



BMJ Open Status of continuous glucose monitoring use and management in tertiary hospitals of China: a cross-sectional study

Liping Chen ^{1,2,3,4} Xiaoqin Liu,^{2,3,4,5} Qin Lin,^{1,2,3,4} Hongmei Dai,^{1,2,3,4} Yong Zhao ⁶, Zumin Shi,⁷ Liping Wu^{2,3,4,5}

To cite: Chen L, Liu X, Lin Q, *et al.* Status of continuous glucose monitoring use and management in tertiary hospitals of China: a cross-sectional study. *BMJ Open* 2023;**13**:e066801. doi:10.1136/bmjopen-2022-066801

► Prepublication history for this paper is available online. To view these files, please visit the journal online (<http://dx.doi.org/10.1136/bmjopen-2022-066801>).

Received 20 July 2022
Accepted 16 January 2023



© Author(s) (or their employer(s)) 2023. Re-use permitted under CC BY-NC. No commercial re-use. See rights and permissions. Published by BMJ.

For numbered affiliations see end of article.

Correspondence to

Liping Wu;
lipingwu@cqmu.edu.cn

ABSTRACT

Objective This study aims to reveal the use and management status of continuous glucose monitoring (CGM) in tertiary hospitals in China and to determine the potential factors affecting the application of CGM, based on which more effective solutions would be produced and implemented.

Design An online, cross-sectional study was conducted from October 2021 to December 2021.

Setting Eighty-three tertiary hospitals in China were involved.

Participants Eighty-three head nurses and 281 clinical nurses were obtained.

Outcome Current condition of CGM use and management, the factors that hinder the use and management of CGM, scores of current CGM use and management, as well as their influencing factors, were collected.

Results Among the 83 hospitals surveyed, 57 (68.7%) hospitals used CGM for no more than 10 patients per month. Seventy-three (88.0%) hospitals had developed CGM standard operating procedures, but only 29 (34.9%) hospitals devised emergency plans to deal with adverse effects related to CGM. Comparably, maternal and children's hospitals were more likely to have a dedicated person to assign install CGM than general hospitals (52.2% vs 26.7%). As for the potential causes that hinder the use and management of CGM, head nurses' and nurses' perceptions differed. Head nurses perceived patients' limited knowledge about CGM (60.2%), the high costs of CGM and inaccessibility to medical insurance (59.0%), and imperfect CGM management systems (44.6%) as the top three factors. Different from head nurses, CGM operation nurses considered the age of CGM operators, the type of hospital nurses worked in, the number of patients using CGM per month and the number of CGM training sessions as potential factors ($p < 0.05$).

Conclusions The study provides a broad view of the development status of CGM in China. Generally speaking, the use and management of CGM in China are not yet satisfactory, and more efforts are wanted for improvement.

INTRODUCTION

¹⁻³As of 2021, approximately 537 million adults in the world are living with diabetes mellitus (DM), 6.7 million lives lost to DM,

STRENGTHS AND LIMITATIONS

- ⇒ This study reflected the current situation of continuous glucose monitoring (CGM) use and management, as well as the factors hindering the use and management of CGM to a certain extent.
- ⇒ Due to the cross-sectional nature of the study, we were unable to determine the causal relationship between the current status of CGM use management and its influencing factors.
- ⇒ The majority of the questionnaires were distributed to tertiary hospitals, resulting in few secondary and primary hospitals being reached by the survey.

and the global health expenditure due to DM is about \$966 billion.^{4 5} In 2018, the prevalence of adult DM reached 14.3% in the USA, and only 21.2% of these patients achieved glycaemic control goals.¹⁻³ Over the past decade, the incidence of DM has rapidly increased in low-income and middle-income countries than that in high-income countries, while the absence of robust policies and healthcare systems in low-income regions has made the conditions for the prevention and treatment of DM even worse.

⁶⁻⁹The incidence of DM in China has also been increasing annually, with a prevalence rate reaching 10.6% in 2021. China has the highest proportion of individuals with DM. Currently, about 140 million adults are suffering from DM, and healthcare expenditures have reached up to \$165 billion.¹⁰ The overall awareness, treatment and control rates of DM among patients in China are 36.7%, 32.9% and 50.1% respectively, which are relatively low.

To treat DM effectively, a collaboration between the government, social sources, patients and manufacturers of medical technologies is required.¹ Effective tools can be used to improve its management, thereby reducing the incidence of complications and

premature deaths associated with diabetes. In the past decades, significant advancements were made in DM management tools and technologies that have resulted in the improvement in glycaemic control of patients with DM. Continuous glucose monitoring (CGM) is one such tool. Although routine self-monitoring of blood glucose is still commonly performed, CGM has shown admirable advantages in providing comprehensive and continuous information on blood glucose, identifying hidden hyperglycaemia and hypoglycaemia, revealing trends in patients' blood glucose fluctuations, and reducing pain from frequent acupuncture.

