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Review Article

Strategies of artificial intelligence and business intelligence applied to immunization in the context of the COVID-19 pandemic

Estratégias de inteligência artificial e Business Intelligence aplicadas à imunização no contexto da pandemia de COVID-19

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ABSTRACT

Introduction: The application of Business Intelligence and Artificial Intelligence has been used in the health sector, especially in the area of immunization, which generates large amounts of data and health records. **Objective:** Investigate how artificial intelligence and business intelligence have been used to increase immunization. **Method:** Integrative review of studies selected through a search strategy in the databases, PubMed/MEDLINE, LILACS, SciELO, after meeting the eligibility criteria of the proposed protocol. **Results:** We obtained a total of 608 records, of which 75 had their titles and summaries read, 25 included. Of these, 5 duplicates were excluded, totaling 20 articles, of which 12 had a direct or indirect relationship with the theme of study in the context of the COVID-19 pandemic. Articles published between 2020 and 2023 were categorized according to the theme addressed as follows: Monitoring (4 studies); Vaccine Development (3 studies); and Health Communication (5 studies). **Conclusion:** The use of these strategies favors the context of immunization with a focus on the COVID-19 pandemic, pointing to the democratization of data to promote public policies, generating ease of access and reading of data to assist decision-making by management, as well as helping to reduce the time for vaccine production.

KEYWORDS: Immunization. Information Technology. Artificial Intelligence. Primary Health Care. COVID-19.

RESUMO

Introdução: As estratégias de inteligência artificial e *Business Intelligence* têm sido empregadas na área da saúde, em especial, na área da imunização, em que há massiva geração de dados e registros em saúde. **Objetivo:** Investigar como a inteligência artificial e o *Business Intelligence* têm sido empregados para o incremento da imunização. **Método:** Revisão integrativa de estudos selecionados por meio de estratégia de busca nas bases de dados, PubMed/MEDLINE, LILACS e SciELO, após enquadramento nos critérios de elegibilidade do protocolo proposto. **Resultados:** Obteve-se um total de 608 registros, dos quais 75 tiveram seus títulos e resumos lidos, sendo 25 incluídos. Desses, foram excluídas 5 duplicatas, totalizando 20 artigos, dos quais 12 apresentaram relação direta ou indireta com o tema de estudo no contexto da pandemia de COVID-19. Os artigos publicados entre 2020 e 2023 foram categorizados de acordo com a temática abordada da seguinte forma: Monitoramento (4 estudos); Desenvolvimento de Vacinas (3 estudos); e Comunicação em Saúde (5 estudos). **Conclusão:** O uso dessas estratégias no contexto da imunização, com o recorte sobre a pandemia de COVID-19, aponta para a democratização de dados no fomento de políticas públicas, gerando maior praticidade de acesso e leitura de dados, a fim de auxiliar a tomada de decisão pela gestão, bem como apoiar a redução do tempo para a produção de vacinas.

PALAVRAS-CHAVE: Imunização. Tecnologia da Informação e Comunicação. Inteligência Artificial. Atenção Primária à Saúde. COVID-19.

INTRODUCTION

Primary health care focuses on the supply and immunization as a strategy for controlling vaccine-preventable diseases, concentrating on producing information about immunization, which is an important public health indicator[1,2].

The complexity of electronic health records, despite the benefits, also exposes the need for financial incentive, technology investments and human resources training, aspects that reverberate the operationalization and quality of data[3]. In addition, the qualification of these data is relevant to the identification of new demands and unfavorable epidemiological conditions, as well as for decision making[4].

The use of computerized systems has repercussions on the provision of health care to the population. Therefore, Immunization Information Systems (IIS) play a significant role in the monitoring and strategic execution of immunization programs, allowing greater transparency in immunization activities, from acquisition to its application[5,6].

Due to the large and growing volume of immunization-related information produced in primary health care, technological support is required to assist data processing and manage it efficiently. For this, the IIS are crucial by enabling the verification of certain aspects, such as vaccine schemes and validation of applied doses. In the context of current technologies, the incorporation of new knowledge, especially in Information Technology, is fundamental for effectiveness[1,4].

