ORIGINAL ARTICLE

Identification and Prioritization of Potential Data Sources for a Biothreat Syndromic Surveillance System in Iran

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Abstract

Background: Syndromic surveillance is considered an effective tool used to detect early manifestations of biothreats and bioterrorism-related diseases. Nowadays, a wide range of data sources has been used in biothreat syndromic surveillance systems. The current study was conducted to identify potential data sources and prioritize the most feasible ones for use in a syndromic surveillance system; we aimed to detect biothreats in Iran.

Methods: Mixed-method research was conducted. Potential data sources and health indicators were investigated and selected through an extensive literature review and interviews with experts. A TOPSIS model was used to prioritize the data sources based on timeliness, usefulness, representativeness and simplicity attributes.

Results: Healthcare providers for humans and animals, schools, pharmacies, laboratories, workplaces, and social media were found as data contributors for syndromic surveillance systems globally. Among identified data sources, a total of 13 health indicators were selected for prioritization. Emergency department (ED) visit chief complaints had priority over other health indicators and were found to be the most useful source for early detection of biothreats. It is followed by over-the-counter (OTC) drug sales and frequency of emergency visit records.

Conclusion: Syndromic surveillance based on different data sources is widely used across the world. The same approach is recommended for the Iranian healthcare system. Hospital-based clinical data platforms, such as EDs, have existed in the country for many years, and these data can be quickly incorporated into the biothreat syndromic surveillance system. For other data sources, such as OTC drug sales and school and work absenteeism, designing a platform for data registration is required.

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Introduction

Biological threat (biothreat) is defined as any threat posed by harmful agents, including bacterial, fungal, and viral pathogens, as well as the toxins they produce.[1] Biothreats are classified as natural, accidental, and intentional threats, and their social, economic, political, and security consequences have been widely discussed in national and international agencies.[2] A wide range of factors, such as population growth, migration, urbanization, climate change, and increasing interconnectedness amongst humans, animals, and the environment, contribute significantly to the increased probability of naturally occurring biothreats.[3] On the other hand, intentional release of biological agents to cause illness or death in humans, animals, or plants is defined as bioterrorism. A bioterrorism attack could occur as part of a government policy in biological warfare or by terrorist groups or criminals.

The emergence of West Nile virus in the United States in 1999,[4] the Amerithrax incidents in 2001; the 2003 outbreak of Severe Acute Respiratory Syndrome coronavirus (SARS-CoV),[5] the 2012 outbreak of Middle East Respiratory Syndrome coronavirus (MERS-CoV),[6] and, more recently, the pandemic of SARS-CoV-2, has intensified the national and international efforts for biothreat preparedness.[2]

Disease surveillance is considered an important epidemiological tool for disease monitoring and detection of new outbreaks. Surveillance for biothreat-related disease outbreaks is a component of surveillance for infectious diseases.[7] Improved preparedness and early detection of intentional biothreats will protect military positions and strategies. Furthermore, it increases the ability to combat naturally occurring epidemics caused by harmful organisms.[8]

Regarding devastating consequences of biothreats, either naturally occurring or intentional release, health agencies are seeking new surveillance methods to facilitate early detection of biothreats and appropriate response. Syndromic surveillance which monitors early manifestations of diseases and non-specific health-related event data has been widely used for this purpose. Syndromic surveillance is defined as the monitoring and detection of non-specific individual and population health indicators without laboratory confirmation.[9]

Syndromic surveillance uses a wide range of clinical and non-clinical data sources and health-related indicators for early detection of biothreats. Maximum temporal, geographical, and demographic coverage, being stored in electronic format and timely available, are characteristic of desired data sources for syndromic surveillance.[10] The system has been widely used in countries with well-established surveillance systems in North America and Europe for early detection of biothreats.[11] Despite the long history of syndromic surveillance systems in Iran, feasibility studies to discover their application for early detection of natural or intentional biothreats, especially in high-risk groups are rare.

Although every country needs to establish its own surveillance system based on the socioeconomic, political, and administrative conditions, previous experiences of countries with well-established procedures and extensive organizational structures will provide valuable resources for this purpose. The current study aimed to (a) identify common data sources that have been used by syndromic surveillance, (b) select the data sources that are feasible to be used in Iran, and (c) prioritize data sources based on their potential for early detection of natural and intentional biothreats.

