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RESEARCH ARTICLE

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Suggesting a framework for preparedness against the pandemic outbreak based on medical informatics solutions: a thematic analysis

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Abstract

Background: When an outbreak emerged, each country needs a coherent and preventive plan to deal with epidemics. In the era of technology, adopting informatics-based solutions is essential. The main objective of this study is to propose a conceptual framework to provide a rapid and responsive surveillance system against pandemics.

Methods: A three-step approach was employed in this research to develop a conceptual framework. These three steps comprise (1) literature review, (2) extracting and coding concepts, and determining main themes based on thematic analysis using *ATLAS.ti®* software, and (3) mapping concepts. Later, all of the results synthesized under expert consultation to design a conceptual framework based on the main themes and identified strategies related to medical informatics.

Results: In the literature review phase, 65 articles were identified as eligible studies for analysis. Through line by line coding in thematic analysis, more than 46 themes were extracted as potential foremost themes. Based on the key themes and strategies were employed by studies, the proposed framework designed in three main components. The most appropriate strategies that can be used in each section were identified based on the demands of each part and the available solutions. These solutions were employed in the final framework.

Conclusion: The presented model in this study can be the first step for a better understanding of the potential of medical informatics solutions in promoting epidemic disease management. It can be applied as a reference model for designing intelligent surveillance systems to prepare for probable future pandemics.

KEYWORDS
civil defence, electronic surveillance system, framework, pandemics, medical informatics

1 | INTRODUCTION

According to World Health Organization (WHO), the pandemic is commonly defined as the worldwide spread of a new communicable disease.[1,2] The randomness and unpredictability of such diseases is a prominent feature of each new pandemic. This feature causes countries to face inevitable challenges.[3–5] When a disease outbreak began, most people lack natural immunity to fight it. It can cause a rapid transmission of new pandemic across countries over a specific amount of time.[6] The unfamiliar aspects and highly contagious nature of the current COVID-19 pandemic, have shown that every country requires a coherent and responsive plan to battle against the current pandemic.[7] By the 10 October 2020, there had been 1083140 COVID-19 deaths worldwide. A high mortality rate of this new virus has raised many concerns about the unpreparedness of countries to use appropriate methods to control, prevent and address unexpected epidemiological conditions.[8] Thus, during a pandemic outbreak, health care system preparedness is essential. In similar epidemics around the world, various countries have taken different approaches based on the last advancement of technologies and health-IT based solutions.[9]

In former pandemics, various digital health strategies have been used with different approaches to control other epidemics such as the Middle East respiratory syndrome, severe acute respiratory syndrome and H1N1 flu.[10–12] For example, a team of scientists from Pakistan invented a smart tool called ID-Viewer as a decision-making system for predicting an infectious disease outbreak in 2016.[13] It was employed to detect the dengue epidemic for 20 weeks earlier by gathering and analysing all related information about dengue disease since 2011.[14] In a similar study conducted in 2012, Chinese researchers were able to predict abnormal outbreaks and warn the health system before its emergence by implementation a continuous and intelligent monitoring system to analyse real-time data of various diseases.[15,16]

The recent global epidemic has proved that e-health technologies can be used to control the spread of disease. In a recent report, Healthcare Information and Management Systems Society reported that digital tools such as telemedicine, remote patient monitoring, data analysis methods and even artificial intelligence (AI)-based solutions could play a significant role in restricting the prevalence of COVID-19.[17]

However, the sudden emergence of the epidemic has proven that just awareness of the latest technologies is not adequate. The most significant point to fight epidemic diseases by applying the latest technologies is to know how to use these tools most appropriately in outbreaks.[18] Consequently, to prepare for combat against the spread of diseases, an appropriate model based on the latest medical informatics solutions is needed. It seems that the time has come to use digital technologies at different levels of the health system based on the experiences of other countries to combat the epidemic of infectious diseases.[19]

The main objective of this study is to propose a conceptual framework for designing an appropriate and comprehensive electronic surveillance system for preparedness against the pandemic. Other aims of this study include identifying the most proper solutions in medical informatics that can be used to predict, diagnose, control and manage the COVID-19 outbreak and other pandemics.

2 | METHODS

In this qualitative research, a three-step approach was applied to outline a conceptual framework. These three steps included (1) literature review, (2) extracting concepts and main themes based on qualitative analysis, and (3) mapping concepts, and synthesizing the results with expert consultation. The qualitative synthesis was conducted based on the Standards for Reporting Qualitative Research checklist, which can help researchers to report their results correctly.[20]

2.1 | Literature review

The systematic search was performed in four scientific databases, Web of Science, Scopus, PubMed and Science Direct from 2000 to August 2020. The search strategy and keywords are shown in Table A1, Supplementary Appendix. All articles retrieved from database searches entered into Mendeley as the resource management software. The systematic review was conducted based on the preferred reporting items for systematic reviews and meta-analyses steps. Some inclusion and exclusion criteria were determined for reviewing articles.

Articles included if they were original articles and if they used solutions or strategies to prepare for a sudden outbreak or control of an epidemic disease based on digital health. Solutions regarding social relations, military and cultural measures are not considered. Non-English papers, letter to editors, commentary papers, book chapters, short briefs, reports, technical reports, any reviews or meta-analysis were excluded.

After duplication removal, the articles were omitted regarding the type of articles. Next, the remaining studies were reviewed based on titles and abstracts. All titles and abstracts of articles were examined to select eligible studies by reviewers. Marsa Gholamzadeh screened all titles and abstracts to find relevant articles. A second reviewer (Hamidreza Abtahi) reviewed a sample of studies randomly. Following, articles that met our inclusion criteria were selected for full-text review. After that, the full texts of relevant studies were screened thoroughly by all authors. If there was a disagreement between the authors, the final decision was made by Reza Safdari. Finally, the information of the included articles extracted based on characteristics such as author name, year of publication, title, purpose of the study, country, institution, proposed solution and type of disease and pandemic.

2.2 | Qualitative and thematic analysis

Since thematic analysis known as one of the best methods in qualitative analysis, we applied it in our research.[21] Following a systematic investigation, the remained articles met our criteria were imported to *ATLAS.ti®* software to conduct an inquiry using inductive thematic analysis. It is a free famous software that is mostly used for content analysis by coding and analysing complex textual data.[22]

All included articles were imported into the *ATLAS.ti®* software. All of the studies were screened line by line to code the preliminary idea. By connecting extracted codes, the fundamental themes were extended to achieve a thematic map. All potential themes were depicted in the form of a thematic tree to define themes and sub-themes. Coding and thematic analysis stages were conducted by one of the authors (Marsa Gholamzadeh) who had experience in analysing and reviewing studies under the supervision of health informatics experts. The information extracted by the researchers was re-examined to reach an agreement. The next reviewers (Hamidreza Abtahi and Reza Safdari) assessed and verified the extracted information.

2.3 | Mapping concepts and designing the conceptual model

Under expert consultation, all of the extracted themes were investigated and integrated. The initial model devised in this step is based on key themes and sub-themes. Then, in an iterative process, a conceptual framework was defined and redesigned to achieve the optimal model. In the following, the suggested conceptual model and the strategies for outbreak preparedness were described. The different parts of the proposed model are defined based on the solutions available concerning the various branches of medical informatics.

