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CardioVerse: The cardiovascular medicine in the era of Metaverse ☆,☆☆

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ABSTRACT

The recent pandemic launched an acceleration in adopting telemedicine by cardiovascular health and triggered the flourishing of technological advancements, such as the metaverse, which is a novel interactive mix of digital worlds that leverages augmented reality with virtual reality. The CardioVerse represents a theoretical term for the embracement of the metaverse by cardiovascular medicine, encompassing the endless possibilities as well as the challenges that it holds and introduces new dimensions to disease education, prevention and diagnosis. Its applications are numerous, notably in enhancing medical visits, assisting cardiovascular interventions and reshaping the way medical education is provided. Although obstacles are expected in diverse domains such as security, technical, legislative and regulatory, the utilization of non-fungible tokens as a security asset for patient data appears as potential solution.

Introduction

Traditionally, the fundamental component of the patient-doctor relationship in cardiovascular medicine has been the hands-on physical encounter. The most recent pandemic has put into challenge this unique connection distancing the patient from the healthcare professionals and arising risks for the quality of patient care. This new reality triggered a revolutionary acceleration in adopting innovative technologies in every sector of daily life from social interactions and entertainment to medical services [1,2]. Telemedicine, Augmented Reality (AR) and Virtual Reality (VR) have flourished on this unprecedented global health landscape opening new horizons in cardiovascular medicine and more than ever attaching it to technological advancements, in order to achieve optimal patient care.

Recently, there has been a surge of widespread interest in one of the most groundbreaking technological breakthroughs identified as "the metaverse" promising a disruptive digital reality poised to bring transformation in many aspects of life, including healthcare. One by one, the biggest tech giants started to actively invest in this previously untraveled area and evaluated the various possible ways in which the technological sector could find applications. Even Facebook declared that it would be officially changing its name to Meta, expressing its ambitious objective to transform the social media colossus into a massive metaverse world [3] The interest was quickly passed on to various industries including business, fashion, sports and even real estate where people started buying virtual properties and land.

Consequently, it appears unavoidable that the healthcare will be next to undergo in-depth analysis of the numerous applications of the metaverse and how it can be implemented in cardiovascular medicine.

Metaverse definition

The term was first described in the 1992 science fiction novel *Snow Crash* where author Neal Stephenson described an internet-connected, immersive virtual universe that served as an alternate reality for its participants, calling it “the metaverse”. Since the internet expanded, the metaverse reference progressively found its place in the tech lexicon describing any large-scale virtual setting in the online space that users can be part of.

Simply put, the metaverse is a digital 3-dimensional (3D) environment where AR/VR and artificial intelligence (AI) serve as the basic visual providers and where individuals can have social, financial and various other interactions using personalized digital avatars mimicking real life experiences. [4] It represents a mix of interconnected digital spaces permitting its users to engage in activities like shopping, gaming and attending virtual events [5].

