Original Article

Healthc Inform Res. 2020 October;26(4):328-334.
https://doi.org/10.4258/hir.2020.26.4.328
pISSN 2093-3681 • eISSN 2093-369X

HIR
Healthcare Informatics Research

Impact of the Fourth Industrial Revolution on the Health Sector: A Qualitative Study

João António Gomes de Melo e Castro e Melo[1], Nuno Miguel Faria Araújo[2]

[1]The Instituto Superior de Ciências Sociais e Políticas (ISCSP), Lisbon University, Lisbon, Portugal
[2]Vale do Ave Higher School of Health (ESSVA) at CESPU-North Polytechnic Institute of Health (CESPU-IPSN), Vila do Conde, Portugal

Objectives: The Fourth Industrial Revolution is changing the way health is understood, transforming the methods of treatment and diagnosis as well as the relationship between health professionals and patients and altering the management and organization of health systems. The main objective of this study was to explore the impact that the Fourth Industrial Revolution is having on the health sector. **Methods:** Conducting interviews consisting of four questions with 10 professionals who had experience working in the health sector to gain their insights and to obtain information to meet the general objective of the study as well as its specific objectives. **Results:** From the analysis of the respondents' responses, it was possible to create five dimensions developed by the topics most addressed by respondents, namely, impact on healthcare efficiency and effectiveness, impact on government action, impact on human resources, impact on health system organization, and financial impact on the health sector. **Conclusions:** Although the Fourth Industrial Revolution is still at an early stage, it has been concluded that it is having a major positive impact on the health sector. For the effective and efficient implementation of these disruptive technologies, a global interaction between governments, health professionals, stakeholders, and society is essential to make this change possible.

Keywords: Artificial Intelligence, Disruptive Technology, Health Care Reform, Health Care Sector, Technology Assessment

I. Introduction

The Fourth Industrial Revolution (FIR) is a recent concept, encompassing the main technological innovations in the fields of automation, control, and information technology applied to production processes. The health sector is one of the sectors that is most exposed to technological evolution, so it is being impacted by digitization, revolutionizing the way healthcare is provided, from the interaction between patients and caregivers to governments and stakeholders [1].

Based on the use of core technologies in the definition of the FIR, new methods of treatment, diagnosis, and monitoring of patients' health status, innovations in the management and organization of health systems are being developed, and the access to healthcare is also being modified.

The purpose of this study was to understand the perceptions of health experts and professionals about the impact the FIR will have on the health sector, based on the use of base technologies in its definition, such as artificial intelligence (AI), the Internet of Things (IoT), cloud computing,

Submitted: April 23, 2020
Revised: July 26, 2020
Accepted: August 6, 2020

Corresponding Author
João António Gomes de Melo e Castro e Melo
The Instituto Superior de Ciências Sociais e Políticas (ISCSP), Rua Conde de Sabugosa, nº15, 6º C, 1700-115, Lisbon, Portugal. Tel: +351-917092365, E-mail: joaomelo.ecastroemelo@gmail.com (https://orcid.org/0000-0002-3297-0517)

Table 1. Specific objectives

	Description
1	Note the changes brought about by industry 4.0 in the health sector
2	Understand the goverment action brought about by the Fourth Industrial Revolution in the health sector
3	Identify the biggest challenges involved in the acquisition of technologies 4.0 in the health sector
4	Understand the risks inherent in the implementation of technologies 4.0 in the health sector
5	Understand the sustainbility of the application of technologies 4.0 in health systems

and data science, among others disruptive technologies, and how they will affect healthcare.

The use and implementation of these technologies are fundamental for disruptive innovation in the health sector and for the construction of people-centered health policies.

II. Methods

This was a descriptive exploratory study with a qualitative approach. A semi-structured interview was used to collect data to meet the general objective of the study as well as its specific objectives, which are listed in Table 1.