3 | RESULTS

3.1 | Literature review

Initial searches in scientific databases yielded 397 citations. After removing 71 duplicated articles, 326 citations were screened based on the type of studies. Next, 300 articles remained due to their relevancy in the abstract

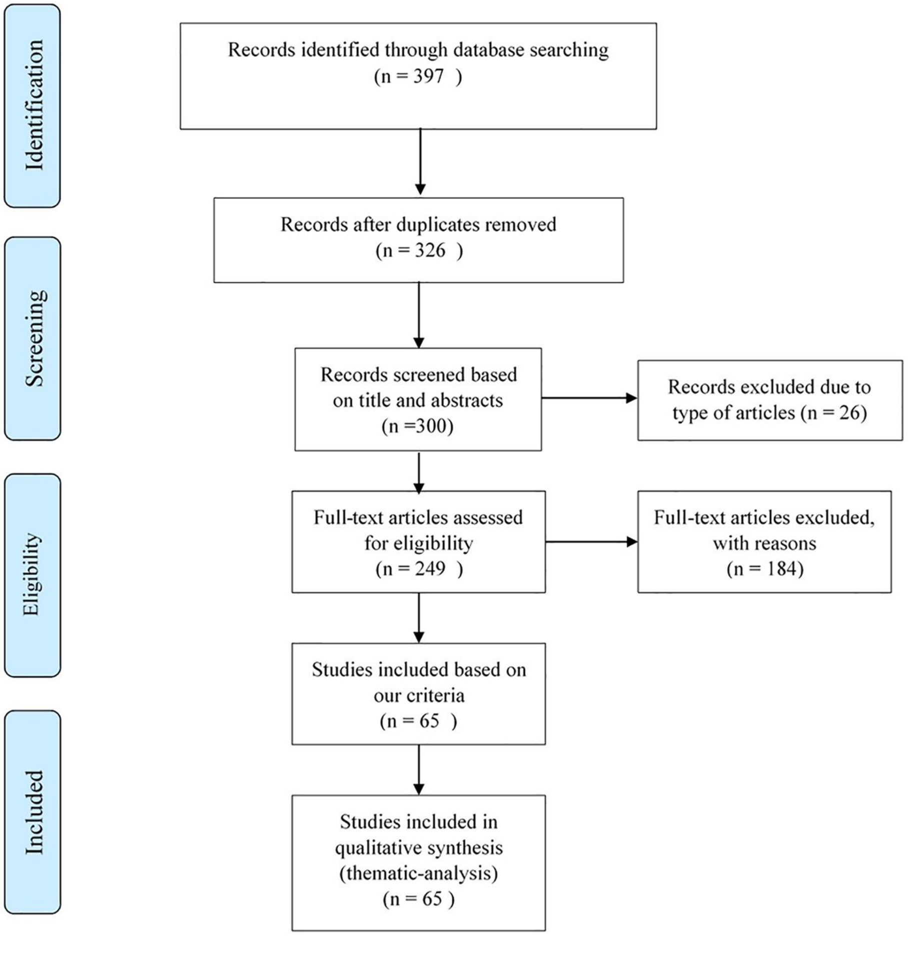

FIGURE 1 Screening flow based on the preferred reporting items for systematic reviews and meta-analyses method [Colour figure can be viewed at wileyonlinelibrary.com]

screening phase. Then, the full-text of 249 studies were reviewed. Finally, 65 citations were identified as eligible studies to meet our criteria. The process of screening articles is shown in Figure 1. A summary of the included articles based on predefined categories is described in Table 1.

The analysis of the most significant features of the reviewed articles is represented in Table 2. Regarding the country, the United States has used medical informatics solutions more than any other country to control pandemics. On the other hand, the analysis revealed that most of the efforts devoted to controlling the spread of influenza outbreaks (41.54%) and employing medical informatics solutions. The trend of published articles regarding our objective had steady growth until the COVID-19 outbreak in 2020. Though, eight articles were published regarding outbreak preparedness from the beginning of 2020 up to 2 August 2020.

Based on the central idea of our research, all studies were examined based on their tactics and strategies related to the medical informatics disciplines. Overall, all of the employed strategies can be devoted to 19 categories. These categories are represented based on their frequency and percentage in Table 3. It is worth noting that most studies used a combination of different techniques and did not focus on just one specific solution but most strategies were related to developing AI-based models.

3.2 | Thematic analysis outcomes

After coding all the themes and sub-themes, more than 46 themes were extracted as potential main themes. By integrating all of the potential themes, the mapped network of themes is devised and illustrated in Figure 2. Conclusively, all of the themes are summarized regarding recommended and applied strategies in three main categories. These categories were used to devise a conceptual model:

1. Epidemiological solutions and surveillance systems
2. Research-based solution to manage and predict an outbreak
3. Clinical care planning, inpatient and outpatient management strategies

3.3 | Suggested conceptual framework

The most appropriate solutions that can be used in each section are identified based on the integration of the requirements and the available solutions in the proposed model. In the following, the most suitable model for better epidemic management is designed in each section using the identified solutions.

3.3.1 | Epidemiological subsystem

Analysis of articles showed that mathematical models have the potential to aid clinical decision-makers to forecast the next epidemic and prepare for a proper pandemic. Besides, the thematic analysis revealed that predictive modelling was the most common solution to develop an early warning system. It has the potential to predict outbreaks for providing emergency response. Analysis of studies showed that outbreak prediction models, AI-based algorithms and early warning systems, in combination with geographical positioning strategies can be adopted in this section. The schematic model of this subsystem is represented in Figure 3.

The first part of this model is an intelligent subsystem that investigates and interprets all recorded data in cross-sectional studies, death reports and case reports continuously to detect an abnormal pattern of a particular disease using built-in AI-based algorithms. In case of occurrence of an abnormal pattern, the system would be

TABLE 1 Summary of reviewed articles

	Author	Year	Journal	Recommended solution	Illness	Main objective	Institution
1	Aaby. K et al.	2006	J Public Health Manag Pract	Develop Clinic Planning Model Generator or computer program	Pandemic influenza outbreak	To determine points of dispensing (pods) for mass distribution of vaccine	Maryland's Advanced Practice Center for Public Health Emergency Preparedness and Response and the Institute for Systems Research at the University of Maryland.
2	Abramovich. M et al.	2017	American journal of infection control	Computer modelling and simulations using various combinations of variables to determine resource needs	Pandemic influenza outbreak	To model many other hospital preparedness issues	Mayo clinic
3	Abramovich. M et al.	2008	Biosecurity and bioterrorism: biodefense strategy, practice and science	Develop a new tool to estimate the likely healthcare consequences of a pandemic and to aid hospitals in the development of mitigation and response strategies	Influenza outbreak	To plan for a 1918-like flu pandemic	Not mentioned
4	Agolory. S et al.	2008	PloS one	School preparedness planning and non-pharmaceutical interventions, including handwashing and use of hand sanitizer	H1N1 pandemic influenza	To mitigate the effects of an influenza outbreak	CDC
5	Akselrod. H et al.	2012	Journal of business continuity & emergency planning	An operational structure that will facilitate the integration of modelling capabilities into action planning for outbreak management	Infectious outbreaks	Real-time modelling output with anticipated decision points	CDC

(Continues)

TABLE 1 (Continued)

	Author	Year	Journal	Recommended solution	Illness	Main objective	Institution
6	Araz. OM	2013	Journal of Systems Science and Systems Engineering	A multi-criteria decision-making framework,	Not mentioned	Predicting temporal and geographic patterns of disease spread	OMAHA
7	Araz. OM et al.	2012	J Med Syst	Simulation model	H1N1 influenza outbreak,	To prepare university emergency response executives, management, and operational emergency response infrastructure to collaboratively evaluate the university's pandemic influenza emergency response plan	Arizona state university
8	Buckeridge. D et al.	2008	AMIA Annu Symp Proc	To develop quantitative models	Not mentioned	To develop quantitative evidence about the determinants of outbreak detection as a means of supporting manual and automated evidence-based method selection for public health surveillance.	Not mentioned
9	Burke. D et al.	2006	Academic emergency medicine: official journal of the Society for Academic Emergency Medicine	Agent-based model	Smallpox epidemic	To evaluate the potential effectiveness of epidemic control strategies that might be deployed in response to a bioterrorist attack	Johns Hopkins

