Yang et al. BMC Medical Informatics and Decision Making (2025) 25:7
https://doi.org/10.1186/s12911-024-02809-4

BMC Medical Informatics and Decision Making

RESEARCH

Open Access

# Digital-based emergency prevention and control system: enhancing infection control in psychiatric hospitals

Mi Yang[1*], Xiaojun Zhu[2], Fei Yan[1], Xincheng Huang[1], Zhixue Wu[2], Xin Jiang[1], Yan Huang[3] and Zezhi Li[4,5,6*]

## Abstract

**Background** The practical application of infectious disease emergency plans in mental health institutions during the ongoing pandemic has revealed significant shortcomings. These manifest as chaotic management of mental health care, a lack of hospital infection prevention and control (IPC) knowledge among medical staff, and unskilled practical operation. These factors result in suboptimal decision-making and emergency response execution. Consequently, we have developed a digital-based emergency prevention and control system to reinforce IPC management in psychiatric hospitals and enhance the hospital IPC capabilities of medical staff.

**Methods** The system incorporates modern technologies such as cloud computing, big data, streaming media, and knowledge graphs. A cloud service platform was established at the PaaS layer using Docker container technology to manage infectious disease emergency-related services. The system provides application services to various users through a Browser/Server Architecture. The system was implemented in a class A tertiary mental health center from March 1st, 2022, to February 28th, 2023. Twelve months of emergency IPC training and education were conducted based on the system. The system's functions and the users' IPC capabilities were evaluated.

**Results** A total of 116 employees participated in using the system. The system performance evaluation indicated that functionality ($3.78 \pm 0.68$), practicality ($4.02 \pm 0.74$), reliability ($3.45 \pm 0.50$), efficiency ($4.14 \pm 0.69$), accuracy ($3.36 \pm 0.58$), and assessability ($3.05 \pm 0.47$) met basic levels (> 3), with efficiency improvement and practicality achieving a good level (> 4). After 12 months of training and study based on the system, the participants demonstrated improved emergency knowledge ($\chi^2 = 37.69$, $p < 0.001$) and skills ($p < 0.001$).

**Conclusion** The findings of this study indicate that the digital-based emergency IPC system has the potential to enhance the emergency IPC knowledge base and operational skills of medical personnel in psychiatric hospitals. Furthermore, the medical personnel appear to be better adapted to the system. Consequently, the system has the capacity to facilitate the emergency IPC response of psychiatric institutions to infectious diseases, while simultaneously optimising the training and educational methodologies employed in emergency prevention and

*Correspondence:
Mi Yang
565136170@qq.com
Zezhi Li
biolpsychiatry@126.com

Full list of author information is available at the end of the article

control. The promotion and application of this system in psychiatric institutions has the potential to accelerate the digitalisation and intelligence construction of psychiatric hospitals.

**Key points**

• Digital Emergency-Plan System Improved Responding Efficiency Of Psychiatry Hospital.
• Digital System Enhanced Knowledge Level and Emergency Responding Ability of Staff.
• Digital Emergency-Plan System Helped Relocation of Emergency Resource.

**Keywords** Emergency plan, Psychiatry hospitals, Infectious disease, Emergency prevention and control

## Introduction

Although the *National Emergency Plan for Public Health Emergencies* [1] issued in 2006 offered clear guidelines for preventing and controlling infectious diseases in healthcare institutions, the limited capacity of most healthcare facilities to handle intensive care and prevent hospital-acquired infections during the three-year COVID-19 pandemic [2] hindered the plan's effective implementation in practical situations. Consequently, this led to inefficiencies in decision-making and implementation of measures for infectious disease prevention and control [3]. The impact of the COVID-19 pandemic has been profound, particularly in hospitals that cater to patients with special care needs [4]. Additionally, mental health institutions have their inherent shortcomings. For instance, these facilities often face challenges due to close staff-patient contact during patient restraint procedures [5]. The limited number of patients also results in restricted activity spaces. Structural barriers exist in the implementation of infection prevention and control (IPC) measures and management in these care settings [6]. The team at the institution possesses expertise primarily in psychiatric specialties, which leads to a lack of knowledge and skills in infectious disease prevention and control [4, 7].

Additionally, the majority of text-based emergency plans designed to prevent and control infectious diseases lack inherent intelligence to iterate and optimize themselves effectively [8, 9], which poses a significant risk of widespread nosocomial infection outbreaks in psychiatric medical institutions during severe public health crises like COVID-19. Consequently, staff members experience significant physical and mental stress while carrying out practical IPC measures. Therefore, staff members face great physical and mental stress while performing their duties in IPC efforts [10, 11]. In the context of significant stress, medical personnel may be prone to engage in the inappropriate utilisation of personal protective equipment (PPE) and disinfectants. Moreover, the absence of monitoring systems for personnel and material resources in IPC measures can lead to insufficient stockpiles of disinfection supplies and PPE, as well as the improper allocation of resources [12]. Furthermore, inadequate support from the team specializing in infectious disease medical technology, coupled with subpar coordination among multiple departments, hampers the emergency management capabilities of frontline medical staff [13, 14]. These shortcomings greatly complicate the implementation of text-based emergency plans, thereby posing significant occupational exposure risks to medical workers [15], and even further escalate into multiple outbreaks of nosocomial infections across different locations.

Digital emergency prevention and control systems have been implemented with considerable success in a number of other fields, including electric power [16], geological disasters [17, 18], smart cities [19], urban flood prevention and control [20]. The emergence of the COVID-19 pandemic has prompted the utilization of technologies such as big data and artificial intelligence (AI) in epidemic prevention, diagnosis, and treatment [21]. These advancements serve to address the limitations associated with precise diagnosis, efficient IPC measures, and prompt treatment [22, 23]. There are also a wide range of applications of AI or big data in psychiatric hospitals [24], such as remote diagnosis and treatment, prediction of psychological state [25], precision diagnosis and prediction of efficacy [26]. Nevertheless, there is a scarcity of reports regarding the implementation of AI-based digital emergency plan systems in psychiatric hospitals. Historically, emergency plan management in such hospitals predominantly relied on text-based (paper) formats. This approach lacked the ability to promptly integrate with the evolving epidemic situation and failed to provide real-time control over the specific execution steps in emergency response [27]. Text-based contingency plans solely rely on manual recording of information generated during the emergency response process, thereby lacking the ability to accurately analyze crucial details like process execution time and communication records afterward. Moreover, psychiatric institutions face limitations in terms of individual disposal capabilities during the fight against COVID-19, which hinders the possibility of achieving effective cooperation in IPC efforts, as well as the sharing of medical resources [28, 29]. Therefore, we have developed a Digital-Based Emergency Prevention and Control System (D-B_EPCS) for infectious diseases, which incorporates modern information technologies such as big data, streaming media technology and knowledge graph technology (KGT) to improve the psychiatric hospital's accurate decision-making ability and enhance the medical staff's skills.

