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Healthcare 4.0 Implementation: Opportunities and Challenges in the Healthcare Sector

Implementação do Healthcare 4.0: Oportunidades e Desafios no Setor da Saúde

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RESUMO

O Healthcare 4.0 é a aplicação dos princípios da Indústria 4.0 na área da saúde, permitindo a personalização em tempo real do atendimento aos pacientes. Embora tenha ganhado relevância nos últimos anos devido aos benefícios da Indústria 4.0, o conceito ainda é pouco conhecido por profissionais do setor de saúde brasileiro e internacional. Usando o método de revisão da literatura e pesquisa de levantamento com 26 especialistas em Healthcare 4.0, este trabalho tem como objetivo identificar as oportunidades e desafios em projetos de implementação do Healthcare 4.0 no setor de saúde do Brasil. A relevância deste estudo é a identificação das principais oportunidades encontradas: tecnologia digital facilita a coleta de dados dos pacientes; a implementação estratégica do Healthcare 4.0 pode trazer vantagens competitivas à organização; e os principais desafios: a necessidade de capacitação digital dos profissionais de saúde para o Healthcare 4.0, e a necessidade de motivar todos os envolvidos para a adoção do Healthcare 4.0, contribuindo para a teoria. A contribuição prática é ajudar os profissionais da área da saúde envolvidos a compreenderem os pontos relevantes para projetos de implementação do Healthcare 4.0 bem-sucedidos.

Palavras-chave: Healthcare 4.0; Indústria 4.0; Oportunidades; Redes; Projetos

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ABSTRACT

Healthcare 4.0 is the application of Industry 4.0 principles in healthcare, enabling real-time personalization of patient care. Although it has gained relevance in recent years due to the benefits of Industry 4.0, the concept is still little known by professionals in the Brazilian and international health sector. Using the literature review method and survey research with 26 experts in Healthcare 4.0, this study aims to identify opportunities and challenges in Healthcare 4.0 implementation projects in the health sector in Brazil. The relevance of this study is the identification of the main opportunities found: digital technology facilitates the collection of patient data; the strategic implementation of Healthcare 4.0 can bring competitive advantages to the organization; and the main challenges: the need for digital training of healthcare professionals for Healthcare 4.0, and the need to motivate everyone involved to adopt Healthcare 4.0, contributing to theory. The practical contribution is to help the healthcare professionals involved to understand the relevant points for successful Healthcare 4.0 implementation projects.

Keywords: Healthcare 4.0; Industry 4.0; Opportunities; Networks; Projects

INTRODUCTION

The term Industry 4.0 was coined in 2011 at the Hannover Fair (SATYRO *et al.*, 2019), as an initiative of the German government to increase the competitiveness of German companies through automation and digitalization of industrial manufacturing (CONTADOR *et al.*, 2020; SATYRO *et al.*, 2023). The concept of Industry 4.0 can be applied in several sectors, including the health area, where it is known as Healthcare 4.0 (LI; CARAYON, 2021). In the context of Healthcare 4.0, the aim is to replace the traditional approach of storing "empirical data" with "precision medicine", providing personalized health services (AL-JAROODI *et al.*, 2020).

Health organizations face growing socioeconomic challenges that demand improvements in efficiency, quality of health care and reduction of operating costs (LUZ *et al.*, 2021). The digital transformation linked to the innovation process, according to Nabeto (2020), has become a necessity in the health sector, offering benefits such as cost reduction, personalization of care, faster and more accurate diagnosis, prognostic, and prediction capacity, in addition to improvements in disease prevention and human longevity.

Healthcare 4.0 can revolutionize the healthcare sector and its entire ecosystem, just as Industry 4.0 is revolutionizing the manufacturing sector (ACETO *et al.*, 2020). However, the incorporation of the basic principles of Industry 4.0 in healthcare practices is not yet widespread (TORTORELLA *et al.*, 2020 a, b), and Healthcare 4.0 needs practical guidance and academic alignment.