Methods

The current study was performed in two phases.

Phases 1: Literature review

The main aim of this phase was to identify key data sources used by syndromic surveillance systems around the world through a comprehensive literature review. A scoping review was conducted by the authors in accordance with Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews[12] protocol. The Arksey and O'Malley[13] framework was used to define the study steps. The steps used in the current study include: (1) identifying the research question; (2) identifying relevant studies; (3) selecting the study; (4) charting the data; (5) collating, summarizing, and reporting results; and (6) consulting with experts for enhancing and refining the findings and providing insights beyond those in the literature. The main question of the study was "What data sources have been used by syndromic surveillance systems to detect natural and intentional biothreats?"

This type of review allowed for broader research questions and redefinition of keywords during search process. All scientific documents published between January 2000 to December 2023 were screened. At the beginning, Google Scholar database was used to define search terms. In the next step, PubMed was searched for scientific publications. Keywords were divided into different categories such as surveillance (i.e., syndromic surveillance, public health surveillance, surveillance), source of data (i.e., data source, healthcare provider centers, Internet), and biothreats (i.e., outbreak, disease outbreak, bioterrorism); also, their combination was used during database screening. To cover all related documents, a manual search of the reference lists of the included articles and redefining new keywords where needed was also conducted.

Studies that described the use of a defined data source in syndromic surveillance systems were included in the study. Non-English studies, studies that did not comply with the goal of the study, and those with unavailable or inaccessible full text were excluded. Studies that discussed a similar data source were considered as double, and only one study was included with emphasis on review articles. Two authors independently screened the articles to make sure that the articles were in line with the goal of the study.

All documents included were studied carefully, and data extraction was performed based on the study question and the goal of the study. The title, authorship, year of publication, and summary of the findings of the included studies were recorded. Regarding the extensive range of data sources and as the complementary step, an interview was conducted with three well-known academic experts in the fields of epidemiology and health service management. Experts were purposively selected based on their professional experience in infectious disease surveillance system in Iran. All three interviews were conducted by one author face-to-face with an average time of 60 minutes. At the beginning of the interview, the experts were informed about the goal of the study, and they were asked to refine the findings of the study by selecting the most feasible data sources regarding administrative and information science structure in the country. These findings and the selected data sources and health indicators were summarized and used in the second phase of the study.

Phase 2: Data source prioritizing

In the next phase, the selected data sources and health indicators were prioritized based on the protocol described in the previous study.[14] The technique for the order of preference by similarity to the ideal solution (TOPSIS) model was used to prioritize the selected data sources. TOPSIS is a simple ranking method which attempts to choose alternatives that simultaneously have the shortest distance from the positive ideal solution (PIS) and the farthest distance from the negative ideal solution (NIS).[15] The technique is a multivariate decision-making method in which M items are ranked based on N criteria. The study population consisted of eight Iranian experts with a prominent research background in the areas of epidemiology, infectious disease, bioterrorism, and health service management with at least five years of experience in the related area. The data sources and health indicators were evaluated based on four attributes including: (i) simplicity (ease of operation and data collection process from data source); (ii) usefulness (contribution of the data source to control and prevention of adverse health-related conditions), (iii) representativeness (accurate describing of the distribution of the health event by person and place), and (iv) timeliness (the difference between the time an health event occurs and the time the reference standard for that event occurs). The experts could use the following points for each attribute related to each data source: (1)=Very low, (2)=Low, (3)=Moderate, (4)=High, and (5)=Very high.

The TOPSIS methodology in the current study consisted of the following steps: 1) Construction of the normalized decision matrix, 2) Establishment of the weighted normalized decision matrix, 3) Determination of the PIS and NIS, 4) Calculation of the distance measure of each alternative from the PIS and

