Data analysis in the use of artificial intelligence in the prevention of vaccine gaps and the return of eradicated diseases

Análise de dados no uso de inteligências artificiais na prevenção de lacunas vacinais e retorno de doenças erradicadas

Análisis de datos en el uso de inteligencias artificiales en la prevención de brechas vacunales y el retorno de enfermedades erradicadas

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RESUMO

Introdução: A cobertura vacinal é fundamental para prevenir doenças infecciosas e preservar a saúde pública. Contudo, lacunas nesse processo podem favorecer o ressurgimento de doenças erradicadas, como sarampo, rubéola e poliomielite, representando desafio constante aos sistemas de saúde. Nesse contexto, a Inteligência Artificial (IA) surge como ferramenta útil na análise de dados de vacinação, capaz de identificar falhas e orientar estratégias preventivas. Objetivo: Explorar o uso da IA na análise de dados de vacinação para prevenir lacunas vacinais e o retorno de doenças erradicadas. Metodologia: Foram analisados artigos científicos sobre o emprego da IA na saúde, com ênfase em sua aplicação para ampliar a cobertura vacinal. Resultados: A IA consegue processar grandes volumes de dados e identificar padrões pouco perceptíveis ao olhar humano. Algoritmos de aprendizado de máquina permitem localizar grupos com baixa adesão vacinal, mapear áreas de risco e apontar fatores que dificultam a imunização. Além disso, possibilitam ações preditivas para antecipar surtos e reforçar campanhas. Conclusões: O uso da IA na saúde pública permite respostas rápidas e efetivas frente às lacunas vacinais, contribuindo para prevenção de surtos e proteção coletiva. A experiência da startup canadense BlueDot, que previu antecipadamente a pandemia de covid-19, demonstra o potencial da tecnologia.

Descritores: Inteligência Artificial, Lacunas vacinais, Doenças Erradicadas.

ABSTRACT

Introduction: Vaccination coverage is essential to prevent infectious diseases and preserve public health. However, gaps in this process may favor the resurgence of eradicated diseases, such as measles, rubella, and poliomyelitis, representing a constant challenge to health systems. In this context, Artificial Intelligence (AI) emerges as a useful tool for analyzing vaccination data, capable of identifying failures and guiding preventive strategies. Objective: To explore the use of AI in vaccination data analysis to prevent immunization gaps and the return of eradicated diseases. Methodology: Scientific articles on the use of AI in healthcare were analyzed, with emphasis on its application to expand vaccination coverage. Results: AI can process large volumes of data and identify patterns that are not easily perceptible to the human eye. Machine learning algorithms allow the identification of groups with low vaccination adherence, the mapping of risk areas, and the recognition of factors that hinder immunization. In addition, they enable predictive actions to anticipate outbreaks and strengthen campaigns. Conclusions: The use of AI in public health enables rapid and effective responses to immunization gaps, contributing to outbreak prevention and collective protection. The experience of the Canadian startup BlueDot, which predicted the COVID-19 pandemic in advance, demonstrates the potential of this technology.

Descriptors: Artificial Intelligence, Vaccination Gaps, Eradicated Diseases.

RESUMEN

Introducción: La cobertura vacunal es fundamental para prevenir enfermedades infecciosas y preservar la salud pública. Sin embargo, las brechas en este proceso pueden favorecer la reaparición de enfermedades erradicadas, como el sarampión, la rubéola y la poliomielitis, lo que representa un desafío constante para los sistemas de salud. En este contexto, la Inteligencia Artificial (IA) surge como una herramienta útil para el análisis de datos de vacunación, capaz de identificar fallas y orientar estrategias preventivas. Objetivo: Explorar el uso de la IA en el análisis de datos de vacunación para prevenir brechas vacunales y el retorno de enfermedades erradicadas. Metodología: Se analizaron artículos científicos sobre el empleo de la IA en salud, con énfasis en su aplicación para ampliar la cobertura vacunal. Resultados: La IA puede procesar grandes volúmenes de datos e identificar patrones poco perceptibles para el ojo humano. Los algoritmos de aprendizaje automático permiten localizar grupos con baja adherencia vacunal, mapear áreas de riesgo e identificar factores que dificultan la inmunización. Además, posibilitan acciones predictivas para anticipar brotes y reforzar campañas. Conclusiones: El uso de la IA en salud pública permite respuestas rápidas y efectivas frente a las brechas vacunales, contribuyendo a la prevención de brotes y a la protección colectiva. La experiencia de la startup canadiense BlueDot, que predijo anticipadamente la pandemia de COVID-19, demuestra el potencial de esta tecnología