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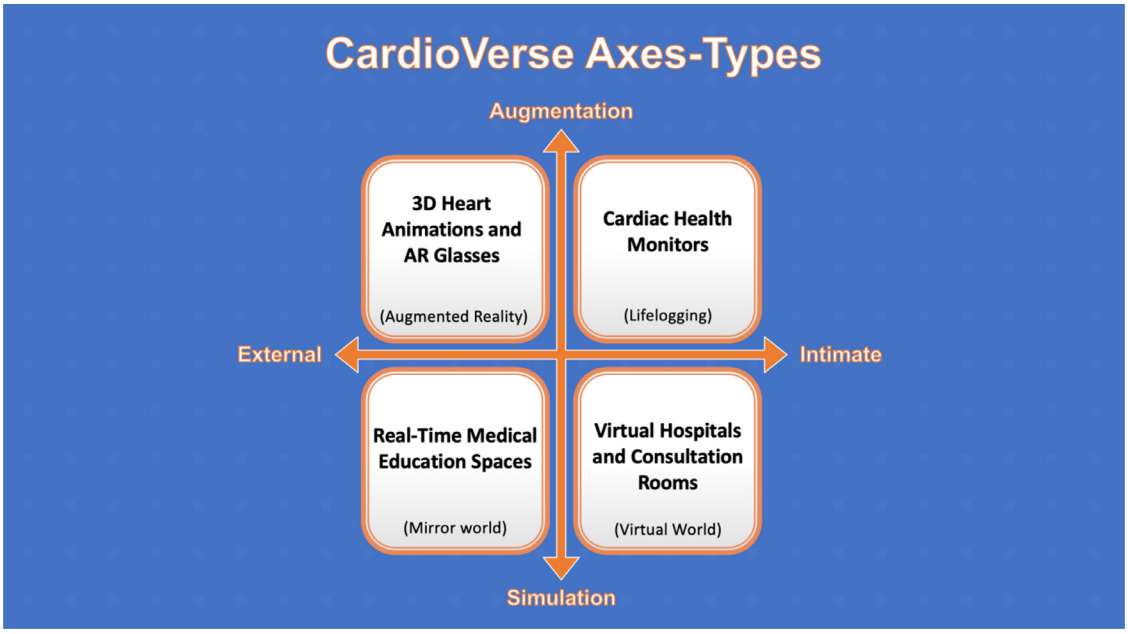

Fig. 1. The modified model of the CardioVerse based on the axes and types of metaverset. The 4 types and 2 axis proposed for the metaverse can also be accordingly applied to the CardioVerse concept. (AR, augmented reality)

Other investigators have categorized the metaverse in 4 different types (augmented reality, lifelogging, mirror world, virtual world) based on 2 axes (external and intimate) [6]. The augmented reality is the augmentation of the external world building a smart digital environment (e.g. Pokemon Go, HoloLens, 3D medical animations), the lifelogging represents the utilization of smart devices to record their daily lives on the internet or smartphones (e.g. Instagram, Facebook, health monitors), the mirror world reflects a map-based simulation of the external world (e.g. Google Maps, Google Earth, educational spaces) and the virtual world constitutes an entirely virtual online 3D reality that one can interact solely via avatars (e.g. online multiplayer video games, virtual hospitals and consultation rooms). The first axis is ranging from augmentation (technologies that build on reality and add new capabilities to existing real systems) to simulation (technologies that are copying reality and perform as novel parallel reality). Finally, the second axis is ranging from the technologies that are focusing on the behavior and actions of individuals that have agency over their environment (intimate) to mechanisms that are centering on the development of the environment that surrounds the users (external).

The key element of its function is that it performs on blockchain highlighting the decentralized nature of its presence without the need of third-party providers [7]. A blockchain is an immutable distributed ledger that stores encrypted data into blocks and records transactions securely eliminating intermediates like a traditional database (for example central bank or servers) [8]. Furthermore, the distributed ledger protocol ensures accessibility of the data from any location (using with the appropriate decryption key), consequently establishing a digital trust that leads to more efficient transaction processing and eliminating the need for expensive interfaces. The implementation of blockchain in healthcare has been actively investigated the recent years since the popularity of cryptocurrencies emerged [9].

Developing the CardioVerse

Although, healthcare and life sciences have been traditionally slow to embrace technology-inspired changes to long-established ways of working [10,11], the cardiovascular community have always been exploring effective ways to apply modern and effective technological innovations into clinical practice [12,13]. The development of an eventual cardiology-targeted metaverse (CardioVerse), a theoretical term representing the adoption of the metaverse by cardiovascular medicine and including all the potential applications and challenges that follow it, would focus on the various ways of how cardiology and heart surgery could benefit in this digital trend. The modified model for the CardioVerse, that is based on the 2 axes and 4 types of metaverse, is being illustrated at Fig. 1. At first glance, the spectrum of possibilities and cutting-edge medical applications provided by a CardioVerse appears immense (Fig. 2), but at the same time, raises lots of security, technical and ethical questions [14].