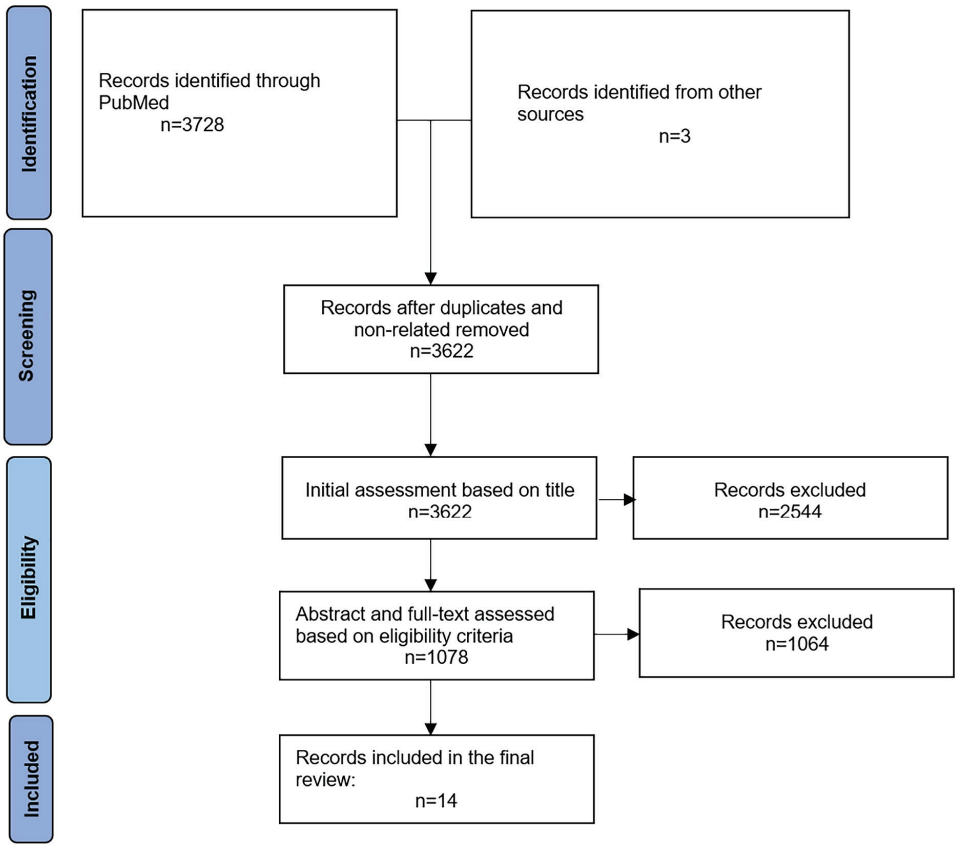

Figure 1: PRISMA flow diagram of study selection

NIS, 5) Calculation of the relative closeness (closeness coefficient) to the ideal solution, and 6) Ranking of preference order. Ranking is done based on the values of the closeness coefficient when the higher value of the closeness coefficient has a high rank and hence the better performance of the alternative.[14] The analysis was performed using BT-Topsis Solver software.

Ethical Considerations

The study was approved by the Ethics Committee of Baqiyatallah University of Medical Sciences, Iran (IR.BMSU.REC.1401.106). In all stages of the study, from data collection to their analysis, maintaining the anonymity of the participants and the confidentiality of the information were taken into consideration.

Results

Literature Review

During the literature review, a comprehensive array of data sources employed by syndromic surveillance systems worldwide was identified. This identification process followed a rigorous screening protocol outlined in the PRISMA flowchart (Figure 1).

Initially, 3728 records were retrieved from PubMed, narrowed to 3622 after removal of duplicates. Through title and abstract screening, 2544 records were excluded for irrelevance, leading to 1078 full-text articles assessed for eligibility. Finally, 14 studies met the inclusion criteria and were synthesized to extract relevant data sources.

Table 1: Summary of the findings from selected scientific reports reviewed during the study