Using the intentional sampling method, 10 national and international professionals who had experience on the health sector, health technology, economics, and health management were selected based on four criteria, namely, experience working in the health sector, having different nationalities, having held government positions, having held positions in the public and private sector, and having more than 15 years of experience working in the health sector. The details of the respondents are presented in Table 2.

The interviews were done individually in person and by videoconference during the period from September 14, 2018 to October 20, 2018. Content analysis was conducted using the method from Bardin's perspective [2].

The results obtained are presented in the form of categories. The main objective of this categorization was to provide, by condensation, a simplified representation of the raw data. Our analysis considered the dimension of analysis defined a priori based on the main challenges and impacts on the subject under study, supported by the existing literature [2].

Table 2. Description of the respondents

	Nationality	Background and experties
1	American	Industry
2	Brazilian	Public sector
3	Belgian	Worlth Health Organization
4	British	Government
5	British	Industry
6	Portuguese	Academic
7	Portuguese	Academic
8	Portuguese	Government
9	Portuguese	Government
10	Portuguese	Industry

III. Results

Addressing the first specific objective of the study, we asked participants how they believe the FIR will transform the health sector. One of the main impacts identified was the efficiency and effectiveness of healthcare. The improved proximity between patient and service providers was also highlighted. They expressed the view that, in the future, patients will be at the center of the health system, with a shift from focusing on the disease to focusing on prevention. They emphasized that the implementation of 4.0 technologies will make it easier to identify risk situations earlier, leading to faster interventions, as patients will be connected by IoT, with one or more devices/wearables, sharing their biodata. Therefore, more important than data collection is the possibility of processing them in real time and screening them by algorithms. This connection to patients by IoT will enable early diagnosis, health/disease monitoring, precision medicine, and medical history intelligence. Thus, we defined the first dimension of the study with its focus on the impact of the FIR on the efficiency and effectiveness of healthcare.

Regarding the second specific objective, where we sought to understand how the role of government should be redefined and how it should adapt to the rapid evolution of the FIR and its impact on the health sector, it was agreed that government should have a determining role in creating various incentives. Legal incentives for digitization should be accompanied by an ecosystem vision, and a transformation of governance models is needed to enable opportunities to be seized and to respond to digital threats within both public

and private systems, thereby reducing barriers to technology incorporation. They also suggested that government should foster innovation through the development of startups and their integration into the healthcare sector through the creation of research and innovation centers with easy funding. They stressed that government should promote incentives for training health professionals in new technologies, so that they can take on the new paradigm. Government and business will need to be able to participate and develop professional retraining programs because workplaces will demand new interactions from professionals with machines and with the physical and virtual world. The socio-technical transformation of the work environment will include automation, robotics, and other technologies that enhance professionals' ability to act, requiring rapid transformation of systems and professionals. Finally, they expressed that government should put in place legislation to promote the protection of user data because huge amounts of data will be generated. Government must step up its role in providing universal health coverage, adapting from a global perspective, across country borders. Thus, we determined another focus of this study, the impact of the FIR on government action.

Regarding the third and fourth specific objectives of the study, because of the way the interviews were conducted, the respondents' answers were relevant to both objectives, so they were aggregated. We sought to identify the biggest challenges involved in the acquisition of 4.0 technologies for the health sector and the risks inherent in their implementation. It was evident that professionals need to be able to incorporate technological innovations and use the available information to make decisions that lead to effective practices, and the transformation of human resource skills is a critical success factor. Some participants considered the relocation of work resulting from the application of 4.0 technologies as a risk factor, while others considered it an added value because professionals can work without physical offices and in a much more flexible manner. Conversely, work situations that require greater human contact and the development of therapeutic relationships will tend to be valued because they require teamwork, supervision, and divergent communication, which cannot be provided by computers. It is well known that repetitive and predictable human activities can be performed by robots and computers, but this is not the case with emergency services or any activities that require rapid response to unpredictable situations. Of course, one can think of the danger of dehumanization, but at some point in the process, there must be human intervention. Although AI can support healthcare, machines do not have the ability to mirror and interpret feelings. Another challenge is related to the current organization and structure of health systems for the implementation of 4.0 technologies. It is essential that we use disruptive technologies, creating synergies across all areas of the health sector to bring about effective change, where various stakeholders share data-centric connectivity platforms with health systems. Based on the answers obtained in our interviews, we determined the two main concerns of the study, namely, the impact of the FIR on human resources and on the organization of health systems.