^{11–14}CGM has been used in medical institutions in various countries, and its implementation has increased annually.¹⁵ In the USA, the use of CGM among those with type 1 DM increased from 7% in 2010–2012 to 30% in 2016–2018.¹⁶ In Germany, the prevalence of CGM use increased from 3% in 2006 to 38% in 2017.¹⁷ In Korea, the use of CGM increased from 1.4% in 2010 to 39.3% in 2019.^{18 19} However, the use of CGM needs to be improved further.^{19–23} Previous studies have indicated that the factors impacting the use of CGM include CGM-associated costs, accessibility to healthcare providers, inadequate CGM training of healthcare workers, limited CGM-related knowledge of patients and inadequate support from CGM manufacturers.²⁴ A review demonstrated that the use of CGM in hospitalised patients has numerous advantages with minimal risks.^{25–27} To promote the standardised use and management of CGM, China published the *Chinese Clinical Guidelines for Continuous Glucose Monitoring* in 2009, which were updated in 2012 and 2017.

In several hospitals in China, implantation, operation and day-to-day management of CGM are generally performed by nurses and head nurses of the endocrinology department. As the key performers, they are familiar not only with the use and management of CGM at their hospitals but also with other details such as the types of CGM used, management system, insurance coverage, training, assessment, etc. In this study, we surveyed the nurses and the head nurses who were involved in CGM use and management in different hospitals in China, attempting to know more about the current status of CGM use, management and the relevant affecting factors. The findings produced would offer targeted information that would help improve the use and management of CGM in future practice. To the best of our knowledge, previously few studies were conducted on a nationwide survey of the status of CGM use and management in China.

METHODS

Patient and public involvement

The public and the patients were not involved in the design, conduct, reporting or dissemination of this survey.

Study design and setting

This online, cross-sectional survey was conducted among nurses who were in charge of CGM use and management in China from October to December 2021. Head nurses and nurses from the department of endocrinology of the 83 hospitals in China were involved. Two different survey forms, *the CGM system use and management questionnaire for head nurses* (abbreviated as *the form for head nurses*) and *the CGM system use and management questionnaire for nurses* (abbreviated as *the form for nurses*), were prepared separately for head nurses and nurses in advance.

Participants and sample size

A convenience sample of 83 head nurses and 281 nurses involved in CGM use and management from 83 tertiary hospitals were enrolled in the survey. Of note, the 'type of hospital' in this study refers to a hospital that is either general or specialised according to the patient population it serves, 'others' refers to the facilities that provide medical care exclusively to children and women; while the 'class of hospital' refers to a hospital with a certain level of medical technology according to the reviews conducted every 4 years by the National Health Commission. Only one head nurse who was responsible for data analysis, decision-making and management system recommendation in the implementation of CGM was selected for each hospital. First, the link to *the form for head nurses* was sent via WeChat (a mobile-based instant social application issued by Tencent. It functions similarly to LINE, Twitter, WhatsApp and Facebook, and has been broadly used by Chinese cell phone subscribers) to several national diabetes committees, the Diabetes Group of the Paediatric Nursing Alliance of the China Children's Medical Centre, the 27th Chinese Nursing Association's Expert Group on Intravenous Therapy and the Nursing Management Group of the China Children's Hospital Branch, etc. The inclusion criteria for the head nurses were the following: (1) who were familiar with the current status of CGM use and management in the hospital and could provide relevant documents; (2) who were currently working as a staff member (not on sick or personal leave); and (3) who signed informed consent to participate in the survey. Then, the head nurses were entrusted to distribute the link of *the form for nurses* to the nurses responsible for CGM operation. Inclusion criteria for the nurses were as follows: (1) were able to install the CGM system independently; (2) were currently working as a staff (not on sick or personal leave); and (3) agreed to participate voluntarily. We collected general information on hospitals, head nurses and clinical nurses, and special information on the use and management status of CGM and its influencing factors.

Questionnaires

The questionnaires were developed in three steps between October and November 2021. First, the initial drafts of the questionnaires were formed based on an extensive research review following the study's purpose. Second,

we invited five specialists in diabetes care to discuss the drafts. Based on the suggestions, we revised the drafts item by item. Finally, a pilot survey was conducted on five head nurses and eight operating nurses. The participants took 2–5 minutes to complete the survey. Then, the questionnaires underwent another revision based on the participants' feedback.