First author, Year	Study title	Data sources and health indicators
Abat C, 2016	Traditional and syndromic surveillance of infectious diseases and pathogens	Drug sales data, laboratory data, Vital statistics and absenteeism, Medical and notifiable disease records, Hospitals and their laboratories, Web queries, Informal rumors, Telephone triage, Hotline data, Environmental and animal health data,
Henning KJ, 2004	Overview of Syndromic Surveillance what Is Syndromic Surveillance.	Emergency department total patient volume, Clinic total patient volume, Total hospital admission from emergency department, Total intensive-care unit admission from emergency department, Emergency department triage log of chief complaint, Emergency department visit outcome (diagnosis), Ambulatory care visit outcome, Emergency medical system (911) call type, Provider hotline volume, Provider hotline chief complaint, Poison control center calls, Unexplained death, Medical examiner case volume, syndromes, Insurance claims or billing data, Clinical laboratory or radiology ordering volume, Absenteeism, Over the counter medication sales, Health care database searches, Volume of internet based health inquiries by public, Internet based illness reporting, Animal illnesses of deaths
Hughes HE, 2020	Emergency department syndromic surveillance systems: a systematic review.	Emergency department
Pivette M, 2014	Drug sales data analysis for outbreak detection of infectious diseases: a systematic literature review	Pharmacy, Retailer
Donaldson AL, 2021	School-based surveillance of acute infectious disease in children: a systematic review	Absenteeism
Paterson B, 2011	Use of workplace absenteeism surveillance data for outbreak detection	Absenteeism
Beckhaus J, 2022	The use and applicability of Internet search queries for infectious disease surveillance in low- to middle-income countries	Internet search query
Aiello AE, 2020	Social media– and Internet-Based Disease Surveillance for Public Health	Social media activity
Neo JPS, 2017	The use of animals as a surveillance tool for monitoring environmental health hazards, human health hazards and bioterrorism	Animal diseases
Spector E, 2022	Syndromic Surveillance Systems for Mass Gatherings: A Scoping Review	Hospital Emergency Department, First Aid Stations or Event-Based Clinics, Mobile phone app, Hospitals/Community Clinics, Sentinel sites, Public, Private and Temporary clinics
Chen H, 2010	Syndromic Surveillance Data Sources and Collection Strategies	Emergency department, Pharmacy medication sales, Absenteeism, Hospital admission, Ambulatory clinics, Triage nurse calls, 911 calls, Ambulance dispatch calls, Internet and social media (discussion forums, mailing lists, government Web sites, news)
Wenger PN, 2009	Public Health Surveillance for Bioterrorism	Outpatient and emergency department visits, Intensive care unit diagnoses, Over-the-counter pharmacy sales, Clinical lab submissions, Medicare or medicaid claims, Nursing homes, Systematic testing for specific disease agents in specimens submitted to public health lab, School and work absenteeism, Ambulance call chief complaints, Poison information center calls, HMO/nurse hotline calls

The selected studies and the specific data sources they reported are summarized in Table 1, providing an overview of the diversity and characteristics of syndromic surveillance inputs across different contexts.

Following this literature synthesis, the study incorporated expert input through structured interviews with three epidemiology specialists. The insights gained helped refine and confirm the feasibility of data sources within the Iranian healthcare context. This collaborative process resulted in a finalized list of prioritized data sources along with associated health indicators, detailed in Table 2, which served as the basis for subsequent TOPSIS modeling and decision analysis.

This mixed-methods approach ensured that both empirical evidence and expert clinical judgment informed the selection and prioritization of data sources, enhancing the relevance and applicability of the syndromic surveillance system design recommended for early biothreat detection in Iran

Prioritization of Data Sources

After identification and selection, prioritization of data sources and health indicators was performed based on simplicity, usefulness, representativeness, and timeliness attributes. The characteristics of the experts in phase two of the study are shown in Table 3.

Table 2: Health indicators extracted from each data source used in syndromic surveillance systems

Data source	Health indicators
Emergency department	Frequency of patient visit Frequency of specific chief complaint recorded in triage log Primary diagnosis during Emergency department visit
Hospitals	Total admission of hospitals
Absenteeism	Frequency of school absenteeism Frequency of work absenteeism
Clinical laboratories	Frequency of test ordering volumes
Animal diseases	Frequency of zoonotic diseases occurrence in wild and domestic animals (reported by government veterinary authorities) Isolation of highly resistant zoonotic strains by private veterinary laboratories
Calls to health helplines (hotlines)	Frequency of calls to hotlines Frequency of specific chief complaints reported during calls to hotlines
Internet	Search query Shared posts and information in social media platforms

Table 3: Basic Characteristics of Experts

Educational background	Experience (year)	Age	Sex
Epidemiology	14 years	40	Male
Epidemiology	8 years	35	Male
Epidemiology	13 years	38	Male
Epidemiology	15 years	46	Male
Epidemiology	24 years	55	Male
Health service management	35 years	59	Male
Health service management	27 years	52	Female
Microbiology	22 years	46	Male

Table 4: Priority of the data sources and health indicators using the TOPSIS method