## Methods

### Brief introduction of the digital-based emergency prevention and control system

Utilizing cutting-edge information technologies including Cloud computing, Big data, Streaming media, and Knowledge Graph, we have developed a comprehensive cloud service: *Platform as a Service* [30, 31], using Docker container technology [32, 33]to effectively manage and segment emergency services pertaining to infectious diseases. The D-B_EPCS further provides application services to diverse users through the *Browser/Server Architecture* [34, 35]. By deploying D-B_EPCD server on a cloud server and leveraging its resources such as virtual machines, storage, and load balancing, we ensure optimal high availability and scalability for the platform.

The D-B_EPCS is designed according to GJB/Z 102A-2012 "*Guide for military software safety design*" (https://www.doc88.com/p-7018433753463.html) and GB/T 39725−2020 " *Information security technology – Guide for health data security*" (http://www.phic.org.cn/zcyjybzpj/bzypj/bzgf/gjbz/202103/P020210331605989883649.pdf), using *HyperText Transfer Protocol Secure* (HTTPS) [36, 37] to encrypt HTTP messages at the application layer, and then use *the Secure Sockets Layer* (SSL) [38] certificate issued by *Certificate Authority* (CA) [39–42] to establish a secure channel at the transport layer to realize data encryption transmission and identity authentication between the client and the server, which not only ensures data security for user login and business operations but also prevents network attacks such as *Domain Name System* (DNS) [43, 44] hijacking and effectively protects user privacy and system security.

D-B_EPCD uses the *Knowledge graph* [45] as the underlying framework to provide data and intelligence functions to the application end. It encompasses functions such as compiling, accessing, presenting, and executing emergency plans. By integrating with hospital information systems (HIS), laboratory information management systems (LIS), electronic medical records (EMR), clinical information systems (CIS), hospital resource planning (HRP), and other medical databases, D-B_EPCD incorporates an intelligent early warning function based on Big data analysis. The technology roadmap of D-B_EPCD is shown in Fig. 1, and the structure of the *Knowledge graph* is shown in Fig. 2. The application software of this system is compatible with a range of devices, including mobile phones, touch screens/tablets, and desktops. It is primarily designed to support various aspects of infectious disease emergency prevention and control, including pre, during, post, and training education. The system deployment is shown in Fig. 3.

#### Pre-event

D-B_EPCD provides a cloud-based comprehensive knowledge base that encompasses emergency-related laws and regulations, case studies, and skills knowledge. The emergency plan management function enables users to edit, delete, store, and rehearse emergency plans. Additionally, D-B_EPCD incorporates an "AI assistant intelligent response" feature based on knowledge mapping technology, allowing for efficient information queries and display. The intelligent question and answer (QA) function facilitates knowledge learning and skills practice through education. It also enables emergency exercises to be conducted in a safe environment, allowing emergency responders to enhance their response preparedness and capabilities by practicing emergency response procedures.Please confirm whether the supplementary files are correctly identified. Amend them if necessary.The supplementary files (table and figures) are correctly identified, and these files are necessary.

#### Mid-event

D-B_EPCD assists emergency-related personnel in carrying out emergency disposal work effectively. On-site executives perform their tasks efficiently through the cell phone terminal. Figure S1 shows the user interface of the cell phone terminal; Figure S2 shows an emergency exercise example on a cell phone.

Peripheral commanders get real-time feedback (video, voice, and short message) on-site execution, realizing comprehensive control of site situation and allowing accurate judgment and efficient decision-making by streaming-technology-based information synchronization in a cell phone, computer terminal, and customized terminal. Figure S3 shows an instance of emergency exercise on a desktop.

#### Post-event

D-B_EPCD provides comprehensive reports, logical analysis, effectiveness evaluation, and information tracing for emergency rehearsals. Figure S4, included as a supplementary material, provides a straightforward illustration of the report format. These features assist in adjusting and revising emergency plans, conducting evidence-based research, and summarizing scientific findings. Regular repetitions of emergency plan deductions and exercises aid staff in becoming thoroughly acquainted with the emergency plan. This iterative optimization process ensures accurate decision-making throughout the emergency phase and enables a smooth transition between regular and contingency periods.

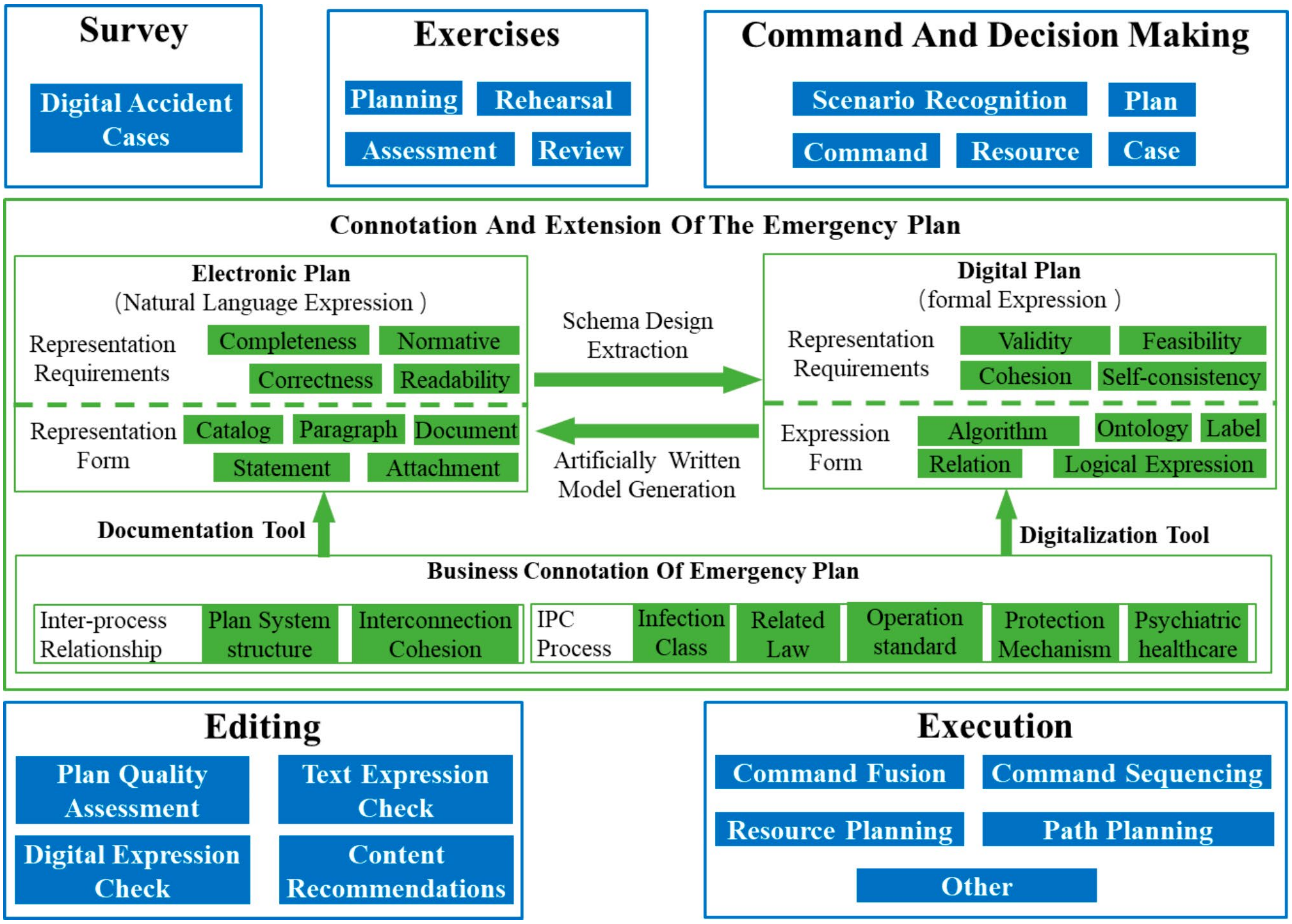


**Fig. 1** Technique roadmap of the system design. The assistant function of this system includes survey, drill, editing, execution, and decision-making. The key technology is based on a knowledge graph, which holds the mutual conversion between electronic and digital emergency plans