Head nurses completed *the form for head nurses*. The final questionnaire consists of questions regarding the demographic information of head nurses, the type of CGM used in their hospitals, usage frequency of CGM, insurance coverage, management department, inspection situation, the process of quality control, personnel responsibilities, the current status of assessment and training, etc.

CGM-operating nurses completed *the form for nurses*. The final questionnaire consists of a section for the nurses' demographic information of the nurses and another section containing the assessment questions (15 items), which were divided into three dimensions: CGM performance requirements and document management, personnel responsibilities, training and examination. Possible scores were 0, 1 and 2, separately corresponding to 'no', 'not sure' and 'yes'. Cronbach's alpha for the questionnaire was 0.867.

Data collection

This survey was carried out in December 2021. Two Wenjuanxing hyperlinks for the questionnaires were distributed to head nurses and CGM-operating nurses via WeChat. Informed consent was provided on the home page on clicking the link. The respondents were required to complete the form within 2 weeks. Two researchers evaluated the validity of the questionnaires.

Bias control

Strict quality control was implemented to ensure data authenticity. Uniform instructions were used to explain the purpose of the study, the content of this survey, and the inclusion and exclusion criteria; and we adopted the logic control design for the electronic questionnaires. Each WeChat account user was only allowed to fill up the form only once, and the process was anonymous. The form could not be submitted until all the questions were completed. Those with the same option were excluded by the two-person data verification methods.

Data analysis

Statistical analysis was performed using the dedicated SPSS V.23.0 software. For descriptive statistics, data were expressed as frequency, proportions and percentages for binary variables (ie, sex), and mean and SD for continuous variables (ie, score). The inferential statistics for the two groups included the χ^2 test for categorical variables and the independent samples t-test for continuous variables. One-way analysis of variance was used to compare the continuous variables in three or more groups. Then a multiple linear regression method was employed to analyse the factors affecting the CGM management



Figure 1 Regional distribution of the 83 hospitals and 281 nurses that were surveyed

evaluation score. A p value of <0.05 was considered significant. The independent variables were assigned as follows: (1) age: 20–30 years old=1, 31–40 years old=2 and >40 years old=3; (2) type of hospitals: general hospital=1, maternal and child healthcare hospital or children's hospital=2; (3) the average number of the patients monitored with CGM per month: ≤ 10 cases = 1, 11–30 cases=2 and >30 cases=3; (4) numbers of training received: ≤ 3 times=1, 4–6 times=2, ≥ 7 times=3.

RESULTS

General characteristics

A total of 83 head nurses completed *the form for head nurses*. All of them satisfied the inclusion criteria and were enrolled in the study. The individuals came from various provinces in China, and their regional distribution was both balanced and representative of the target population. The regional distribution of the 83 hospitals and 281 nurses is shown in figure 1. The inclusion and exclusion process was summarised in figure 2. Of the 83 hospitals, 60 were general hospitals (72.3%) and 23 were maternal and children's hospitals (27.4%); according to the results of the questionnaire, there are 15 training bases for diabetes specialist nurses (17.9%). Two hundred and eighty-seven operators completed *the form for nurses*; however, six forms with the same option for all items were excluded, leaving a total of 281 valid responses with an efficiency rate of 97.9%.

Head nurses' perception regarding the status of CGM use and management

The current status of CGM use and management in the 83 hospitals is minutely shown in table 1. According to the survey responses, the patients who used CGM were patients with type 1 diabetes (92.8%), patients with type 2 diabetes who experience large blood sugar fluctuations (72.3%), patients with type 2 diabetes requiring intensive

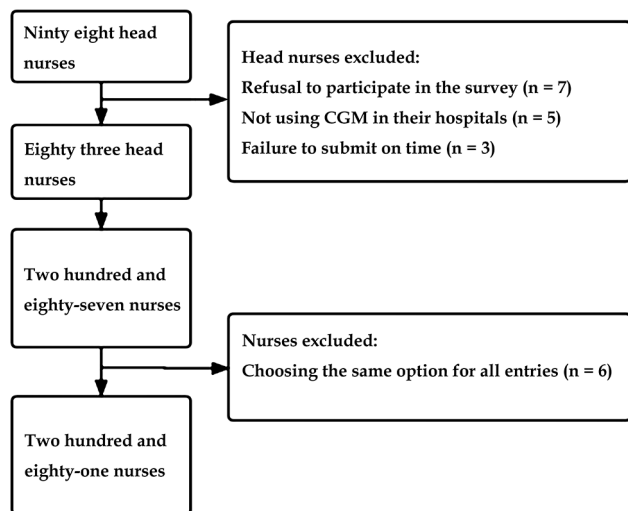


Figure 2 The inclusion and exclusion process of participants. CGM, continuous glucose monitoring.

insulin therapy (68.7%), patients with gestational diabetes or people with diabetes who are pregnant now (49.4%) and patients with specific types of diabetes (45.8%). In the opinion of head nurses, the top four factors that hinder the application and management of CGM were as follows: patients' lack of recognition of CGM (60.2%), high and non-reimbursable costs associated with CGM (59.0%), inadequate management mechanism (44.6%) and refusal of patients to use CGM (36.1%).