Thus, Artificial Intelligence (AI) and Business Intelligence (BI) strategies emerge as important tools for managing information for primary health care, considering the large volume of information continuously generated, which cannot be processed by traditional software[7].

The implementation of information technology strategies tends to influence the optimization of vaccine application and reduce dose wasting, as well as mitigate failures and fraud in queues[8,9]. With the support of technology and the structuring of this data, it is possible to identify patterns and behaviors, enabling the analyst and/or manager to predict certain scenarios and anticipate the facts[10].

The COVID-19 pandemic has arisen as an innovation catalyst, profoundly modifying the way vaccine products are designed, manufactured, tested, and delivered[11]. Therefore, the mapping of strategies and experiences, as well as its applicability using technology in the context of health management, is critical, especially in the context of immunization as a measure of collective health[12].

Given the above, considering the complexity of immunization during the pandemic, as well as the need for improvements and updates in the management of immunization information

systems, this study aims to investigate how artificial intelligence and business intelligence strategies have been employed to increase immunization in the context of the COVID-19 pandemic.

DEVELOPMENT

Methodology

This study is an integrative literature review with a qualitative approach of a descriptive methodological nature. It used secondary data from complete papers, including national and international journals. The research began by formulating the following guiding question: How have Artificial Intelligence and Business Intelligence been employed to increase immunization?

For this, we developed a Boolean search strategy using the elements of the PICO model (P: population/patient; I: intervention/indicator; C: comparator; O: outcome/outcome) to research relevant studies. The search expression used the descriptors of the Medical Subject Headings (MeSH) and Descriptors in Health Sciences (DECs). The search strategy developed included the following descriptors: “inteligência artificial”, “Business Intelligence” and “imunização” in Portuguese; "Artificial Intelligence", "Business Intelligence" and "immunization" in English; and “inteligencia artificial”, “inteligencia empresarial” and “inmunización” in Spanish. The research used Boolean operators OR and AND.

We surveyed scientific production that addresses the use of artificial intelligence and business intelligence strategies in the context of immunization in the electronic databases Medline via PubMed, Scielo, and Lilacs. The papers included were published between 2013 and 2023. As for the language, we considered papers published in Portuguese, English, and Spanish.

The survey was conducted between September and October 2023. Review stages were illustrated with the PRISMA tool (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)[13], presenting the quantity of journal articles selected in each stage.

In the identification stage, the search strategy was performed on the selected databases, considering eligible the original papers with quantitative, qualitative, or mixed methodology that presented information regarding the subject addressed.

Inclusion criteria have considered studies on the application or implementation of artificial intelligence or Business Intelligence strategies in the context of the COVID-19 pandemic immunization in relation to measurement management, use of algorithms and improvements for access, reading and decision making, production and distribution of immunization information, and communication on immunization.

The exclusion criteria covered: studies without full text available; studies on animals; and studies that did not address the application of artificial intelligence or business intelligence to immunization. In addition, we excluded dissertations, meta-analyses, theses, event summaries, undergraduate theses, prefaces, interviews, summaries, and letters to the editor.

For the triage stage, three reviewers (EL, LS, and WS) independently inspected the titles and summaries of the studies found. Studies that fit the proposed criteria or raised questions were separated for reading and complete analysis of the paper.

In the eligibility stage, all records included were fully read by the three reviewers. After complete reading, in case of non-compliance with the inclusion criteria, the journal article was excluded.

The data available in the text was extracted from the paper, considering the author, year of publication, type of design, study theme, country of origin, type of technology used, developed strategy, actors involved, and observed impacts.