Given the complexity of implementing Industry 4.0 technologies and concepts (AL-JAROODI *et al.*, 2020; ALJUAID and PARAH, 2021), several authors have developed research on the opportunities and challenges encountered in this implementation: in the industrial sector, Industry 4.0 (CONTADOR *et al.*, 2020), Agribusiness 4.0 (SILVA *et al.*, 2023), Supply Chain 4.0 (AGRAWAL *et al.*, 2023), but the opportunities and challenges for implementing Healthcare 4.0 in the health sector are scattered , with a shortage of academic studies in this area of knowledge (GARDAS, 2021; TORTORELLA *et al.*, 2020 a, b), a research gap, making it relevant to formulate the following research question:

RQ1: **What are the relevant opportunities and challenges for the implementation of Healthcare 4.0 in the healthcare sector?**

As a contribution, the survey of opportunities and challenges for the implementation of Healthcare 4.0 provides subsidies to understand the context, identify areas for improvement, anticipate obstacles and develop effective strategies. This approach enables a focused and successful implementation of advanced technologies in the healthcare sector, aiming to improve outcomes for patients, healthcare professionals and healthcare systems as a whole.

THEORETICAL REFERENCE

Industry 4.0

There were four industrial revolutions. The first industrial revolution or Industry 1.0 began around 1780, with the discovery of the mechanized loom and the improvement of the steam engine, bringing mechanization to industrial production. The second industrial revolution or Industry 2.0 occurred around 1780, with the mass production, steel and oil industries, bringing electrification to factories. The third industrial revolution or Industry 3.0 began in 1969, with automation and the use of electronics in support of production processes. The fourth industrial revolution or Industry 4.0 began in 2011, bringing connectivity to production processes, through cyber-physical systems (CPS), Internet of Things (IoT) and Internet of Services (IoS) (CONTADOR *et al.*, 2020; DEL RIO *et al.*, 2023; RIBEIRO *et al.*, 2022; SATYRO *et al.*, 2019, 2021, 2023).

Healthcare 4.0

Healthcare 4.0 (H4.0) aims to personalize healthcare in real time, thus acting as a facilitator in the transition to a patient-centered environment (ALLOGHANI *et al.*, 2018).

In Healthcare 1.0, health care is physician-centered, and the patient's history is kept in manual records. In Healthcare 2.0 these records are replaced by records made possible by microelectronics, computer science and automation, locally. Healthcare 3.0 is characterized by being more patient-centered, with the use of wearable devices (WD) for remote, real-time monitoring of the patient's physical conditions, and at this stage, computer records become electronic healthcare records (EHR), which can be accessed over the Internet. Healthcare 4.0 uses Industry 4.0 technologies such as CPS, IoT, IoS, enabling remote patient care and monitoring, as well as sharing patient data with various stakeholders (ALLOGHANI *et al.*, 2018; HATHALIYA and TANWAR, 2020; KUMARI *et al.*, 2018).

In addition to the term Healthcare 4.0, there are other similar denominations: Hospital 4.0, Health 4.0. Healthcare 4.0 is a continuous but disruptive process of transformation of the entire health value chain, whose transformation goes through the production of medicines and medical equipment, hospital care, care, health logistics, and other advances, to digitize not only health products and technologies, but also health services and companies (PANG *et al.*, 2018), leading to real-time personalization of health care, such as accurate diagnoses (THUEMMLER; BAI, 2017).

Opportunities with Healthcare 4.0

Scattered in the academic literature are the opportunities arising from the implementation of Healthcare 4.0.

The use of electronic medical records (EMR) allows to better understand the patient, enabling more assertive diagnoses (TORTORELLA *et al.*, 2021). By personalizing healthcare in real time, Healthcare 4.0 enables improved health system performance with better patient outcomes (WANG *et al.* 2019; WU *et al.*, 2018), allowing greater interaction of the patient with their treatment (SHARMA *et al.*, 2019; KREPS; NEUHAUSER, 2013).