The last specific objective of the study was related to the sustainability of the application of FIR technologies in health systems. From the analysis of the interview findings, we verified that the participants believed that the implementation of 4.0 technologies in the health sector will help reduce the costs of health services. Despite this consensus, there was a divergence regarding the sustainable implementation of disruptive technologies in health systems. Some believed that it is sustainable because it is not necessary to create a new "digital health system" or "health industry 4.0". Rather, existing health systems need to adapt to an increasingly digital context. These interviewees believed that applying these technologies would reduce the costs of health systems rather than increase them, provided that the selection and introduction of technologies is planned to be sustainable. However, other participants believed that it is not sustainable because the acquisition and maintenance of new technologies require strong investments that are not compatible with the levels of expenditure and waste identified for health, consequently it was possible to create the financial impact study dimension.

IV. Discussion

1. The Impact of the FIR on Healthcare Efficiency and Effectiveness

It is unequivocal that 4.0 technologies are being designed to empower consumers by providing health information [3]. Mobile technologies will increase the number of people who are covered by diagnostic, treatment, and follow-up interventions, improving the access to healthcare [4]. The latter is not only characterized by its physical aspect, but also by an acceptability aspect. This acceptability depends on various factors, such as social and cultural, which may discourage users from seeking health services [5]. Therefore, the use of customized technologies will reduce the impact of these factors on patients, improving the acceptability of these technologies in healthcare. These technologies, based on

 https://doi.org/10.4258/hir.2020.26.4.328

algorithms and data analysis, take account of various conditioning factors. Translation applications improve the quality of the relationship between healthcare providers and patients of different languages; language differences can be a barrier in diagnosis and the relationship between patients and caregivers, making healthcare inefficient [4].

The Smart Home Healthcare concept aims to help the inhabitants of smart homes in their daily activities by monitoring them [6]. These homes are equipped with sensors and devices that extend their functionality, remotely adding intelligence, automation, adaptability, and functionality, improving the health and well-being of their inhabitants and assisting in the provision of health services, functioning as a decentralizer in the health sector. This is important because the average life expectancy has increased, which has increased the aging population [6,7].

Another example of how disruptive technologies have a positive impact on healthcare efficiency and effectiveness is precision medicine that uses 4.0 technologies to develop personalized treatments based on instant health monitoring, anticipating many diseases [8]. Precision medicine in cancer treatment plays a fundamental role, starting from the DNA sequencing of tumors and their specific genetic mutations [9]. This genetic sequencing coupled with data analysis and AI allow the development of innovative cancer treatments that go beyond current treatments, increasing the chances of survival with less invasive treatments [8,9]. Allied to precision medicine are devices/wearables that, linked by IoT, promote a positive feedback loop through the production of biodata. These devices are capable of automatic learning, pattern recognition, generation of biodata that will be monitored, consideration of risk assessment, and the promotion of early medical interventions and behavior changes [10].

Some studies have shown the benefits of using disruptive technologies in reducing misdiagnosis. IBM Watson can classify large amounts of data, including clinical knowledge, case histories, and molecular and genomic data that can help oncologists diagnose and treat cancer. Unlike traditional big data systems, Watson understands data through the use of AI, promoting better data processing and analysis, generating new knowledge [11,12].

Surgery 4.0 currently incorporates various technologies, such as robotics, big data, and IoT technologies; it is as safe and effective as traditional surgery in certain diseases and even safer in other diseases. This form of surgery allows the patient to recover faster because it is less invasive [13,14].