## System application

D-B_EPCD was applied to a class-A tertiary mental health center from 1 March 2022 to 28 February 2023, including 1800 beds, 23 clinical departments, and 8 medical and technical auxiliary departments. During this period, D-B_EPCD was also implemented in two class-A tertiary hospitals and four class-B tertiary hospitals. The lack of adequate infrastructure for the digital system resulted in the expenditure of several months on system commissioning. Consequently, the training and education programme was not conducted.

The capacity of medical personnel to prevent and control infection may be contingent upon their familiarity with infectious disease and proficiency in the requisite skills during the ongoing pandemic [46]. It is of the utmost importance that PPE is worn correctly in order to effectively deal with an infectious disease outbreak and to ensure the safety of personnel undergoing virtual reality training [47, 48]. The participants' emergency knowledge level and three-level protective clothing-wearing capability were tested before the application and after twelve months of use. Four emergency IPC drills utilising the D-B_EPCD were conducted during this period. The programme comprised two pneumonia outbreak IPC drills, scheduled for the first and sixth months, a medical waste exposure IPC drill, scheduled for the ninth month, and a fire emergency IPC drill, scheduled for September, which was conducted as a routine exercise.

## System evaluation and application effect evaluation

In order to improve the potential value of promotion, D-B_EPCD need to be assessed by the staff of the psychiatric hospitals [41], including intervention adaption, communication effectiveness, learning environment. Therefore, through a questionnaire survey as shown in Table S1, individuals who have used the software were surveyed to evaluate whether the software has application and promotion value from six aspects and five degrees (1- None, 2- Slightly, 3- Basic, 4- Good, 5- Excellent), *Functionality*: The functions implemented meet users' needs. *Practicality*: D-B_EPCD is convenient for users, especially for mobile or desktop applications, which can produce positive effects without increasing the user's burden. *Reliability*: The information that replies to

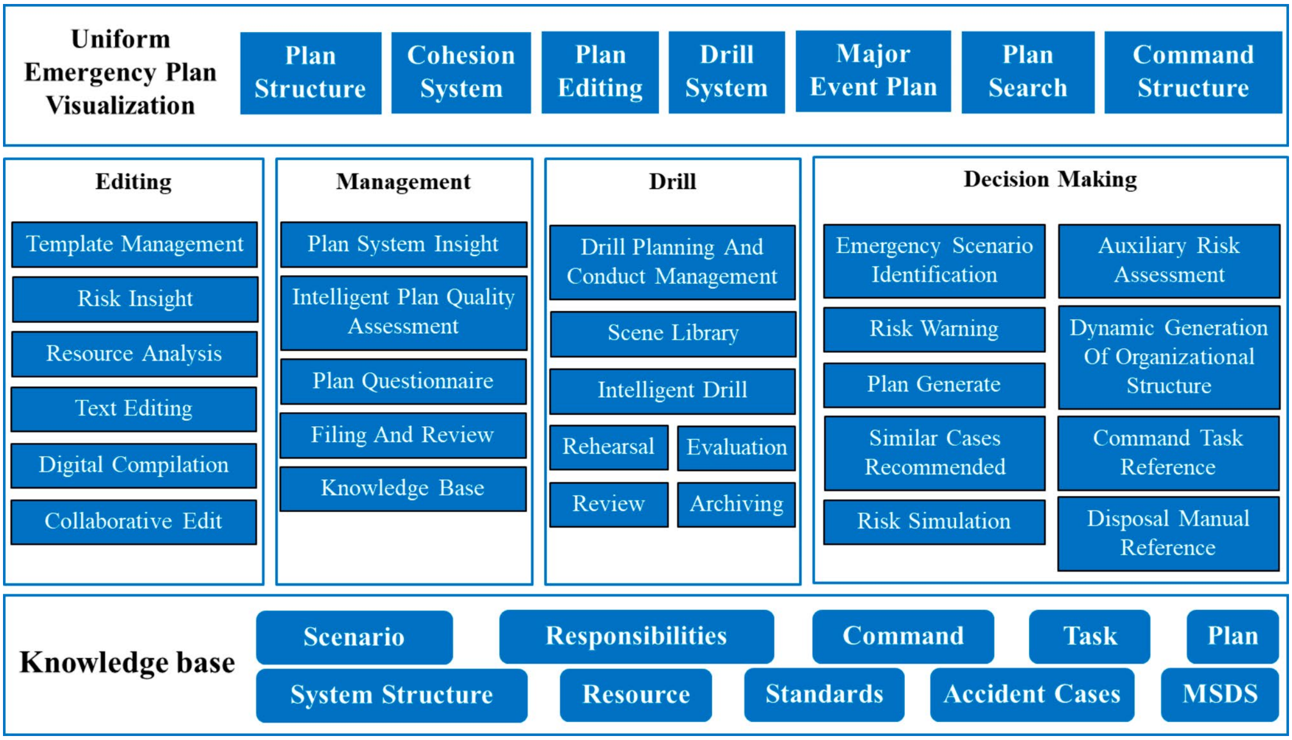


**Fig. 2** The design of the Uniform Contingency Plan Visualization System is based on knowledge bases, including a responsibility knowledge base and a command knowledge base. Based on this knowledge base, The system can implement functional modules such as contingency plan editing, contingency plan management, contingency plan drills, and contingency plan assistance, which finally make contingency plan visualization comes true