Using digital technology and integrated digital platforms, Healthcare 4.0 enables a new philosophy of patient-centered care (CHUTE and FRENCH, 2019, SOLTANISEHAT *et al.*, 2020), facilitating the collection of patient data by health professionals (MOREIRA and SANTOS, 2020), enabling collaborative sharing of patient data and information (ALMULHIM *et al.*, 2019; HASSAN *et al.*, 2019; MUNZER *et al.*, 2019; RAJAN and RAJAN, 2018; SANNINO *et al.*, 2019), in real time for decision-making (KRISHNAMOORTHY *et al.*, 2021).

Healthcare 4.0 enables collaboration between different health services, resources, patient data, and healthcare professionals (AL-JAROODI *et al.*, 2020), enabling the health institution to be seen as innovative, thus generating competitive advantages to the institution.

The Healthcare 4.0 adoption allows better control, which can bring cost savings to the organization (BARDHAN; THOUIN, 2013; BATES *et al.*, 2014; WANG *et al.*, 2018b), senior management is the one who should create strategies for the implementation of Healthcare 4.0 (SANAL *et al.*, 2019), and should create a collaborative environment to disseminate Healthcare 4.0 in their respective departments, encouraging everyone to collaborate in this digital transformation.

Its adoption also optimizes and improves resource allocation (AL-JAROODI *et al.*, 2020; BATES *et al.*, 2014; DUC *et al.*, 2023; WANG *et al.*, 2018), allowing the mitigation of adverse events (SANAL *et al.*, 2019), and the improvement in organizational culture through greater interaction between all those involved (ACHARYULU, 2011; CAVALLONE; PALUMBO, 2020; MANOGARAN *et al.*, 2017).

Healthcare 4.0 allows a better interaction between health professionals (multidisciplinary team) as well with patients (MEISTER *et al.*, 2019), improving the work routine of health professionals (PAN *et al.*, 2019; TORTORELLA *et al.*, 2020b). The new health service models enabled by Healthcare 4.0 allow the personalization of medicine (DILSIZIAN; SIEGEL, 2014), through direct interaction between the health sector and its customers, generating value co-creation (KREPS; NEUHAUSER, 2013). Table 1 summarizes the opportunities found in the literature with the implementation of Healthcare 4.0.

Table 1: Expected Opportunities with the Implementation of Healthcare 4.0

DESCRIPTION	REFERENCES
1. Electronic medical records (EMR) enable more assertive patient diagnosis	TORTORELLA *et al.* (2021)
2. Healthcare 4.0 improve healthcare systems performance and outcomes for patients	WANG *et al.* (2019), Wu *et al.* (2018)
3. Healthcare 4.0 adoption enable increased opportunities for patient empowerment and engagement	SHARMA *et al.* (2019), KREPS and NEUHAUSER (2013)
4. Healthcare 4.0 enable new patient-centered philosophy of care	CHUTE; FRENCH (2019), SOLTANISEHAT *et al.* (2020)
5. Digital technology enables enhanced ability for health professionals to collect personal information about patients	MOREIRA; SANTOS (2020)
6. Digital platforms from Healthcare 4.0 enable for collaborative sharing of patient data and information	ALMULHIM *et al.* (2019), HASSAN *et al.* (2019), MUNZER *et al.* (2019), RAJAN; RAJAN (2018), SANNINO *et al.* (2019)
7. Data is available in real time for decision making In Healthcare 4.0	KRISHNAMOORTHY *et al.* (2021)
8. Enhanced sharing and collaboration opportunities across different healthcare services, resources, patients' data, and healthcare professionals, through Healthcare 4.0, for hospital departments benefit	AL-JAROODI *et al.* (2020)
9. The strategic implementation of Healthcare 4.0 can make the health institution be seen as innovative	Prepared by the authors
10. The strategic implementation of Healthcare 4.0 can bring competitive advantages to the institution	Prepared by the authors
11. The Healthcare 4.0 adoption strategy can bring costs reduction to the organization	BARDHAN; THOUIN (2013), BATES *et al.* (2014), WANG *et al.* (2018b)
12. There is a strategy to encourage employees to collaborate in digital transformation	Prepared by the authors
13. Strategy creation for the implementation of Healthcare 4.0 by top management	SANAL *et al.* (2019)
14. Leadership is responsible for creating a collaborative environment to disseminate Healthcare 4.0 across their respective departments	Prepared by the authors
15. Greater participation in the entire healthcare delivery process with the Healthcare 4.0 adoption enables the mitigation of adverse events	SANAL *et al.* (2019)
16. Healthcare 4.0 adoption enable optimization and better allocation of resources	AL-JAROODI *et al.* (2020), BATES *et al.* (2014), WANG *et al.* (2018)