This efficiency and effectiveness of 4.0 technologies can be seen using machine learning and AI in the health sector in developing countries, where there is an increase in mortality from various diseases due to the lack of medical specialists [15,16]. Machine learning and AI are important in reducing mortality; access to specialist physicians can be facilitated because these technologies emulate human intelligence. They can help non-expert physicians in decision-making because they can predict certain health conditions and illnesses by using algorithms, leading to more accurate diagnoses and producing medical history intelligence [15].

2. Impact on Government Action

It was found that it has an essential role in creating incentives, in the form of investments and collaboration between health professionals, institutions, and other agents, such as startups and the industry in general, to help the digital transformation of the health sector. The results of the study show that there is strong evidence that the training of health professionals is essential in the implementation of strategic actions. In addition to health policies, professionals are the instruments of these strategic axes regarding health systems. For the effective implementation of this transformation, it is essential that professionals have the necessary training and guidance [17]. Communication and a strong relationship between health sector stakeholders and governments is also essential. With the introduction of 4.0 technologies, we are seeing new stakeholders coming in, leading to changes in the market. Currently players who previously did not play an important role in healthcare are operating as standalone providers or in partnership with existing suppliers, creating value chains [18]. Thus, governmental involvement with stakeholders is essential to solidify the pillars of the digital transformation process, whose relationship allows the establishment of priorities and the creation of intervention axes.

The main axis of digital transformation of the health sector is the use of large-scale data. Governments must enact legislation and regulations to manage it. Several governments around the world are currently implementing eHealth programs in their healthcare systems, but the use of these technologies can compromise patient safety in many ways [19]. While health data is critical to creating health policies and determining at-risk populations, patients' medical records currently accumulate various types of personal information. The problem is that this data is in government databases and non-governmental databases [20].

Therefore, it is important that databases are protected from cyber-attacks. Authors argue that to counter these threats, security measures, such as encryption and authentication mechanisms, should be implemented to prevent unauthor-

ized modification of data while ensuring that only legitimate devices can create and enter data into networks [21,22].

3. Challenges and Risks

There was a concern about the lack of human contact in the development of therapeutic relationships that the application of new technologies may generate. Although new technologies can provide personalized counseling and can be built to detect nonverbal activities, they cannot incorporate all aspects of people's daily lives [23,24]. Patients' concerns and symptoms sometimes manifest indirectly and require interpersonal interaction for their understanding [25]. Thus, the health professional/patient relationship should not be completely replaced by technologies; rather, they should be used to enhance and optimize this relationship [26,27]. Doctors usually use their intuition when making treatment decisions, but in recent years there has been a move toward evidence-based medicine. The aggregation of individual medical datasets into large data algorithms provides more robust evidence that is subsequently subjected to data analysis using machine learning and AI. This is a great advantage in cases that require rapid response, such as emergencies. The judgment of physicians is not eliminated; rather, their decision-making is supported [28].

4. The Impact on Human Resources

It is noteworthy that the participants were not concerned about the risk of losing their positions or being replaced by machines. According to a study on the susceptibility of professions to computerization, healthcare professionals are among the least likely to be replaced by computerization or automation, but this does not imply that they do not have to integrate technologies from the FIR. On the contrary, professionals need to be properly trained in the use of new technologies because issues related to mismanagement and misuse of health technologies weaken patient-centered care [1,17]. Therefore, the implementation of these technologies within the organizational culture in a uniform manner is necessary to avoid misalignment between people, processes, and technologies. It is essential that they are implemented in such a way as to preserve and enhance relationships in healthcare [29].

