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Prioritisation of functional needs for ICU intelligent robots in China: a consensus study based on the national survey and nominal group technique

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ABSTRACT

Objective This study aims to define the prioritisation of the needs for an intelligent robot's functions in the intensive care unit (ICU) from a clinical perspective.

Design This study introduces a nominal group technique.

Setting This study uses national setting.

Participants This study includes a total of 851 respondents from 34 provinces in China who participated in the survey. A nominal group of 12 members was organised by the research group; there were seven experts with a background in critical care, two junior attending physicians with a background in critical care and three experienced nurses.

Results A total of 50 needed intelligent robot functions in ICUs were obtained from the questionnaire data. Through three rounds of nominal group voting and discussion, a consensus was reached on 44 items, which were categorised into 29 high-priority needs, 13 medium-priority needs and two low-priority needs. The functionalities in areas such as 'sleep and pain assessment,' 'monitoring of sedation, agitation, and delirium,' and 'robot-assisted rehabilitation and physical therapy' were particularly favoured by the ICU medical and nursing staff.

Conclusions This study has defined the functional needs and priorities for ICU intelligent robots from the perspective of ICU clinical medical and nursing staff. It has been concluded that 'disease assessment function' and 'rehabilitation and physical therapy' are most needed by clinical doctors and nurses. The results presented in this study could serve as a useful reference for future research and development of medical robots.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ This study is a consensus study based on the national survey and nominal group technique.
- ⇒ Members of the nominal group (NG) in this study include senior doctors, junior doctors and nurses.
- ⇒ During the discussion phase, the nursing experts expressed their opinions relatively less.
- ⇒ The professional background of the NG members has been relatively limited, mainly in the field of critical care medicine and nursing.

INTRODUCTION

Over the past few decades, artificial intelligence has developed rapidly and has been widely used in the medical field.[1] An extensive application of artificial intelligence in the medical field has notably enhanced the quality and efficiency of healthcare.[2] However, in the ward care domain, represented by the intensive care unit (ICU), the application of intelligent robots is still in the preliminary exploration stage.[3] Recently, multimodal foundation models, such as the GPT-4 model, have initiated the era of general intelligence. The combination of these models and robots' capabilities in vision, hearing and touch could potentially cause a profound change in the critical care service model in ICUs.[4]

The ICU patients have elevated requirements for medical service quality and monitoring intensity. An ICU generates a massive amount of medical data daily during patient monitoring, which makes it an ideal candidate for the application of artificial intelligence.[5 6] The ICU physicians are required to conduct round-the-clock monitoring of patients, which faces high workloads, especially during the outbreaks of significant infectious diseases. Nevertheless, intelligent robots, as vital components of smart healthcare and telemedicine, have the potential to reduce the workload of medical staff, thus enabling more time for patient diagnosis and treatment and improving patient services. In recent years, many studies have used image intelligence recognition for pain and delirium assessment[3 7 8] and intelligent robots for remote ultrasound,[9] telesurgery,[10] remote ventilator adjustment,[11] rehabilitation and physiotherapy[12] and sterilisation logistics.[13] Nonetheless, these robots have not been applied to the ICU areas, which could be due