Enhanced medical visits

Metaverse aspires to augment cardiology medical visits, where patients and physicians can meet in a 3D virtual clinic giving a much better user experience when it comes to telemedicine services. A cardiologist or a cardiac surgeon can do virtual consultations and follow-ups with patients to assess disease progress and discuss exam results. Although haptic method technologies mimicking physical touch are at early stages, not all cardiovascular conditions are essentially depending on physical examination, introducing unique advantages as many physical visits can be done virtually no matter the participants' physical location [15]. It is undeniable that the physical contact cannot be easily reproduced in a virtual world and the CardioVerse doesn't aspire to replace physical meetings. However, it aims to actually ameliorate the telemedicine visits and make them approach as much as possible the physical ones which would be a noteworthy asset, particularly for those who live in remote areas or have trouble attending visits at the hospital or clinic. (e.g., physical disabilities). The patient could measure his blood pressure, his glucose levels, his heart rate and even do an electrocardiogram by distant 12-lead ECG devices [16] (based on smartphone apps and to directly integrate and project all of the results to the metaverse platform where the physician and patient can in-

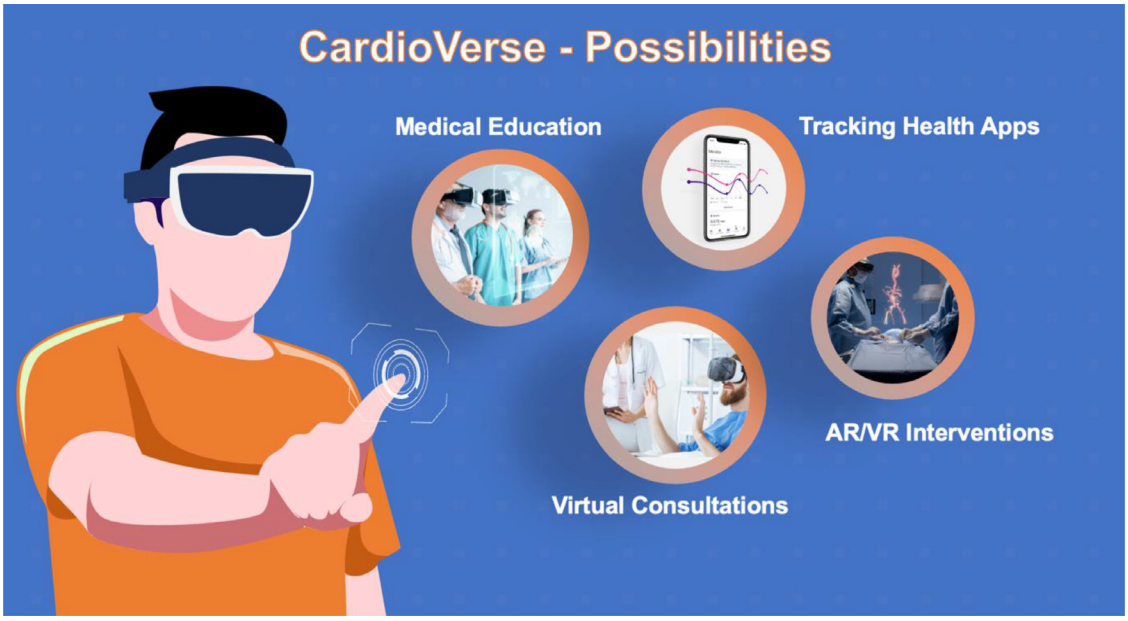

Fig. 2. The possibilities of the CardioVerse. The CardioVerse (a term used to describe the adoption of the metaverse concept by cardiovascular medicine) introduces a brand-new digital world full of possibilities to cardiovascular medicine. AR, augmented reality; VR, virtual reality

terrogate, examine and discuss the results making a virtual diagnosis. Virtual representation via avatars can transform the already existing remote video-call-based consultations to a more vivid interaction between patient and doctor by providing high-resolution illustrations, 3D character and environment reconstruction (face-scan applications are already being developed) and eventually safe and efficient data management. The younger patients are the ones that will initially be easier to adapt and follow such technologies that are focusing more on the young generation as they are also more familiarized to the gamification of various aspects of everyday life. Virtual hospitals are already being built targeting to accommodate this new way of delivering healthcare with parallel possibilities for disease education, prevention and diagnosis [17].