TABLE 1 (Continued)

	Author	Year	Journal	Recommended solution	Illness	Main objective	Institution
10	Ceccato. P et al.	2007	The American journal of tropical medicine and hygiene	Developing malaria early warning program	Malaria	To define five areas with distinct malaria intensity and seasonality patterns, to guide future interventions and development of an epidemic early warning system.	Brazilian agencies CAPES
11	Colon-Gonzalez. F et al.	2018	BMC public health	Syndromic surveillance systems	Influenza outbreak	To investigate how the characteristics of different disease outbreaks affected and the time to detection.	University of East Anglia
12	Cruz. A et al.	2010	Annals of emergency medicine	A mobile paediatric emergency response team	H1N1 influenza outbreak,	Describe the implementation of a mobile paediatric emergency response team for mildly ill children with influenza-like illnesses during the H1N1 swine influenza outbreak.	Not mentioned
13	Daniel. J et al.	2005	MMWR. Morbidity and mortality weekly report	Syndromic surveillance systems	Not mentioned	To identify and report acute illness clusters to health departments	State laboratory institute
14	Dias. T et al.	2013	2013 BRICS Congress on Computational Intelligence and 11th Brazilian Congress on Computational Intelligence	Development of a semantic platform for decision support based on the DOODA cycle	Dengue	To help dengue epidemics control	Not mentioned

(Continues)

TABLE 1 (Continued)

	Author	Year	Journal	Recommended solution	Illness	Main objective	Institution
15	Dopson. S	2009	Biosecurity and bioterrorism: biodefense strategy, practice and science	Early Warning Infectious Disease Surveillance program (EWIDS)	Not mentioned	To develop and implement a program to collaborate with states or provinces across international borders, to provide rapid and effective laboratory confirmation, and to expand surveillance capabilities	CDC
16	Drumright. L et al.	2015	BMC Infectious Diseases	Early warning and robust estimation of influenza burden system	Influenza	To inform hospital preparedness and operational, treatment and vaccination policies	Not mentioned
17	Eichner. M et al.	2007	BMC infectious diseases	Complex computer simulations	Not mentioned	To operate with an optimal combination of the competing requirements of precision, realism and generality.	Not mentioned
18	Ekong. I et al.	2020	JMIR mHealth and uHealth	Designing mobile position data contact tracing	COVID-19	To survey strategies for digital contact tracing for the COVID-19 pandemic and to present how using mobile positioning data conforms with Nigeria's data privacy regulations	Not mentioned
19	Fan. C et al.	2010	Canadian Journal of Public Health	Automated Mortality Surveillance System (MSS)	Pandemic H1N1 (ph1n1) influenza	To support evidence-based decision-making by physicians and public health.	Not mentioned
20	Farias. D et al.	2010	Disaster Medicine and Public Health Preparedness	Integrated data management system	Influenza A (H1N1) pandemic,	To create a single daily monitoring tool that could integrate multiple information sources	Not mentioned

TABLE 1 (Continued)

	Author	Year	Journal	Recommended solution	Illness	Main objective	Institution
21	Gould et al.	2017	Public health reports	Prevention-centric program to one focused on building syndromic surveillance capacity at the state and local level	Various hazardous events and disease outbreaks	Establishing a nationwide integrated public health surveillance system for early detection and assessment of potential bioterrorism-related illness	CDC
22	Guo. D et al.	2014	8th International Symposium of the Digital Earth, ISDE 2014	Cloud computation environment, supports aggregation of massive unstructured and semi-structured data, integration of various computing model sand algorithms;	Various hazardous events and disease outbreaks	Propose a three-tier collaborative Spatio-temporal visual analysis architecture to support emergency management.	Not mentioned
23	Horad. M et al.	2005	International Journal of Hygiene and Environmental Health	To create computer simulation models as 'what-if' tools for disaster preparedness planners. We have recently applied the approach to the issue of hospital surge capacity, and have reached some preliminary conclusions	Rural disaster	To introduce a conceptual framework for a study that applies a rigorous systems approach to rural disaster preparedness and planning	Not mentioned
24	Hutchins. S et al.	2008	Clinical infectious diseases: an official publication of the Infectious Diseases Society of America	Developing an algorithm for clinical evaluation of suspected smallpox disease.	Suspected smallpox	Developed an algorithm to evaluate patients rapidly for suspected smallpox.	CDC

(Continues)

TABLE 1 (Continued)

	Author	Year	Journal	Recommended solution	Illness	Main objective	Institution
25	James. A et al.	2007	Proceedings. Biological sciences	Developing a super spreading model	severe acute respiratory syndrome (SARS) and Ebola	To increase the probability that an outbreak will eventually cease, rather than continuing indefinitely	Not mentioned
26	Kahn. R et al.	2019	Prehospital and Disaster Medicine	Developing a simple model to forecast areas at highest risk of a cholera outbreak	Cholera	Determining when and where outbreaks happen and spread	Not mentioned
27	Lee. E et al.	2009	INTERFACES	Developing a fast and practical emergency-response decision-support tool	All disasters	To analyse planning strategies, compare the various options, and determine the most cost-effective combination of dispensing strategies is critical to the ultimate success of any mass dispensing effort	Not mentioned
28	Li. Y et al.	2017	Disaster medicine and public health preparedness	Mobile-based database with the application-based server	Infectious outbreaks	To build a database to collect infectious disease information at the scene of a disaster, with rapid acquisition of information regarding the infectious disease and rapid questionnaire customization at the scene of disaster relief by the use of a personal digital assistant (PDA)	Not mentioned

TABLE 1 (Continued)

	Author	Year	Journal	Recommended solution	Illness	Main objective	Institution
29	Loonsk. J et al.	2004	MMWR. Morbidity and mortality weekly report	Near-real-time electronic transmission of data to local, state and federal public health agencies from national regional, and local health data sources	All disasters	To enhance the nation's capability to detect, quantify and localize public health emergencies rapidly	Department of Defence and Veterans Administration medical treatment
30	Luo. W	2016	International journal of health geographics	Geo-social visualize model	All disasters	To examine the effectiveness of control strategies taking into account geo-social interaction patterns	Not mentioned
31	Mahmood. I et al.	2020	International Conference on Computational Science	Developing a simulation framework that models population dynamics and the interactions of both humans and mosquitoes	Dengue	To analyse and forecast the transmission and spread of an infectious disease in specific areas	Not mentioned
34	Murray et al.	2007	Developments in Biologicals	Modelling	All disasters	The effectiveness of modelling in outbreak control	Not mentioned
35	Ndeffo. M et al.	2011	PloS one	Our model provides new insights for policymakers in the optimal deployment of limited resources for control in the event of epidemic outbreaks at the landscape scale.	All disasters	To minimize the discounted number of infected individuals during an epidemic by designing a simple SIRS model	Not mentioned

(Continues)

TABLE 1 (Continued)