5. Impact on the Structure of Organizations of Health Systems

Another challenge is related to the need for a change in organizational structures to create integrated models. This integration involves comprehensive digital transformation. The lack of transformation of organizational models can lead to the realization of digital initiatives in various areas, but without relevant impact on the digital transformation of the organization. Indeed, it is essential that this integration/evolution is accompanied by an ecosystem vision that evolves from an early stage of connectivity of various role-centered resources. Ultimately, health systems should be understood as integrated systems of resources with customer-centered connections to the FIR level. Thus, health systems should be understood in the context of a broad citizen-centered ecosystem, considering unwanted externalities and societal consequences that may arise from disruptive technologies.

6. The Financial Sustainability of the Application of 4.0 Technologies on Health Systems

We determined that these technologies have a great potential for benefits because approximately 60% of the activities established within the health services sector involve information exchange capable of automation. This would reduce costs and increase productivity, enabling organizations to be more autonomous and placing them as protagonists in problem solving and allowing for greater versatility to strategically monitor market changes [27]. It is important to consider cost-benefit and cost-utility analyses regarding the financial impact of the implementation of 4.0 technologies on the health sector.

From the cost-benefit view point, there is an economic benefit over the initial investment, not only because most activities are automation-friendly, but also because they can reduce treatment costs. It should be noted that many of these 4.0 technologies are digitally designed, which promotes ease of replication, leading to very low marginal cost. Hence, their application within health systems will lead to cost savings in health services and greater effectiveness and efficiency of services. In contrast, from the point of view of cost-utility analysis, new technologies are being designed and engineered to improve the quality of human life, reducing the burden of disease and contributing to health sustainability [30].

The FIR is having a major positive impact on the health sector. It is important to note that this impact is being assessed at a very early stage, and it is not yet possible to identify the long-term effects, given the time taken by previous Industrial Revolutions to take place. Many of the disruptive technologies mentioned are still at an early stage and many more will emerge; therefore, it is impossible to have a real sense of their future impacts. At this early stage, the results of our study suggest that the 4.0 technologies currently de-

 https://doi.org/10.4258/hir.2020.26.4.328

ployed in the healthcare sector are enabling greater effectiveness and efficiency in care delivery as well as cost reduction and information management. Thus, global engagement by governments, health professionals, stakeholders, and society are essential to create the necessary infrastructure for change, eliminating certain risks and enhancing the positive effects of their use.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

ORCID

João António Gomes de Melo e Castro e Melo (https://orcid.org/0000-0002-3297-0517)
Nuno Miguel Faria Araújo (https://orcid.org/0000-0002-0586-0873)