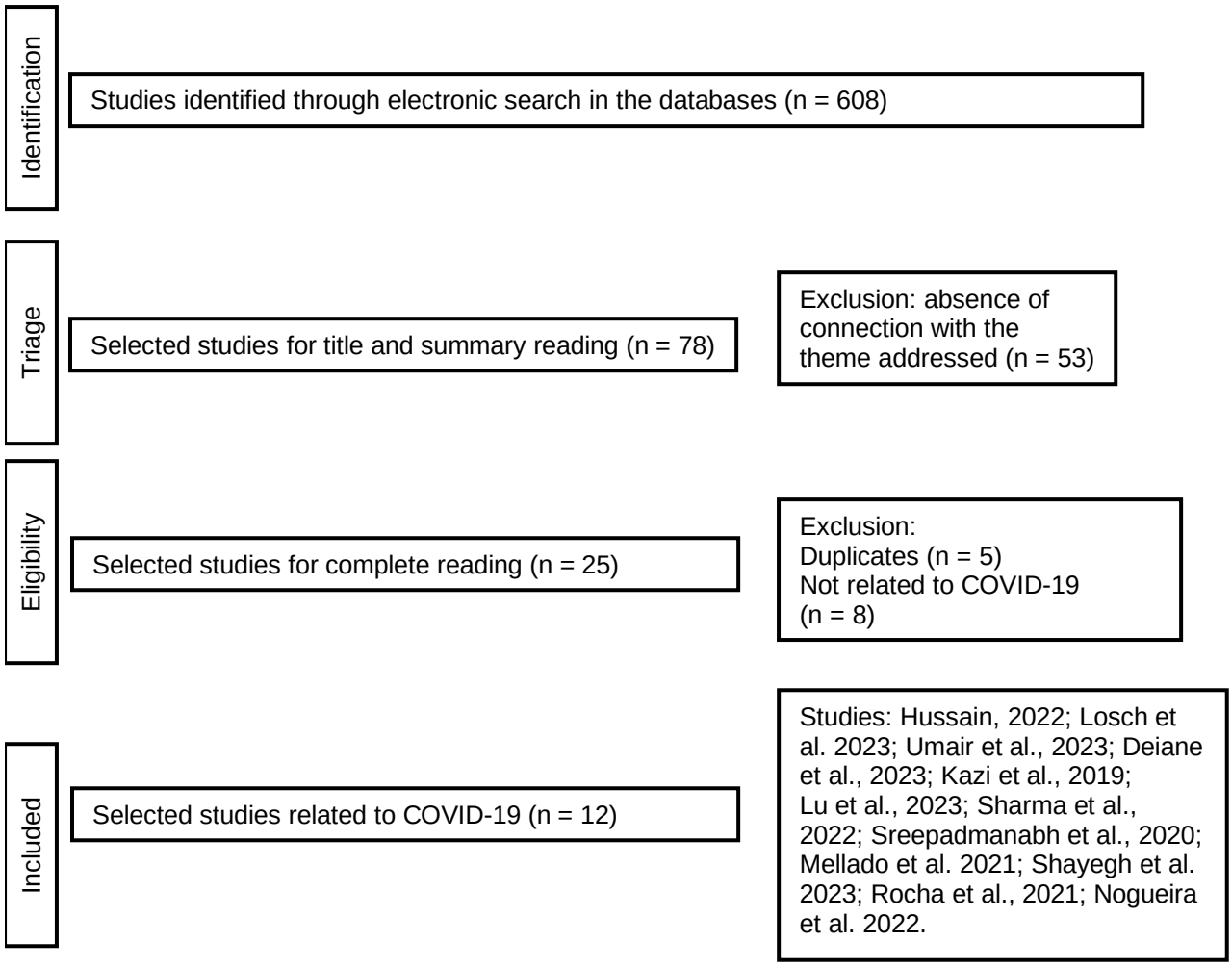
The analysis and interpretation of qualitative and quantitative data from the integrative review were performed with the organization, classification, and final analysis of the surveyed data.

As it is a documentary study, without direct involvement of human beings, this project did not need referral for the appreciation of the Research Ethics Committee, according to Resolution 196/1996.

Results

The application of search expression in the databases resulted in the identification of 608 papers. Duplicate findings, systematic reviews, and journal articles that did not have a complete manuscript available were excluded, resulting in 78 studies selected after reading the summary and title. Of these, 25 papers were in accordance with the eligibility criteria. 5 duplicate papers were excluded, totaling 20 papers for reading the text. After full reading, 12 studies were selected because they have a direct or indirect relationship with the context of COVID-19, as shown in Figure 1 (on the next page).