	Author	Year	Journal	Recommended solution	Illness	Main objective	Institution
36	Nguyen et al.	2018	BMC public health	Mathematical models that we simulated mechanistically its transmission parameters.	Ebola virus	A multiscale approach showing that individual dynamics were able to reproduce population-level observations.	Not mentioned
37	Nuño. M et al.	2008	Proceedings of the National Academy of Sciences of the United States of America	On pharmaceutical interventions mathematical model to model a residential care facility	Influenza pandemic	To determine whether an intrinsic ability to control access to these facilities provided a basis for protection against pandemic influenza	Not mentioned
38	Patroniti. N et al.	2011	Intensive care medicine	Set up a national referral network of selected intensive care units (ICU) able to provide advanced respiratory care up to extracorporeal membrane oxygenation (ECMO) for patients with acute respiratory distress syndrome	H1N1 and SARS	To centralize all potentially severe patients and all necessary resources in a limited number of tertiary hospitals to provide advanced treatment options including ECMO	Italian Ministry of Health
39	Paul. J et al.	2012	Journal of Homeland Security and Emergency Management	Graph matching methods	H1N1	A mixed-integer programming model (MIP) that analyses patient symptom data available at hospitals to generate patient graph match scores.	Kennesaw state university
40	Piltch-Loeb. R et al.	2014	Biosecurity and bioterrorism: biodefense strategy, practice and science	Critical incident registry	H1N1 influenza pandemic	To identify the optimal characteristics of a critical incident registry (CIR) for public health emergency preparedness	Not mentioned

TABLE 1 (Continued)

	Author	Year	Journal	Recommended solution	Illness	Main objective	Institution
41	Pogreba-Brown. K et al.	2013	Disaster Medicine and Public Health Preparedness	Syndromic surveillance system	All disasters	To develop an onsite syndromic surveillance system for the early detection of public health emergencies and outbreaks at large public events	The Maricopa County Department of Public Health(MCDPH)
42	Raude. J and Setbon. M	2011	PLoS ONE	Factor analyses to provide insight into the nature and predictors of the protective patterns	Influenza outbreak	To protect people from the risk of infection in the case of an avian influenza outbreak, as well as the lay perceptions of the threat that underlie these risk reduction strategies.	Not mentioned
43	Riley. S and Ferguson. N	2006	Proceedings of the National Academy of Sciences of the United States of America	Developing the Markov chain Monte-Carlo algorithm to generate sociospatial contact networks that were consistent with demographic and commuting data.	Smallpox epidemic	To ensure that widespread community transmission does not occur.	Not mentioned
44	Rosenfeld. R et al.	2009	Journal of public health management and practice: JPHMP	Use of preparedness modelling to enhance the planning for vulnerable and at-risk populations, all-hazard emergencies and infectious disease containment strategies	Pandemic influenza	using computer modelling and scenario-based analyses to better frame problems and opportunities, integrate data sources, expect outcomes and improve multistakeholder decision-making	CDC

(Continues)

TABLE 1 (Continued)

	Author	Year	Journal	Recommended solution	Illness	Main objective	Institution
45	Sacks. J et al.	2015	Global health, science and practice	Building the mobile application compare and business intelligence software for real-time identification of contacts and contact tracers through timestamps and collection of GPS points with their surveillance data.	Ebola virus	To develop a smartphone-based contact tracing system that is linked to analytics and data visualization software as part of the Ebola response in Guinea	Not mentioned
46	Schwartz. R and Bayles. B	2012	American journal of infection control	Developing university pandemic influenza-dedicated Web sites as an information source	H1N1 influenza pandemic	Representing information regarding preparedness and response plans against outbreaks at pandemic-dedicated university Web sites	Not mentioned
47	Senel. K et al.	2020	Disaster Medicine and Public Health Preparedness	Proposing an 'Single Parameter Estimation' approach to circumvent potential problems and check the robustness of this new approach by model variation and structured permutation tests.	COVID-19	To predict the progress of COVID-19 worldwide, despite their rather simplistic nature.	Not mentioned
48	Shearer. F et al.	2020	PloS one	Propose a decision support system	Infectious disease	To synthesize the available data to provide enhanced situational awareness, to predict the future course of the pandemic and likely associated social and economic costs, and to plan mitigation strategies	Us army international technology center Pacific (itc-pac)

TABLE 1 (Continued)

	Author	Year	Journal	Recommended solution	Illness	Main objective	Institution
49	Shimoni. Z et al.	2006	Medical Hypotheses	Developing automate disease surveillance system with online monitoring, be independent of the medical personnel	Influenza	Acute planning of distribution of medical resources	Not mentioned
50	Shin. E et al.	2020	Studies in health technology and informatics	Developing a Globally Localized Epidemic Knowledgebase (GLEK) that can be utilized for efficient and optimal epidemic surveillance	SARS and Middle East respiratory syndrome	Customizing the local needs by developing best-tailored intervention	Ministry of Education of the Republic of Korea
51	Stein. M et al.	2012	BMC public health	Developing the asiaflucap Simulator which was built in MS Excel© and contains a user-friendly interface which allows users to select mild or severe pandemic scenarios, change resource parameters and run simulations for one or multiple regions	H1N1	To implement response measures or interventions described in plans and trained in exercises based on the available resource capacity	National Institute for Public Health and the Environment (RIVM)
52	Steward. D et al.	2007	Journal of medical systems	Simulation model	All disasters	Preparation and evaluation of the model	Not mentioned
53	Suganthe. R and Sreekanth. G	2016	Journal of Medical Imaging and Health Informatics	Epidemic routing (ER) protocol within the cluster	All disasters	To decrease a Delay Tolerant Network environment typically contains comparatively sparse nodes which leads to a network partition.	Not mentioned

(Continues)

TABLE 1 (Continued)

	Author	Year	Journal	Recommended solution	Illness	Main objective	Institution
54	Tiwari. S et al.	2020	Disaster Medicine and Public Health Preparedness	Developing a prediction model with machine learning methods	COVID-19	The objective of this paper is to prepare the government and citizens of India to take or implement the control measures proactively to reduce the impact of coronavirus disease 2019 (COVID-19).	Not mentioned
55	Tizzoni. M et al.	2014	PLoS computational biology	Modelling Human mobility as a large-scale spatial-transmission model of infectious diseases	Influenza-like-illness epidemic	Correctly modelling and quantifying human mobility	Not mentioned
56	Todkill. D et al.	2017	Prehospital and Disaster Medicine	Presenting Ambulance data syndromic surveillance system (ADSSS)	All disasters	Feasibility of ambulance Data Syndromic Surveillance System (ADSSS) and utility in enhancing the existing suite of PHE syndromic surveillance systems	Mfph public health England,
57	Turner. A et al.	2018	Disaster medicine and public health preparedness	Developing an Infectious disease network (IDN)	Ebola virus disease (EVD)	To provide a coordinated response and utilize appropriate personal protective equipment (PPE) for the transport or treatment of a suspected or confirmed serious communicable disease patient.	Georgia Department of Public Health

TABLE 1 (Continued)

	Author	Year	Journal	Recommended solution	Illness	Main objective	Institution
58	Vokinger. N et al.	2020	Swiss medical weekly	Developing a mobile-based framework for applications	COVID-19	Building on an existing trustworthiness checklist for digital health applications to contribute to controlling the current epidemic or mitigating its effects.	Institute for Implementation Science in Health Care
59	Wallace. D et al.	2006	Resuscitation	Designing robotic patient simulators or Simulation resource utilization	Influenza	To resuscitate simulators and actors during a drill and compares the times required to perform procedures on simulator patients to published values for real patients.	Kings county hospital center
60	Wang. J et al.	2008	Journal of public health (Oxford, England)	Data-based analysis to find link and association	Severe acute respiratory syndrome (sars)	To develop a mathematically rigorous and scientifically meaningful SARS modelling framework that accounts for the crucial epidemic associations	Beijing Center for Disease Control
61	Wu. J et al.	2011	Experimental Biology and Medicine	Developing mathematical models of infectious diseases	Influenza pandemics 2009	Developing mathematical models have been widely used in the past decade to aid pandemic planning by allowing detailed predictions of the speed of the influenza pandemic and the likely effectiveness of alternative control strategies	Harvard Center for Communicable Disease Dynamics