Data sources	Separation from the PIS*	Separation from the NIS*	Closeness coefficient	Rank
Patient visit load to the emergency department	0.008	0.042	0.825	3
Chief complaint recorded in triage log in emergency department	0.007	0.04	0.840	1
Primary diagnosis during emergency department visit	0.028	0.02	0.418	10
School absenteeism	0.008	0.039	0.825	4
Work absenteeism	0.015	0.031	0.671	6
Test ordering volume	0.028	0.036	0.747	5
Over-the-counter drug sales	0.007	0.041	0.840	2
Zoonotic disease occurrence in animals	0.024	0.023	0.395	11
Isolation of highly resistant zoonotic strains	0.03	0.019	0.493	7
Search query	0.024	0.022	0.479	9
Shared posts in social media platforms	0.026	0.024	0.481	8
Frequency of calls to hotlines	0.045	0.002	0.050	13
Chief complaints reported during calls to hotlines	0.044	0.004	0.082	12

PIS: Positive ideal solution; NIS: Negative ideal solution

The experts who contributed to this phase of the study brought substantial expertise and experience. As summarized in Table 4, most experts were male, held PhD degrees, and had an average of 14 years of work experience in relevant fields. This diverse and seasoned panel provided informed judgments that enhanced the robustness of the prioritization process. According to expert consensus and TOPSIS ranking, emergency department (ED) chief complaints emerged as the highest priority due to their accessibility, routine availability, and epidemiological relevance. They were closely followed by patient visit load to EDs, over-the-counter (OTC) medical sales, and school absenteeism, all recognized for their timeliness and potential for early outbreak detection.

Discussion

The current study was conducted to identify and prioritize the potential data sources and health indicators used by syndromic surveillance systems aiming to detect biothreats. The biothreats pose a significant risk to community health and national security; thus, all outbreaks of especially dangerous pathogens must be viewed as potential proliferation events. Despite the ratification of the Biological and Toxic Weapons Convention, the incidence and potential of biothreats have witnessed a substantial increase over the past few decades. It is attributed to significant advances in biological warfare research and enhanced global competition.[3] Syndromic surveillance has been widely used for the detection of potential bioterrorism events at the earliest possible time and dissemination of the information promptly for appropriate interventions.[16] Surveillance of naturally occurring infectious diseases shares the same surveillance characteristic as detecting the intentional release of bioagents.

The results of the first phase of the current study showed that a wide range of data sources have been used by syndromic surveillance systems. Furthermore, most of the syndromic surveillance systems use a combination of data sources and health indicators. Our findings showed that healthcare providers (EDs, hospitals, ambulatory centers), schools, pharmacies, laboratories, military medical facilities, Internet and social media, veterinary health records, and triage nurse calls act as a contributors for data collection.[17] The type of data sources usually varies among surveillance systems based on their goals. Findings of a previous study showed that out of 56 syndromic surveillance systems, 80% used ED chief complaints as a timely public health indicator, showing the importance of ED as a data source for syndromic surveillance. Furthermore, 50% of the systems used OTC drug sales, and 30% used hospital admission data.[17] Likewise, an investigation on 19 syndromic surveillance systems which aimed at detecting biothreats during mass gatherings showed that 53% used data from hospital EDs; 32% used the first aid stations and temporary or mobile clinics, and 21% used hospitals or care sites as data sources. In total, 42% of surveillance systems used multiple data sources.[18] International Society for Disease Surveillance investigated the distribution of the use of data sources by the surveyed syndromic surveillance system. The results showed that ED visits, outpatient visits, OTC medical sales, and school absenteeism were among the most data sources used, which is in agreement with the findings of the current study.[17]

In the second phase of the study, the data sources and health indicators were prioritized. Our results showed that ED chief complaints, OTC drug sales, ED patient visits, and school absenteeism were ranked first based on timeliness, representativeness, simplicity, and usefulness attributes. Chief complaints as a syndromic data source present many advantages as they are routinely generated and become available typically on the same day the patient is seen.[19] Furthermore, they are typically accessible in an electronic format with wide availability and timeliness. The results of previous studies showed that most old syndromic surveillance systems considered ED chief complaints as an important and primary data source which is largely in accordance with our findings. Syndromic surveillance system based on ED is recognized as an effective form of surveillance, providing information for action across a wide range of situations, both infectious and non-infectious conditions.[20] This valuable source of data enhances traditional laboratory-based surveillance of infectious diseases. The findings of a previous study showed that the chief complaint was that ED-based syndromic surveillance system was able to predict health events 2.5 days before the local surveillance system, with 90.3% specificity and 72.9% sensitivity, which is in accordance with the current study.[21]