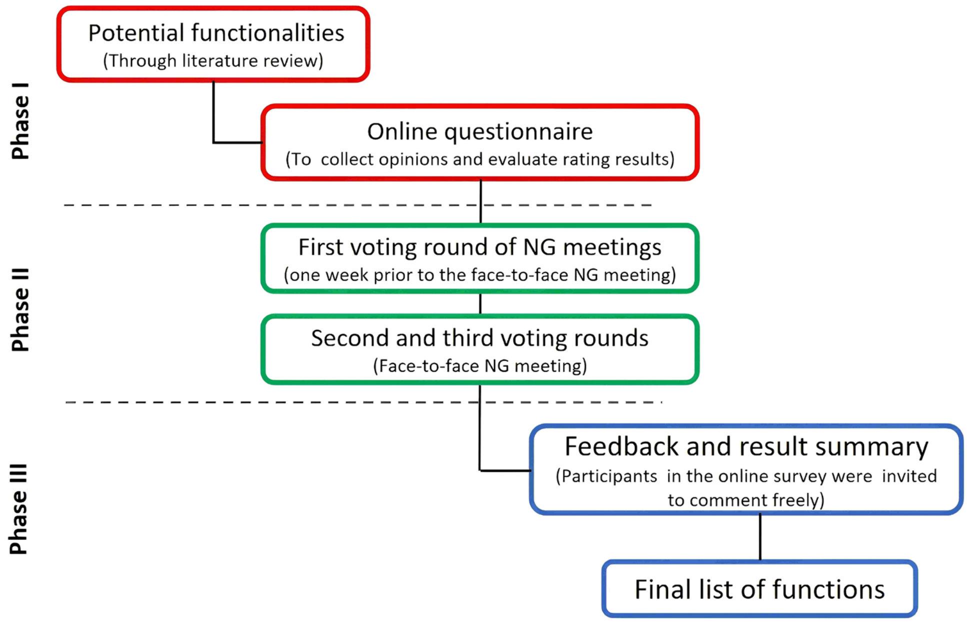

Figure 1 The study was conducted in three phases. In phase I, an online questionnaire was published to collect opinions and evaluate rating results. In phase II, three rounds of voting were held to finalise the list and determine the priority of the items. In phase III, participants who provided an email address in the online survey were contacted and invited to comment freely.

to the lack of clarity regarding the clinical needs and their importance in the ICUs.

The development of smart device functions should be driven by the requirements of clinical practice. However, there have been no studies on the priority functions of intelligent robots in the ICUs from a clinical perspective. In 2021, the Ministry of Science and Technology of China initiated the task of 'developing intelligent critical care medical systems,' with Beijing Jishuitan Hospital collaborating with the Hefei University of Technology and eight other institutions in this project.

This study identifies the clinical needs through a nationwide survey and subsequently achieves consensus and evaluates priorities by employing the nominal group technique (NGT). To the best of the authors' knowledge, this has been the first consensus that presents the functional needs of intelligent robots from a clinical perspective. This study could provide a reference for future development of intelligent devices in the ICUs.

METHODS

The research presented in this study was conducted in three phases from February 2023 to September 2023, as illustrated in figure 1.

Patient and public involvement

Patients and/or the public were not involved in this study.

Ethics approval

The study protocol was approved by the Institutional Review Board of Beijing Jishuitan Hospital, Capital Medical University (No. K2022-116-00). Since no patients were involved in this study, the local IRB approved a waiver of informed consent.

Phase I: clinical needs based on online questionnaire

An online preliminary survey was designed to determine the needs for robot functionalities from data collected from different ICU professionals and stakeholders (ie, patient families) (https://www.wjx.cn/vm/h10EOeF.aspx).

The survey was divided into three sections: characteristics of respondents, clinical needs for an intelligent robot's functionalities in the ICUs and a survey on the current work situation in the ICUs. Through the related literature review,[1 3 7 8] 18 potential functionalities of intelligent monitoring robot systems were initially identified, as shown in online supplemental appendix 1; then, they were categorised into five groups corresponding to five themes, as shown in figure 2: autonomous patrol functions, disease assessment functions, remote functions, rehabilitation and physical therapy, emotional support. Participants were asked to rate each functionality on a nine-point Likert scale, where one meant not needed at all, and nine indicated extremely needed. An open-ended question of 'What other clinical tasks do you wish the intelligent robot to perform?' followed each section.

The survey was published on the official website of the Chinese Society of Critical Care Medicine (https://csccm.org.cn/?p=23531), as well as on the official account of the Department of Critical Care Medicine of Capital Medical University (https://mp.weixin.qq.com/s/s29ef1UkuNFPlkyN5dUBWA), on 13 February 2023, and was closed for responses on 14 May 2023. Based on the data acquired from the online survey, a list was constructed after the inductive integration of similar feedback. This list included all suggestions collected from the questionnaire, along with the initial 18 functionalities.