Assisting surgical and interventional procedures

Building on the existing use of surgical robots via AR/VR and AI, the metaverse could considerably contribute to increasing efficiency and precision in cardiovascular interventional procedures of various complexity along with decreasing the probabilities of complications. Adopting such a technology will add another depth in visualizing cardiac cavities, coronary anatomy and vascular system, granting better operability with real-time guidance through integration with surgical navigation systems and blending of data from multiple imaging sources. A digital environment where highly-skilled cardiac surgeons-interventionalists can operate across the world as well as train the new generation of physicians would drastically remold healthcare. The Seoul National University Hospital in Korea created in 2021 a combination of smart operating room and metaverse environment, where more than 200 thoracic surgeons from various countries attended and received lung cancer surgery education with high-resolution virtual reality cameras broadcasting all surgical scenes in 360° [18]. The participants either wore a VR headset in their respective laboratories or joined the virtual environment with their laptops and indicated that it seemed like they were observing the procedure in the actual operating room underlining the metaverse as a reproduction of reality in a virtual space. This example could potentially be adapted by cardiac surgery and interventional cardiology and even go further than that inside a CardioVerse.

Reshaping cardiovascular education

Last but not least, medical education seemingly holds unlimited prospective in a CardioVerse adoption [19]. Since medical training varies by region and by time, all the healthcare staff can experience via the metaverse the same standardized, evidence-based education, regardless where or when they are educated [20]. The combined use of AR/VR and AI opens new perspectives for medical training allowing to see a virtual patient, make a diagnosis and treat. It may even allow students to “enter” a virtual human body, allowing for a 360° full-scale view of the cardiovascular system or simulating actual cardiac procedures. Colored virtual anatomical projections of the coronary arteries and heart valves are already getting developed in 3D and could be integrated inside the metaverse to create complete AR/VR cardiology courses for medical students and fellows. Even virtual representations of coronary angioplasties that can guide step by step interventional cardiology trainees appear as possible educational application inside the metaverse. As the opportunities for on-hand training in interventional cardiology and cardiac surgery are not always easy to find considering the rising demand and not sufficient training centers, virtual educational courses could be a useful alternative in such cases. There is vast potential for surgical and interventional training and also for medical schools to be completely revolutionised within the metaverse [21]. In January 2022, medical students at the Queen Mary hospital of London received the first surgery lecture in the metaverse and the participants were connected via a VR computer desktop application or via a VR headset, which gave them the ability to enjoy a more interactive experience within the metaverse compared to conventional online experiences [22]. As a final point, patient education inside the CardioVerse will be upgraded. The traditional explanation approaches via only graphs and conversations can be tough and difficult to follow. With 3D simple animations and VR equipment, patients can actually find out what kind of cardiac problem they have, understand the basics of their disease and adequately engage in the treatment decision options. (e.g., surgical vs percutaneous interventions)

Connecting with telemedicine technologies

Although the whole concept of the metaverse seems immense and, it is not planning to be isolated from existing technologies and telemedicine services. One of the biggest and most effective functions is the integration and compatibility with currently available medical devices that will evolve the metaverse by building on already working innovations. An optimal model of the CardioVerse would be based on interoperability by integrating health devices and applications available to the patient at home (distant 12-lead electrocardiogram, blood pressure-heart frequency monitors, oxygen saturation meters, blood glucose calculators) the results of whom will be projected directly in the metaverse. The physician will then discuss via a virtual avatar with the patient according to the medical anamnesis and interpret the results of all the health monitor devices reaching to a final diagnosis that can share to the patient. A blending of telemedicine innovations with the metaverse is considered as a key component to a functional, concrete and evolving CardioVerse.

Challenges to face and the NFTs integration

As anticipated, with opportunities we can also presume encountering many challenges. (Fig. 3) The obstacles will likely engage in diverse domains such as security, technical, legislative and regulatory. The privacy and security of patient data is a major concern in the metaverse, as breaches and violations could lead to exposure or theft of sensitive information. The decentralized essence of the metaverse running on blockchain could bring entirely new ways of encrypting patient data and enforcing compliance to medical standards in practices and processes.