(Continues)

TABLE 1 (Continued)

	Author	Year	Journal	Recommended solution	Illness	Main objective	Institution
62	Yaylali. E et al.	2014	Public health reports	Simulation model -Markov modelling	2009 H1N1 outbreak	To provide sophisticated techniques that can model the system, simulate, and optimize complex systems, even under uncertainty.	CDC and North Carolina Preparedness and Emergency Response Research Center
63	Zaric. G et al.	2002	IMA Journal of mathematics applied in medicine and biology	Computational analyses or some reallocation of resources over the time horizon of the problem	All disasters	To develop a dynamic resource allocation model in which a limited budget for epidemic control is allocated over multiple periods that affect multiple populations.	Not mentioned
64	Zhan. Y et al.	2010	2010 International Conference on Management and Service Science, MASS 2010	Developing a GIS and decision support model	All disasters	To assist government authorities to identify evacuation strategy shortly after the outbreak of disasters, and proposes a GIS-based urban emergency decision support model for large-scale crowd evacuation.	Not mentioned
65	Zhang. X et al.[23]	2020	Wuhan Daxue Xuebao (Xinxi Kexue Ban)/Geomatics and Information Science of Wuhan University	Integration of vertical system and horizontal system, based on the idea of 'let data run more, rely on accurate information, and outperform viruses with electromagnetic waves'.	COVID-19	Providing a solution to increase speed for efficient management of time, data, information and resources in disease outbreaks	Geomatics and Information Science of Wuhan University

Abbreviations: CDC, Centers for Disease Control and Prevention; GIS, geographic information system.

TABLE 2 Analysis of some characteristics of included articles

Article type	Frequency	Percentage
Conference proceedings	8	12.7%
Journal	55	87.3%
Year of publication		
2000–2004	2	3.2%
2005–2008	18	28.6%
2009–2012	16	25.4%
2013–2016	11	17.5%
2017–2020	16	25.4%
Country		
USA	17	27.0%
UK	5	7.9%
Canada	3	4.8%
China	3	4.8%
Georgia	3	4.8%
Germany	2	3.2%
Argentina	1	1.6%
Brazil	1	1.6%
More than two European countries	1	1.6%
France	1	1.6%
Guinea	1	1.6%
India	1	1.6%
Israel	1	1.6%
Italy	1	1.6%
Korea	1	1.6%
Montgomery	1	1.6%
Mozambique	1	1.6%
Switzerland	1	1.6%
Not mentioned	18	28.6%
Problems		
All disasters	15	23.08%
H1N1 and Influenza outbreak	27	41.54%
COVID-19	5	7.69%
Ebola virus disease	4	6.15%
Severe acute respiratory syndrome	1	1.54%
Smallpox epidemic	3	4.62%
Dengue	2	3.08%

(Continues)

TABLE 2 (Continued)

Article type	Frequency	Percentage
Middle East respiratory syndrome	1	1.54%
Cholera	1	1.54%
Malaria	1	1.54%
Rural disaster	1	1.54%
Other infectious diseases	4	6.15%

TABLE 3 Applied medical informatics-based solutions with their frequency

Applied solutions	Frequency	Percentage
Emergency response system	31	47.7%
Computational methods	30	46.2%
Outbreak prediction models	26	40.0%
Resource allocation systems	23	35.4%
AI-based algorithms	22	33.8%
Epidemiological model	20	30.8%
Database and registry systems	18	27.7%
Warning system	17	26.2%
Simulation models	17	26.2%
Patient management systems	14	21.5%
Geographic positioning	12	18.5%
Geographic transmission model	10	15.4%
Clinical decision support system (CDSS)	9	13.8%
Syndromic surveillance systems	8	12.3%
Network of information	8	12.3%
Mobile-based system	4	6.2%
Providing preparedness information	2	3.1%
Cloud computing	1	1.5%
Computerized network protocol	1	1.5%

placed in alert mode. Later, the subsystem of outbreak prediction will activate. Once epidemiologists confirm the outbreak, a survival system begins to run. Then the subsystems concerning clinical care and outbreak management will start to operate. The results of the epidemiological subsystem can also be used by clinical researchers for further studies. By integrating this subsystem with geographic systems, a model can be designed to visualize how the disease is transmitted, identifying infected areas and finding people at risk. Through analysing the obtained data and connecting the results to mobile applications, it is also possible to inform people who live in high-risk areas.

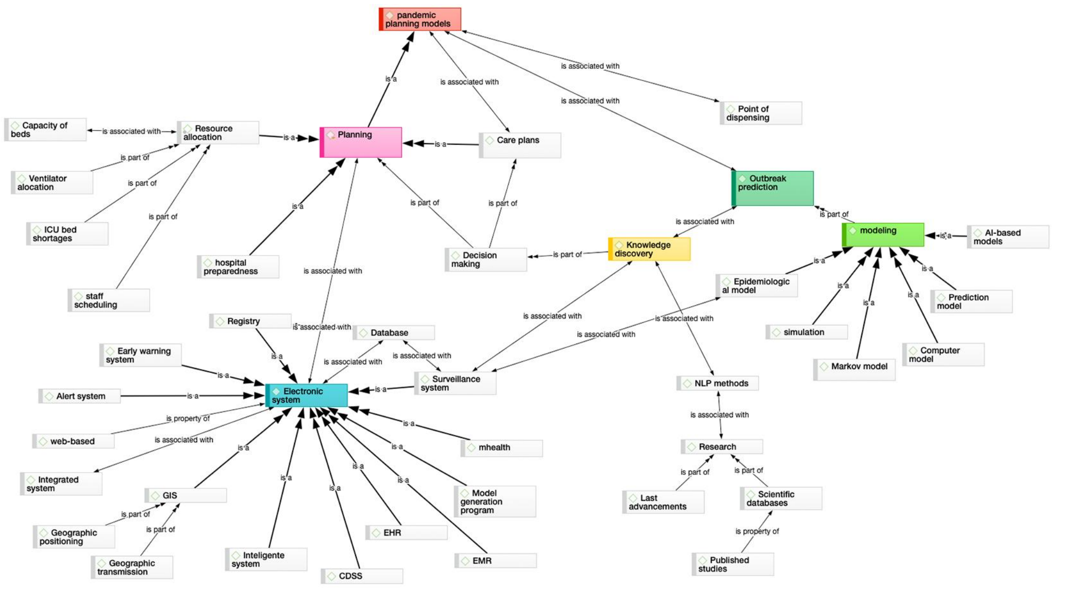

FIGURE 2 Thematic map of main concepts extracted from the literature review [Colour figure can be viewed at wileyonlinelibrary.com]