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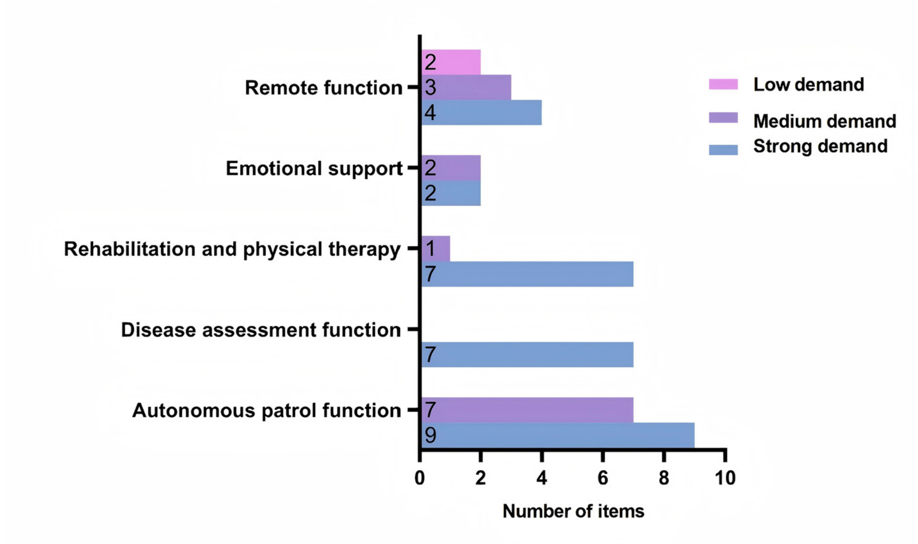

Figure 2 Intelligent robot functions divided into five groups corresponding to five themes; the figure shows the number of strong-demand, medium-demand and low-demand items in each theme.

Phase II: nominal group (NG) voting

NG formation

Considering the size of the NG in previous studies,[14] the research group decided to formulate an NG with 12 members. Seven ICU specialists were invited via email to participate in the research, all of whom were directors of different ICUs, including two junior attending physicians and three nurse managers, who were ICU physicians from seven tertiary hospitals affiliated with Capital Medical University. Furthermore, one doctor with extensive experience in the field of surgical robot development and three engineering experts in robot development were invited to participate in the discussion but were excluded from the voting process. All the ICU specialists and nurse managers accepted the invitation.

First voting round of NG meetings

To improve efficiency, 1 week before the face-to-face NG meeting, the NG members were requested to independently rate the functions in the list on a Likert scale. A score of 1–3 represented low need, a score of 4–6 denoted medium need and a score of 7–9 indicated high need. Consensus was considered to be achieved when it reached 75 per cent; the consensus entries would not proceed to the next round of voting.

Face-to-face NG meetings: second and third voting rounds

Before the meeting, the voting results of the first voting round were provided to the NG members. When the meeting started, the NG members took turns to speak, presenting their views in relation to the results of the previous round, whereas the others were prohibited from interrupting during this process. After the speeches, there was a 5 min free discussion. During the discussion, the NG members were reminded to protect the views of vulnerable groups, which included junior doctors and nurses. After the discussion, the NG members independently evaluated each functional entry. The third round was conducted in the same manner as the first two rounds, and the iteration process ended after three rounds. Functions that did not reach consensus were regarded as controversial and thus excluded from the final list of functions.

Phase III: feedback and result summary

All participants who provided an email address in the online survey were reached out and invited to comment freely.

Statistical analysis

Categorical data were presented in numerical format, expressing the corresponding data in percentages. Continuous data were denoted by the median value and the mean absolute deviation from the median value (MADM). All data were analysed using SPSS V.21.0.

RESULTS

Phase I: clinical needs based on online questionnaire

During the 3 month publication period of the questionnaire on the official website of the Chinese Society of Critical Care Medicine, a total of 851 participants completed the online survey. Among them, 343 were ICU physicians, and 378 were ICU nurses, accounting for 84.5% of the total number of participants. In addition, 96 doctors and nurses from other departments (11.3%), eight respiratory therapists (0.9%), seven rehabilitation therapists (0.8%), six ultrasound department physicians (0.7%) and 13 patient family members (1.5%) also completed the questionnaire. A majority of 810 participants (95.2%) were from tertiary hospitals, of which 465 had been in clinical practice for more than 10 years (55.5%). Participants were from 34 provinces in China, with Beijing (244, 28.7%), Hubei Province (112, 13.2%) and Liaoning Province (97, 11.4%) having the highest number of participants.