One promising solution that is currently beginning to be evaluated is the use of non-fungible tokens (NFTs) that have also seen a surge of interest, simultaneously with the metaverse [23] An NFT is a unique and non-interchangeable unit of data, registered in a blockchain, that is used to record ownership of a digital asset [24]. It relies on a decentralised network of computers employing advanced cryptography to verify the validity of a transaction similar to what cryptocurrencies like Bitcoin are based on. Unlike cryptocurrencies, which are considered as a form of money or digital asset, NFTs are intended to be the equivalent of a certificate of authenticity or a digital fingerprint of data and can hold numerous files, with transaction IDs and detailed history [25] At first, NFTs gained huge popularity in the art sector that were mostly being used as validation of authenticity and rarity of specific digital art creations [26] For example, an artist could make an NFT of a digital artwork which would represent a limited edition of this art, making it valuable for digital art collectors or to investors that believe that it's value would rise in the future. The core clue of all this remains the ability of NFTs to have their digital warranty of authenticity as a unique and immutable gather of data.

But how could NTFs be introduced in healthcare? What is so valuable to remain secured, anonymized, well-guarded and impossible to copy, transfer or delete without permission? The patient medical status, data and disease information represents one of the most precious assets in healthcare that their management, safe utilization and sharing remains a non-stop pursuit. Tokenizing and converting patient data (medical information, health conditions, exam results and consent forms) into NFTs could enhance privacy and assure patient data integrity and confidentiality in clinical practice as well as in research initiatives. Patients could visit the emergency department and have their whole medical history, disease, medication and allergies stored in their own personalized NFT that only them and their doctor can access it (or any other individual that the patient decides to give access to). This could save time, effort and money for hospitals and patients instead of waiting for external documents that many times are distributed to various different physicians or hospitals and also gives more power to the patients regarding their own medical dossier [27]. Nonetheless, regulatory oversight and standardization is required to establish trust to the technological enablers and eventually test their impact in real-world settings.

Exploiting the full potential of the CardioVerse will require state-of-the-art technology, the cost of which is definitely non-negligible. More specifically, it requires high-tech hardware that ideally demands the newest VR headsets, wireless blood pressure and heart frequency monitors, future haptic gloves to mimic physical touch and the latest computer processors and graphic cards