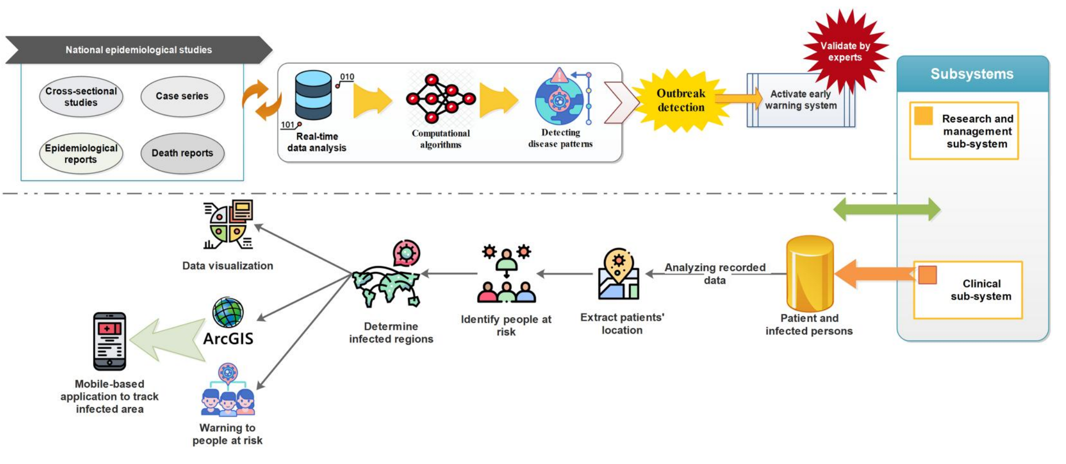

FIGURE 3 The epidemiological subsystem model [Colour figure can be viewed at wileyonlinelibrary.com]

3.3.2 | Research and management subsystem

During the disease outbreak, one of the challenges was considered by most articles is how to allocate health and human resources during the epidemic. Therefore, it is necessary to consider a subsystem to manage the proper allocation of resources to the health system. Reviewing literature showed that after a new disease outbreak, resource allocations could be handled by defining appropriate heuristic algorithms and analysing real-time data. The schematic model of the suggested subsystem is represented in Figure 4.

Fair and efficient resource allocation is one of the biggest challenges for health care managers in the recent epidemic, COVID-19. Even one of the most notable problems in developed countries was allocating well-equipped health resources such as beds and staff to the areas that need them most as soon as possible. Therefore, in an

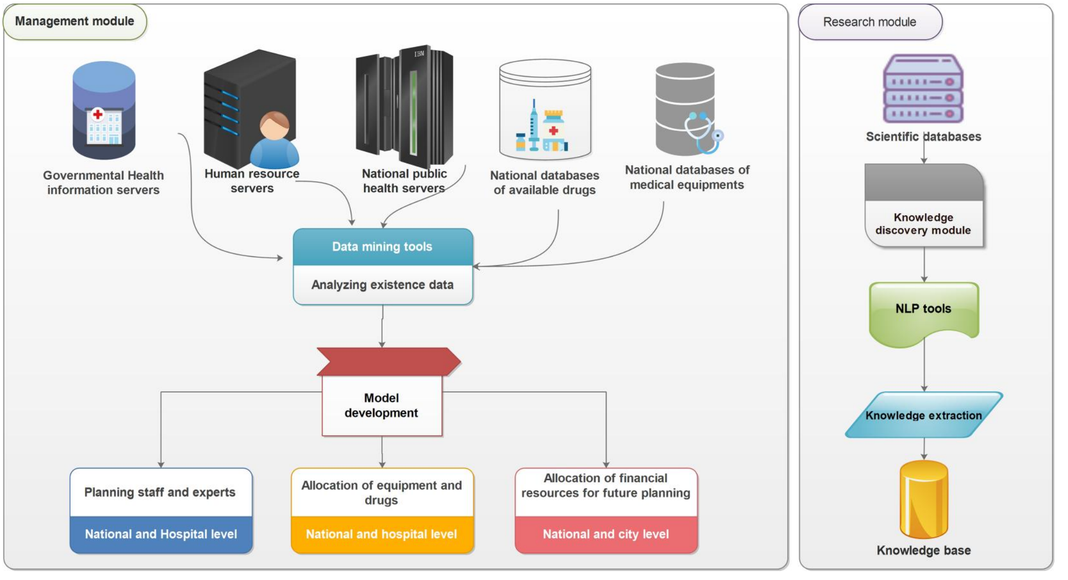

FIGURE 4 The research and management subsystem model; NLP, natural language process [Colour figure can be viewed at wileyonlinelibrary.com]

epidemic, efficient resource allocation could be provided by applying machine learning algorithms. Such algorithms provide a health system. Such algorithms enable health systems to make the best decisions about allocating the most appropriate facilities by using real-time data analysis and learning from past experiences in low- and middle-income countries. The developed model in Figure 4 refers to the smart allocation model which will be created based on machine learning methods.

Given the importance of understanding the latest scientific evidence and the pattern of disease outbreak, a separate section is set up to extract the necessary knowledge under the management system for the automated extraction of information from published literature. Biomedical text extraction or the use of natural language process techniques can be used in this section to find the latest published literature and achievements through biomedical databases. Researchers and physicians can use this tool to enjoy the benefits of easier access to the latest scientific evidence and automating data abstraction in a short time. Extracted and classified knowledge can also be used to enhance the quality of outbreak control or as a source of knowledge in other subsystems.

3.3.3 | Clinical care subsystem

In an epidemic event, patient treatment and follow-up are the most significant issue to decrease the mortality rate. Hence, the clinical care subsystem is explained in the following based on the most useful strategies applied in reviewed articles. In a thematic analysis of the most influential ideas, clinical care planning was one of the most repetitive concepts extracted in the qualitative analysis stage of this research.

The most common solutions that appeared in the analysis regarding this section include (1) implementing electronic health records for patient management, (2) using decision support systems and computerized physician order entry tool to make better decisions and prevent medical errors, and (3) model generation. Moreover, telemedicine can be utilized in clinical care planning. Due to the importance of the clinical system and its complexities, this system is better designed in two subsystems of monitoring outpatients and inpatients.

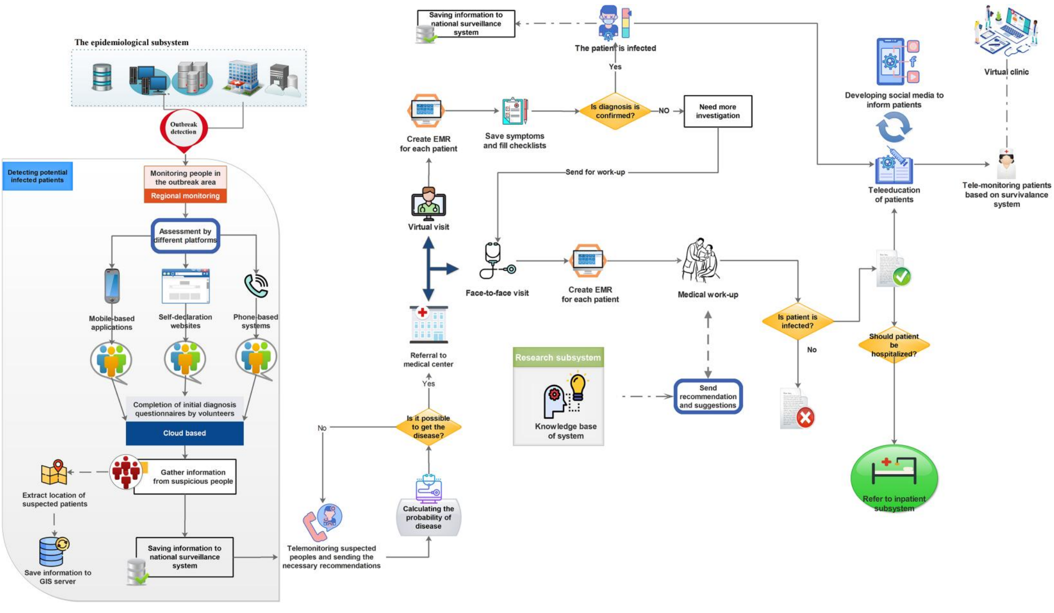

FIGURE 5 The outpatient subsystem model [Colour figure can be viewed at wileyonlinelibrary.com]