Table 1 Items with no consensus

Demand entry	Strong demand (votes)	Medium demand (votes)	Low demand (votes)	Median score of Round 3 (MADM)
A17: Autonomous recording of a patient's claims and reporting back	6	5	1	7.0 (1.42)
A18: Autonomous rounds for acquiring data on basic patient vital signs (eg, blood pressure, heart rate and oxygenation and respiration levels)	4	7	1	6.0 (1.17)
A19: Integration of bedside examination (X-ray and ultrasound examinations)	3	6	3	5.0 (0.58)
B8: Assessment of a patient's breathing patterns (ie, chest breathing and abdominal breathing) and breathing amplitude	3	6	3	6.0 (1.42)
C10: Remote palpation	3	6	3	5.0 (1.33)
D9: Assisted or autonomous completion of suctioning	5	4	3	7.0 (1.75)

A, autonomous patrol function; B, disease assessment function; C, rehabilitation and physical therapy; D, emotional support.

The participants offered 609 open-ended suggestions, and a team composed of two doctors and two engineering technicians deliberated on each comment. Ensuring that all opinions were included, the team consolidated duplicate entries and rephrased the language. This process resulted in a list of 50 functional needs categorised into five groups corresponding to five themes, as shown in online supplemental appendix 1, these data were used by the NG for subsequent analysis.

Phase II: NGT voting

Through three rounds of voting and discussion, a total of 44 functions reached consensus, as shown in online supplemental appendix 1: eight in the first round, 19 in the second round and 17 in the third round. Among them, 29 were strong needs (greater than or equal to seven points), 13 were medium needs (greater than or equal to four points) and the needs 'Q31: Remote tracheal intervention' and 'Q36: Remote puncture and injection' were classified as weak needs due to a median score of fewer than four points, as presented in online supplemental appendix 1. According to the function classification, the experts had a high demand for functions related to assisted rehabilitation, as well as for those related to physiotherapy and condition assessment, and 7/9 (77.8%) and 7/8 (87.5%) of the entries were rated as strong needs, respectively, as shown in figure 2.

However, six entries did not reach the consensus, as shown in table 1.

Phase III: feedback and result summary

During the initial online survey phase, 184 participants provided their email addresses, and the final prioritisation list was dispatched to these participants via email for feedback and 24 responses were received. These responses expressed anticipation for the application of large language models to assist ward rounds in the ICUs and for performing robot-assisted rehabilitation in the ICUs. Certain concerns were also raised about the current inadequacies of the domestic ICU database and the low level of intelligence. Moreover, two respondents showed support for item A17, which denoted autonomous recording and reporting of patient requests, but this item did not reach a consensus.

DISCUSSION

Considering the future development needs of intelligent robots and other intelligent devices in the ICUs, this study presents 50 needs for intelligent robots' functionalities determined by the consensus-forming method (refer to table 1 and online supplemental appendix 1), combining the online survey with the NGT from the perspective of clinical medical staff. In this study, the voting data were used to prioritise the introduced needs. The needs were defined as clinical tasks that currently have poor medical quality or high labour consumption and could potentially benefit from the introduction of intelligent devices.

The consensus techniques have been widely used in critical care medicine; for instance, they have been used in 'determining the top research priorities in UK prehospital critical care' and 'research priorities in paediatric onco-critical care'.[15 16] This study conducted an online survey, which was integrated with an NGT that represents a method that has been repeatedly used in previous related research.[17 18] To improve efficiency, the size of the group typically does not exceed 12 people. In the competency-based training programme in intensive care medicine for Europe study (CoBaTrICE),[18] an 11-member NG was selected, with eight experts, two trainees and a nurse; in the study of Chinese College of Intensive and Critical Care Medicine,[17] a 13-member NG was selected, with nine experts, two trainees and a respiratory therapist and nurse. Similarly, in this study, 12 experts were selected, whose professional backgrounds were mainly critical care medicine (nine experts) and nursing (three experts), including two neurointensive care experts and seven senior physicians who were postgraduate supervisors. In addition, this study conducted face-to-face discussions before voting, which could be regarded as a more comprehensive and efficient approach compared with the traditional Delphi method (correspondence).[15] Furthermore, this study adopted the protocol of CoBaTrICE Collaboration and designated it as a modified NGT.[18] The aim of the online questionnaire was to collect as many clinical needs as possible to avoid missing clinical needs provided to the NG. The NG meetings were designed such that to identify and prioritise the needs for which consensus could be reached, and during the meeting, the coordinator controlled the process so that all participants had the opportunity to express their opinions. Nevertheless, in contrast to the senior experts, the junior ICU staff and nursing experts still expressed personal ideas less frequently. The possibility that their scoring might converge could not be excluded. Readers should consider the potential underestimation of functions in the areas related to the interests of the junior ICU staff and nursing experts, such as Q11, Q37 and Q32.

