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Artificial Intelligence for Cluster Detection and Targeted Intervention in Healthcare: An Interdisciplinary System Approach

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ABSTRACT

Early detection of clusters of health conditions is essential to proactive clinical and public health interventions. Effective intervention strategies require real-time insights into the health needs of the communities. Artificial Intelligence (AI) systems have emerged as a promising avenue to detect patterns in health indicators at an individual and population level. The purpose of this paper is to describe the novel expanded application of AI to detect clusters in health conditions and community health needs to facilitate real-time intervention and prevention strategies. Case-use examples demonstrate the capabilities of AI to harness a variety of data to improve health outcomes in conditions ranging from infectious diseases, non-communicable diseases, and mental health disorders. AI systems have been utilized in syndromic surveillance to detect cases of infectious diseases prior to laboratory-confirmed diagnosis. These AI systems can analyse data from healthcare facilities, laboratories, and online self-reported symptoms to detect potential outbreaks and facilitate timely vaccination, resource allocation and public health messaging to mitigate the spread of disease. Similarly, the spread of vector-borne diseases can be anticipated through the analysis of historical data, weather reports and incidence of disease to identify areas to deploy vector control measures. In the area of mental health, AI algorithms can analyse diverse data sources such as social media posts, emergency hotline calls, emergency department visits, and hospital admissions to identify clusters related to mental health issues including overdoses, suicides, and burnout. The timely detection of such clusters enables prompt intervention, facilitating deployment of targeted mental health support services and community outreach programs to address these issues in a targeted and proactive manner. Identifying trends and characteristics in chronic disease data can guide screening and intervention strategies in real time. Similarly, AI can enhance pharmacovigilance by identifying previously unknown patterns in adverse drug reactions to inform regulatory bodies, healthcare providers and researchers in efforts to provide data-driven, real-time patient safeguards. By harnessing data from air-quality monitors, health records, and meteorology reports, AI systems identify correlations between environmental factors and health issues to empower efforts to address specific environmental health risks. These case-use examples illustrate the potential for AI to serve as a valuable tool to facilitate real-time, data-driven insights to inform proactive clinical and public health intervention strategies. Ongoing challenges in harnessing AI technology for public health surveillance include data privacy, accessing quality data from diverse data sets, and establishing effective communication channels between AI systems and public health authorities. The use of anonymized data to detect clusters and identify the health needs of health regions is a potential strategy to mitigate these challenges. Available resources are limited and must be deployed in a targeted, informed, and timely manner to be most effective. The integration of AI into an expanded all-risks approach to syndromic surveillance represents the next step in identifying and responding to clusters of health-related events in a proactive manner that aligns with community needs while upholding ethical standards and privacy considerations.

Keywords: Artificial intelligence, Syndromic surveillance, Cluster detection, Public health, Preventative medicine, Outbreak control, Mental health

INTRODUCTION

Early identification of clusters of health-related events is a key component of effective public health interventions. Traditional surveillance methods have relied on manual data collection and analysis often resulting in delays. The frequency and magnitude of emerging health threats and global pandemics has created a pressing need to find innovative solutions to surveillance challenges. The introduction of Artificial Intelligence (AI) presents an opportunity to enhance health surveillance by providing timely insights into a wide array of health conditions (Yoon et al., 2017). AI technologies, driven by machine learning algorithms, have demonstrated the capacity to process vast amounts of data in real-time (Yoon et al., 2017). The applicability AI is best highlighted through case-use examples, showcasing how real-time insights facilitate timely intervention, resource allocation, and inform public health messaging. The purpose of this paper is to explore emerging applications of AI in detecting clusters of health conditions and to assess the potential impact of AI on proactive intervention and prevention strategies.

INFECTIOUS DISEASE SURVEILLANCE

AI systems have demonstrated increasing capabilities in syndromic surveillance for infectious diseases. Case-use examples serve to illustrate the tangible advantages of integrating AI into infectious disease surveillance systems. AI systems have detected potential outbreaks before laboratory confirmation by analysing data from healthcare facilities, laboratories, and self-reported symptoms (Lucero-Obusan et al., 2017). AI algorithms have detected patterns of various emerging health threats and facilitated early intervention (Nolan et al., 2017). These early warning systems are being increasingly utilized to curb the rapid spread of infectious diseases (Lucero-Obusan et al., 2017). AI- augmented analysis of emergency department visits has provided insights into the spread and treatment compliance of zoonotic infections such as rabies (Bemis et al., 2017). Through early detection and warning systems, AI systems have given health authorities actionable data to inform targeting vaccination campaign to the populations and areas at highest risk (Lucero-Obusan et al., 2017). This targeted resource allocation is essential in strengthening the capacity of healthcare systems to address the needs of the communities they serve in times of crisis (Nolan et al., 2017). By providing real-time insights into the dynamics of an outbreak, AI informs tailored and up-to-date public health messages (Nolan et al., 2017). The spread of vector-borne diseases is closely related to environmental factors. AI systems have been leveraged to analyse disease incidence, historical data, and weather reports, and to detect patterns related to the spread of vector-borne diseases (Pley et al., 2021). By integrating changes in temperature and humidity into the analysis, AI enhances our capacity to predict spread of vector borne diseases in high-risk areas (Pley et al., 2021). As we navigate the emergence and spread of infectious diseases, AI will serve as a key tool to safeguard health at a regional and global level.