Descriptores: Inteligencia Artificial, Aprendizaje Automático, Brechas Vacunales, Enfermedades Erradicadas.

REVIEW

Introduction

The technological era enabled by the Fourth Industrial Revolution was crucial for the emergence of tools that simplified human needs. Inherent to this, the hype surrounding Artificial Intelligence (AI) in the 21st century is enhancing the relationship between humans and machines to achieve previously unseen levels of productivity in computing, given its increased analytical power to process the Big Data available on the internet[1].

AI is essentially based on analyzing a massive amount of data in a short period of time to generate probabilistic results—outputs—according to commands—inputs—entered during its training. This agility in data processing favors the implementation of actions by humans more assertively than an ordinary person would, given that it would take a long time for an individual to analyze a large set of data and develop an action for a given previously processed activity[1].

AI plays a significant role in medicine, enabling a wide range of applications, such as the probabilistic generation of diagnoses based on pre-established algorithms, whether through ultrasound, magnetic resonance imaging, positron emission tomography (PET), or wearable/body-worn devices. AI can collect data from these different types of exams and subsequently produce results based on the information collected from each individual, all based on algorithms trained to perform specific tasks[2].

AI, thus, becomes a viable alternative for contributing to medical applications, particularly in preventing vaccine gaps and the return of previously eradicated diseases in Brazilian society, such as measles, rubella, and polio. Its use can mitigate the country's technological inequality, given the lack of therapeutic resources to support certain areas. These areas will be monitored and studied using trained algorithms. Subsequently, an action plan can be effectively implemented in these locations to prevent people in these regions, such as the interior of the North and Northeast regions of Brazil, from lacking a basic humanitarian resource: vaccines.

The decline in Brazilian vaccination coverage is associated with a decreased awareness of the consequences of diseases, economic, political, and cultural factors, and an increase in vaccine refusal due to the spread of fake news. However, to overcome these obstacles, Artificial Intelligence has the potential to locate and monitor target audiences so that vaccination campaigns achieve vaccination coverage close to the maximum possible number of immunized individuals. Furthermore, AI can mitigate previous failures of vaccination processes that did not achieve a significant immunization rate[3].

Only when the target audience is well defined, with the exact location and total number of people present in the area in question, can public health strategies and campaigns be effectively implemented. However, the complete population delimitation of a given area is a task that demands significant time and resources when performed by human hands, given that it requires working with enormous amounts of data and complex analyses of population censuses, many of which are outdated[3].

In this context, the use of artificial intelligence can facilitate broad and continuous monitoring of populations and territories most in need of public policies related to vaccination. This technology, if used well, will facilitate the organization of information so that it can be processed into data and subsequently converted into practical results that are satisfactory for public health managers. They will then be able to more effectively implement well-defined immunization campaigns in areas where the population is below the acceptable immunization threshold . This practice will ultimately prevent not only vaccination gaps but also reduce wasted doses, misdirection of government resources, and inadequate planning of ineffective campaigns[3].

Therefore, AI, if implemented correctly, has the chance to more effectively cover Brazilian territory with regard to the National Immunization Plan stipulated by the Government.