Figure 1 – PRISMA flowchart with the discrimination of search, selection and inclusion of papers for integrative review



Source: prepared by the authors (2023)

After analysis, we categorized the studies into three groups according to the topics covered: monitoring, health communication, and vaccine development. The description is the following:

Group I. Monitoring: papers that used AI and/or BI strategy to increase, develop, monitor, or organize data related to immunization.

Group II. Health Communication: papers that have addressed AI and/or BI strategies to study, monitor, or identify the effect of health communication regarding information sharing on digital media and social media, knowledge about adverse immunization, and results on the vaccination process.

Group III. Vaccine Development: papers that presented AI and or BI strategies for the purpose of enhancing or reducing vaccine elaboration time, as well as other factors related to the production of immunizers as a function of the COVID-19 pandemic.

Thus, arranged by theme, Group I concentrated 3 papers concerning artificial intelligence, two performed in Brazil; Health Communication (Group II) addressed 5 papers, developed in countries of the European and Asian continent; and the theme related to Vaccine Development (Group III) included 4 papers, produced in India and China, all published from 2020 to 2023, according to Figure 2.

Figure 2 - Papers based on the use of AI and BI strategies in the context of immunization

(it continues)

Authors (year)	Title	Journal	Country	Group
Mellado *et al*.[11] (2021)	Leveraging artificial intelligence and Big Data to optimize COVID-19 clinical public health and vaccination roll-out strategies in Africa	International Journal of Environmental Research and Public Health	South Africa	Monitoring
Shayegh *et al*.[14] (2023)	Prioritizing COVID-19 accine allocation in resource poor settings: towards an artificial intelligence-enabled and geospatial-assisted decision support framework	PLoS One	Italy	Monitoring
Rocha *et al*.[15] (2021)	Plano nacional de vacinação contra a COVID-19: uso de inteligência artificial espacial para superação de desafios	Ciência & Saúde Coletiva	Brazil	Monitoring
Nogueira *et al.*[16] (2022)	O uso da inteligência artificial como ferramenta de apoio à gestão das ações em saúde na Secretaria de Estado da Saúde de Goiás	Revista Científica da Escola Estadual Saúde Pública de Goiás Cândido Santiago	Brazil	Monitoring
Hussain *et al*.[17] (2022)	Artificial intelligence-enabled social media analysis for pharmacovigilance of COVID-19 vaccinations in the United Kingdom: observational study	JMIR Public Health and Surveillance	UK	Health Communication

(Conclusion)

Authors (year)	Title	Journal	Country	Group
Lösch *et al*.[18] (2023)	Capturing emerging experiential knowledge for vaccination guidelines through natural language processing: proof-of-concept study	Journal of Medical Internet Research	Netherlands	Health Communication
Umair, Masciari e Ullah[19] (2023)	Vaccine sentiment analysis using BERT + NBSVM and geo-spatial approaches.	The Journal of Supercomputing	Italy	Health Communication
Deiana *et al*.[20] (2023)	Artificial intelligence and public health: evaluating ChatGPT responses to vaccination myths and misconceptions	Vaccines	Italy	Health Communication
Kazi *et al*.[21] (2020)	An artificial intelligence–based, personalized smartphone app to improve childhood immunization coverage and timelines among children in Pakistan: protocol for a randomized controlled trial	JMIR Research Protocols	Pakistan	Health Communication
Lu *et al*.[22] (2023)	Reinforcement learning relieves the vaccination dilemma	Chaos	China	Vaccine Development
Sharma *et al*.[23] (2022)	Artificial intelligence-based data-driven strategy to accelerate research, development, and clinical trials of COVID vaccine	BioMed Research International	India	Vaccine Development
Sreepadmanabh *et al*.[24] (2020)	COVID-19: advances in diagnostic tools, treatment strategies, and vaccine development	Journal of Biosciences	India	Vaccine Development

Source: prepared by the authors (2023)

In the Monitoring category (Group I), we identified studies published since 2021 reporting the use of AI and BI strategies for natural language processing[11,14,16], Machine Learning (ML) and Deep Neural Network (DNN)[11], as well as AI applications linked to the use of spatial resources[15] and Big Data[11].