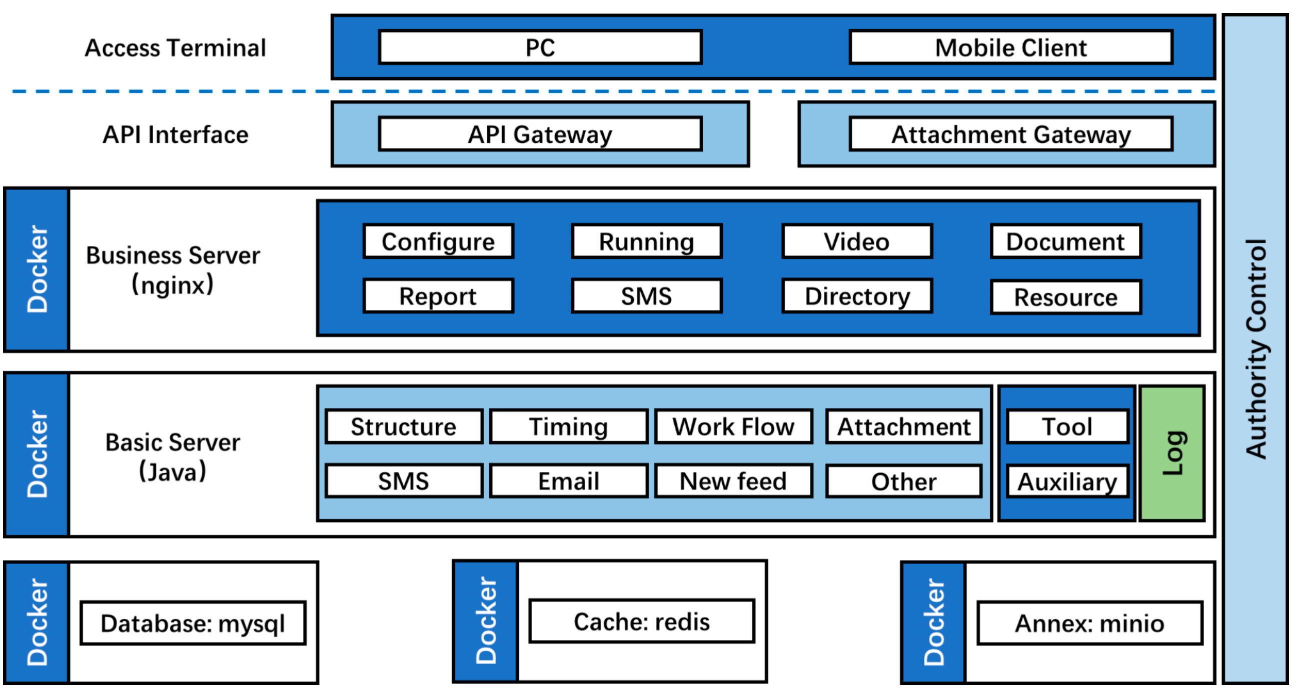


**Fig. 3** The brief deployment of the digital-based emergency prevention and control system

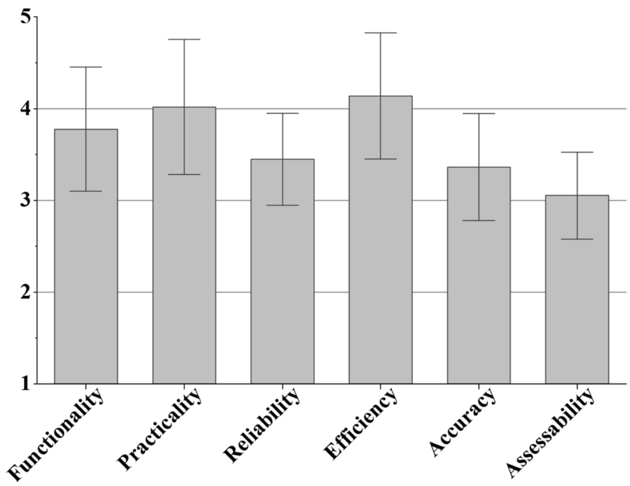


**Fig. 4** The evaluation of this digital contingency prevention and control system in six aspects of users. 1- None, 2- Slightly, 3- Basic, 4- Good, 5- Excellent

**Table 1** Comparison of emergency response ability before and after training with emergency plan system in two psychiatric hospitals

| | Before (*n* = 116) | After (*n* = 116) | $\chi^2$ | *P* |
|---|---|---|---|---|
| **Knowledge assessment** [score] * | | | 37.69 | < 0.001 |
| Excellent (≥ 90) | 7 | 19 | | |
| Pass (60 ~ 89) | 64 | 90 | | |
| Failure (< 60) | 45 | 7 | | |
| **Level 3 PPE**: wearing and taking off speed [minutes] | | | | |
| Very fast (<6) | 1 | 23 | 91.51 | < 0.001 |
| **On** Fast (6 ~ 12) | 54 | 93 | | |
| Slow (≥ 12) | 61 | 0 | | |
| Very fast (<6) | 7 | 47 | 64.80 | < 0.001 |
| **OFF** Fast (6 ~ 12) | 74 | 69 | | |
| Slow (≥ 12) | 35 | 0 | | |

* The score is in the centennial.

queries in emergency drills helps staff effectively handle and increases users' knowledge and skill levels in education. *Efficiency*: D-B_EPCD can timely reflect the status of various disposal processes during emergency drills and can provide services to users promptly. *Accuracy*: The accuracy of implementing various measures has been improved during emergency drills. *Assessability*: After emergency drills and teaching, D-B_EPCD can evaluate and quantify the execution effect of each step, making it convenient for users to review and optimize.

### Ethics approval
This study was approved by the Institutional Review Board of Chengdu Fourth People's Hospital. All participants were provided written informed consent.

### Statistical analysis
The data was analyzed by SPSS 26 (IBM Corporation, New Orchard Road, Armonk, NY 10504, USA). Paired T-test or Mann-Whitney U test is used to analyze continuous variables, and the Chi-squared test is used to analyze categorical variables. $P<0.05$ is considered statistically significant.

## Results
The participants who used this system for education were from 10 departments: 27 medical staff, 49 medical nurses, 16 caregivers, 19 cleaners, and 5 administrators. After 12 months of systematic multimedia case study or training, the users showed a significant improvement in emergency knowledge level ($\chi^2=37.69$, $p<0.001$) and wearing and taking off PPE (both $p<0.001$), as shown in Table 1.

Fig. 4 shows that D-B_EPCD's functionality (3.78±0.68), practicality (4.02±0.74), reliability (3.45±0.50), efficiency (4.14±0.69), accuracy (3.36±0.58), and assessability (3.05±0.47) have all met the emergency exercise and education requirements (>3), with efficiency and practicality improvement reaching level Good. All staff using this system for infectious diseases emergency IPC knowledge and skills training have an average use frequency of 1.74±0.69 times per week.

## Discussion
### The significance of the D-B_EPCD application in psychiatric hospitals
#### *Application necessity in psychiatric hospitals*
The implementation of D-B_EPCD in a psychiatric hospital has led to an improvement in the IPC capabilities of these institutions, as well as an enhancement in the abilities of staff members to respond to personal emergency situations. In China, healthcare personnel in psychiatric inpatient wards demonstrated a lack of compliance with IPC standards [49]; Those suffering from severe mental illness may be reluctant to be vaccinated and may also find it challenging to adhere to IPC measures [50]. In addition, due to their strong professionalism, psychiatric hospitals involve fewer departments in the emergency IPC management of infectious diseases than general hospitals, which is conducive to the construction of D-B_EPCD.