Method

Given the current evolutionary context, this study used up-to-date scientific articles. The research databases were concentrated in the following collections: PubMed, Scielo, and Google Scholar. The analysis focused on studies containing records and data on vaccination and disease outbreaks, as well as demographic information about Brazil. Furthermore, clear and specific terms from the Health Sciences Descriptors (DeCS) were used: Artificial Intelligence, Machine Learning, Vaccine Gaps, and Eradicated Diseases. The search period was limited to 2017 and later to maintain the study's current relevance. Studies were sought that preferably addressed vaccination criteria in underserved regions. Finally, this work is committed to detailing each stage in a clear and direct manner so that readers can understand the objective and subsequently process and reproduce the results obtained to contribute to mitigating the growing vaccination gap in Brazil, especially by using technologies, such as AI, to carry out this task.

Results

Scientific articles strictly related to the scope of the study were selected, whose central focus is the use of artificial intelligence to mitigate the growing vaccination gap in Brazil. Articles with titles related to AI and vaccination in a more generalized manner were excluded from the search criteria, even if they addressed the topic in question in depth. For the study, the focus during this stage was on analyzing a specific disease: measles.

Despite significant progress in eliminating disease transmission, the resurgence of certain diseases previously considered eradicated is a cause for serious concern. Given that Brazil was certified as measles-free in 2016 by the World Health Organization (WHO)—which indicates a measles-free rate of less than one case per million over a full year—the resurgence of this disease in 2017 is considered a serious public health problem, given the potential for triggering new outbreaks and severely compromising the health of a large population in a highly populated country like Brazil[4].

Measles vaccination is provided free of charge to the population through the Sistema Único de Saúde (SUS) and is part of the National Immunization Program, thus constituting a favorable public policy to curb the increase in the incidence of this disease. Two doses of the vaccine are recommended with a minimum window of 30 days between them, with the first dose administered at 12 months of age and the second at 15 months, thus ensuring approximately 97% protection against this disease from the moment the vaccination schedule is completed[5].

A study analyzed the administration of the first dose of the MMR vaccine (measles, mumps, and rubella) in children under one year of age. A temporal analysis of the period 2011–2021 in all Brazilian states revealed a sharp decline in the vaccination rate related to the disease in question[6].

Satisfactory vaccination coverage is equivalent to at least 95% of immunizations in different regions. This occurred until 2014 and declined further in early 2015, resulting in lower vaccination coverage. As of 2016, no region managed to achieve the 95% immunization target[6].

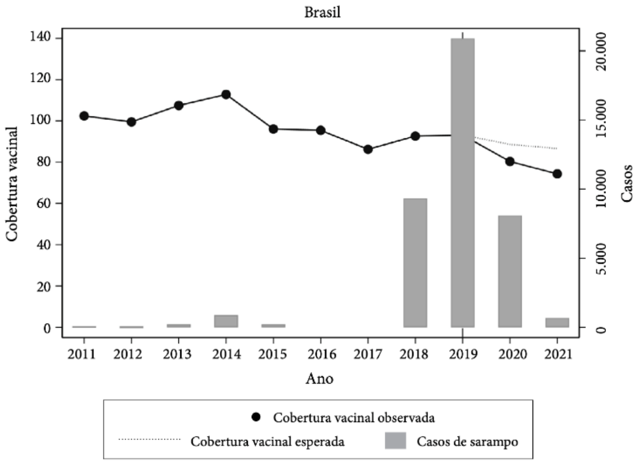

Figure 1 – Time series of first dose of MMR vaccination coverage and measles cases in Brazil and by region. Brazil 2011–2021.