Mellado *et al*.[11], researchers from universities in Canada and South Africa who employed data from nine African countries, demonstrated that techniques and collaborations of Machine

Learning, Big Data, and Artificial Intelligence can be fundamental for precise analysis, considering nuances of multiple data sources to support decisions in public health, as well as vaccination strategies and their implementation.

To identify and prioritize target groups with the most benefit from vaccination, a pilot study was conducted with DNN algorithms and model applications. Researchers used data about age, comorbidities, ethnicity, type of care provided, and outcome. The DNN model indicated that by vaccinating about 20 % of the adult population, the likelihood of severe COVID-19 disease could be reduced to 80 %[12].

Like Mellado and collaborators, Shayegh *et al*.[14] also addressed the impacts on population immunization, with reference to disparities between low and medium-income countries. Originating in Italy, the study focused on the application of AI strategies in an African country: Kenya. In this case, a new arrangement was proposed for the assignment of COVID-19 vaccines based on three components – vulnerability, vaccination, and values (3 Vs) – through a structure for data collection and integration, risk assessment, and prioritization of vaccine doses.

The viability of the multidimensional vulnerability index was tested with Kenyan health data by combining microdata. The analysis of the findings allowed the identification of more vulnerable and more inaccessible areas in the concentration of health services. The authors indicated that these tools can be integrated into existing systems, aiming at national or local decision-making in developing countries with limited access to high-quality data[14].

Setting the discussion about the use of AI tools aimed at geospatial information in Brazil, the study by Rocha *et al.*[15] focuses on the primary health units in the country to define the target population of vaccination more precisely in the context of COVID-19. The researchers conducted an ecological study, with the health units registered in the National Register of Health Establishments (CNES) as the unit of analysis. It aimed to add information about the population, the epidemiological situation of COVID-19, internet access to vaccine rooms, and thus identify priority regions.

The crossing of the data conducted in this study exposed different regional realities and allowed managers to identify critical points for vaccination plan management. The authors pointed to regions where the electronic registration of vaccination required attention, as the data presented weaknesses regarding internet access in vaccine rooms. The authors also suggested the development of steering wheel vaccination strategies in remote locations for public vaccination, far from health facilities[15].

Finally, addressing BI, the article by Nogueira *et al*.[16] presented Flink, an intelligent platform used to democratize data and health indicators by the Goiás State Secretariat of Health. The platform was developed and structured with artificial intelligence techniques, such as recommendation systems and natural language processing, and is used to support health

managers in planning, evaluation, and management.

In this study, a field of interaction available is the mapping of geographical distribution, which makes it possible to explore the interface through cuts in the state scenario, by health region, microregion, and municipality, allowing the comparison and indicators through maps[16].

In the Health Communication category (Group II), the study by Deian *et al*.[20] was based on the large language models, focusing on ChatGPT, to verify the assertiveness, clarity, and complexity of answers generated to questions characterized as myths and misconceptions regarding vaccination and immunization processes. This procedure aimed to evaluate whether this tool could provide relevant and correct information regarding vaccination adherence, indicating the possibility of artificial intelligence assisting the promotion of health literature and reducing hesitation in vaccination.

The evaluated answers provided comprehensive information on myths and misconceptions that permeate vaccination, with clear representation. However, evaluators have identified some inaccuracies related to the transmission of disease, circumstances of eradication, side effects, and other aspects capable of limiting the transparency of responses and inducing users to errors of interpretation and vision regarding immunization[20].

The study by Kazi *et al*.[21] addressed the development of an application for mobile devices, capable of text, voice, images, and video messages, related to content in educational message domains, reminders, religious aspects, and adverse effects. The proposal was to evaluate the acceptability and usability of personalized behavioral intervention, aiming to increase children's visits between 10 and 14 weeks of life to primary health units and, consequently, vaccination coverage.