The 44 items that reached consensus included 29 strong needs (refer to online supplemental appendix 1), with two high-scoring items reaching a median score of nine: sleep assessment (Q1) and pain assessment (Q2). Sleep deprivation was labelled as a common complaint and source of distress for ICU patients; also, sleep disruption, for the first time in recent years, was written into the ICU's Clinical Practice Guidelines as an independent section.[19] However, sleep monitoring and treatment have been missing in ICU clinical practice due to insufficient human resources and a lack of monitoring tools. Pain is one of the main symptoms to be assessed in critically ill patients; namely, 70% of critically ill patients are in moderate or severe pain, and untreated pain can have a severe negative effect on critically ill patients.[19] It has been very common in clinical practice that patients are in pain due to the inability to assess pain accurately and timely, which has been mainly due to the limitation of human resources for nursing and a large workload in the ICUs. Therefore, the traditional pain assessment model (intermittent manual assessment) cannot adapt to the current situation of pain assessment in the ICUs. In this study, in addition to sleep and pain assessment, all of the monitoring entries for sedation, agitation and delirium were strongly recommended (ie, Q26 and Q28), which might reflect the clinical experts' attention to the issues related to the Pain, Agitation/Sedation, Delirium, Immobility and Sleep Disruption in Adult Patients in the ICU (PADIS) guideline as well as the real needs in clinical practice.[19] With the development of artificial intelligence, recent studies have attempted to assess patients and their environment in the ICU automatically, such as assessing pain in newborns[7] and patients with dementia,[20] and the results have shown promising applications. Furthermore, integrating artificial intelligence into the existing assessment processes could provide ICU healthcare providers with the necessary references and reduce their workload. However, there is still a certain distance to pass from the laboratory application to the clinic usage, and the most important challenge refers to the lack of clinical datasets and the variability of clinical patient conditions.[1]

Items related to theme D (ie, the rehabilitation and physical therapy) were also favoured by the experts, with 7/9 items rated as strong needs and all scoring above eight (ie, Q3, Q6, Q7, Q10, Q12, Q14 and Q15). In the expert discussions, functions such as assisted turning, transferring and sputum clearance were most valued by nursing experts. Early rehabilitation could promote physical function, prognosis and medical costs for critically ill patients,[21] but due to the limited healthcare resources, rehabilitation has been typically insufficient or absent in the ICUs. The strong recommendation for rehabilitation and physical therapy has indicated that they might probably be one of the clinical areas where the intervention of intelligent robots is most needed from the clinical perspective of physicians and nurses.

Items related to theme C (ie, the remote function) could be a promising application direction for the ICU intelligent robots, particularly because the COVID-19 pandemic has spurred enthusiasm for developing remote operations, such as remote ultrasound,[9] remote bedside device control[11] and remote consultations.[22] Nevertheless, in this study, the voting results of the nominal group were not exactly as expected. For instance, teleconsultation (Q8), teleteaching (Q9), remote control rounds (Q16) and televisitation (Q29) for telemedicine via voice and video were more accepted and denoted as strong needs. For teleoperation functions, including remote ultrasound (Q35), remote manipulation of instruments (Q36) and remote auscultation (Q39), experts generally believed that although there had been an application demand in specific scenarios (eg, isolation wards), there was little demand in daily practice. For high-risk operations, such as remote bronchoscopic intervention (Q43) and remote puncture (Q44), clinical experts were generally resistant, considering that the value could be small (the operation was not complex), whereas the introduced risk might be high (unnecessary harm to a patient might be caused). Apart from the clinical demands, the technical capabilities at the present stage might also be one of the reasons for the experts' concerns, such as the stability of the network and the accuracy of remote operations. In addition, it should be noted that this research was carried out after the COVID-19 pandemic. In specific scenarios, for instance, during a pandemic of infectious diseases or in a ward for severe infectious diseases, different considerations might arise. There was a certain difference in the enthusiasm for the remote function development between the engineering departments and the clinical experts, which might be considered a reminder to pay more attention to the clinical needs and research direction of the remote function, such as the tendency to be located in certain scenarios, including infectious diseases or medical and teaching support in remote hospitals.[23]