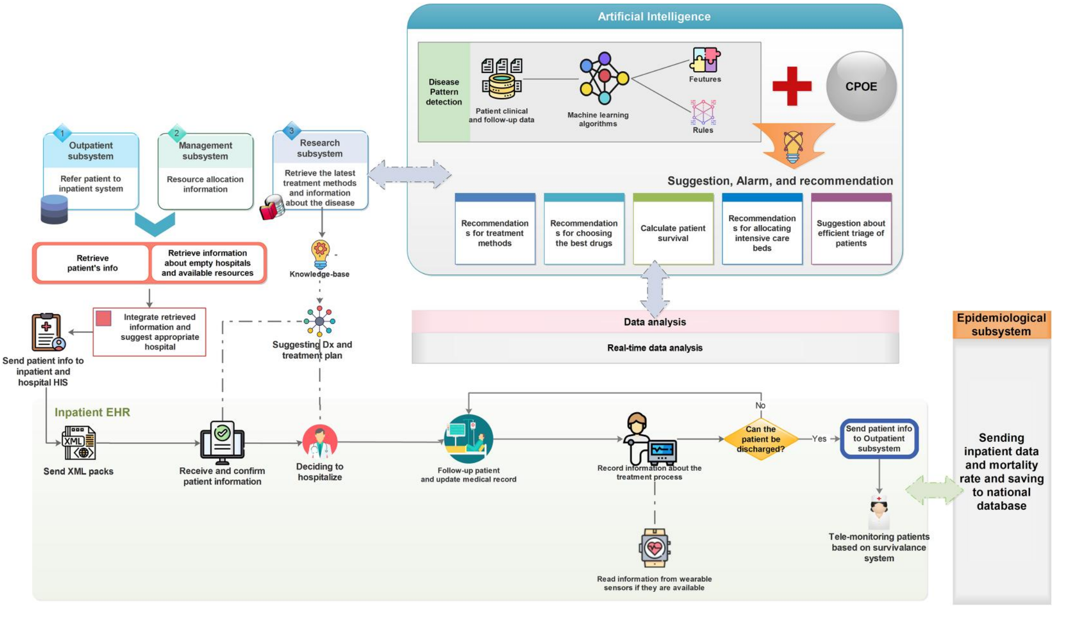

FIGURE 6 The inpatient subsystem model [Colour figure can be viewed at wileyonlinelibrary.com]

3.3.4 | Outpatient care subsystem

The proposed system can be designed in such a way that the rapid alert system is activated when the disease is detected. By activating the alert status, this system will automatically give the necessary alerts to medical centres. Additionally, the latest treatment protocols will be provided to specialists in the form of embedded knowledge in such a framework.

As it is apparent in Figure 5, an appropriate strategy can be employed in this section to identify people at risk using knowledge obtained from evidence, and regular monitoring of epidemiological data. The early screening module is one of the main parts of the proposed framework.

As soon as the imminent alert system is activated, the infected geographical areas could be recognized. The necessary warning messages can then be sent to residents of high-risk areas to prevent further outbreaks. Early screening of patients could be conducted in infected areas by applying different methods such as developing self-assessment websites and mobile-based applications, and telephone-based counselling. Accordingly, all of the people who were at the risk of exposure can be determined. Taking such an approach can also be effective in reducing the prevalence of COVID-19 in low- and middle-income countries.

If the person is suspected of having the disease, he/she will be assessed based on standard checklists by health care providers. Then, the risk of disease in each person will be calculated. If the risk of disease is high, the patient will be monitored remotely through regular telephone consultation. For more investigation, the patient will be referred to medical centres if he needs it. Then, a medical record will be created for him. If he needs to be hospitalized, his information will be referred to the hospital subsystem. In a viral illness, the patient must be quarantined. To better communicate, secure social networks can be designed for patients to discuss their problems and share their experiences. These social networks should be managed under the supervision of health professionals to prevent the spread of untruths.

Developing telemedicine programs is crucial to monitor non hospitalized patients in severe communicable diseases like COVID-19. So, monitoring patients through telemonitoring programs and virtual clinics could reduce disease transmission. It can be helpful in better controlling the spread of diseases such as COVID-19.

Self-monitoring of people who have some symptoms is possible by employing such a system. Through telemonitoring, if the patient has the initial symptoms of the disease, it can first be followed remotely. After an initial investigation, the system referred the patient to medical centres if it is required. According to other studies, tele-education can be used to better educate patients for the prevention and control of the disease using social networks and distance education.

3.3.5 | Inpatient care subsystem

In the proposed model, once the patient's referred, the information is automatically entered into the system to create a file for the patient. During patient monitoring, control, and follow-up, all recorded information is continuously analysed to extract the disease pattern. At the same time, due to the connection of the system to the knowledge base, patients are followed according to the treatment protocols based on standard treatment steps. Physicians are also asked to enter their new findings concerning the disease in the relevant section. These new achievements could be added to the knowledge-base after expert approval. The details of the suggested strategy are shown in Figure 6.

At the time of hospitalization, the knowledge regarding the disease symptoms and its characteristics are extracted for better management and disease control using machine learning algorithms and real-time data analysis. The knowledge can be used for appropriate resource allocations in critically ill patients, prescribing the most effective drugs and prioritizing patients.

4 | DISCUSSION

Through this survey, the published articles regarding medical informatics application for preparedness against disease outbreak were investigated to extract topics of interest. The evidence showed that more developed countries such as the United States have more tendency to apply medical informatics strategies to fight epidemics