Nurses' perception regarding the status of CGM use and management

The scores of the variables related to CGM use and management based on the nurses' responses were summarised in [table 2](#). Nurses did not think highly of CGM use and management. Univariate analysis of the results showed that the age of nurses, the type of hospital that nurses worked at, the average number of patients per month and the frequency of training received were statistically significant variables.

The score for CGM use and management status was assigned as the dependent variable, the variables of statistical significance in the univariate analysis were taken as independent variables, and a multiple linear regression method was used to identify the independent factors. The nurses' age, type of hospital, the average number of patients per month and frequency of training were the factors independently affecting the score, as shown in [table 3](#). In maternal and children's hospitals, the younger the operators, the higher the number of patients that they handled per month; moreover, the higher the frequency of training, the higher the score for CGM use and management.

DISCUSSION

The introduction of CGM into Chinese hospitals was relatively late. People are still unfamiliar with this new generation of glucose monitoring technology in general.

²⁸This study surveyed 83 hospitals in various regions of China. According to the data issued by the National Health Commission, by the end of 2021, there are a total of 3275 tertiary hospitals in China. Despite accounting only for 4% of them, the hospitals surveyed represent the best hospitals in our country. About 140 million adults are living with DM in China. However, as shown in this study, approximately 70% of the hospitals surveyed use CGM for no more than 10 patients per month; moreover, the CGM management teams that should comprise the staff from medical offices, nursing departments, laboratory departments, equipment departments and other departments have not yet been well established possibly due to the low frequency of CGM usage and lack of sufficient attention.^{15–17 29 30} In developed countries, such as Germany and the USA, nearly 40% of patients with DM are using CGM, while 52.6% of children with type 1 DM underwent CGM in Norway, with the usage rate continuing to increase. Therefore, we indirectly infer that the utilisation rate of CGM among patients with DM in China is much lower than that in some developed countries, which also indicates the need for improvement in its clinical application.

In this survey, the most commonly used type of CGM was retrospective CGM and followed by real-time CGM. Notably, the results were obtained only based on the responses of the participants, not based on quantitative data. Strictly following the standard procedures is a prerequisite for the successful implementation of CGM. This survey showed that 12.0% of the hospitals still lack CGM standard operating procedures, which should be established as soon as possible to facilitate the standardised adoption of CGM. The CGM-related risks have not as well gained adequate recognition.^{29 31 32} CGM-related adverse events include contact dermatitis, allergies and hypoglycaemia. The survey shows that only one-third of the hospitals have formulated emergency plans to manage these adverse events. Besides, 37.3% of the hospitals have yet not implemented regular supervision over the use and management of CGM, indicating that the quality check systems in some hospitals still require continuous improvement.

Of the hospitals surveyed in this study, around two-thirds of them conducted CGM training and evaluation using slightly different methods, but they still preferred offline forms of training and demonstration.^{33 34} With the persistence of COVID-19, many online education or training platforms have emerged and become increasingly mature, and the use of virtual reality and other new technologies in the teaching and training process has also been widely explored. Hospitals can make full use of such tools and techniques for CGM training while reducing the risk of aggregation and infection. The entry 'regularly conduct operational assessments on personnel operating CGM' gained the lowest score, which served as a reminder that hospitals should regularly carry out CGM-related training based on actual situations in the future while implementing operational assessments to consolidate the knowledge and skills of trainees.

Table 1 Use and management status of CGM (n=83)