DESCRIPTION	REFERENCES
17. Healthcare 4.0 provides an improvement in organizational culture through greater interaction between all involved	ACHARYULU (2011), CAVALLONE; PALUMBO (2020), MANOGARAN *et al.* (2017)
18. Healthcare 4.0 enables a better interaction between health professionals (multidisciplinary team)	MEISTER *et al.* (2019)
19. Healthcare 4.0 enables better interaction between health professionals and patients	MEISTER *et al.* (2019)
20. Healthcare 4.0 adoption strategy improves the work routine of healthcare professionals	PAN *et al.* (2019), TORTORELLA *et al.* (2020b)
21. The new health service models enabled by Healthcare 4.0 allow direct interaction between the health sector and its clients (co-creation of value)	KREPS; NEUHAUSER (2013)
22. Healthcare 4.0 enables personalization of medicine	DILSIZIAN; SIEGEL (2014)

Source: Prepared by the authors

Challenges for Healthcare 4.0

Scattered in the academic literature are the challenges arising from the implementation of Healthcare 4.0.

Patient privacy needs to be preserved (AL-JAROODI *et al.*, 2020; ALJUAID; PARAH, 2021; HUANG, Z. *et al.*, 2019; JAMAI *et al.*, 2020; KRISHNAMOORTHY *et al.*, 2021), however, it is complex to establish adequate access control for the use of electronic medical records (EMR) (MANDL *et al.*, 2001), since it must be available for consultation by several professionals, which can bring problems related to the security of sensitive data, according to the general data protection law of each country (AL-JAROODI *et al.*, 2020; ALJUAID; PARAH, 2021; HUANG, Z. *et al.*, 2019; JAMAI *et al.*, 2020; KRISHNAMOORTHY *et al.*, 2021). Added to this is the need for training, as complex digital platforms require time and effort to learn how to use them safely and properly (HUANG, M. *et al.*, 2016; TONETTO et. al., 2021), as well as the difficulty with the integration of the different information and registration systems, which takes time (TONETTO et. al., 2021).

The implementation of Healthcare 4.0 causes concern about the unemployment of the workforce replaced by technology (FREY; OSBORNE, 2017; QURESHI; SYED, 2014), and there is, therefore, the need to create a strategy that motivates all those involved for the Healthcare 4.0 adoption (ABDELLATIF; MOHAMED, 2019; ALMULHIM *et al.*, 2019; ONASANYA; ELSHAKANKIRI, 2019; PAN *et al.*, 2019; SANNINO *et al.*, 2019), and the need to create a strategy for the digital training of health professionals for Healthcare 4.0 (MAVROGIORGOU *et al.*, 2019).