Thus, artificial intelligence was used in two ways. First, it was applied to base data, which guides automated text messages and voice calls intervention, as well as its use in the decision tree, aiming to adapt the system to predict the likelihood of a family failing in health unit visits. As a result, text messages were well accepted by children's guardians, with a positive impact evidenced in the significant reduction in absences on return dates due to frequent reminders[21].

Umir, Masciari, and Ullah[19] employed the analysis technique by identifying people's feelings through text data to obtain insights based on individuals' feedback. Thus, the authors proposed the use of AI methods to classify vaccination tweets, particularly against COVID-19, based on their polarity values, including negative, positive, and neutral words on this theme. For this, a combination was used between the BERT (Bidirectional Encoder Representations for Transformers) and the NBSVM (a hybrid of Naive Bayes and Support Vector Machine) tools.

The authors highlighted that feeling analysis demonstrated a low disposition for the vaccination process. Geospace analysis of comments was critical to indicate barriers, such as access to vaccines, including lack of transportation, long waiting periods, and difficulty scheduling

consultations[19].

Hussain *et al*.[17] conducted a study in the UK aimed at evaluating the frequency and nature of related mentions to the adverse effects developed after the vaccination process present on social media, providing information about the public's feelings of vaccines, especially against COVID-19. A hybrid analysis model was used using the VADER (Valence Aware Dictionary for Sentiment Reasoning) and TextBlob tools to extract posts from two social media platforms (Twitter and Facebook).

Thus, the public feeling was categorized as consistently positive about vaccines, highlighting the success of the UK immunization process and the reflection of government and political announcements. Thus, the authors showed the potential of artificial intelligence tools in analyzing data from social media to complement the conventional sources of knowledge employed in pharmacovigilance[17].

Lösch *et al*.[18] also used textual data extracted from social media (Facebook), as well as from internal databases from the Netherlands National Institute of Public Health and Environment, to collect knowledge based on the experience of individuals and value considerations to make vaccination guidelines more inclusive and representative, with the development of natural language processing filtering techniques (NLP).

Thus, the authors observed that users' posts presented distinct types of doubts and concerns expressed in comments, while the data from internal databases demonstrated the search for counseling on practical issues linked to the organization of vaccination. Plural data channel analysis was essential to include a wide range of knowledge and value considerations based on the experience of citizens and professionals[18].

In the Vaccine Development category (Group III), Sreepadmanabh *et al*.[24] employed a review of Indian researchers who gathered the main information on the tools for diagnosis, treatment, and development of vaccines. The use of AI and Machine Learning was highlighted as tools for processing large volumes of information, applied to the acceleration of vaccine development, as well as for the monitoring of outbreaks, efficiency containment programs, and risk assessment with minimal human intervention.

Sharma *et al*.[23] published an experience report that presented the role of AI and Machine Learning as tools for accelerating vaccine development with Reserve Vaccinology (RV) technology, reducing the time for antigen detection from 5 to 15 years to 1 to 2 years. The study by Lu *et al*.[22], developed by Chinese researchers, evaluated the reduction of the epidemic spread by vaccination. For this, they used a Bush-Teteller (BM) model, a reinforcement learning methodology that demonstrated the possibility of predicting various scenarios and thus making the best vaccination strategy decision.

DISCUSSION

In terms of monitoring information and data, it should be considered that good use of health data is presented as an alternative to overcoming the inefficiencies of health care provided to the population[25], so that more accurate data available during the planning phase allows a more efficient programming of the resources needed to perform the campaign micro-planning[15].

There is the proposition of AI use to mitigate the effects of these disparities in the context of immunization. This fact becomes even more relevant considering that the COVID-19 pandemic generated and still causes huge sanitary, social, and economic costs, amplifying existing inequalities and disparities, and creating new ones.

The studies point to the importance of understanding social vulnerabilities, as lack of access to vaccination during the COVID-19 pandemic reflects inequities in health. In addition, there is a high demand regarding the use of these data to guide the decisions of public health management, as the COVID-19 pandemic coincides with a rapid digitization economy and improvements in public health surveillance systems, creating rich data sources to feed Big Data and IA applications[11].

