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Review Article

A review of emerging innovations in COVID-19

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ABSTRACT

The COVID-19 pandemic has globally impacted humanity. Human health, productivity, social life and function is affected. Every country has felt effects, domestic as well as international. Emerging technologies also known as disruptive technologies have played a significant role in the pandemic. This literature review is a manifest overview on the utilization of existing technologies during the COVID-19 pandemic. The strengths, weakness, opportunities and threats of the innovative technologies under review have been summarized. Their benefits and further scope of disruptive innovations have been reviewed. The review aims to identify and highlight approaches/gaps for improvement and future application.

Keywords: Artificial intelligence, Big data, COVID-19, Disruptive innovation, Internet of Things, Virtual reality

INTRODUCTION

The theory of disruptive innovation was coined by Harvard professor Clayton M. Christensen in the early 1990’s where he explained the concept as an innovation which had the capability to transform an existing sector or market on the strength of its simplicity, ease of use, tht is, convenience, ease of access and affordability to a wider population. A disruptive innovation takes place in an established market/sector but eventually completely redefines it such that the entire network of the said industry, prospers along with the success of the disruptive technology.[1]

The advent of the rapidly evolving COVID-19 has led to global pressure on the healthcare system, presenting mankind with a dire need yet a strong possibility for innovation, an opportunity to explore and accept disruptive change, technological evolution and innovative application, necessary for combatting and controlling the unprecedented pandemic. In such disparaging times, disruptive technologies have taken a lead in providing critical infrastructure, augmenting the global fight against the pandemic.

This literature review aimed to document disruptive innovations in use in the global fight against COVID-19 with a view to identifying techniques, advancements, success and suitability. An analysis of strengths, weakness, opportunities and threats (SWOT) is conducted, highlighting the contribution of scientific knowledge, identifying the gaps if any to shed light on future pathways and shortcomings for address by the scientific community and policy makers, suggesting meaningful direction for future research, in COVID-19 care.

Disruptive innovations under review were artificial intelligence (AI), internet of things (IOT), virtual reality (VR) and augmented reality (AR) and big data.

Methods

A secondary study of reviews and previous research on the chosen technologies. Key search terms included

COVID-19, virus, risk factors, disruptive technology, AI, IOT, VR and AR, big data, innovation effects, epidemic trend, machine learning, revolutionary technology, deep learning. Research was accessed from publications and data sources such as COVID Scholar, Google Scholar, PubMed, Elsevier, Science Direct and Research Gate.[2]

Inclusion and exclusion criteria

AI, IOT, VR and AR and big data have been selected for review based on frequency of peer reviewed research on the use of these innovations in COVID-19 where the maximum relevant literature found is on AI and Big Data followed by IOT and VR/AR.

Relevant articles/reviews that described the application of the disruptive innovations to address COVID-19 have been included. Literature review is from a public health perspective. Languages other than English, other innovations like robotics, 5G, blockchain have been excluded. Literature on the use of AI in cardiology, pathology, radiology, potential drug treatments only have been included as pathbreaking findings have been recorded. IOT literature for the efficacy of wearable device testing, sample studies for brand promotion have been excluded as they do not meet criteria for public health.

DISCUSSION

AI

The Oxford dictionary defines AI as the theory and development of computer systems able to perform tasks normally requiring human intelligence such as visual perception, speech recognition, decision-making and translation between languages. It is leveraging computers and machines to simulate human problem-solving and decision-making capabilities.[3] AI had been a useful tool in COVID-19, in multiple medical fields with AI-driven advancements in areas like diagnosis, prognosis and treatment. The onset of COVID-19 was reported as a potential pandemic by AI based models such as HealthMap, which on 30 December 2019 at Boston children's hospital in the USA, issued a warning predicting a possible outbreak in China. This was followed by another warning prediction by another AI, Canadian BlueDot. AI has successfully diagnosed COVID-19 pneumonia in chest computed tomography (CT) scans.[4] Pankhania 2021 reviewed literature on the utilisation of AI-assisted technology in diagnosing and monitoring COVID-19, the usage of both high-resolution computerised tomography (HRCT) scans and X-ray images of the chest, to diagnose and/or monitor COVID-19. It was found that early stages of COVID-19 pneumonia in the lungs of COVID affected patients showed differences in imaging from those suffering from other types of pneumonia/viral disease.[5,6] The study concluded that HRCT of the chest was rapidly replacing pathological tests in the early diagnosis of COVID-19 but though AI based radiology models offer many advantages, they warranted larger, well-annotated training datasets for diagnostic utility yet.[5,6] Born et al conducting a meta-analysis of 463 manuscripts established that AI had greater diagnostic accuracy for CT scans than X-ray and concluded that as many as 72% research papers focused predominantly on the use of AI for chest X-ray and for diagnosis purposes more than for severity and prognosis.[7]