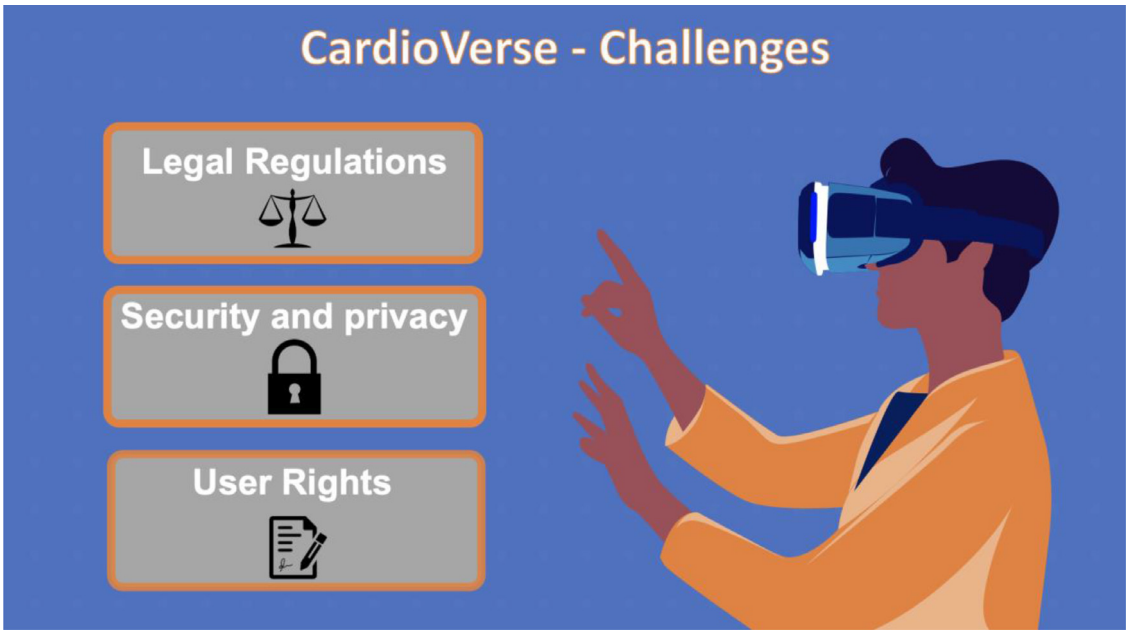

Fig. 3. The Challenges of the CardioVerse. Overcoming challenges is essential that mainly concern legal regulation, security and privacy of patient data as well as clear definition of patients' rights, as users of the CardioVerse.

to support the CardioVerse at its maximum. On top of that, high-end internet connectivity (5G and fiber-optic internet) and energy-demanding blockchain deployments are essential for the smooth function of the virtual environments, the economic aspect of which is also considerably high. Although we can expect the cost to possibly progressively reduce as the adoption expands, it is undeniable that it will be more difficult for unprivileged minorities to gain access, in contrast to more advanced countries and parties that could easier afford it [28] The overall infrastructure costs for healthcare providers will not permit of imminent mass adoption and the disproportionately large amounts of energy consumption necessitate alternative sources of energy [29]. Future studies that could provide specific financial data aiming to accurately investigate and assess the economic requirements of a CardioVerse adoption are of special interest.

Tackling legislation and regulation issues will be necessary when insurances, pharmaceutical companies and governments will eventually become involved. It is essential to establish policies and protective procedures that could protect the users in case of criminal or abusive behaviors under a clear legal framework [30]. It still remains unclear who is responsible in case of such an event and clarifying who bears the responsibility in a decentralized network needs to be addressed. In an effort to promote fair competition between participating companies and corporations, it is indispensable that the businesses conform to a well-defined regulating law, avoiding anti-trust concerns [31].

One of the main issues still in question, is the where the metaverse could or should truly stay decentralized and public, once multi-million companies start to join and participate in developing and evolving the field. Decentralization offers more fair opportunities, less anti-trust challenges but could also masquerade as control behind the scenes, making it harder to track or monitor actions. As the concept is still in its infancy and continues to evolve, the advantages and disadvantages of a private, public or decentralized administration, are expected to be more diaphanous.

Last but not least, the implementation of the CardioVerse will require the development of trust among the participants to the idea of the concept. There are many valuable elements that make the physical encounter unique such as facial expressions and non-verbal language, that can be missed in virtual visits, as face-to face contact is essential for building trust. The technology should be evolved in a way that provides trust to the doctors that they will require all the information needed for an optimal medical consultation but also to the patients that they will be able to communicate and create a strong relationship with their doctor inside the CardioVerse.

Conclusion

The metaverse promises an unparalleled leap in the way medicine is delivered and the development of a CardioVerse, focusing exclusively on cardiovascular medicine, will introduce extraordinary dimensions to the medical ecosystem for patients' physicians and trainees. Further research, primarily regarding the moral and credibility aspects, is mandatory in order to leverage a universal metaverse adoption in healthcare. Having used a digital avatar for a virtual event or meeting, provides a glimpse of what the future might hold. However, whether it truly represents an emerging technology bound to redefine our society and healthcare or just an immature futuristic state, remains to be discovered.

Ethical Statement

We the undersigned declare that this manuscript is original, has not been published before and is not currently being considered for publication elsewhere.

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

We confirm that all authors are responsible for the content and have read and approved the manuscript; and that the manuscript conforms to the Uniform Requirements for Manuscripts Submitted to Biomedical Journals published in Annals in Internal Medicine

We understand that the Corresponding Author is the sole contact for the Editorial process. He/she is responsible for communicating with the other authors about progress, submissions of revisions and final approval of proofs.