#### *Application possibility in psychiatric hospitals*
Preliminary results from D-B_EPCD's implementation in psychiatric hospitals demonstrate its ability to meet the hospital's requirements in terms of functionality, practicality, reliability, accuracy, efficiency, and evaluability. Notably, D-B_EPCD proves to be highly efficient and practical in assisting emergency response efforts. For instance, during the initiation phase of an emergency

plan, D-B_EPCD's synchronous issuance of messages and commands, along with the intellectual formation of the emergency expert group, significantly saves time in emergency response [27]. The advent of the COVID-19 pandemic has precipitated a significant acceleration in the development of digital health technologies within the psychiatric domain [51]. The most effective weapons against the COVID-19 pandemic are big data, artificial intelligence, and cloud computing [52]. These technologies offer the potential for accessible and scalable interventions that can augment traditional care. For example, some research indicated the mobile system can capture behavioral change in patients with psychiatric disorders during COVID-19 pandemic [53]. The application of machine learning enables the prediction of the severity of psychiatric symptoms based on demographic and clinical characteristics [54]. It is therefore evident that the development of a digital-based system to assist emergency responders in psychiatric hospitals is both promising and critical.

### Changes in emergency plan management

#### *Technologic improvements*

The implementation of this system marks a shift in emergency plan management from traditional text-based and manual approaches towards a more advanced direction of informatization and intelligence [22]. A expected digital emergency management (EDEM) framework based on digital technology has recently been proposed in China as a potential solution to the challenges faced by emergency management agencies in the digital age [55]. The utilisation of knowledge graphs has been demonstrated to facilitate enhanced emergency decision-making in disaster management [56]. Consequently, the D-B_EPCD, which is based on knowledge graph technology, has been developed with the specific objective of facilitating the IPC measures of severe infectious diseases. Consequently, D-B_EPCD provides assistance to relevant personnel in the implementation of interventions that facilitate the formulation of reasonable and timely decisions.

#### *Functional improvement*

At the present time, digital systems are capable of performing a number of functions in the context of health emergencies. These include monitoring and surveillance, as well as the provision of healthcare and logistical assistance [57]. The analysis of potential scenarios is a crucial function of digital information systems [58]. It enables the provision of timely warnings and information on material allocation in the emergency response chain. Furthermore, the digital information system is capable of meticulously recording a multitude of data types during emergency drills [59], including SMS messages, call records, operational records, material consumption and so forth. Therefore, D-B_EPCD significantly incorporates knowledge graph technology, intelligent warning capabilities, and comprehensive documents, effectively transforming text plans into digital plans and markedly enhancing the efficacy and convenience of infectious disease prevention and control operations within mental health institutions.

### Improvement of emergency response capabilities

#### *Management and command improvements*

At the command level, D-B_EPCD empowers emergency command personnel with global control over the entire emergency response process [60]. This enables them to coordinate joint actions among multiple departments, ensuring a seamless and efficient emergency response [61]. However, it is common for psychiatric hospitals to have untrained infection management personnel in charge of emergency events. This lack of professional expertise may result in weak control over various aspects of the emergency response and uncertainty about the required abilities throughout the process [62]. To address this challenge, D-B_EPCD incorporates an intelligent question and answer (QA) function that facilitates convenient detailed queries and point-to-point visualization docking. This function assists commanders in promptly responding to on-site feedback and proposing solutions to specific problems that arise during each stage of the emergency response [63]. As a result, this system significantly improves the capabilities of emergency commanding and on-site emergency response, enhancing overall effectiveness in managing emergency situations. Some research found communication problems exist in previous emergency drills [64], especially that personal protective equipment (PPE) will form Communication disorder [65]. The mobile terminal and the command terminal can freely and easily mutual-communicate via text, voice, or video, resulting in much smoothing communication and improving the implementation efficiency of emergency response [66].

#### *Training and education improvements*

With the help of this system, the physical and mental pressure of front-line medical staff facing the severe infectious disease [67, 68] has been reduced, and the focus level of emergency response command personnel has been improved. Through QA and multimedia technology, the cell phone client can directly view emergency-related knowledge and case studies of emergency events, transferring previous offline training and education to a flexible online approach, bringing incredible flexibility and autonomy in learning to medical and healthcare staff, thus enhancing their participation and interest [60]. The test results showed that the use of D-B_EPCD had improved their emergency knowledge base and emergency response capabilities. Some studies have shown that emergency drills can improve organizational decision-making and coordination [69]. With China's vigorous information technology infrastructure development, this flexible online education mode has become indispensable for communication and learning [70].

### Limitations

#### Insufficiency of D-B_EPCD

Our system is committed to maximizing emergency response capabilities within limited resources, including resources of prevention and control, personnel and their capabilities, and regional assistance. Research and evidence-based decision-making capabilities, laboratory diagnostic capabilities, infrastructure, health system capabilities, and even climate and environmental health [71, 72] are topics worth paying attention to but limitate the application and improvement of this system. We also have identified some shortcomings that urgently need to be addressed [27]. For example, D-B_EPCD lacks humanized design, the accuracy of predicting infection risk is insufficient, and D-B_EPCD's adaptability in different hospitals is weak.

#### Challenges associated with the implementation

The emergence of a global village highlights the need for collaborative response efforts among multiple medical institutions to effectively address outbreaks like COVID-19. Regional cooperation among a diverse range of medical institutions is crucial. While D-B_EPCD has been successfully implemented in several psychiatric hospitals, including two class-A tertiary hospitals and four class-B tertiary hospitals, its current scope is limited to local emergency information infrastructure. However, the capacity for cooperation among multiple psychiatric hospitals is still being tested, particularly in terms of information and resource sharing, as well as the planning of material transportation routes for regional joint prevention and control. These aspects are essential for establishing a robust network that enables efficient coordination and response across psychiatric hospitals within a region. To help psychiatric hospitals break through the previous regional material and personnel mobilization challenges [73] and achieve joint IPC of regional infectious diseases within the mental health consortium [28], functional optimization, wide application, and joint emergency drills are steadily underway.

#### Insufficient assessment system

Additionally, it is plausible that inconsistencies may emerge in the responses of healthcare professionals across diverse roles to our assessment instruments, potentially influenced by factors such as gender, educational- or -work background [74], and age [75]. However, these discrepancies may not be subjected to in-depth analysis due to the insufficient sample size. In order to enhance the statistical efficacy, it is recommended that an additional control group be incorporated into the study without utilizing the system. However, the aforementioned limitation may potentially give rise to unforeseen complications [76, 77]. After meticulous deliberation, it is deemed prudent to incorporate a control group in the forthcoming phase of the investigation.

The ongoing process of functional optimisation will facilitate the implementation of the system in psychiatric institutions, enabling the effective management of potential infectious disease outbreaks, such as the current pandemic caused by the SARS-CoV-2 virus. Accordingly, the training and education programme will be adhered to, and the evaluation system will be constructed with consideration of factors such as job, sex, age, and other relevant aspects.