Google's DeepMind released AI structure predictions for proteins with high biological significance for the SARS-CoV-2. They made the data available for collaboration and helped scientists around the globe assimilate knowledge and understanding of the virus based on genome sequencing.[4,8]

United Kingdom, Singaporean, Indo-German organisations have made use of AI for drug repurposing for COVID-19.[9] Utility has been found for AI use in repurposing of approved or investigational drugs against COVID-19 as potential treatment drugs.[9,10] A COVID-19 host genetics initiative is underway for data generation, sharing and analysis to identify the genetic determinants of COVID-19 susceptibility, severity and outcomes and personalised treatment.[10]

AI based smartphone applications using machine learning can classify SARS-CoV-2 serological rapid diagnostic test results, reducing reading errors in comparison to reading by the naked eye thereby improving result interpretation.[11]

AI in the field of cardiology during the pandemic has proven to be useful in providing advanced technology-based treatment and to predict the survival/mortality of a COVID-19 patient from heart failure.[12] By using algorithms, AI can predict and help treat complex heart-related problems of COVID-19 patients, monitor information, raise timely alerts, repeatedly learn from the input dataset, assess congenital heart disease, angina and fibrillation issues.[12] AI can analyse the heart's anatomy, monitor the appropriate segmentation of the cardiac MRI ventricle, detect arrhythmias analyse heart imaging, blood pressure, oxygen saturation, heart rate and also predicted a heart attack.[12-18]

IOT

IOT is a network of devices and systems, internet connected, consisting of physical objects, interrelated and able to exchange/transfer data with other such objects without human intervention.[25]

In the detection of COVID-19, IOT has been utilised for screening via elevated body temperature, thermal screening at public places such as at airports. IOT has played a significant role in COVID-19 especially in early diagnosis, during quarantine and post recovery making healthcare more affordable, accessible and available, IOT smartphone applications, wearables, drones, robots, IOT buttons have been effectively utilised in COVID-19.[26-30] IOT smart thermometers have been used to monitor and report temperatures, vital to the disease. China, Italy and UAE have deployed smart helmets with thermal sensors to sound an alarm when elevated body temperature was found within a 2-metre radius of the wearer of the device.[26] IOT drones have been used for disinfection and to reach supplies to affected areas.[31] By collating and analysing data in record time with IOT smart devices, smart hospitals can function at minimal contact with COVID-19 patients.[26,29] Dong et al 2021 reviewed the use of IOT framework for identifying COVID-19 positive patients in quarantine and bio sensors as quarantine sensors. They suggested further integration of IOT into cloud-based applications and use of IOT for prediction of COVID-19, concluding that IOT using RFID (radio-frequency identification) was a cost-effective information delivery system.[32] Javaid et al suggested that IOT due to interconnected devices, can unceasingly and accurately monitor affected COVID-19 patients and provide personalisation.[33,26]

VR and AR

Virtual reality is a computer simulated environment with a 3D interface that allows human interaction as an experience. Augmented reality is a digital experience where real world and virtual objects can be enhanced. VR thus works to enhance real environments while AR can augment virtual environments. During COVID, VR has been used for medical interventions such as pain management, physical therapy, rehabilitation, cognitive therapeutic treatments, rehabilitative measures, medical training/learning methodologies and patient education.[34,40]

Mantovani et al studied telerehabilitation and VR for cognitive rehabilitation during COVID-19.[38] They acknowledged gains in health, found limitations for cognitive rehabilitation but consider VR use promising for remote care programs.