The approach in Brazil is no different, since only through the correct identification of the target audience is it possible to estimate the necessary resources and the costs associated with the conduct of health campaigns[15]. Given this, primary care is highlighted, since immunization practices are important activities of primary health care offered by the Estratégia de Saúde da Família program (Family Health Strategy)[4].

In addition, there are influential factors that significantly contribute to low vaccination coverage, including fear of exposure to the virus in health facilities, the scarcity of protective professionals and equipment, and the diversion of health resources to confront the pandemic[26.27]. Thus, the decline in vaccination coverage and refusal to vaccinate during the pandemic can negatively impact the spread of a vaccine, maintaining the viral agent and its impacts on public health.

Low vaccine coverage is also related to the geographical inequality regarding the distribution of immunobiologicals[28], an aspect that intensifies in Brazil, which presents a territory with continental proportions. Therefore, high-resolution spatial and temporal data are a unique opportunity to develop AI-supported transparent and reliable strategies, which can interoperate existing health data platforms and integrate various expert opinions[15].

Among the challenges for structuring effective health campaigns, the definition and location of the target population emerge as points to be discussed[15]. In addition to group prioritization and plan definition, monitoring of these data is critical. Therefore, strategies that allow facilitated reading of information produced in the context of immunization are of utmost

importance.

In the case of Brazil, systems such as e-SUS Hospitalar and e-SUS Atenção Básica have been enabling health data collection, updating, and expansion efficiently. At the same time, the Conecte SUS program and the Rede Nacional de Dados em Saúde (RNDS – National Health Data Network) have been promoting integration and interoperability between the various information systems, contributing to more qualified management of clinical data, and stimulating innovation in health services[29].

In the pandemic context, the confrontation of the emergency of public health against COVID-19 was initiated with the elaboration of the Plano Nacional de Operacionalização da Vacinação contra a COVID-19 (National Plan for Operationalization of Vaccination against COVID-19), in 2020, which aimed to develop solutions for the planning and operationalization of vaccination against the disease[30]. In this period, RNDS was significantly important, as it began to receive the records of COVID-19 vaccines in 2021, according to Ordinance GM/MS No. 69/2021[31]. In the following year, routine vaccine records were integrated. In 2023, data entry began more quickly in the average time taken to register vaccinated individuals in the Sistema de Informações do Programa Nacional de Imunizações (SI-PNI – National Immunization Program Information System)[32].

The mapping of the examples already recorded in the current literature is interesting to replicate for the development or implementation of AI and BI strategies for the elaboration of indicators by other institutions or management instances. In the context of innovation, RNDS can appear as a massive source of data sets for training AI algorithms and tool development with data from the Brazilian population. This denotes a significant contribution to the creation of AI tools that work properly for the country's specific needs[32].

In terms of communication, artificial intelligence can be employed with two main biases. The first one corresponds to the capture of data available on social media, by both users and professionals, approaching multiple directions, from the perception of feelings facing the vaccination process, side effects, and even misconceptions linked to the general immunization process. The second bias would be related to the development of media tools, aiming to facilitate access to crucial information on immunization, having personalized characteristics to enhance users' awareness of the importance of these procedures, as well as date and availability reminders, to increase the search for vaccines in primary health units[17,18,19].

Artificial intelligence tools play a fundamental role in the extraction and refinement of information available in the digital environment, being performed agilely and efficiently, allowing the reduction of time to select data, enabling professionals to dedicate themselves to further analysis of this information[17,19,33].

It is also worth considering that the levels of feeling in the face of immunization in the

context of the COVID-19 pandemic were also properly classified by artificial intelligence[17,18,19]. This process is extremely important to analyze the opinion and reactions of health users, attending successful vaccination campaigns and the improvement of political movements, both in maintaining current strategies, whether the feelings are positive, and in the adoption of new strategies to adjust conduct in case of negative feelings[34,35].

Artificial intelligence applied to health can represent potential benefits to society and health risks, and finally for fundamental human rights[36]. The findings indicate that artificial intelligence tools have proven to be valuable in the process of developing and disseminating factual and simplified information to users, directly from digital tools[20]. This information demands careful use to avoid harmful uses, such as ignoring medical advice and ethical issues[37,38].