Category	N (%)	Hospital type		P value
		General hospital	Other type	
The type of CGM most commonly used CGM				0.710*
Retrospective CGM	29 (34.9)	21 (25.3)	8 (9.6)	
Real-time CGM	53 (63.9)	38 (45.8)	14 (16.9)	
Miscellaneous	2 (2.4)	1 (1.2)	1 (1.2)	
Number of patients using CGM per month				0.057*
≤10	57 (68.7)	38 (45.8)	19 (22.9)	
11–30	15 (18.1)	11 (13.3)	4 (4.8)	
> 30	11 (13.3)	11 (13.3)	0 (0)	
Is CGM covered by insurance?				0.978
Yes	25 (30.1)	18 (21.6)	7 (8.4)	
Partial	35 (42.2)	25 (30.1)	10 (12.0)	
No	23 (27.7)	17 (20.5)	6 (7.2)	
The organisation or department that manages CGM				0.580*
Clinical laboratory	1 (1.2)	1 (1.2)	0 (0)	
Medical department	3 (3.6)	2 (2.4)	1 (1.2)	
Medical ward	78 (94.0)	57 (68.8)	21 (25.3)	
No	1 (1.2)	0 (0)	1 (1.2)	
Whether CGM is regularly inspected?				0.835
Yes	52 (62.7)	38 (45.8)	14 (16.9)	
Whether CGM-related training and evaluation is conducted?				0.690*
Training only	24 (28.9)	17 (20.5)	7 (8.4)	
Training and evaluation	55 (66.3)	39 (47.0)	16 (19.3)	
No training and evaluation	4 (4.8)	4 (4.8)	0 (0)	
Ways of conducting CGM-related training				1.000*
Offline theory explanation and operation demonstration	71 (85.5)	51 (61.4)	20 (24.1)	
Online theory explanation and operation demonstration	10 (12.0)	7 (8.4)	3 (3.6)	
Theoretical explanation only	0 (0)	0 (0)	0 (0)	
Demonstration of operation only	2 (2.4)	2 (2.4)	0 (0)	
CGM is managed by a dedicated person				1.000*
Yes	65 (78.3)	47 (56.7)	18 (21.7)	
Has a CGM standard operating procedure				0.270*
Yes	73 (88.0)	51 (61.4)	22 (26.5)	
Has a CGM emergency plan				0.620
Yes	29 (34.9)	20 (24.1)	9 (10.8)	
Has a dedicated person to install CGM				0.028
Yes	28 (33.7)	16 (19.3)	12 (14.4)	
Professional level needed to install CGM				0.156*
Primary	7 (8.4)	4 (4.8)	3 (3.6)	
Middle	32 (38.6)	20 (24.1)	12 (14.5)	
Senior	4 (4.8)	3 (3.6)	1 (1.2)	
No job title required	40 (48.2)	33 (39.8)	7 (8.4)	
Has a dedicated staff to explain the CGM monitoring report				0.099
Yes	42 (50.6)	27 (32.5)	15 (18.1)	
Professional level needed to explain the CGM monitoring report				0.051*

Continued

Table 1 Continued

Category	N (%)	Hospital type		P value
		General hospital	Other type	
Primary	3 (3.6)	1 (1.2)	2 (2.4)	
Middle	31 (37.3)	19 (22.9)	12 (14.5)	
Senior	14 (16.9)	10 (12.0)	4 (4.8)	
No job title required	35 (42.2)	30 (36.1)	5 (6.0)	
Is quality control performed regularly ?				0.204
Yes	59 (71.1)	45 (54.2)	14 (16.9)	
Do you think CGM use management is insufficient ?				1.000*
Yes	70 (84.3)	50 (60.2)	21 (24.1)	

*Fisher exact test.
CGM, continuous glucose monitoring.

Table 2 CGM use and management scores

Dimensions and items	Score (x±s)
Dimension 1. Performance requirements and file management	5.30±1.27
1.1 Whether the accuracy of CGM has been assessed before entering your hospital/ department	1.77±0.54
1.2 There are CGM standard operating procedures	1.85±0.49
1.3 There are CGM failure causes and emergency treatment plan	1.67±0.69
Dimension 2. Responsibilities of personnel	5.01±2.33
2.1 Dedicated person to manage CGM	1.50±0.85
2.2 Dedicated person to install CGM	1.20±0.96
2.3 Dedicated person to interpret the CGM report	1.52±0.79
2.4 Think that CGM use management is insufficient	0.80±0.78
Dimension 3. Training and evaluation	12.01±4.49
3.1 Regularly carry out training related to CGM	1.34±0.87
3.2 The content of the training is reasonable, comprehensive and clear	1.65±0.63
3.3 The methods of conducting CGM-related training are scientific and diversified	1.56±0.71
3.4 The frequency of training is reasonable	1.53±0.73
3.5 The duration of each training is reasonable	1.69±0.60
3.6 Periodically conduct a theoretical evaluation	1.70±0.62
3.7 Regularly conduct operational evaluation	1.23±0.91
3.8 Satisfied with the overall effect of CGM training	1.32±0.88

CGM, continuous glucose monitoring.