## Conclusion

The digital, informative and intelligent management of emergency prevention and control of infectious diseases in psychiatric hospitals represents an inevitable trend of development in this field. It was determined that the system enhances the emergency IPC knowledge base and operational skills of medical personnel, and that the medical personnel are better adapted to the system. Consequently, the system can facilitate the emergency prevention and control response to infectious diseases, while simultaneously enhancing the training and educational methodologies employed in emergency prevention and control. Furthermore, it can facilitate the expansion of knowledge regarding the management of emergency IPC of infectious diseases. The next stage of research will focus on enhancing the system's functionality, promoting its wider application, and developing more effective evaluation methods.

## Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12911-024-02809-4.

Supplementary Material 1

#### Acknowledgements

Not available.

#### Author contributions

MY analyzed and interpreted the patients' data. FY, XH, and XJ collected data. XZ and ZW and carried out the application of the digital system. YH and ZL reviewed the manuscript. All authors read and approved the final manuscript.

#### Funding

This study was funded by the National Natural Science Foundation of China [grant number 62073058, 62373079], Science and Technology Department of Sichuan Province [gran number 24ZYZYTS0107, 25NSFSC0577], Health Commission of Sichuan Province [grant number 24CXTD11], Sichuan medical association [grant number S23012], Chengdu Science and Technology Bureau [grant number 2022-YF05-01867-SN], Chengdu Municipal Health Commission [grant number 2024141], Guangzhou Research-oriented Hospital, the Science and Technology Plan Project of Guangdong Province [grant number 2019B030316001], and Guangzhou municipal key discipline in medicine (2021–2023). The funding bodies played no role in the design of the study and collection, analysis, and interpretation of data and in writing the manuscript.

### Data availability
The data set analysed may be obtained from the corresponding author upon reasonable request.

### Code availability
The underlying code for this study [and training/validation datasets] is not publicly available for proprietary reasons.

## Declarations

### Ethics approval and consent to participate
This project was approved by the Ethical Committee of the Fourth People's Hospital of Chengdu. All participants were provided written informed consent. All procedures performed were following the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

### Consent for publication
Not applicable.

### Competing interests
The authors declare no competing interests.


### Author details
[1]Department of Infection Management, The Fourth People's Hospital of Chengdu, No.8 Huli- West 1st-Alley, Jinniu District, Chengdu 610036, China
[2]School of Software Engineering, Chengdu University of Information Technology, No.24 Block 1, Xuefu Road, Chengdu 610225, China
[3]Department of Psychiatry, Chongqing Mental Health Center, No. 102 Jinzishan, Jiangbei District, Chongqing 401147, China
[4]Department of Nutritional and Metabolic Psychiatry, The Affiliated Brain Hospital, Guangzhou Medical University, No. 36 Fangcun Mingxin Road, Liwan District, Guangzhou 510370, China
[5]Department of Psychiatry, Guangdong Engineering Technology Research Center for Translational Medicine of Mental Disorders, No. 36 Fangcun Mingxin Road, Liwan District, Guangzhou 510370, China
[6]Key Laboratory of Neurogenetics and Channelopathies of Guangdong Province and the Ministry of Education of China, Guangzhou Medical University, Guangzhou, China


Received: 21 September 2023 / Accepted: 5 December 2024
Published online: 06 January 2025

### References

1. National Emergency Plan for Public Health Emergencies. [http://www.gov.cn/yjgl/2006-02/26/content_211654.htm]
2. Liu YC, Kuo RL, Shih SR. COVID-19: the first documented coronavirus pandemic in history. Biomed J. 2020;43(4):328–33.
3. Cao Y, Shan J, Gong Z, Kuang J, Gao Y. Status and Challenges of Public Health Emergency Management in China related to COVID-19. Front Public Health. 2020;8:250.
4. Xiang YT, Zhao YJ, Liu ZH, Li XH, Zhao N, Cheung T, Ng CH. The COVID-19 outbreak and psychiatric hospitals in China: managing challenges through mental health service reform. Int J Biol Sci. 2020;16(10):1741–4.
5. Weltens I, Drukker M, van Amelsvoort T, Bak M. Staff and ward factors associated with aggression development on an acute closed psychiatric ward: an experience sampling method study. BMJ Open. 2023;13(2):e067943.
6. Li L. Challenges and priorities in responding to COVID-19 in Inpatient Psychiatry. Psychiatr Serv. 2020;71(6):624–6.
7. Wang J, Sun X, Lu S, Wang F, Wan M, Chen H, Tan Y. Disaster preparedness and Associated factors among emergency nurses in Guangdong Province, China: a descriptive cross-sectional study. Disaster Med Public Health Prep. 2021;17:e65.
8. Cai H, Tu B, Ma J, Chen L, Fu L, Jiang Y, Zhuang Q. Psychological impact and coping strategies of Frontline Medical Staff in Hunan between January and March 2020 during the outbreak of Coronavirus Disease 2019 (COVID19) in Hubei, China. Med Sci Monit. 2020;26:e924171.
9. Hui Z, Jian-Shi H, Xiong H, Peng L, Da-Long Q. An analysis of the current status of hospital emergency preparedness for infectious disease outbreaks in Beijing, China. Am J Infect Control. 2007;35(1):62–7.
10. Liu Q, Luo D, Haase JE, Guo Q, Wang XQ, Liu S, Xia L, Liu Z, Yang J, Yang BX. The experiences of health-care providers during the COVID-19 crisis in China: a qualitative study. Lancet Global Health. 2020;8(6):e790–8.
11. Liu Q, Luo D, Haase JE, Guo Q, Wang XQ, Liu S, Xia L, Liu Z, Yang J, Yang BX. The experiences of health-care providers during the COVID-19 crisis in China: a qualitative study. Lancet Glob Health. 2020;8(6):e790–8.
12. Moradian ST, Mahmoudi H. Experience of frontline nurses who managed the COVID-19 crisis: a qualitative study. Front Public Health. 2023;11:1070916.
13. Li H, Cui Y, Efstathiou N, Li B, Guo P. Experiences of redeployed healthcare workers in the fight against COVID-19 in China: a qualitative study. PLoS ONE. 2022;17(8):e0273429.
14. Montemurro N. The emotional impact of COVID-19: from medical staff to common people. Brain Behav Immun. 2020;87:23–4.
15. Huang Z, Chen M, Duan T, Chen X, Hu W, Zhu Y, Zhang H. Influencing factors of the implementation of community-based public health emergency prevention and control policies: based on grounded theory. Chin J Med Manag Sci. 2021;11(2):7–16.
16. Guan C, Fang D, Li T, Zhang X, Wei F, Zhao H. The Research on Current Status of Digital Technology System of Electric Power Emergency Plan. In: 2024 *IEEE 14th International Conference on Electronics Information and Emergency Communication (ICEIEC): 24–25 May 2024 2024*; 2024: 1–4.
17. Ma X, Rong H, Yan Y. GPS-RTK Mapping Technology in Remote Sensing Dynamic Monitoring of Geological Disasters Under Artificial Intelligence Technology. In: *2024 Second International Conference on Data Science and Information System (ICDSIS): 17–18 May 2024 2024*; 2024: 1–5.
18. Fei L, Li T, Ding W. Dempster–Shafer theory-based information fusion for natural disaster emergency management: a systematic literature review. Inform Fusion. 2024;112:102585.
19. Alawad W, Halima NB, Aziz L. An unmanned aerial vehicle (UAV) System for Disaster and Crisis Management in Smart cities. In: Electronics 12; 2023.
20. Bakhtiari V, Piadeh F, Behzadian K, Kapelan Z. A critical review for the application of cutting-edge digital visualisation technologies for effective urban flood risk management. Sustainable Cities Soc. 2023;99:104958.
21. Alghamdi AM, Al Shehri WA, Almalki J, Jannah N, Alsubaei FS. An architecture for COVID-19 analysis and detection using big data, AI, and data architectures. PLoS ONE. 2024;19(8):e0305483.
22. Dong J, Wu H, Zhou D, Li K, Zhang Y, Ji H, Tong Z, Lou S, Liu Z. Application of Big Data and Artificial Intelligence in COVID-19 Prevention, diagnosis, treatment and management decisions in China. J Med Syst. 2021;45(9):84.
23. Baumgart DC. Digital advantage in the COVID-19 response: perspective from Canada's largest integrated digitalized healthcare system. NPJ Digit Med. 2020;3:114.
24. Terra M, Baklola M, Ali S, El-Bastawisy K. Opportunities, applications, challenges and ethical implications of artificial intelligence in psychiatry: a narrative review. Egypt J Neurol Psychiatry Neurosurg. 2023;59(1):80.
25. Msosa YJ, Grauslys A, Zhou Y, Wang T, Buchan I, Langan P, Foster S, Walker M, Pearson M, Folarin A, et al. Trustworthy data and AI environments for clinical prediction: application to Crisis-Risk in People with Depression. IEEE J Biomedical Health Inf. 2023;27(11):5588–98.
26. McCradden M, Hui K, Buchman DZ. Evidence, ethics and the promise of artificial intelligence in psychiatry. J Med Ethics. 2023;49(8):573.
27. Sun M, Xu N, Li C, Wu D, Zou J, Wang Y, Luo L, Yu M, Zhang Y, Wang H, et al. The public health emergency management system in China: trends from 2002 to 2012. BMC Public Health. 2018;18(1):474.
28. Yang M, He M, Gao S. A joint infection control system is needed in mental health institutions during outbreaks of major respiratory infectious diseases. Public Health. 2020;189:12–3.
29. Wang X, Zhang X, He J. Challenges to the system of reserve medical supplies for public health emergencies: reflections on the outbreak of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) epidemic in China. Biosci Trends. 2020;14(1):3–8.