After the third round of voting, six items were eliminated due to the lack of consensus (refer to table 1), with certain controversies during the discussion, such as for A18 (autonomous patrol of basic vital signs) and A19 (integration of bedside examinations). Some experts regarded these items as important ICU robot functions, whereas others considered these functions easily obtainable in clinical practice, with a low need for new development or integration. It should be noted that although these items did not reach a consensus due to controversy, they should not be considered unimportant. For instance, for items A17 and A18, the vast majority of experts voted as strong or medium need. Therefore, these items should be considered in specific situations and for certain application scenarios.

This study focuses on the clinical needs of ICU robots because these robots have practical value in epidemic outbreaks and certain special scenarios (eg, infectious disease wards), and our research team plans to develop a ward rounds robot, which was funded by the National Key Research and Development Programme. The results presented in this study will be used in the coming years, and future work will focus on developing robot functions with higher clinical needs.

Although this study offers valuable data for future research, there are some potential limitations. First, in the online preliminary survey phase, the questionnaire was used to collect data on clinical needs, but this method has the disadvantage that the response rate cannot be identified. Nevertheless, the authors deemed that the online questionnaire stage was accomplished satisfactorily, collecting a large amount of data on numerous needs from the ICU clinical medical staff and stakeholders, extending the questionnaire's influence. Participants covered all provinces and cities in China, and they provided numerous valuable suggestions. Eventually, 68% (30/44) of the items in the final list originated from the online survey questionnaire. Second, although the participants were repeatedly reminded to protect the opinions of vulnerable groups, the nursing experts expressed their opinions relatively less during the discussion phase. Therefore, in future research, greater attention should be paid to emphasising the priority of vulnerable groups. Third, despite the involvement of many experienced doctors with different specialities in the online questionnaire stage, the professional backgrounds of the NG members were mainly in the field of critical care medicine and nursing. The final item ranking could potentially be controversial, and low-rated or non-consensus items might also have stronger value in specific scenarios. In future research, more NG members from different professional backgrounds, such as rehabilitation therapists and respiratory therapists, could be included. Fourth, the final list was formed based on established methodology, but there might be cases of incompleteness, and future research could further refine it with technological progress.

Conclusion

This study constructs a list of ICU intelligent robot functionality needs from the perspective of ICU clinical medical staff. The selected needs are prioritised. It is shown that 'disease assessment function' and 'rehabilitation and physical therapy' are most needed by clinical doctors and nurses. The results presented in this study could provide a reference for the future development of ward robots, particularly those intended for the ICUs.

NG member list

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Zhimin Li (Beijing Jishuitan Hospital, Capital Medical University);
Shuya Wang (Beijing Tiantan Hospital, Capital Medical University);
Xiuming Xi (Fuxing Hospital, Capital Medical University);
Jianxin Zhou (Beijing Shijitan Hospital, Capital Medical University);
Wenxiong Li (Beijing Chaoyang Hospital, Capital Medical University);
Meili Duan (Beijing Friendship Hospital, Capital Medical University);
Li Jiang (Xuanwu Hospital, Capital Medical University);
Linlin Zhang (Beijing Tiantan Hospital, Capital Medical University);
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Na Yang (Beijing Chaoyang Hospital, Capital Medical University);
Dan Zhang (Beijing Jishuitan Hospital, Capital Medical University).

Contributors BO and XW conceived the study. Statistical design and analysis were done by ZC, HW, YB, LZ. MY, FZ, XY, SW, ZC, YY and BO drafted the initial version of the manuscript. All authors revised and approved the final version of the paper. BO is the guarantor.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, conduct, reporting or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and was approved by Ethics approval: The study protocol was approved by the IRB of Beijing Jishuitan Hospital, Capital Medical University (No. K2022-116-00). Since no patients were involved in the study, our local IRB approved a waiver of informed consent. Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. Researchers with legitimate academic or scientific interests may contact the corresponding author at cuizhen0825@sina.com to request access to the data. Access will be granted only for non-commercial purposes and is subject to appropriate conditions and institutional approval.

Supplemental material This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been

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