Alyaquot et al presented a case series demonstrating how AR can assist in controlling infection and may be of use in the treatment of COVID-19 surgical patients.[39] AR eased time constraints with patient data dispatched directly in health systems, permitted visualization of unseen scenarios and found use in industries, education and governance during COVID-19 lockdowns and quarantines.[40,41] Atli et al evaluated a neurosurgery elective course during COVID-19, using an interactive VR platform as the primary teaching tool, for continuing student training using safe distance for COVID-19 safety protocol. 100% of the participating neurosurgery students reported VR to have given them better understanding of neuroanatomy/neurosurgery and 92% reported better retention of information.[41] A study conducted with participants across 47 countries reported higher VR use during COVID-19 with positive mental and physical wellbeing outcomes in all age groups including elders.[42]

A study on major depressive disorder, depression and the use of VR during the pandemic, concluded positively on the feasibility, acceptability and tolerability of VR for behavioural activation/change for an adult with depression during the pandemic.[43]

Big Data

Big data refers to large, complex information that continues to grow and cannot be reviewed using traditional methodologies. The COVID-19 pandemic has led to colossal and crucial information generation on data pertaining to the disease, treatment and other correlated aspects. These data banks can assist the scientific community if Big Data tools are utilised appropriately, providing significant breakthroughs in preventive methodologies.

A team from Johns Hopkins School of Public Health utilised Big Data analytics to develop a mortality risk calculator for COVID-19 and a dashboard to track real time cases worldwide.[44]

Alsunaidi et al reviewed literature that presented solutions in diagnosis, prediction and healthcare decision making in COVID-19 using Big Data applications. They studied COVID-19 risk assessment, high risk area analysis, understanding hospital operational capacities, use of clinical variables as basis for ICU admission. Regional distribution and healthcare consumption per region, prediction of the pandemic’s course was also analysed, among others.[45]

Wu et al have discussed the utilization of Big Data technology in China when the COVID-19 pandemic broke in Wuhan to contain and control COVID-19. They identified some difficulties such as low efficiency of data collection and data quality, inefficient use of data limitations in data sharing and privacy concerns.[46]

The use of Big Data utilising public digital footprints by many countries whether consented or under directive, has raised ethical concerns. Countries like China, Hong Kong, Taiwan, Singapore, South Korea have accessed public data using technologies like e-wallets, smartphone applications, travel history logs from travel applications to assimilate data on persons in contact with infected persons.[47] Ngan et al concluded that Big Data assimilation needed to meet the four principles of double effect, not cause any evil, intend only good effect, carried out as precautionary and used proportionally.[47] It was their contention that if these parameters were met, then such data may be acceptable for public welfare during pandemics as long as it was reasonable, explained, could account for the privacy violations it caused.[47]

Use of Big Data analytics together with IOT for the prediction of a novel disease like COVID-19 has been suggested for the extensive data that IoT devices have generated during the pandemic.[48]

Table 1: SWOT of AI.