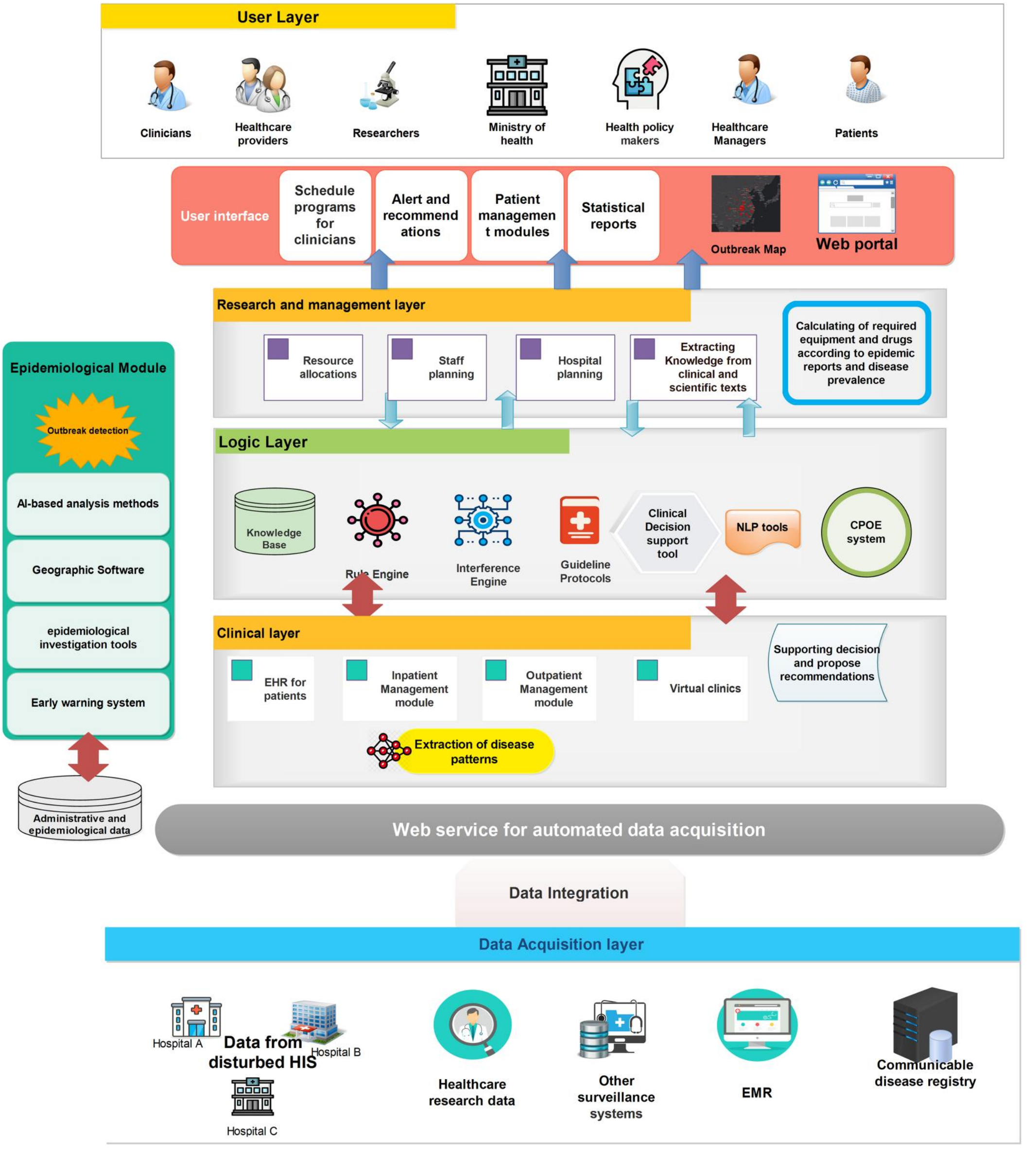

FIGURE 7 Overall conceptual model [Colour figure can be viewed at wileyonlinelibrary.com]

more efficiently. Through this survey, the highest frequency of epidemics related to the influenza outbreak. However, this result was expected due to the worldwide outbreak of influenza.

Based on the experiences of countries in similar diseases epidemic, it is possible to control the spread of the virus more effectively with the appropriate use of modern technologies.[24,25] Hence, valuable experiences and applied strategies were explored through thematic analysis. According to the extracted main themes, we devised an appropriate conceptual framework for better prevalence control. After identifying the main themes, solutions concerning medical informatics were specified in each section. A suggested model according to these strategies was represented in terms of sub-systems. The proposed model can be summarized in the form of an ultimate model represented in Figure 7. This notation ties well with previous studies wherein effective preparedness should include prevention, control and management planning.[26–29]

From the medical informatics view, AI-based strategies are the most common technique applied in studies. By applying AI methods, researchers developed intelligent systems such as early warning applications, prediction models, epidemiological systems and intelligent surveillance systems to help healthcare organizations to fight outbreaks easier. Most of these systems were related to disease management after the emergence of the outbreak. Thus, developing an integrated intelligent system could fight disease outbreak at organizational and clinical levels can be accounted for a research gap. Such a system should be fighting against pandemic before and after a disease outbreak.

The proposed framework is a type of intelligent clinical surveillance system for real-time monitoring of infectious and epidemic diseases such as COVID-19, which is equipped with patient monitoring systems, prevention and analytical tools for further research and study. Because this model is customized for contagious disease monitoring, we tried to define the proposed system in such a way it can prevent, control, and follow patients at the national level. Similarly, Oppenheim et al.[30] declared that an outbreak preparedness plan involves early detection, disease management and control, surveillance, case findings, patient treatment and management. The final system should be designed in such a way to benefit all of the patients and health care providers in clinical fields. Based on the main categories identified through thematic analysis, as a result of analysing the main concepts presented in the studies, solutions appropriate to each section have been proposed in each part. As shown in Figure 7, the proposed model is a four-layer model. These layers comprise the user interface layer, the logic layer, the application layer and the data layer. Despite each layer of the layered architecture pattern has a specific role and responsibility, all layers have interacted with each other to pass the information up to the presentation layer. Layered architecture pattern is the most common architecture pattern for developing web-based applications in healthcare settings.[31]

Analysis of related articles showed that the most common strategy applied by researchers was designing early warning systems. In line with previous studies, it is apparent that the first step of 'preparation' is the continuous investigation and prevention of further outbreaks.[27] Accordingly, the popularity of mathematical models to forecast epidemic diseases has been increased to better help policy-makers in decision-making with the development of AI-based methods in other studies.[32] Consequently, outbreak investigation and prediction are considered as a prerequisite of preparedness to activate other subsystems in the form of an early detection system in the epidemiological section.

In an epidemic, physicians should be aware of the best available evidence as soon as possible. Meanwhile, the work of the medical staff increases during the outbreak of the disease. Therefore, limited time is a common challenge in critical situations. As in the Coronavirus pandemic, the workload of healthcare providers has increased, and health care providers have to work in heavy workload conditions.[33,34] To address this challenge, an AI-based technique such as text mining in the research and management section was considered to retrieve the required evidence as soon as possible. Recently, some studies were conducted to extract valuable knowledge from published literature and summarizing the most up-to-date research using natural language processing.[35] This solution can enable clinicians to access information from a huge amount of scientific evidence published recently.[36]

Allocation of the appropriate resources and well-coordinated care during the time of the outbreak is one of the main themes and strategies extracted through our analysis. It accounted for another challenge that we usually face in an outbreak.[37] Thus, an intelligent procedure was considered in our proposed model using data mining mechanisms to solve this problem.

Case findings and accurate diagnosis are crucial in controlling the outbreak of an epidemic.[38] Hence, a systematic process in patient management and clinical care planning is embedded to find infected people in the proposed model. The next important issue is related to the continuous care of infected patients. Thus, establishing a standard of care for triage and treatment could be remarkably efficient during a disease outbreak in disease control and enhance patient safety.[39] Patient management is also considered in two parts for an effective clinical care program. It comprises outpatient and inpatient modules using solutions such as applying decision support systems, implementing electronic health records, remote monitoring and utilizing data mining tools in the presented model.

The proposed model tries to provide a framework to prepare for a sudden outbreak of disease by considering usable medical informatics methods. This model could provide deeper insights into the designing of a surveillance system for public health professionals from a medical informatics perspective. Such a framework can be optimized to be applied in different situations. Moreover, this study is the first stage of further research to validate the framework through focus group discussions, Delphi survey, or expert consensus. Once the model is validated, it can be considered as a reference framework in developing surveillance systems to prepare for the next epidemic.

There are several limitations to this research. The proposed framework was designed from the author's point of view. However, this is only a proposed model for further studies and a new perspective on the control of communicable diseases regarding medical informatics solutions. Also, this is a non-validated model, and its validation will be examined in future studies.

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ETHICS STATEMENT

The study involves only a review of literature without involving humans and/or animals. The authors have no ethical conflicts to disclose.

CONFLICT OF INTERESTS

The author(s) declared no potential conflicts of interest concerning the research, authorship, and/or publication of this article.

AUTHORS CONTRIBUTION

Reza Safdari: Conception and design of study, Acquisition of data, Analysis and/or interpretation of data, Revising the manuscript critically for important intellectual content. Hamidreza Abtahi: Conception and design of study, Acquisition of data, Draughting the manuscript. Marsa Gholamzadeh: Conception and design of study, Acquisition of data, Analysis and/or interpretation of data, Draughting the manuscript, Revising the manuscript critically for important intellectual content. Approval of the version of the manuscript to be published

DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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