^{18 19 35 36} Similar to the studies conducted in the USA, Korea and other countries, head nurses in this study agreed that the factors hindering the use and management of CGM include patients' limited knowledge about CGM (60.2%), the high costs of CGM and inaccessibility to medical insurance (59.0%) and the non-standardised CGM management systems (44.6%). This finding suggests that while conducting CGM training for medical staff, it may be necessary to invite relevant patients and healthcare personnel to participate in the training to increase their awareness related to CGM.^{37 38} The insurance coverage of CGM-related expenses has been advocated in the literature.^{13 39} For instance, the Australian government fully covers CGM-related costs for patients with DM under 21 years old and those with gestational diabetes.^{29 40 41} In Norway and the USA, the CGM-related expenses of patients with DM are also reimbursed, although the reimbursement rates vary. China has not yet included CGM within the coverage of national medical insurance. CGM-related costs can be reimbursed for only a fraction of patients through social funds or research funds. This may be one of the main factors hindering the wide adoption

Table 3 Multiple linear regression analysis results of CGM use and management evaluation scores (n=281)

Variable	Regression coefficient	P value	95% CI
Age of nurse	-1.37	0.029	-2.595 to 0.138
Hospital type	3.18	0.001	1.314 to 5.045
The average number of use cases per month	1.71	0.001	0.716 to 2.699
The frequency of training	1.81	0.001	0.791 to 2.830

Note: R=0.369, R²=0.136, adjusted R²=0.124, F=10.882, P<0.001.
CGM, continuous glucose monitoring.

of CGM in China. More generous insurance policies give patients more chances to access CGM.

Data obtained from the CGM-operating nurses showed other factors that hinder the use and management of CGM. Multiple linear regression analysis demonstrated that the major factors that independently affect CGM use and management are the age of CGM operators, type of hospital, number of patients using CGM per month and number of CGM training sessions. The age of CGM operators showed a negative correlation with CGM use and management score, while the other three factors showed a positive correlation with CGM use and management score. The older the operator, the lower their evaluation of the status of CGM use and management. This may be due to the fact that older operators have more experience: therefore, any problems that existed during the process of CGM use and management can be identified more easily. The score of CGM use and management in children's hospitals or maternity and childcare hospitals was better than that in general hospitals as such hospitals usually pay more attention to device management given the uniqueness of their patient populations. Hospitals that performed CGM on no more than 10 patients per month scored lower, mainly due to the lack of opportunity to practise CGM use and management. Few training sessions also produced low scores, suggesting the need for increased training opportunities.

The major limitations of this study at least included (1) the inability to reveal the causal relationship between CGM management and use due to the inherent deficiencies of cross-sectional studies; and (2) in this study, questionnaires were distributed mostly to tertiary hospitals. As a result, few secondary hospitals and primary hospitals were reached by the survey, which makes it impossible to obtain the current status of CGM use and management in secondary and primary hospitals.

CONCLUSION

In summary, by investigating the status of CGM use and management in 83 tertiary hospitals, this study provides a broad view of the development status of CGM in China, problems that existed in CGM use and management, and the factors affecting its promotion, etc. In general, the use and management of CGM in China are far from satisfactory. Many efforts are warranted to promote its use and improve its management, such as insurance coverage of related expenses, provision of more training sessions, provision of more opportunities to practise and development of a standardised management system.

Author affiliations

¹Department of Endocrinology, Chongqing Medical University Affiliated Children's Hospital, Chongqing, China

²National Clinical Research Center for Child Health and Disorders, Chongqing, China

³Ministry of Education Key Laboratory of Child Development and Disorders, Chongqing, China

⁴Chongqing Key Laboratory of Paediatrics, Chongqing, China

⁵Department of Nursing, Chongqing Medical University Affiliated Children's Hospital, Chongqing, China

⁶School of Public Health and Management, Chongqing Medical University, Chongqing, Chongqing, China

⁷Human Nutrition Department, Qatar University, Doha, Ad Dawhah, Qatar

Contributors LC wrote the first draft. LW conceptualised and designed the study, and responsible for the overall content as the guarantor. XL and LC performed the statistical analysis. QL and HD supervised the research. YZ and ZS reviewed the draft.

Map disclaimer The inclusion of any map (including the depiction of any boundaries therein), or of any geographic or locational reference, does not imply the expression of any opinion whatsoever on the part of BMJ concerning the legal status of any country, territory, jurisdiction or area or of its authorities. Any such expression remains solely that of the relevant source and is not endorsed by BMJ. Maps are provided without any warranty of any kind, either express or implied.

Competing interests None declared.

Patient and public involvement Neither the patients nor the public were involved in the design, conduct, reporting or dissemination plans of our research.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and was approved by Institutional Review Board, Children's Hospital of Chongqing Medical University. Ethical approval number is 2021-241. 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. Data are available upon reasonable request. The datasets used and/or analysed during the current study are available from the corresponding author (LW) on reasonable request.

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 peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

Open access This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>.