References

1. Schwab K. The Fourth Industrial Revolution. London, UK: Portfolio Penguin; 2017.
2. Bardin L. Content analysis [Análise de conteúdo]. Lisbon, Portugal: Edições 70 Publisher; 2009.
3. Eysenbach G, Jadad AR. Evidence-based patient choice and consumer health informatics in the Internet age. J Med Internet Res 2001;3(2):E19.
4. Free C, Phillips G, Watson L, Galli L, Felix L, Edwards P, et al. The effectiveness of mobile-health technologies to improve health care service delivery processes: a systematic review and meta-analysis. PLoS Med 2013;10(1):e1001363.
5. Evans DB, Hsu J, Boerma T. Universal health coverage and universal access. Bull World Health Organ 2013;91(8):546-546A.
6. Moreno LV, Ruiz ML, Hernandez JM, Duboy MA, Linden M. The role of smart homes in intelligent homecare and healthcare environments. In: Dobre C, Mavromoustakis CX, Garcia N, Goleva R, Mastorakis G, editors. Ambient assisted living and enhanced living environments. Oxford, UK: Butterworth-Heinemann; 2017. pp. 345-394
7. The World Bank. Life expectancy at birth, total (years) [Internet]. Washington (DC): World Bank; c2020 [cited at 2020 Sep 15]. Available from: https://data.worldbank.org/indicator/SP.DYN.LE00.IN.
8. Garraway LA, Verweij J, Ballman KV. Precision oncology: an overview. J Clin Oncol 2013;31(15):1803-5.
9. Schwaederle M, Parker BA, Schwab RB, Daniels GA, Piccioni DE, Kesari S, et al. Precision oncology: The UC San Diego Moores Cancer Center PREDICT experience. Mol Cancer Ther 2016;15(4):743-52.
10. Rhee H, Miner S, Sterling M, Halterman JS, Fairbanks E. The development of an automated device for asthma monitoring for adolescents: methodologic approach and user acceptability. JMIR Mhealth Uhealth 2014;2(2):e27.
11. Lee WS, Ahn SM, Chung JW, Kim KO, Kwon KA, Kim Y, et al. Assessing concordance with Watson for Oncology, a cognitive computing decision support system for colon cancer treatment in Korea. JCO Clin Cancer Inform 2018;2:1-8.
12. Bringing precision medicine to community oncologists. Cancer Discov 2017;7(1):6-7.
13. Bodner J, Wykypiel H, Wetscher G, Schmid T. First experiences with the Da Vinci operating robot in thoracic surgery. Eur J Cardiothorac Surg 2004;25(5):844-51.
14. Bonjer HJ, Deijen CL, Haglind E; COLOR II Study Group. A randomized trial of laparoscopic versus open surgery for rectal cancer. N Engl J Med 2015;373(2):194.
15. Ishak WH, Siraj F. Artificial intelligence in medical application: an exploration. Kedah, Malaysia: Universiti Utara Malaysia; 2008.
16. Rowe AK, Rowe SY, Vujicic M, Ross-Degnan D, Chalker J, Holloway KA, et al. Review of strategies to improve health care provider performance. In: Peters DH, El-Saharty S, Siadat B, Janovsky K, Vujicic M, editors. Improving health service delivery in developing countries: from evidence to action. Washington (DC): World Bank; 2009. p. 101-26.
17. Khalil MM, Jones R. Electronic health services: an introduction to theory and application. Libyan J Med 2007;2(4):202-10.
18. Jee K, Kim GH. Potentiality of big data in the medical sector: focus on how to reshape the healthcare system. Healthc Inform Res 2013;19(2):79-85.
19. Melchiorre MG, Papa R, Rijken M, van Ginneken E, Hujala A, Barbabella F. eHealth in integrated care programs for people with multimorbidity in Europe: Insights from the ICARE4EU project. Health Policy 2018;122(1):53-63.
20. Machluf Y, Tal O, Navon A, Chaiter Y. From population databases to research and informed health decisions and policy. Front Public Health 2017;5:230.
21. Rallapalli S, Minalkar A, Gondkar RR. Improving

healthcare-big data analytics for electronic health records on cloud. J Adv Inf Technol 2016;7(1):65-9.
22. Furnell S, Lambrinoudakis C, Pernul G. Trust, privacy and security in digital business. Cham, Switzerland: Springer International Publishing; 2018.
23. Weizenbaum J. ELIZA: a computer program for the study of natural language communication between man and machine. Commun ACM 1966;9(1):36-45.
24. Shortliffe EH, Perreault LE. Medical informatics: computer applications in health care. New York (NY): Springer; 2001.
25. Suchman AL, Markakis K, Beckman HB, Frankel R. A model of empathic communication in the medical interview. JAMA 1997;277(8):678-82.
26. Quill TE. Recognizing and adjusting to barriers in doctor-patient communication. Ann Intern Med 1989;111(1):51-7.
27. Charon R. Narrative medicine: a model for empathy, reflection, profession, and trust. JAMA 2001;286(15):1897-902.
28. Mercuri RT. The HIPAA-potamus in health care data security. Commun ACM 2004;47(7):25-8.
29. Gallouj F. Innovation in services and the attendant old and new myths. J Socio Econ 2002;31(2):137-54.
30. Schwab K, Davis N. Shaping the future of the fourth industrial revolution. Redfern, Australia: Currency Press; 2018.

 https://doi.org/10.4258/hir.2020.26.4.328