It is feared that replacing presential face-to-face contact with remote face-to-face contact may cause depersonalization of the health system (AL-JAROODI *et al.*, 2020; FINCH *et al.*, 2007; RAGHUPATHI; RAGHUPATHI, 2014; TONETTO *et. al.*, 2021), and that regulatory changes with the implementation of Healthcare 4.0 may impact the

governance of the organization (ACETO *et al.*, 2018; ALI *et al.*, 2018; HAMIDI, 2019; HSU and LI, 2019; ZHANG *et al.*, 2018).

It is believed that high costs may derail the implementation of Healthcare 4.0 (ALBESHER, 2019; DIN; PAUL, 2019; KRISHNAMOORTHY *et al.*, 2021; PACE *et al.*, 2019; WANG *et al.*, 2019), which can lead to resource scarcity before the final phase of the implementation project (SCHRÖDER, 2016).

The inappropriate use of Healthcare 4.0 tools by health professionals can cause risks to patients; due to the lack of health professionals trained to deal with Healthcare 4.0 technologies (KHAREL *et al.*, 2019; MUTLAG *et al.*, 2019; PACE *et al.*, 2019; PAN *et al.*, 2019; WANG *et al.*, 2019), or because they have not yet been able to use Healthcare 4.0 technologies (BUCHELT *et al.*, 2020; LI *et al.*, 2015; RYAN and WATSON, 2017).

Therefore, few health professionals rely on the benefits of Healthcare 4.0 (TORTORELLA *et al.*, 2021), facing its implementation ethical and cultural challenges (AL-JAROODI *et al.*, 2020; ARBAOUI *et al.*, 2012; MAHMUD *et al.*, 2016; PANG *et al.*, 2018), which can create a negative attitude of the health professional, hindering its implementation (KLICH, 2018). In this way, it is relevant to seek the commitment of these professionals with Healthcare 4.0, in order to take the hospital forward (TORTORELLA *et al.*, 2021). Table 2 lists the challenges identified in the literature.

Table 2 – Expected challenges with the implementation of Healthcare 4.0

DESCRIPTION	REFERENCES
23. It is complex to establish adequate access control for the use of electronic medical records (EMR)	MANDL *et al.* (2001)
24. Digital transformation can bring problems related to the security of sensitive data (LGPD Brazilian law)	AL-JAROODI *et al.* (2020), ALJUAID; PARAH (2021), HUANG, Z. *et al.* (2019), JAMAI *et al.* (2020), KRISHNAMOORTHY *et al.* (2021)
25. Digital transformation brings problems related to patient privacy	AL-JAROODI *et al.* (2020), ALJUAID; PARAH (2021), HUANG, Z. *et al.* (2019), JAMAI *et al.* (2020), KRISHNAMOORTHY *et al.* (2021)
26. Complex digital platforms require time and effort to learn how to use them safely and properly	HUANG, M. *et al.* (2016), TONETTO *et. al. (*2021)
27. Healthcare 4.0 adoption may cause unemployment	FREY; OSBORNE (2017), QURESHI; SYED (2014)
28. Different information and registration systems may present difficulties to be integrated	TONETTO *et. al. (*2021)
29. Healthcare 4.0 adoption may cause the depersonalization of the healthcare system	AL-JAROODI *et al.* (2020), FINCH *et al.* (2007), RAGHUPATHI; RAGHUPATHI (2014), TONETTO *et. al. (*2021)
30. There is a need to create a strategy that motivates everyone involved to adopt Healthcare 4.0	ABDELLATIF; MOHAMED (2019), ALMULHIM *et al.* (2019), ONASANYA; ELSHAKANKIRI (2019), PAN *et al.* (2019), SANNINO *et al.* (2019)
31. There is a need to create a strategy for the digital training of healthcare professionals for Healthcare 4.0	MAVROGIORGOU *et al.* (2019)
32. Regulatory changes with the Healthcare 4.0 adoption can impact the governance of the organization	ACETO *et al.* (2018), ALI *et al.* (2018), HAMIDI (2019), HSU; LI (2019), ZHANG *et al.* (2018)