SWOT	AI	References
Strength	Radiology: 95-97% mean accuracy rate in diagnosis; prediction of pneumonia/mortality; reduction in diagnosis and process time compared to RT-PCR; monitoring of treatment effectiveness; understanding human lung pathology; improves the performance of junior radiologists; can be updated with subsequent findings.	4, 6, 7, 19, 20
	Cardiology: Efficient in assessment of congenital heart disease in COVID-19 patients; precise outcome prediction using from cardiac-based algorithms of the COVID-19 patient; prediction of a heart attack; reduced work load; increased doctor productivity; quick identification of heart issues; reduction in time and cost of cardiac surgery; understanding patients' behaviour.	12,13,16-18
	Drug repurposing: Cost effective drug repurposing; minimizes clinical trial failure; rapidly identify drugs effective against COVID-19 leverage; genomic and genetic data for drug repurposing.	4, 8-10
Weakness	Large number of stakeholders needed for effective utility; lack of geographical data restricts generalisation; lack of international collaboration.	7, 21, 22
	Larger, well-annotated training datasets needed, especially for use in ultrastructural analysis; excessive focus on diagnosis; less focus on prognostics and prognostic assessments such as treatment outcome prediction, assessing risk; clinically relevant tasks like monitoring/severity estimation are not the main focus; less focus on vital management tasks such as ventilation equipment and bed allocation; manual annotation of CT data leads to inter-rater variability, susceptible to bias; most current tools do not translate AI model decisions to forms easily interpretable by humans; in radiology, the current AI models are trained on ground truths fed by radiologists' annotation/interpretations, restricted to time and resource saving rather than arriving at better decisions; small number of interdisciplinary studies; less multinational, interdisciplinary collaboration of medical professionals and technological field researchers.	4, 6, 7, 23
Opportunity	Follow up radiological imaging for monitoring COVID-19 progression using AI; preliminary diagnosis of noncritical, suspected patients; developing AI to become a trusted aide in diagnosis and treatment; potential drug generation using genomic sequencing; use of computer vision in COVID-19 histopathology; training AI to work with datasets including those of higher clinical relevance; predict anti-viral therapeutics, track and predict social measure, geographically.	4, 6, 7, 9, 12
Threat	Burdensome and time consuming for clinicians; focus is on short term goals (diagnosis)instead of solution finding; quality of data available for drug repurposing is poor; data security, privacy; risk of demographics and DNA sequencing data disclosing patient identity.	7, 10, 24

Table 2: SWOT of IOT.

SWOT	IOT	References
Strength	Encouraging results in early detection, during quarantine and post recovery; prediction based on accurate and appropriate data capture, even without human interaction at times, well informed decisions, reduction in errors; useful in tracking health conditions of the elderly, real time movement of medical equipment; interconnectivity of tools, devices and databases facilitates digital storage and access of patient information; telemedicine and a wireless health network can lead to timely treatment.	26, 29, 33-35
	Smart wearables like thermometers, helmets for quick monitoring.	27, 26
	Smart phone applications for IOT connectivity.	27-29, 36, 37
Weakness	Costs of large-scale data storage and management.	29
Opportunity	Integration of AI and IOT to harness the power of AI, minimise contact between healthcare workers and COVID-19 patients; facilitation of intelligent healthcare	26, 29, 32, 34

Continued.

SWOT	IOT	References
	services with real monitoring vitals of patients. IOT enabled smart cities and smart infrastructure to assist in social distancing, smart transport systems to control and monitor crowds. Outbreak. forecasting/prediction with cloud applications and AI.	
Threat	Privacy issues related to patient information, cybercrime, misuse of patient data.	26

Table 3: SWOT of VR and AR.

SWOT	VR and AR	References
Strength	Reduction in face-to-face interaction between patients and doctors; application in physical, rehabilitative, cognitive and psychological aspects of COVID-19 management; access to remote regions; good resource to plan, treat and control the disease with awareness generation.	34, 35, 38, 40, 42, 43
	Counters the disadvantage of physical distancing for medical students during neurosurgery; increases confidence and knowledge in diagnosis and treatment.	41
	Reduction in anxiety caused by COVID-19 lockdowns, promotes a positive mind frame.	42, 43
	High patient engagement rate, provision of instant feedback, adaptability as per patients' performance, can combine with other tools and equipment.	38
Weakness	Need and lack of trained personnel to operate equipment (example-neuropsychologist to handle the patient and equipment); cost of hardware and software. Barriers of accessible technology, internet availability.	38
Opportunity	Potential public health aids to ease the burden on healthcare, social support workers, front line workers.	42
	Involving stakeholders for faster and better adoption.	38
Threat	Patient safety. Sickness. Dropouts due to boredom, lack of compliance due to self-administration, decrease in effect due to reduction in the novelty.	38

Table 4: SWOT of Big Data.