References

[1] Wosik J, Fudim M, Cameron B, Gellad ZF, Cho A, Phinney D, et al. Telehealth transformation: COVID-19 and the rise of virtual care. J Am Med Inform Assoc 2020 Jun 1;27(6):957–62. doi:10.1093/jamia/ocaa067.
[2] Colbert GB, Venegas-Vera AV, Lerma EV. Utility of telemedicine in the COVID-19 era. Rev Cardiovasc Med 2020 Dec 30;21(4):583–7. doi:10.31083/j.rcm.2020.04.188.
[3] Bobrowski M. Mark Zuckerberg sets Facebook on long, costly path to metaverse reality. https://www.wsj.com/articles/mark-zuckerberg-sets-facebook-on-long-costly-path-to-metaverse-reality-11635252726c (1 December 2021)
[4] Wiederhold BK. Ready (or Not) Player One: Initial Musings on the Metaverse. Cyberpsychol Behav Soc Netw Jan 2022;25(1):1–2 editorial. Epub 2021 Dec 29. doi:10.1089/cyber.2021.29234.
[5] Liu Z, Ren L, Xiao C, Zhang K, Demian P. Virtual reality aided therapy towards Health 4.0: a two-decade bibliometric analysis. Int J Environ Res Public Health 2022 Jan 28;19(3):1525. doi:10.3390/ijerph19031525.
[6] Smart J, Cascio J, Paffendorf J. Metaverse roadmap: pathway to the 3D web [Internet]. Ann Arbor (MI): Acceleration Studies Foundation; 2007 [cited 2021 Nov 29]. Available from: https://metaverseroadmap.org/MetaverseRoadmapOverview.pdf.
[7] Krittanawong C, Rogers AJ, Aydar M, Choi E, Johnson KW, Wang Z, et al. Integrating blockchain technology with artificial intelligence for cardiovascular medicine. Nat Rev Cardiol Jan 2020;17(1):1–3. doi:10.1038/s41569-019-0294-y.
[8] Krittanawong C, Aydar M, Hassan Virk HU, Kumar A, Kaplin S, Guimaraes L, et al. Artificial Intelligence-Powered Blockchains for Cardiovascular Medicine. Can J Cardiol Feb 2022;38(2):185–95. doi:10.1016/j.cjca.2021.11.011.
[9] Shukla M, Lin J, Seneviratne O. BlockIoT: Blockchain-based health data integration using IoT devices. AMIA Annu Symp Proc 2022 Feb 21;2021:1119–28.
[10] Werner H, Ribeiro G, Arcoverde V, Lopes J, Velho L. The use of metaverse in fetal medicine and gynecology. Eur J Radiol 2022 Mar 9;150:110241. doi:10.1016/j.ejrad.2022.110241.
[11] Lee J, Kwon KH. The future value and direction of cosmetics in the Era of Metaverse. J Cosmet Dermatol 2022 Jan 24. doi:10.1111/jocd.14794.
[12] Silva JNA, Southworth M, Raptis C, Silva J. Emerging applications of virtual reality in cardiovascular medicine. JACC Basic Transl Sci 2018 Jun 25;3(3):420–30. doi:10.1016/j.jacbts.2017.11.009.
[13] O'Sullivan DM, Foley R, Proctor K, Gallagher S, Deery A, Eidem BW, et al. The use of virtual reality echocardiography in medical education. Pediatr Cardiol Apr 2021;42(4):723–6. doi:10.1007/s00246-021-02596-z.
[14] Phillips AA, Sable CA, Atabaki SM, Waggaman C, Bost JE, Harahsheh AS. Ambulatory cardiology telemedicine: a large academic pediatric center experience. J Investig Med 2021 Oct;;69(7):1372–6. doi:10.1136/jim-2021-001800.
[15] Skalidis I, Muller O, Fournier S. The Metaverse in cardiovascular medicine: applications, challenges and the role of non-fungible tokens. Can J Cardiol 2022 Apr 14;S0828-282X(22) 00222-7. doi:10.1016/j.cjca.2022.04.006.
[16] Maurizi N, Faragli A, Imberti J, Briante N, Targetti M, Baldini K, et al. Cardiovascular screening in low-income settings using a novel 4-lead smartphone-based electrocardiograph (D-Heart®). Int J Cardiol 2017 Jun 1;236:249–52. doi:10.1016/j.ijcard.2017.02.027.
[17] "Health City" - Aimedis Publishes Health-Metaverse and Will Soon Open the First Clinic In It https://finance.yahoo.com/news/health-city-aimedis-publishes-health-174400175.html?soc_src=social-sh&soc_trk=tw&tsrc=twtr, yahoo finance (December 10,2021)
[18] Koo H. Training in lung cancer surgery through the metaverse, including extended reality, in the smart operating room of Seoul National University Bundang Hospital. Korea. J Educ Eval Health Prof. 2021;18:33. doi:10.3352/jeehp.2021.18.33.
[19] Kye B, Han N, Kim E, Park Y, Jo S. Educational applications of metaverse: possibilities and limitations. J Educ Eval Health Prof 2021;18:32. doi:10.3352/jeehp.2021.18.32.
[20] Chen FQ, Leng YF, Ge JF, Wang DW, Li C, Chen B, et al. Effectiveness of Virtual Reality in Nursing Education: meta-Analysis. J Med Internet Res 2020 Sep 15;22(9):e18290. doi:10.2196/18290.
[21] Suh W, Ahn S. Utilizing the Metaverse for learner-centered constructivist education in the Post-pandemic Era: an Analysis of Elementary School Students. J Intell 2022 Mar 7;10(1):17. doi:10.3390/jintelligence10010017.