DESCRIPTION	REFERENCES
33. High costs can make the implementation of Healthcare 4.0 unfeasible	ALBESHER (2019), DIN; PAUL (2019), KRISHNAMOORTHY *et al.* (2021), PACE *et al.* (2019), WANG *et al.* (2019)
34. Lack of strategy for implementing Healthcare 4.0 can lead to resource shortages	SCHRÖDER (2016)
35. Inappropriate use of Healthcare 4.0 tools by healthcare professionals can cause risks to patients	Prepared by the authors
36. Few healthcare professionals trust the benefits of Healthcare 4.0	TORTORELLA *et al.* (2021)
37. Ethical and cultural challenges are barriers to adopting Healthcare 4.0	AL-JAROODI *et al.* (2020), ARBAOUI *et al.* (2012), MAHMUD *et al.* (2016), PANG *et al.* (2018)
38. The attitude of the health professional can hinder the implementation of Healthcare 4.0	KLICH (2018)
39. Lack of healthcare professionals trained to handle Healthcare 4.0 technologies	KHAREL *et al.* (2019), MUTLAG *et al.* (2019), PACE *et al.* (2019), PAN *et al.* (2019), WANG *et al.* (2019)
40. The need for training of healthcare professionals for Healthcare 4.0 technology can negatively impact its implementation	LI *et al.* (2015), RYAN; WATSON (2017)
41. The commitment of healthcare professionals can determine whether Healthcare 4.0 can move the hospital forward	TORTORELLA *et al.* (2021)
42. The need for training for Healthcare 4.0 can generate apprehension for health professionals	BUCHELT *et al.* (2020)

Source: Prepared by the authors

METHOD

For empirical testing of the relevance of opportunities and challenges for the implementation of Healthcare 4.0, a sample survey was used (GIL, 2022; LAKATOS; MARCONI, 2017), with the use of a structured questionnaire, where the experts could assign grades on a scale from zero (0) to ten (10) points, according to the degree of importance they attributed to each opportunity and challenge in Tables 1 and 2. The literature review used the Scopus and Web of Science databases.

Pre-test of the research instrument

After the elaboration of the questionnaire, a pre-test was performed with a teacher with more than five years of experience who suggested changes, which were incorporated into the research instrument. Some considerations about unemployment and training were left strategically in more than one question, to control the reliability of the respondents, but no relevant differences were proven in the answers of these experts.

Sample and data collection

The initial intention was to interview the experts in person or via digital platform, but there was difficulty in getting experts in Healthcare 4.0 who proposed to participate in these interviews. We opted for the questionnaire described above, using the

QuestionPro® tool, sent to experts, and one specialist indicated another, according to the snowball technique, obtaining 13 answers.

A professional social network was used to reach experts in the subject, using as search criteria the terms "Healthcare 4.0"and "Health 4.0", and applied the filters "People" and "Locality" as Brazil, when 153 experts were contacted, obtaining 14 responses. Of the total, one questionnaire was excluded, for marking 50% of the answers with the same grade, and the other 50% with another grade, totaling 26 valid questionnaires.

Data processing

Data analysis and interpretation was performed using descriptive statistics, using the IBM® SPSS Statistics *v.*26 software. For the classification in order of relevance of the answers, the Coefficient of Variation (CV) was used. Therefore:

$$CV = \frac{S}{\bar{x}} . 100\% \text{.....(1)}$$

where: S = sample standard deviation

$\bar{X}$ = sample mean

The following empirical rule was used to interpret the coefficient of variation, according to Contador *et al.* (2020):

CV ≤ 25% (low dispersion): indicates a high agreement among experts.
25% < CV ≤ 50% (median dispersion): indicates median agreement among experts.
CV > 50% (high dispersion): indicates low agreement among experts.