30. Boniface M, Nasser B, Papay J, Phillips SC, Servin A, Yang X, Zlatev Z, Gogouvitis SV, Katsaros G, Konstanteli K et al. Platform-as-a-Service Architecture for Real-Time Quality of Service Management in Clouds. In: 2010 Fifth International Conference on Internet and Web Applications and Services: 9–15 May 2010 2010; 2010: 155–160.
31. Zhang L, Li J, Li P, Lu X, Gong M, Shen P, Zhu G, Shah SA, Bennamoun M, Qian K, et al. MEDAS: an open-source platform as a service to help break the walls between medicine and informatics. Neural Comput Appl. 2022;34(8):6547–67.
32. Chouliaras N, Kantzavelou I, Maglaras L, Pantziou G, Amine Ferrag M. A novel autonomous container-based platform for cybersecurity training and research. PeerJ Comput Sci. 2023;9:e1574.
33. Jackman SD, Mozgacheva T, Chen S, O'Huiginn B, Bailey L, Birol I, Jones SJM. ORCA: a comprehensive bioinformatics container environment for education and research. Bioinformatics. 2019;35(21):4448–50.
34. Zhen Z, Jing Y. Design and implementation of computer aided physical education platform based on Browser/Server Architecture. Int J Emerg Technol Learn. 2019;14(15):40–51.
35. Lidan M, Jun M. Application of Browser/Server Architecture in College English Online Learning System Design. Int J Emerg Technol Learn. 2018;13(3):129–40.
36. Kirilov N, Bischoff E. Networking aspects of the Electronic Health Records: hypertext transfer Protocol Version 2 (HTTP/2) vs HTTP/3. J Med Syst. 2024;48(1):61.
37. Rescorla E, Schiffman A. The secure hypertext transfer protocol. In.; 1999.
38. Oppliger R. SSL and TLS: theory and practice. Artech House; 2016.
39. Al-Janabi SF, Obaid AK. Development of Certificate Authority services for web applications. In: 2012 International Conference on Future Communication Networks: 2–5 April 2012 2012; 2012: 135–140.
40. Scheitle Q, Chung T, Hiller J, Gasser O, Naab J, Rijswijk-Deij Rv, Hohlfeld O, Holz R, Choffnes D, Mislove A, et al. A First look at Certification Authority Authorization (CAA). SIGCOMM Comput Commun Rev. 2018;48(2):10–23.
41. Khan S, Zhang Z, Zhu L, Li M, Khan Safi QG, Chen X. Accountable and Transparent TLS Certificate Management: an alternate public-key infrastructure with verifiable trusted parties. Secur Communication Networks 2018:1–16.
42. Aitizaz A, Hasliza AR, Jehad A, Muhammad Fermi P, Mehedi M, Ateeq Ur R, Can C, Mohammed B. A Novel Secure Blockchain Framework for Accessing Electronic Health Records Using Multiple Certificate Authority. Applied sciences. Volume 11. MDPI AG; 2021. pp. 9999–9999.
43. Pope MB, Warkentin M, Mutchler LA, Luo XR. The domain name system—past, present, and future. Commun Association Inform Syst. 2012;30(1):21.
44. Khormali A, Park J, Alasmary H, Anwar A, Saad M, Mohaisen D. Domain name system security and privacy: a contemporary survey. Comput Netw. 2021;185:107699.
45. Takan S. Knowledge graph augmentation: consistency, immutability, reliability, and context. PeerJ Comput Sci. 2023;9:e1542.
46. Pollock A, Campbell P, Cheyne J, Cowie J, Davis B, McCallum J, McGill K, Elders A, Hagen S, McClurg D, et al. Interventions to support the resilience and mental health of frontline health and social care professionals during and after a disease outbreak, epidemic or pandemic: a mixed methods systematic review. Cochrane Database Syst Rev. 2020;11(11):CD013779.
47. Verbeek JH, Rajamaki B, Ijaz S, Sauni R, Toomey E, Blackwood B, Tikka C, Ruotsalainen JH, Kilinc Balci FS. Personal protective equipment for preventing highly infectious diseases due to exposure to contaminated body fluids in healthcare staff. Cochrane Database Syst Rev. 2020;4(4):CD011621.
48. Tsukada K, Yasui Y, Miyata S, Fuyumuro J, Kikuchi T, Mizuno T, Nakayama S, Kawano H, Miyamoto W. Effectiveness of virtual reality training in Teaching Personal Protective Equipment skills: a Randomized Clinical Trial. JAMA Netw Open. 2024;7(2):e2355358.
49. Lau LHW, Lam QSK, Siu MMY, Tang TSK, Suen LKP, Lam SC. Compliance of healthcare workers in a psychiatric inpatient ward to infection control practices during the COVID-19 pandemic: a participant observation study supplemented with a self-reported survey. BMC Infect Dis. 2024;24(1):592.
50. Bai W, Feng Y, Cheung T, Su Z, Ng CH, Xiang YT. Strategies for managing patients with psychiatric illness in the reopening period of the COVID-19 pandemic in China. Lancet Psychiatry. 2022;9(9):691–2.
51. Torous J, Bucci S, Bell IH, Kessing LV, Faurholt-Jepsen M, Whelan P, Carvalho AF, Keshavan M, Linardon J, Firth J. The growing field of digital psychiatry: current evidence and the future of apps, social media, chatbots, and virtual reality. World Psychiatry. 2021;20(3):318–35.
52. Wang Q, Su M, Zhang M, Li R. Integrating Digital Technologies and Public Health to Fight Covid-19 pandemic: Key Technologies, Applications, challenges and Outlook of Digital Healthcare. Int J Environ Res Public Health 2021, 18(11).
53. Jagesar RR, Roozen MC, van der Heijden I, Ikani N, Tyborowska A, Penninx B, Ruhe HG, Sommer IEC, Kas MJ, Vorstman JAS. Digital phenotyping and the COVID-19 pandemic: capturing behavioral change in patients with psychiatric disorders. Eur Neuropsychopharmacol. 2021;42:115–20.