SWOT	Big Data	References
Strength	Real time tracking of global cases integrated into a dashboard, timely dissemination of public health policy related information and prevention measures.	44
	Availability of easily accessible large samples, fast response.	49
	Control of misinformation, warning public on its existence and removal from the internet.	45, 50
	Big data models such as machine learning (ML)) can assist in identification of new patterns of disease, symptoms, factors contributing to elevated risk, early warning etc) and can be integrated with IOT devices and AI.	45, 48, 49
	Recognition, understanding and monitoring new disease.	49
Weakness	There is a need for systems, strategies and regulations to guide data access without violation of patient privacy.	45
	Many patients are hesitant to share data such as personal records, health records, gender etc which are important for research. Availability of data to researchers is difficult.	45
	Inefficient data collection, poor data quality, inefficient use of data.	46
	Correlation of search engine keywords and data may be affected by user's limited knowledge of keywords which change as the knowledge on the dynamic virus increases, uncertain user behaviour, extraneous factors such as educational differences, economic conditions etc, and may not represent the entire population as primary users may be younger users and not elders, depending on region and demography.	49
Opportunity	Averting the death of people isolated at home, due to lack of monitoring mechanisms.	45, 51
	Identify vital and changing aspects of the outbreak, for early prediction and preparedness in future outbreak; conducting health drives and awareness camps	45

Continued.

SWOT	Big Data	References
	for citizens. Using machine learning/deep learning models, respiratory diseases can be classified based on large coughing/ breathing sound samples; centralising medical staff duty allocations; distribution and estimation of ventilator requirement at government level; governments can collate large amounts of data on social media to formulate policies, detect depression and psychological disturbances during lockdowns, contain misinformation.	
	Combining search engine data related to COVID-19 with actual medical information systems for medical development.	49
Threat	Sharing of data blindly, without knowing its end use, Biased results due to absence of data validation.	45

An analysis of COVID-19 symptom characteristics was made using a search engine index and the website of the country's center for disease control and prevention (China) to ascertain the volume of keywords used for symptoms associated with COVID-19. It was established that patients who made internet searches of the relevant symptoms were likely to visit a doctor 2/3 day post and receive a confirmed diagnosis 3-4 days subsequently. Big Data analysis thus showed a positive correlation between internet search and suspected/confirmed cases.[49]

Limitations

This review was limited to the disruptive innovations studied and medical fields as mentioned. There were other fields of medicine that have utilised disruptive innovations and which stand to benefit similarly, that have not been reviewed.

CONCLUSION

Disruptive innovation such as AI, IOT, Big Data, VR and AR have undoubtedly contributed to identification of COVID-19, scaling up of treatment and prevention protocols in the pandemic. Innovative use in screening, treatment, quarantine, testing, contact tracing is underway, attributed to the multifaceted interfaces that they provide. Important solutions have been developed but there no optimization for early clinical or public health application, due to lack of preparedness. Concerns related to data security and appropriate privacy norms exist, which may be mitigated with higher transparency and giving feedback and sharing research results with participants in research/patients to increase involvement and build trust.

This literature review finds that a lot of research study is available but limitations on collaborations, interdisciplinary study are found. Large data sets and research, generated during the pandemic have been made freely available for researchers by stakeholders like Google Cloud. These data sets hold the key to future strategies and quantum leaps in public health and policy. More research from multi-disciplinary teams using data driven disruptive innovations with cross disciplinary data inputs, inclusive of gender, demographics, severity, outcomes, geographical locations is advocated. Research findings may be made available to policy makers and considered for application in preventive and social medicine (PSM). These findings can support stakeholders such as policymakers and clinicians in preparing predesigned operationalization for application in future pandemics. There is a paucity of COVID-19 gender data. Resourceful technologies can be leveraged to gather gender sensitive data thereby reducing the gap, globally. Data if made available to policy makers, will assist in identification and resolution of gender sensitive impacts of COVID-19; assist in identification of structural gender bias in fields like cardiology which arise from a gender imbalance in research. Interdisciplinary collaboration including technology, medicine and behavioural sciences will allow identification of behaviour change methodologies which are necessary to achieve community behaviour change outcomes needed for pandemic handling.

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