The questionnaire was then divided into two sections for analysis, one for opportunities (22 assertions) and the other for challenges (20 assertions). The questions were classified in descending order of arithmetic mean. Soon after, the assertions with the highest and lowest scores were analyzed individually, applying the coefficient of variation (CV) to verify the degree of agreement between the experts.

Reliability analysis

Cronbach's alpha statistic was used to measure the reliability and internal consistency of the scale (BLAND; ALTMAN, 1997), to verify that the experts had knowledge even about Healthcare 4.0, using IBM® SPSS Statistics *v.* 26 software. The reliability of the research regarding opportunities based on standardized items obtained a Cronbach's alpha of 0.931, which according to the classification of Landis and Koch (1977) is considered almost perfect, indicating high reliability of the data. The result of

Cronbach's alpha for the challenges, based on standardized items, had the value of 0.792, which according to the classification of Landis and Koch (1977) is considered substantial reliability of the data.

RESULTS AND DISCUSSION

The conceptual research question that guided this study was the determination of the main opportunities and challenges for the implementation of Healthcare 4.0 in the healthcare sector. The findings should take into account the particularities of the sample, which are health sector professionals working in Brazil, a country with a low level of digital readiness (CONTADOR *et al.*, 2020), scarce skilled labor, low investments and difficulties with infrastructure.

Most relevant opportunities

Below is the analysis of the four highest-scoring opportunities.

According to the report of the 26 experts, the greatest opportunity for the implementation of Healthcare 4.0 is that digital technology facilitates the collection of patient data by health professionals (question 5, average: 9.42) confirming Moreira and Santos (2020), who attributed great importance to this opportunity, and which was highly agreed by the experts (CV: 9.1%). This approach enables the integration and sharing of data between health systems and healthcare professionals, improving the quality of patient care and the efficiency of the healthcare system as a whole.

Secondly, in the opinion of the experts, it was that the strategic implementation of Healthcare 4.0 can bring competitive advantages to the organization (question 10, average: 9.35), an assertion elaborated in this article, and which was highly agreed by the experts (CV: 9.0%). Competitive advantages include improved operational efficiency, improved patient experience, improved diagnostic accuracy, and reduced costs.

Thirdly, in the opinion of the experts, it was that the strategic implementation of Healthcare 4.0 can cause the health institution to be seen as innovative (question 9, average: 9.15), an assertion elaborated in this article, and which was highly agreed by the experts (CV: 12.6%). The image of an innovative institution can improve its image before patients and the community at large, helping to attract new patients and healthcare professionals, as well as increasing patients' trust in the institution.

Fourthly, in the opinion of the experts, was that the integrated digital platforms of Healthcare 4.0 allow the collaborative sharing of patient data and information (question

6, average: 9.12), confirming Almulhim *et al.* (2019), Rajan and Rajan (2018) and Sannino *et al.* (2019), and which was highly agreed by the experts (CV: 10.9%). Collaborative sharing improves patient care by providing information for diagnosis and treatment. Patients can monitor their health and share real-time data with professionals, making it easier to follow up on treatment and providing personalized and efficient care.

Less relevant opportunities

Below is the analysis of the two least relevant opportunities.

According to the report of the 26 experts, the least relevant opportunity for the implementation of Healthcare 4.0 is the existence of a strategy to encourage employees to contribute to digital transformation (question 12, average: 6.81), a statement elaborated in this article, and which was partially agreed by the experts (CV: 33.0%). Despite the low relevance for experts, encouraging the contribution of employees to digital transformation can improve internal processes and develop innovative solutions.

Secondly, in the opinion of experts, there is little relevance in the assertion that top management is the one who creates strategies for the implementation of Healthcare 4.0 (question 13, average: 7.12), contrary to Sanal *et al.* (2019) and which was partially agreed by the experts (CV: 30.6%). Implementing Healthcare 4.0 requires the participation of the entire organization, not only top management. From IT staff to healthcare professionals and beyond, collaboration and teamwork are essential to ensuring the success of digital transformation.