54. D'Urso G, Magliacano A, Rotbei S, Iasevoli F, de Bartolomeis A, Botta A. Predicting the Severity of Lockdown-Induced Psychiatric symptoms with machine learning. Diagnostics (Basel) 2022, 12(4).
55. Lee C-H, Wang D, Lyu S, Evans RD, Li L. A digital transformation-enabled framework and strategies for public health risk response and governance: China's experience. Industrial Manage Data Syst. 2023;123(1):133–54.
56. Chen M, Tao Z, Tang W, Qin T, Yang R, Zhu C. Enhancing emergency decision-making with knowledge graphs and large language models. Int J Disaster Risk Reduct 2024:104804.
57. Fitriani WR, Sutanto J, Handayani PW, Hidayanto AN. User compliance with the Health Emergency and Disaster Management System: systematic literature review. J Med Internet Res. 2023;25:e41168.
58. Dash BP, Dixit V. Disaster supply chain with information and digital technology integrated in its institutional framework. Int J Prod Res. 2024;62(8):3003–22.
59. Oikawa K, Murakami M, Ochi S. Use of personal health records during and after a disaster including a nuclear accident: a scoping review. Int J Disaster Risk Reduct. 2024;111:104698.
60. Mahon SE, Rifino JJ. 3 - Role of Emergency Medical Services in Disaster Management and Preparedness. In: *Ciottone's Disaster Medicine (Third Edition)*. Edited by Ciottone G. New Delhi: Elsevier; 2024: 12–18.
61. Bagot KL, Bladin CF, Vu M, Bernard S, Smith K, Hocking G, Coupland T, Hutton D, Badcock D, Budge M, et al. Factors influencing the successful implementation of a novel digital health application to streamline multidisciplinary communication across multiple organisations for emergency care. J Eval Clin Pract. 2024;30(2):184–98.
62. Shao Y, Shao Y, Fei JM. Psychiatry hospital management facing COVID-19: from medical staff to patients. Brain Behav Immun. 2020;88:947.
63. Perry O, Jaffe E, Goldberg A, Bitan Y. Incident Commander decision making: quantitative evaluation of instantaneous and considered decisions. Appl Ergon. 2024;114:104139.
64. Qiu W, Chu C, Mao A, Wu J. Studying Communication Problems for Emergency Management of SARS and H7N9 in China. J Glob Infect Dis. 2018;10(4):177–81.
65. Jayes M, Borrett S, Bose A. Mental capacity legislation and communication disability: a cross-sectional survey exploring the impact of the COVID-19 pandemic on the provision of specialist decision-making support by UK SLTs. Int J Lang Commun Disord. 2022;57(1):172–81.
66. Bressman E, Long JA, Burke RE, Ahn A, Honig K, Zee J, McGlaughlin N, Balachandran M, Asch DA, Morgan AU. Automated text message-based program and use of Acute Health Care resources after Hospital Discharge: a Randomized Clinical Trial. JAMA Netw Open. 2024;7(4):e243701.
67. Liu YE, Zhai ZC, Han YH, Liu YL, Liu FP, Hu DY. Experiences of front-line nurses combating coronavirus disease-2019 in China: a qualitative analysis. Public Health Nurs. 2020;37(5):757–63.
68. Adams JG, Walls RM. Supporting the Health Care Workforce during the COVID-19 Global Epidemic. JAMA. 2020;323(15):1439–40.
69. Savoia E, Lin L, Bernard D, Klein N, James LP, Guicciardi S. Public Health System Research in Public Health Emergency Preparedness in the United States (2009–2015): actionable knowledge base. Am J Public Health. 2017;107(S2):e1–6.
70. Liu S, Yang L, Zhang C, Xiang Y-T, Liu Z, Hu S, Zhang B. Online mental health services in China during the COVID-19 outbreak. Lancet Psychiatry. 2020;7(4):e17–8.
71. Lee JM, Jansen R, Sanderson KE, Guerra F, Keller-Olaman S, Murti M, O'Sullivan TL, Law MP, Schwartz B, Bourns LE, et al. Public health emergency preparedness for infectious disease emergencies: a scoping review of recent evidence. BMC Public Health. 2023;23(1):420.
72. Tan MMJ, Neill R, Haldane V, Jung AS, De Foo C, Tan SM, Shrestha P, Verma M, Bonk M, Abdalla SM, et al. Assessing the role of qualitative factors in pandemic responses. BMJ. 2021;375:e067512.
73. Wang QL, Huang BH, Liu WP, Yi HG, Tang SW. Development Trend of Infectious Disease hospitals in China 2002–2018: a longitudinal analysis of National Survey Data. Risk Manag Healthc Policy. 2021;14:155–62.
74. Toren O, Kerzman H, Kagan I. The difference between professional image and job satisfaction of nurses who studied in a post-basic education program

and nurses with generic education: a questionnaire survey. J Prof Nurs. 2011;27(1):28–34.
75. Yarali M, Parvizi A, Ghorbani Vajargah P, Tamimi P, Mollaei A, Karkhah S, Firooz M, Hosseini SJ, Takasi P, Farzan R, et al. A systematic review of health care workers' knowledge and related factors towards burn first aid. Int Wound J. 2023;20(8):3338–48.
76. Perez-Guerrero EE, Guillen-Medina MR, Marquez-Sandoval F, Vera-Cruz JM, Gallegos-Arreola MP, Rico-Mendez MA, Aguilar-Velazquez JA, Gutierrez-Hurtado IA. Methodological and statistical considerations for cross-sectional, Case-Control, and Cohort studies. J Clin Med 2024, 13(14).
77. Munnangi S, Boktor SW. Epidemiology Of Study Design. In: *StatPearls.* Treasure Island (FL); 2024.

## Publisher's note