Recent studies must be developed to refine communication criteria and minimize misconduct by citizens. In addition to this process of data capture and interpretation, artificial intelligence proves to be promising in the coming years for the development of applications to increase the population's awareness of the aspects linked to immunization[39].

Based on this, AI enables an improved distribution of resources, as it can efficiently interconnect the perception of the population about their needs and yearnings, enabling an improvement in public management. Thus, artificial intelligence proves to be an extremely relevant tool in monitoring the perception of the population, as well as in the search for new strategies to reach the health care users, aiming at better awareness and enhancement of vaccination coverage.

In the field of vaccine and immunizer development, AI has been applied beyond diagnosis and treatment when the pandemic has brought an enormous demand for vaccine production in record time to save lives[23,24]. AI stands out as an important tool for coping with the global epidemic, as well as its use for outbreak monitoring, impact assessment of risk programs, and risk assessment with minimal human intervention[24]. AI potentialities can be used as solutions in a shorter time and more assertively.

In the context of vaccination pandemic control and already with consolidated experience in COVID-19 management, technology has been widely used in the development and discovery of drugs and vaccines against COVID-19. The models that use AI and ML have demonstrated speed and optimization in the discovery of new vaccines[22].

In general, the challenges faced during the COVID-19 pandemic provided the restructuring of public health surveillance models, highlighting the potential of artificial intelligence in identifying patterns and trends that enabled more agile responses. For this, it was necessary to strengthen the national data processing infrastructure, including investments in equipment, connectivity, organized systems, and properly qualified teams, culminating in the dissemination of timely information and facilitated access to epidemiological data for managers, health professionals,

researchers, the press, and all of society. However, it is important to emphasize that this process is continuous and should be perfected progressively and constantly.

This study has limitations. The analyzed papers are limited to the use of AI and BI in immunization in the context of COVID-19. The COVID-19 pandemic, which originated from the Sars-Cov-19 virus, has been a public health emergency. Thus, the methods of clinical management, vaccine, and medicine production occurred concomitantly[41]. In addition, the effects of the pandemic have still not ended, an aspect that can bring new panoramas and create public health demands.

This study effectively collected studies in different countries in three different fields, although only in the context of the pandemic. The observed results can serve as a reference for the development and implementation of new technological strategies to strengthen the immunization policy in Brazil.

CONCLUSION

Based on the studies analyzed, it was possible to conclude that both Artificial Intelligence and Business Intelligence are tools with high ability to increase immunization in its cycle, including vaccine creation and the distribution and management of records in different realities, based on the particularities of each region. Given the challenging context imposed by the COVID-19 pandemic, these resources have allowed managers to identify gaps in vaccination coverage, estimate resources with greater accuracy, and plan more effective campaigns.

In addition, the application of these resources in the monitoring of feelings and communication with the population stands out as an innovative tool in understanding social perceptions on related themes to vaccination. By capturing social media information and producing personalized content, Artificial Intelligence promotes the confrontation of vaccine hesitation and expands the engagement of the population, being relevant to elaborate more sensitive campaigns to local realities and combating misinformation, especially in highly polarized contexts.

Thus, this scenario reinforces the importance of interoperability between systems and the qualified use of information as a way of mitigating inequalities, optimizing resource allocation, and enhancing the reach of public health actions. In this sense, the pandemic played a provocative role in the incorporation of these technologies within the development of immunizer development, communication, and monitoring, reaffirming their impact on the management of sanitary crises and the advancement of translational biomedical research.

Finally, despite the advances observed, it is necessary to recognize the limitations of the use of these resources in the health field, especially related to data quality, ethical issues, and

the need for continuous evaluation of these tools. This study addresses international and multidisciplinary evidence. However, it highlights that the results are still restricted to the context of the COVID-19 pandemic. Thus, the importance of more studies is reinforced, aiming at the evaluation of sustainability and applicability of these technologies in post-standard scenarios, considering the socioeconomic and regional particularities, which directly influence the effectiveness of immunization policies.

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