 2020a; Ienca and Vayena, 2020). The need for quantum computing is more urgent for swift drug discoveries and coordinated clinical trials for vaccine development in the response to variants of Covid-19. However, implementing such a technology will require the restructuring of existing digital infrastructure of a healthcare organization and thus may results in the conflict between firm operations and technological acceptance (Rippa and Secundo, 2019). Existing research is more inclined towards technological know-how of quantum computing, generating advanced quantum based algorithms (Cho, 2018), quantum RAM (Blencowe, 2010), quantum speed (Bub, 2010), quantum states (Nakamura et al., 1999), application of quantum computing in other fields as highlighted earlier, such as drug discovery, knowledge management, predictive health, to name a few. Few studies also indicate the value creation and digital transformation by adopting the technologies such as blockchain and other data-driven technologies (Basile et al., 2022; Spanò et al., 2021). Apart from this, literature also indicate the role of telemedicine in healthcare (Biancone et al., 2021; Drago et al., 2021), that can be further revolutionized with quantum computing by offering near to accurate examination and prescription. Further, existing literature lack the focus on organizational processes based on information processing technology and capabilities. The major challenge for any healthcare kind of organization is to implement quantum technology that can entirely change its processes and operations and find a way to ease the transition across existing operations. In this way, the present study indicates the potential benefits of employing quantum computing in developing the information processing capabilities to attain quick and accurate response to situations like Covid-19. This study made an effort to ignite the thought of organizational information processing theory with respect to the current pandemic situation and innovative technological changes that will follow. This study

contributes to quantum technology domain by highlighting its many possibilities with respect to healthcare industry from different stakeholder's (Pharmaceutical organization, Hospitals, Insurance and Patients) perspective and how a patient can be true point of care.

5.2. Implications for practice

The study presents insights for healthcare industry professionals including clinicians, nurses, hospital staff, pharmaceutical organizations, healthcare insurance companies as well as patients during Covid-19 and beyond. The potential applications of quantum computing in healthcare industry can improve the information processing capabilities of different stakeholders that can be critical to offer seamless services in dynamic times. However, before considering employing quantum computing the executives need to consider (i) the amount of *data* generated in the system (ii) what are the points of *concern* in the present system (iii) the *role* in healthcare (insurance company or pharmaceutical company). Professionals (clinicians, top managers, and support staff from insurance companies) from healthcare industry must analyze the challenges in employing quantum computing. The silico clinical trials can be further integrated with quantum computing for advancing the virtual clinical trials. The advantage of quantum computing can be viewed as a mean of saving the lives those may be in threat in the traditional setting of clinical trials in healthcare sector. The healthcare insurance organizations and professionals can drive benefits of precise risk modeling and offer the price in mapping the requirement and conditions of individual's health. The inter-departmental and inter-industry coordination can be further advanced with quantum computing to offer best experience to a customer in healthcare industry through quantum computing. Further the healthcare organizations can receive the auto payment and supply the funds when required after full-filling all the criteria's. For professionals from pharmaceutical companies, quantum computing can be very helpful in drug composition, scalability and its production. Through quantum computing, the healthcare industry can focus on the patient, while offering maximum safety to data generated from clinical trials or electronic health records. The healthcare professionals from core pharmaceutical sector, health insurance and hospitals along with patients can consider the elements from the proposed framework to employ quantum computing led innovation to develop a new landscape during and beyond Covid-19 era.

5.3. Limitations and scope for future research

The concept of information processing in healthcare system is mostly manual expect large hospitals, larger pharmaceutical companies and pharmacies. Organizational information processing theory does not include the outside players who influence the activities of an organization. For instance, the health insurance organization directly influences the day to day operations of a hospital, and they affect the pharmaceutical company operations, that in turn impact the patient. To develop an eco-system for quantum computing, one has to have a basic computing infrastructure, and the volume of operations. Our study employs clear theoretical and managerial implications, and it is having certain limitations. For instance, the study witness handful of respondents, as most of them are not aware about quantum computing potential in healthcare, hence their views are only captured, converted and analyzed. Future research can consider a large sample from well established players from pharmaceutical, health insurance and hospital sector across the globe to understand the geographical advancements. From the findings it is evident that how potentially quantum computing can be helpful to the industry, though it does not highlight the specific role of artificial intelligence and machine learning. Hence, future studies can explore the role of machine learning and artificial intelligence in enabling quantum computing in healthcare industry. Future work can also consider how quantum computing can lead to changes in healthcare industry in post-Covid world and can play a critical role in integrating the diverse stakeholders such as insurance agent, hospital, pharmaceutical company, payer and patient. Our study considers the region specific orientation towards quantum computing that can be compared with multi-country studies in near future. The upcoming studies can also test the propositions and framework proposed in this study. The common quantum computing techniques can be identified for a group or type of sub-industry. For instance, a type of hospital or size of a pharmaceutical or health insurance company and type of data they generate in their day to day operations. In nutshell, our study offers different options for futuristic, topical and promising future work.

6. Conclusion

In view of organizational theory, this study contributes to literature by highlighting the appropriateness of OIPT with respect to the disruptive technologies such as quantum computing. Study highlights the traditional OIPT's focus to tackle uncertainty for better decision making. Study move forward by highlighting the disruptive nature of quantum technology with respect to healthcare industry. A semi-structured approach is adopted to design, develop and conduct the survey through OIPT lens, where professionals from the healthcare industry have been interviewed and data captured was analyzed. OIPT is more suitable in this study because of its ability to counter information gap processed by an organization. Quantum computing can disrupt the operations of key stakeholders of healthcare industry such as pharmaceutical, hospitals, health insurance organizations and patients. Thus, making a sense of the significant characteristics of technological disruption would be important for recovering the organizational efforts with respect to information processing. The pursuit for pushing the boundaries of technological singularity has always been a top priority for many organizations. This has been made possible with the constant and yet dynamic growth in computing prowess that study have highlighted here with respect to healthcare industry.

Declaration of competing interest

None.

Appendix A. Semi-structured interview schedule

1. In your views, how can quantum computing aid in speedy drug development or vaccine development?
2. Can we use quantum computing to adopt in silico clinical trials instead of animal and human clinical trials?
3. What role can quantum computing play in sequencing and analyzing DNA during pandemic situations?
4. How can we transition from preventive health to predictive health by using quantum computing based technology?
5. In your opinion, how can we benefit by using quantum computing in analyzing the existing body of medical knowledge?
6. How important is it to develop and maintain an ethical, compliant and encrypted data system?

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