MENTAL HEALTH DISORDERS

AI augmented analysis has been applied to identify clusters of mental health concerns. Sources of input data that have informed these algorithms include social media posts, emergency hotline calls, and hospital admissions (Thieme et al., 2020). Social media platforms provide valuable data about language patterns, sentiment analysis, and behavioural cues, that can be provide insights into early signs of mental health distress in particular communities and subgroups of the population (Graham et al., 2019). Analysing the frequency and nature of hotline calls enables AI to identify trends in mental health and responses to particular events and stressors (Graham et al., 2019). AI algorithms analyse social media posts, emergency hotline calls, and hospital admissions to identify clusters related to issues such as overdoses, suicides, and burnout, enabling timely and targeted intervention strategies (Thieme et al., 2020). These insights are instrumental in planning community outreach and additional resources where they are needed most. By analysing mental health related hospital admissions, AI can assess the capacity and needs of different health regions (Nolan et al., 2017). Through the insightful interpretation of these diverse datasets, AI offers a nuanced understanding of the evolving mental health landscape.

CHRONIC DISEASE AND PHARMACOVIGILANCE

Chronic diseases pose a growing healthcare challenge. Subtle trends in chronic diseases often require the analysis of tremendous amounts of detailed data. AI systems have demonstrated the capability to efficiently detect these subtle patters to often go unrecognized through traditional health surveillance methods (Thiébaut and Cossin 2019). Chronic disease management often involves various pharmaceutical combinations and schedules (Thiébaut and Cossin 2019). Close monitoring of these combinations is essential for safety monitoring., making it imperative to monitor and understand the safety profiles of various medications (Thiébaut and Cossin 2019). By promptly recognizing Adverse Drug Reactions patterns, AI can assist in optimizing patient care, minimizing risks, and maximizing therapeutic benefits (Liang et al., 2022). These insights will allow for more informed decision making for healthcare-providers, regulatory bodies, and researchers (Liang et al., 2022). By harnessing the power of AI to better understand intricate patterns in chronic disease data and identify gaps in pharmacovigilance, healthcare systems are empowered to implement proactive and data-driven interventions (Thiébaut and Cossin 2019).

ENVIRONMENTAL HEALTH RISKS

In the field of environmental health, AI offers capabilities to better understand correlations between environmental factors and public health outcomes (Fan et al., 2023). By cross-referencing health data with environmental factors, AI can identify associations between exposure to certain pollutants or environmental conditions and specific health issues (Yoon et al., 2017). Air-quality monitors provide a real-time data on pollutants and particulate matter concentrations in the atmosphere (Yoon et al., 2017). AI can provide predictions of prevalence of respiratory conditions during periods of poor air quality and inform health system surge planning (Fan et al., 2023). In these ways, AI is expected to be a valuable tool in safeguarding public health in evolving environmental challenges.

CHALLENGES AND RECOMMENDATIONS

Despite the far-reaching potential applications of AI in health surveillance, various challenges exist. The sensitive nature of health data privacy must be considered when balancing the risks and benefits of utilizing health information for public health purposes (Yoon et al., 2017). The effectiveness of AI algorithms is dependent on both the quantity and the quality of available data (Kalra and Seitzinger 2022). Accessing data from various sources presents logistical challenges and introduces the potential for misleading and biased results. The collection of health data is often healthcare systems (Yoon et al., 2017). Addressing these challenges requires collaborative efforts to standardize data collection. Establishing effective communication channels between AI systems and public health authorities is an ongoing challenge that necessitates interdisciplinary collaboration and continuous refinement. The balance between public health objectives and individual privacy may be found in anonymizing health data (Yoon et al., 2017). This would protect the confidentiality of personal information while still allowing for the identification of clusters and health needs at a population level.

CONCLUSION

The integration of AI into an all-risks approach to syndromic surveillance represents an important step in a proactive approach to addressing clusters of health-related events. This approach has diverse applications in infectious diseases, vector-borne diseases, mental health disorders, chronic diseases, and environmental health risks. These applications will have important implications on shaping policies, public health campaigns, and regulatory measures. It is crucial to navigate challenges surrounding data privacy and quality to ensure the highest ethical standards privacy considerations are maintained while also protecting the health of the population. Continued research and collaboration are required to appropriately realize the potential applications of AI in shaping public health strategy.

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