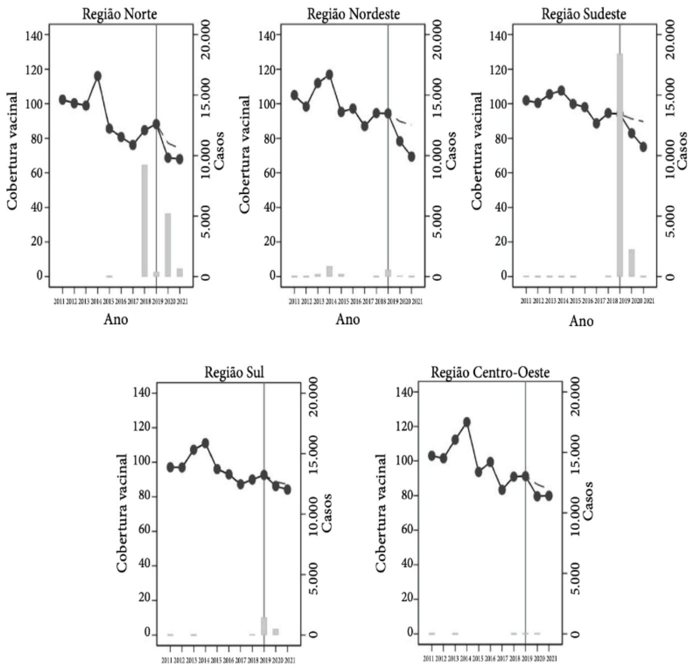

Figure 2 - Overview of vaccination coverage in different regions of Brazil.

Figure 1 shows that the best vaccination coverage rates are in the South, with approximately 86% immunization between 2020 and 2021, while the lowest are in the North, with approximately 68% immunization for the same period. The information obtained in Figure 1 shows a stark contrast between the country's main regions, especially regarding areas of continuous technological development (the South) and areas that have historically been underserved by this development (the North).

Another important fact is the explosion of measles cases in 2019, which, when compared to 2018, doubled the total number of people infected with this disease. It is possible to infer that this result was catalyzed by the Covid-19 pandemic, which occurred precisely in the year of the increase in these occurrences.

Given these results, it's worth correlating the decline in vaccination coverage with numerous factors, such as the spread of fake news, popular beliefs, and poorly targeted public immunization policies. Furthermore, social isolation due to the COVID-19 pandemic can be considered a significant contributing factor to the rise in these cases[7].

Artificial Intelligence has the potential to address this gap in vaccination coverage and thus prevent vaccine gaps in the country, given its clear potential for processing and analyzing large amounts of data. Using it to systematically collect, analyze, interpret, and share health data can aid in disease prevention and control. This technology operates through the analysis of electronic health records, social media, and mass media outlets, such as newspapers and newscasts. When deviations from acceptable standards are identified, the system provides accurate, real-time data to health authorities, who can then develop faster and more assertive containment and prevention strategies against the spread of diseases easily prevented through immunization. AI would be more effective when compared to electronic tools that merely capture data, as it has the capacity for dynamic and recursive learning from the data itself, which facilitates the development of more accurate and reliable responses over time[8].

Using this tool would shorten the government's efforts to achieve desired immunization levels. Furthermore, AI can perform surveillance tasks and predictive analysis of trends observed in data collection. This is because it can monitor regions and individuals, recovering people whose vaccination schedules are behind and keeping their status updated as the vaccination schedule demands are established, in addition to identifying priority areas for immunization campaigns, thus preventing vaccination gaps[9].

Final Considerations

Therefore, the use of AI to map regions and entire populations for subsequent development of strategic immunization plans is gaining momentum given the vast amount of data and the need for continuous, targeted monitoring of large population groups. The portability or conversion of physical data in hospitals and primary care units (UBS) can transform the way public policy is created, as data is the masterpiece of Artificial Intelligence.

After accessing patient data ethically, securely, and confidentially, safeguarding sensitive information about these individuals, as well as regularly updated geographic information, the AI-based operating system will be able to identify locations and population groups so that vaccination campaigns can be developed that are more targeted to their specific needs, resulting in more effective actions. This monitoring could begin at birth, with the individual being monitored for immunization needs as their vaccination schedule approaches vaccination dates for specific diseases.

When the operating system alerts about the need for immunization, the individual or guardian would be alerted to attend strategic vaccination centers so that the prevention policy is actually implemented, favoring the maintenance of vaccination rates above the minimum acceptable by the State in order to avoid outbreaks, epidemics and vaccination gaps in the Brazilian immunization schedule.

Vaccination gaps are unfortunately linked to low human development indicators, significant social inequality, and reduced access to family health strategies. Continuous AI-based surveillance must be conducted to ensure consistent target audience definition. This will ensure an understanding of the disease's profile and its spread across the country, the implementation of targeted public policies, and the use of more effective vaccination strategies.

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