Most relevant challenges

Below is the analysis of the four highest-scoring challenges.

According to the report of the 26 experts, the biggest challenge for the implementation of Healthcare 4.0 is that there is a need to create a strategy for the digital training of health professionals for Healthcare 4.0 (question 31, average: 9.00) confirming Mavrogiorgou *et al.* (2019), which emphasizes this challenge, and which was highly agreed by the experts (CV: 11.8%). Digital training should meet the individual needs of healthcare professionals, taking into account their experience, knowledge and skills.

Secondly, in the opinion of the experts, there is a need to create a strategy that motivates all those involved for the Healthcare 4.0 adoption (question 30, average: 8.73), confirming Almulhim *et al.* (2019), Pan *et al.* (2019), Sannino *et al.* (2019), which emphasized the difficulty of this challenge, and which was highly agreed by the experts (CV: 16.1%). The implementation of Healthcare 4.0 requires the involvement of diverse

stakeholders: healthcare professionals, patients, managers, regulatory bodies, and technology developers.

Thirdly, in the opinion of the experts, was the lack of health professionals trained to deal with the technologies of Healthcare 4.0 (question 39, average: 8.31), confirming Pace *et al.* (2019), Pan *et al.* (2019), Wang *et al.* (2019) and which was highly agreed by the experts (CV: 18.9%). Digital transformation in healthcare requires up-to-date digital skills from healthcare professionals to deliver efficient care. Institutions should invest in ongoing training and capacity building, recognizing that it is an ever-evolving process to improve long-term health care.

Fourthly, in the opinion of the experts, it was that different information and registration systems may present difficulties to be integrated (question 28, average: 8.15), confirming Tonetto et. al. (2021), and which was highly agreed by the experts (CV: 15.44%). The lack of integration generates communication problems, duplicate data, and outdated information, affecting the quality of care and operational efficiency in health.

Less relevant challenges

Below is the analysis of the two least relevant challenges.

According to the report of the 26 experts, the least relevance among the challenges for the implementation of Healthcare 4.0 is that the Healthcare 4.0 adoption can cause the depersonalization of the health system (question 29, average: 3.12), contrarily to Finch *et al.* (2007), and which was lowly agreed by the experts (CV: 79.3%). Patients may feel isolated when replacing human contact with technologies such as telemedicine or automated treatment. Humanized care, with empathy and compassion, is essential in all stages of the patient care process.

Secondly, in the opinion of experts, there is little relevance in the statement that the Healthcare 4.0 adoption can cause unemployment (question 27, average: 4.31), contrarily to Frey and Osborne (2017), Qureshi and Syed (2014), and which was lowly agreed by the experts (CV: 69.1%). The Healthcare 4.0 adoption brings significant changes, such as automation of tasks and reduction of workers in certain areas. Healthcare professionals can focus on complex tasks, increasing the demand for qualified experts in treatment planning and medical decisions.

CONCLUSIONS

The implementation of Healthcare 4.0 represents a significant shift in the healthcare sector. Opportunities abound, including improving access to healthcare, reducing costs, optimizing diagnosis, treatment and prevention of disease, and personalizing healthcare to individual patients' need. However, implementing Healthcare 4.0 also presents challenges, such as the need for adequate training for healthcare professionals, protecting patient data and ensuring that technology is being used ethically and responsibly.

The present study reviewed the literature and interviewed 26 experts to identify opportunities and challenges, bringing two theoretical contributions: (1) mapping opportunities and challenges for the implementation of Healthcare 4.0 (2) helping to understand important points for successful implementation of Healthcare 4.0. This provides valuable theoretical contributions for healthcare professionals, manufacturers, governments, and patients to understand the obstacles and areas to be explored in the successful implementation of Healthcare 4.0.

Although the research has limitations, such as the limited number of experts interviewed, future research is suggested that addresses other opportunities and challenges in the area, if possible, applied to a larger number of experts.

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