Most of the patients prefer to do self-medication using OTC drugs when the symptoms are mild. Drugs are easily accessible in many countries, and OTC drug sales provide population health status at the beginning of symptom appearance. Furthermore, the specificity of data may increase by monitoring groups of drugs used for a specific disease or disease syndrome of interest.[22] ESSENCE is an example of a syndromic surveillance system that utilizes OTC drug sales as a source of data.[23] OTC drug sales could be timelier than patient visits, as people may visit a drug store before visiting a physician. However, patient visits data is usually accompanied with demographic information, while these data are not provided in OTC drug sales.

Patient visit load to ED has been found as a useful health indicator in syndromic surveillance for early detection of health events, particularly in conjunction with other ED data.[24] A previous study demonstrated the utility of a syndromic surveillance system based on hospital admissions to monitor and identify potential surges in severe COVID-19 infection within the community on time and provide situational awareness to inform preventive and preparatory health interventions.[25] The first victims are most likely to visit the ED in the beginnings of natural and intentional biothreats.

Absenteeism data reported by schools and workplaces provide a novel and valuable dataset to syndromic surveillance systems as they utilize an existing and timely source of data in the form of daily attendance registers with acceptable temporal resolution.[26] Infectious diseases are easily spread in schools.[27] Furthermore, children are considered an important transmitter of infection from schools to the community.[28] Therefore, school absenteeism data facilitates early detection and timely intervention during infectious disease outbreaks.

Given that most of the health indicators and data sources are nonspecific and not based on diagnostic testing, the majority of syndromic surveillance systems were using a combination of data sources to increase their efficacy. For example, Biosense program in USA which was established for early detection and assessment of potential bioterrorism-related illness is using a wide range of data sources, such as data from US department of veteran's affairs and US department of defense hospitals, ambulatory care clinics, test orders from the laboratory corporation of America, data from state health departments' syndromic surveillance systems, anti-infective prescription data, and test orders.[29] Likewise, the French syndromic surveillance system relies on EDs, emergency general practitioners' service and city registry offices as a source of data.[30] Previous studies have investigated the efficacy of using different data sources for earlier detection of outbreaks. Hogan et al. (2003) demonstrated that sales of electrolyte products contain a signal of outbreaks of respiratory and diarrheal diseases in children and are usually an earlier signal than hospital diagnoses.[31] Likewise, Papadomanolakis-Pakis et al. (2021) found that laboratory-confirmed hospital admissions for COVID-19 were strongly and significantly correlated with suspected COVID-19 hospital admissions.[25]

Conclusion

Syndromic surveillance systems have been widely utilized to monitor and detect natural and intentional biothreats. A wide range of data sources, alone or in combination, have been used during data collection by these systems. Based on expert opinions, the majority of these data sources have the capacity to be used in Iran. Data sources such as EDs, pharmacies, laboratories, and animal disease reports are currently available for data acquisition. For other data sources, such as schools, workplaces, the Internet and telephone triage, improving infrastructure is needed before using them as a data source for syndromic surveillance data. Based on expert opinions, EDs, pharmacies, schools, and workplaces were considered as the best data source for biothreat syndromic surveillance in Iran. Establishing a new surveillance system requires time, money, and human resources. Development of new surveillance systems and improvements in existing systems to better detect bioterrorist-related disease activity should include the capacity to monitor other infectious diseases of public health importance, including emerging infectious diseases and vaccine-preventable diseases. Monitoring changes in healthcare utilization is essential to analyze syndromic surveillance data, which can then be used to better understand the impact of biothreats on the population.

Authors' Contribution

Concept and design: MS, SMH and NJ. Data collection: SJE and YA. Data analysis: RZ, SJE and YA. Writing—original draft preparation: SJE and YA; writing—review, and editing: MS, MHS and NJ. Supervision: MS. All authors approved the final manuscript and agreed to be accountable for all aspects of this research.

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Conflict of interest

The authors declared no potential conflicts of interest.

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