ORCID iDs

Liping Chen <http://orcid.org/0000-0001-6309-8875>

Yong Zhao <http://orcid.org/0000-0001-9290-109X>

REFERENCES

- 1 World Health Organization. Global report on diabetes. Available: https://apps.who.int/iris/bitstream/handle/10665/204871/9789241565257_eng.pdf [Accessed 2 May 2021].
- 2 American Diabetes Association. 2. classification and diagnosis of diabetes: *standards of medical care in diabetes-2021*. *Diabetes Care* 2021;44(Suppl 1):S15–33.
- 3 International Diabetes Federation. *IDF diabetes atlas*. 10th edn. Brussels, Belgium: International Diabetes Federation, Available: <https://diabetesatlas.org/> [accessed 1 Feb 2022].
- 4 Wang L, Li X, Wang Z, *et al*. Trends in prevalence of diabetes and control of risk factors in diabetes among US adults, 1999–2018. *JAMA* 2021;326:1–13.
- 5 Fang M, Wang D, Coresh J, *et al*. Trends in diabetes treatment and control in U.S. adults, 1999–2018. *N Engl J Med* 2021;384:2219–28.
- 6 International diabetes federation [China diabetes report 2000–2045]. In: *IDF Diabetes Atlas*. Available: <https://diabetesatlas.org/data/en/country/42/cn.html> [accessed 1 Mar 2022].