[22] Queen Mary University of London Queen Mary students receive first lecture in the metaverse; 2022. https://www.qmul.ac.uk/media/news/2022/pr/queen-mary-students-receive-first-lecture-in-the-metaverse.html 2022 Jan 19.
[23] Bamakan SMH, Nezhadsistani N, Bodaghi O, Qu Q. Patents and intellectual property assets as non-fungible tokens; key technologies and challenges. Sci Rep. 2022 Feb 9;12(1):2178. doi:10.1038/s41598-022-05920-6.
[24] Kostick-Quenet Kristin, Mandl Kenneth D, Minssen Timo, Glenn Cohen I, Gasser Urs, Kohane Isaac, et al. How NFTs could transform health information exchange. Science 2022;375(6580):500. doi:10.1126/science.abm2004.
[25] Jones N. How scientists are embracing NFTs. Nature Jun 2021;594(7864):481–2. doi:10.1038/d41586-021-01642-3.
[26] Kostick-Quenet K, Mandl KD, Minssen T, Cohen IG, Gasser U, Kohane I, et al. How NFTs could transform health information exchange. Science 2022 Feb 4;375(6580):500–2. doi:10.1126/science.abm2004.
[27] Subramanian H, Subramanian S. Improving diagnosis through digital pathology: proof-of-Concept implementation using smart contracts and decentralized file storage. J Med Internet Res 2022 Mar 28;24(3):e34207. doi:10.2196/34207.
[28] Abu-Elezz I, Hassan A, Nazeemudeen A, Househ M. Abd-Alrazaq A. The benefits and threats of blockchain technology in healthcare: a scoping review. Int J Med Inform Oct 2020;142:104246. doi:10.1016/j.ijmedinf.2020.104246.
[29] Xi N, Chen J, Gama F, Riar M, Hamari J. The challenges of entering the metaverse: An experiment on the effect of extended reality on workload. Inf Syst Front 2022 Feb 12:1–22. doi:10.1007/s10796-022-10244-x.
[30] Bundi D, Bourgaux V,. Legal & compliance in the Metaverse https://www.pwc.ch/en/insights/regulation/legal-compliance-metaverse.html (January 2022)
[31] Kumar N. Six unaddressed legal concerns for the Metaverse. https://www.forbes.com/sites/forbestechcouncil/2022/02/17/six-unaddressed-legal-concerns-for-the-metaverse/?sh=376b07287a94 (17 February 2021)