- 7 Li Y, Guo C, Cao Y. Secular incidence trends and effect of population aging on mortality due to type 1 and type 2 diabetes mellitus in china from 1990 to 2019: findings from the global burden of disease study 2019. *BMJ Open Diabetes Res Care* 2021;9:e002529.
- 8 Li Y, Teng D, Shi X, *et al.* Prevalence of diabetes recorded in mainland China using 2018 diagnostic criteria from the American diabetes association: national cross sectional study. *BMJ* 2020;369:m997.
- 9 Wang Z, Wu Y, Wu J, *et al.* Trends in prevalence and incidence of type 2 diabetes among adults in Beijing, China, from 2008 to 2017. *Diabet Med* 2021;38:e14487.
- 10 Wang L, Peng W, Zhao Z, *et al.* Prevalence and treatment of diabetes in China, 2013–2018. *JAMA* 2021;326:2498–506.
- 11 Bouillet B, Tscherter P, Vaillard L, *et al.* Frequent and severe hypoglycaemia detected with continuous glucose monitoring in older institutionalised patients with diabetes. *Age Ageing* 2021;50:2088–93.
- 12 Aleppo G, Beck RW, Bailey R, *et al.* The effect of discontinuing continuous glucose monitoring in adults with type 2 diabetes treated with basal insulin. *Diabetes Care* 2021;44:2729–37.
- 13 Johnson SR, Holmes-Walker DJ, Chee M, *et al.* Universal subsidized continuous glucose monitoring funding for young people with type 1 diabetes: uptake and outcomes over 2 years, a population-based study. *Diabetes Care* 2022;45:391–7.
- 14 Vijayanand S, Stevenson PG, Grant M, *et al.* The utility of continuous glucose monitoring systems in the management of children with persistent hypoglycaemia. *J Pediatr Endocrinol Metab* 2021;34:1567–72.
- 15 Foster NC, Beck RW, Miller KM, *et al.* State of type 1 diabetes management and outcomes from the T1D exchange in 2016–2018. *Diabetes Technol Ther* 2019;21:66–72.
- 16 van den Boom L, Karges B, Auzanneau M, *et al.* Temporal trends and contemporary use of insulin pump therapy and glucose monitoring among children, adolescents, and adults with type 1 diabetes between 1995 and 2017. *Diabetes Care* 2019;42:2050–6.
- 17 Choe J, Won SH, Choe Y, *et al.* Temporal trends for diabetes management and glycemic control between 2010 and 2019 in Korean children and adolescents with type 1 diabetes. *Diabetes Technol Ther* 2022;24:201–11.
- 18 Yoo JH, Kim JH. Time in range from continuous glucose monitoring: a novel metric for glycemic control. *Diabetes Metab J* 2020;44:828–39.
- 19 Rodbard D. Continuous glucose monitoring: a review of successes, challenges, and opportunities. *Diabetes Technol Ther* 2016;18 Suppl 2(Suppl 2):S3–13.
- 20 Messer LH, Tanenbaum ML, Cook PF, *et al.* Cost, hassle, and on-body experience: barriers to diabetes device use in adolescents and potential intervention targets. *Diabetes Technol Ther* 2020;22:760–7.
- 21 Cappon G, Vettoretti M, Sparacino G, *et al.* Continuous glucose monitoring sensors for diabetes management: a review of technologies and applications. *Diabetes Metab J* 2019;43:383–97.
- 22 Vettoretti M, Cappon G, Acciaroli G, *et al.* Continuous glucose monitoring: current use in diabetes management and possible future applications. *J Diabetes Sci Technol* 2018;12:1064–71.
- 23 Forlenza GP, Buckingham B, Maahs DM. Progress in diabetes technology: developments in insulin pumps, continuous glucose monitors, and progress towards the artificial pancreas. *J Pediatr* 2016;169:13–20.
- 24 Gothong C, Singh LG, Satyarengga M, *et al.* Continuous glucose monitoring in the hospital: an update in the era of COVID-19. *Curr Opin Endocrinol Diabetes Obes* 2022;29:1–9.
- 25 General Administration of Food and Drug Administration. Announcement of the general 410administration on the release of the medical device classification catalog (no. 104 of 2017)[411EB/OL]. (2017-08-31). 2021. Available: <https://www.nmpa.gov.cn/ylqx/ylqxggtg/ylqxqgtg/20170904150301537.html>
- 26 Diabetes Society. Chinese clinical guidelines for continuous glucose monitoring. *Chinese Journal of Diabetes Mellitus* 2012;10:582–90.
- 27 Diabetes Society. Chinese clinical guidelines for continuous glucose monitoring. *Chinese Journal of Diabetes Mellitus* 2017;11:667–75.
- 28 National Health Commission of people's Republic of China. *Statistical bulletin on china's health and wellness development in 2021 [EB/OL]*. Available: <http://www.nhc.gov.cn/cms-search/xxgk/getManuscriptXxgk.htm?id=51b55216c2154332a660157abf28b09d> [accessed 18 Nov 2022].
- 29 Bratke H, Margeirsdottir HD, Assmus J, *et al.* Does current diabetes technology improve metabolic control? A cross-sectional study on the use of insulin pumps and continuous glucose monitoring devices in a nationwide pediatric population. *Diabetes Ther* 2021;12:2571–83.
- 30 Hood KK, DiMeglio LA, Riddle MC. Putting continuous glucose monitoring to work for people with type 1 diabetes. *Diabetes Care* 2020;43:19–21.
- 31 Slover RH, Tryggstad JB, DiMeglio LA, *et al.* Accuracy of a fourth-generation continuous glucose monitoring system in children and adolescents with type 1 diabetes. *Diabetes Technol Ther* 2018;20:576–84.
- 32 Oskarsson P, Antuna R, Geelhoed-Duijvestijn P, *et al.* Impact of flash glucose monitoring on hypoglycaemia in adults with type 1 diabetes managed with multiple daily injection therapy: a pre-specified subgroup analysis of the impact randomised controlled trial. *Diabetologia* 2018;61:539–50.
- 33 Zhang J, Xing J, Zheng M, *et al.* Effectiveness of virtual simulation and jaw model for undergraduate periodontal teaching. *BMC Med Educ* 2021;21:616:616..
- 34 Kim Y-J, Ahn S-Y. Factors influencing nursing students' immersive virtual reality media technology-based learning. *Sensors (Basel)* 2021;21:8088.
- 35 Soni A, Wright N, Agwu JC, *et al.* A practical approach to continuous glucose monitoring (rtcgm) and freestyle libre systems (iscgm) in children and young people with type 1 diabetes. *Diabetes Res Clin Pract* 2022;184:109196.
- 36 Addala A, Maahs DM, Scheinker D, *et al.* Uninterrupted continuous glucose monitoring access is associated with a decrease in HbA1c in youth with type 1 diabetes and public insurance. *Pediatr Diabetes* 2020;21:1301–9.
- 37 Dos Santos TJ, Dave C, MacLeish S, *et al.* Diabetes technologies for children and adolescents with type 1 diabetes are highly dependent on coverage and reimbursement: results from a worldwide survey. *BMJ Open Diabetes Res Care* 2021;9:e002537.
- 38 Grace T, Salyer J. Use of real-time continuous glucose monitoring improves glycemic control and other clinical outcomes in type 2 diabetes patients treated with less intensive therapy. *Diabetes Technol Ther* 2022;24:26–31.
- 39 Swaney EE, McCombe J, Coggan B, *et al.* Has subsidized continuous glucose monitoring improved outcomes in pediatric diabetes? *Pediatr Diabetes* 2020;21:1292–300.
- 40 Isaacs D, Bellini NJ, Biba U, *et al.* Health care disparities in use of continuous glucose monitoring. *Diabetes Technol Ther* 2021;23:S81–7.
- 41 Kruger DF, Anderson JE. Continuous glucose monitoring (CGM) is a tool, not a reward: unjustified insurance coverage criteria limit access to CGM. *Diabetes Technol Ther* 2021;23:S45–55.